United States Army

Mad Scientist: Megacities and Dense Urban Areas in 2025 and Beyond

Training and Doctrine Command (TRADOC) G-2, Fort Eustis, VA.

U.S. Army Training and Doctrine Command

Arizona State University

SMALL WARS JOURNAL

DISTRIBUTION RESTRICTION:
Approved for public release; distribution is unlimited

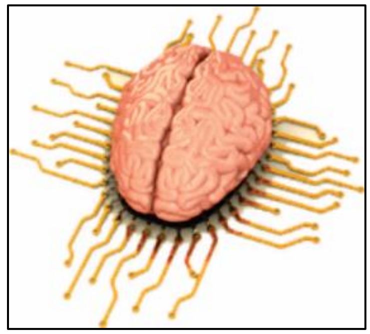
Created and edited by: Joel Lawton and Major Lori Shields

This page was intentionally left blank

Table of Contents

INTRODUCTION

Mad Scientist Overview



Mad Scientist, organized by the Army's Training and Doctrine Command (TRADOC) G-2 (Intelligence), provides a continuous dialogue with academia, industry, and government on the concepts and capabilities needed for the future operational environment (OE). Mad Scientist also facilitates dialogue in order to define the future OE through 2050. Mad Scientist supports the examination of the future OE through exploring innovative ways to improve the effectiveness of the future force to ensure it can accomplish a diverse set of missions throughout the full range of military operations.

Since 2015, TRADOC G-2 has conducted three Mad Scientist events. During 2015, TRADOC G-2 conducted two Mad Scientist conferences in April and October. The April conference, co-sponsored with Georgetown University and Army Capabilities Integration Center's (ARCIC) Science and Technology Division, focused on how the U.S. could maintain its relative technological advantage over increasingly capable adversaries. The October conference, conducted with Army University, Army Recruiting Command, and the Army Center for Initial Military training studied the Human Dimension of warfare to look at steps the Army must take today to ensure highly capable Soldiers tomorrow. Finally in April of 2016, Mad Scientist cohosted an event with Arizona State University Research Enterprise (ASURE) and the Army's Intelligence Center of Excellence (ICoE) designed to examine complexities of future land forces operating in megacities and dense urban areas.

Insights from these events are used to provide input into concepts and capabilities documents, including the Commanding General's annual requirement to recommend science and technology investment priorities to the Army Staff and the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA/ALT). They also provide technology based assessments to support Army Capability Development activities and provide input to the Army's Centers of Excellence (CoE) concept and capability development.

Mad Scientist Event	Theme	Outcome	Partnership
April 2015, "Challenges in the Future World"	Event focused on the unique challenges of disruptive technologies and examined emerging technologies to mitigate potential overmatch areas.		Georgetown University
October 2015, "Human Dimension in 2025 and Beyond"	Event examined how to optimize individual, team, and organizational emerging concepts and capabilities that will disrupt current structures, systems and processes.	Informed CAC Human Dimension Strategy	Army University (AU)
April 2016, "Megacities and Dense Urban Areas in 2025 and Beyond"	Event looked at how future forces will gain situational understanding; freedom of movement and access; conduct expeditionary operations, and discussed future training challenges in megacities and dense urban areas.	Informed ARCIC Megacities Information Paper; ARCIC S&T Needs; MCOE scenario development, and MATDEV communities	Arizona State University (ASU) and ICoE

Figure 1: Mad Scientist Events

Objectives of Megacities and Dense Urban Areas Event

The Army has studied megacities and dense urban areas for a considerable amount of time. Building upon previous work, to include a 2015 report completed by the Chief of Staff of the Army (CSA) Strategic Studies Group on megacities, TRADOC G-2 partnered with ASURE and ICoE to conduct a Mad Scientist conference (21-22 April 2016, with a focus on "Megacities and Dense Urban Areas in 2025 and Beyond"). This event was critical in supporting megacity and dense urban areas concept and capability development. The conference was used as a venue to validate assumptions or propose concepts to interested academic, material developer, and Joint communities. Speakers at this event included senior military leadership, ASU professors, engineers, and other world renowned experts. In order to ensure that the presenters were subject matter experts in their respective fields of study, a call for papers was conducted during the selection process.[1]

The event was organized to study four overarching problem sets that future land forces are likely to encounter while operating in megacities or dense urban areas. These problem sets additionally served as the conference's objectives: 1) gain situational understanding, 2) enable future force freedom of movement and access, 3) conduct

[1] Information extracted from Military Intelligence Professional Bulletin (MIPB) article to be published 4th Quarter Fiscal Year 2016 (PB 34-16-3). The MIPB article also serves as Section 1 of this document.

expeditionary operations, 4) and mitigate future training challenges. These problems sets, formulated as conference objectives, were used as a basis to explore concepts and capabilities to match the complexities of these environments.[2]

The four problems sets were associated questions to serve as essential elements of analysis:

(1) Situational understanding: What emerging concepts and capabilities will enable Intelligence Preparation of the Battlefield (IPB); Intelligence Surveillance and Reconnaissance (ISR) capabilities; Mission Command Systems; electronic warfare (EW), and a human, demographic, and cultural understanding within megacities/dense urban areas?

(2) Freedom of movement and protection: What emerging concepts and capabilities will enable access and freedom of movement in, above (buildings and airspace), below (sub-terrain), and around megacities? What new capabilities for Decentralized Urban Logistics can improve sustainment efficacy in urban areas? What will protect vehicles and Soldiers, while enabling freedom of movement, from multitude of advanced and conventional military technologies as well as environmental threats (e.g., water, sanitation, air pollution; etc.)?

(3) Expeditionary operations: What emerging concepts and capabilities will enable expeditionary maneuver; evolve Army Health Support of Operations; enhance the ability to manage or influence large population centers, and offer solutions for achieving partner interests and strategic objectives throughout a range of military operations (during peace and combat operations)?

(4) Future training challenges: What emerging technologies and capabilities must the Army explore and adopt in order to realistically represent the complexities of a megacity to a training audience (home station and Combat Training Centers) allowing the development of cohesive teams that thrive in ambiguity, austerity, or chaos within OE of 2025 and Beyond.

Insights from Megacities and Dense Urban Areas Event

Through presentations by subject matter experts on various megacity or dense urban area related issues, open discussion, and attendee discourse, TRADOC G-2 and ASURE was supplied with insights, technological solutions, and issues to consider as they relate to the event's four core objectives. Over 140 participants attended the conference at ASU, nearly 40% from outside the Army. Also more than 500 individuals participated

[2] Information extracted from Military Intelligence Professional Bulletin (MIPB) article to be published 4th Quarter Fiscal Year 2016 (PB 34-16-3). The MIPB article also serves as Section 1 of this document.

through web streaming and a chat room.[3] Finally open discourse, the call for papers, and presentations ASURE, ICoE, and TRADOC G-2 captured the following insights, which will be discussed in greater detail in Sections 1 and 2 of this document:

Future land forces must develop situational understanding in complex terrain and within adaptive systems: The challenge of megacities is density, not just in people, but also in data and infrastructure. Understanding terrain is key, particularly physical overlaid with cyber-social. Another notion is the invisible geography requires understanding of the formal and informal social networks, not obvious to those unfamiliar with the region.

Other technological solutions enabled by big data analytics of social media will provide access to a population's collective intelligence; insights are achieved through examination of aggregate behaviors. This will have to be developed through common data sets for megacity models is critical for building a commander's visualization. Although each megacity is unique (e.g., demographics, infrastructure, threats), there are similarities in data to frame analysis.

Situational understanding must also consider how disease vectors are drivers of instability in megacities. Surveillance through integrated sensor architectures, of which humans are a critical component, is required to achieve accurate, timely diagnosis during a humanitarian crises. The interconnectedness of biosecurity underpins a "one health" concept. The health of the planet cannot be maintained by ensuring health in first world countries. Disease does not recognize socio-economic borders.

Considering the human dimension is critical: Cyber space must be defined as a human space, a global commons of human practice, rapidly becoming the preferred space to engage. Additionally, the future will be increasingly populated by a new species: "Homosapiens.net," which will live their entire lives connected to a global virtual network. This notion, Homosapiens.net, will gravitate towards virtual environments for learning and engagement, and this virtual world will change the concept of identity.

Protection - Medical considerations are preeminent: Humanitarian missions will require a surge capacity due to the sheer density of people. Response forces require innovative ways to manage waste disposal and protective suits with communications for long duration operations. Capabilities such as 'Hot Zone Robotics' could mitigate some of the problems with golden hour care for thousands of casualties. Robots will likely be capable of conducting triage, providing emotional support, remotely diagnosing, and providing basic care.

[3] For a list of the presenters, biographies, and presentations, please visit the TRADOC G-2 All Partners Access Network (APAN) "Megacities and Dense Urban Areas page at: https://community.apan.org/wg/tradoc-g2/mad-scientist/p/mc

The Army will have to expand expeditionary operations capabilities: Future forces will likely be enabled by virtual humans or "avatars" in the field, capable of face-to-face interactions and conducting interviews, as well as assist Leaders in language translation and decision making. The Army must also recognize that human-machine teaming will outperform a group of humans working together or a computer working independently. This teaming is critical if the environment is too dangerous, imposing restrictions on human access.

Traditional concepts of land warfare of "laying siege" to a megacity or dense urban area is an outdated notion. Formations and force structures will have to largely independently and dynamically adjust to complex environments. Unmanned systems will help to enable this concept and will provide many opportunities for freedom of movement. Such as vertical takeoff and landing will be critical in megacities.

Innovative and new approaches to training must be considered: Due to the challenges replicating a megacity training area, virtual environments will be needed to emulate specific areas and provide home-station training repetitions. Some of the expertise needed to facilitate this will be gained through interdisciplinary collaboration. This is critical to understanding and addressing complex problems in megacities. We must also recognize that most of this expertise will be outside of the Army.

Army Warfighting Challenges (AWfC) Alignment of Insights

Each year the U.S. Army conducts a Campaign of Learning to help model Army concepts that may lead to capabilities or support acquisition efforts corresponding to a projected OE. Learning Campaigns include "studies, science and technology, seminars, wargames, experiments, and live exercises."[4] TRADOC Pamphlet 525-8-2, the Army's overarching guide to 2016's campaign objectives states that its purpose is to describe "an Army learning model that meets the All-Volunteer Army's need to develop adaptive, thinking Soldiers and leaders capable of meeting the challenges of operational adaptability in an era of persistent conflict."[5] Learning Concepts are largely derived from definitions of the SE by national or service specific documents that may include: The National Intelligence Council's *Global Trends 2030: Alternative Worlds*, The U.S. *Army's Operating Concept Win in a Complex World*, and TRADOC's *Operational Environments to 2028: The Strategic Environment for Unified Land Operations.*[6]

---

[4] US Army. *TODAY'S FOCUS: 2013 Army Campaign of Learning.* September 21, 2012. http://www.army.mil/standto/archive/issue.php?issue=2012-09-21.
[5] US Army. "The U.S. Army Learning Concept for 2015." TRADOC Pam 525-8-2. 2011, 5.
[6] Section extracted from: Lawton, Joel and John Hoven, PhD. 2015. "Qualitative Analysis Concept in Support of Force 2025 and Beyond (F2025B) Maneuvers. " Small Wars Journal. (14 July). http://smallwarsjournal.com/jrnl/art/qualitative-analysis-concept-in-support-of-force-2025-and-beyond-f2025b-maneuvers

During successive learning campaigns, the Army identifies broad functional areas needed to maintain a decisive advantage in the future OE. These functional areas are supported and defined by AWfCs and are given a proponent Army Center of Excellence or directorate to advance the development of concepts or capabilities based on their respective mission or utility. AWfCs are identified and enduring gaps in current Army capabilities that must be addressed to improve chances of success in future conflict. The current AWfCs are modeled to support the generating and operational force of 2025 and beyond (or F2025B). The 2015- 2016 AWfCs that the Army is using to develop concepts include some 20 “first-order problem” areas[7]: Develop Situational Understanding; Shape the Security Environment; Provide Security Force Assistance; Adapt the Institutional Army; Counter WMD; Homeland Operations; Conduct Space and Cyber Electromagnetic Operations and Maintain Communications; Enhance Training; Improve Soldier, Leader, and Team Performance; Develop Agile and Adaptive Leaders; Conduct Air-Ground Reconnaissance; Conduct Entry Operations; Conduct Wide Area Security; Ensure Interoperability and Operate in a Joint, Interagency, Intergovernmental, and Multinational Environment; Conduct Combined Arms Maneuver; Set the Theater, Sustain Operations, and Maintain Freedom of Movement; Integrate Fires; Deliver Fires; Exercise Mission Command, and Develop Capable Formations.[8][9]

The Mad Scientist Megacities and Dense Urban Areas event provided an unique opportunity to help the Army address AWfCs. Through the use of a survey tool, insights captured during the conference, and analysis conducted by TRADOC G-2 and the MITRE Corporation, AWfCs were associated to capability and technology ideas to address these enduring gaps. Section 2 of this document will address AWfC development in more detail (Quantitative Summary of Data section). Figure 2 broadly links the objectives of the event with four AWfCs.

[7] US Army. *Army Warfighting Challenges.* Information Paper, ARCIC, TRADOC, 2015, 1.
[8] Ibid, 5-6.
[9] Section extracted from: Lawton, Joel and John Hoven, PhD. 2015. “Qualitative Analysis Concept in Support of Force 2025 and Beyond (F2025B) Maneuvers.“ Small Wars Journal. (14 July). http://smallwarsjournal.com/jrnl/art/qualitative-analysis-concept-in-support-of-force-2025-and-beyond-f2025b-maneuvers

Mad Scientist Objectives and AWfC Association	
OBJ 1: Gain situational understanding	AWfC #1, Develop Situational Understanding
OBJ 2: Enable future force freedom of movement and access	AWfC #16, Set the Theater, Sustain Operations, and Maintain Freedom of Movement
OBJ 3: Conduct expeditionary operations	AWfC #12, Conduct Joint Expeditionary Maneuver and Entry Operations
OBJ 4: Mitigate future training challenges	AWfC #8, Enhance Realistic Training

Figure 2: Mad Scientist Objectives and AWfC Association

Compendium Section Overview

Section 1, "Army Operation in Megacities and Dense Urban Areas: A Mad Scientist Perspective": This section includes an article written for ICoE's Military Intelligence Bulletin (MIPB) titled, "Army Operation in Megacities and Dense Urban Areas: A Mad Scientist Perspective." The article was written by TRADOC G-2 personnel, Joel Lawton, Matthew Santaspirt, Michael Crites, and Major Lori Shields. The article will be published during 4th Quarter FY16 (PB 34-16-3). The article details the complexities of land forces operating in megacities and dense urban areas (DUAs) and how they are exacerbated by geopolitical factors, proliferation of advanced technologies, terrain, demographics, and a potential mix of state, non-state, and hybrid actors. It also details the Mad Scientist Megacities and Dense Urban Areas conference and defines specific concepts and capabilities that future land forces will need to operate in megacities and dense urban areas.

Section 2, MITRE Comprehensive Analysis: This section is a comprehensive report developed by the MITRE Corporation. The report provides an overview of capability and technology ideas generated through the Mad Scientist Megacities initiative that address challenges posed by megacities and dense urban areas. Data for this report was captured from the Mad Scientist Megacities and Dense Urban Areas event, Megacity publications, and a Mad Scientist technology survey. Material generated through these forums is examined from the perspective of four primary Megacity Objectives (Situational Understanding, Freedom of Movement and Protection, Expeditionary Operations, and Future Training Challenges).

Section 3, Situational Understanding: This section includes published articles from Small Wars Journal that we received from the call for papers. The section will explore issues, concepts, and capabilities as they relate to future land forces gaining situational understanding in megacities or dense urban areas in 2025 and beyond. Featured articles include:

(1) "An Analytic Framework for Operations in Dense Urban Areas" by William Hedges. Excerpt: Even though the Army has revised a great deal of its doctrine and associated tactics, techniques, and procedures in an effort to adapt to an evolving OE landscape, our situational understanding largely remains anchored to IPB's role as a MDMP catalyst for all environments. IPB's orientation is towards linear engagement areas and a specific threat methodology and model. It is essentially reductionist and quantitative in nature, still supportive of a structurally complex OE; but, often fails to gain sight of the dynamics between the components of problems within an interactively complex system.

(2) "Anticipating Megacity Responses to Shocks: Using Urban Integration and Connectedness to Assess Resilience" by Shade T. Shutters, Wes Herche and Erin King. Excerpt: Over half of humanity now lives in cities, a proportion rising to 80% by 2100. With this rapid demographic shift has come a new type of geographical entity – the megacity. In parallel with this trend is a diffusion of world power from traditional hegemonic states to networks of diverse types of actors, including non-state entities such as megacities.

(3) "Atmospheric Impacts and Effects Predictions for Applications for Future Megacity and Dense Urban Area Operations." by David Knapp, Robb Randall and Jim Staley. Excerpt: Weather conditions within these dense urban and complex terrain (DUCT) environments will influence a greater populace and can negatively influence military operations, community services, and overall situational understanding needed for Intelligence Preparation of the Battlefield (IPB) and Intelligence, Surveillance, and Reconnaissance (ISR). Extreme weather conditions will impact DUCT areas often already overstressed by uncontrolled growth and a degraded public infrastructure.

(4) "Complex IPB" by Tom Pike and Eddie Brown. Excerpt: The last 15 years of conflict have shown the difficulty in understanding the internal dynamics of a foreign population. Understanding these internal dynamics, however, is essential to implementing policies and taking action to influence the foreign population's behavior in pursuit of U.S. goals. The U.S. Government must improve its capability to rapidly analyze foreign populations and the need for this capability will only increase as megacities, with their incredibly complex population systems become more numerous.

(5) "Identity and Biometrics Enabled Intelligence (BEI) Sharing for Transnational Threat Actors" by Victor R. Morris. Excerpt: This article outlines initiatives to enhance international identity operations and intelligence product sharing, which are the result of compliant biometric data capture, transmission and intelligence fusion among intergovernmental law enforcement and military organizations to identify threats. The

proposed initiatives describe what is required within international biometric cycles and frameworks once an interoperable and compliant environment has been established.

(6) "It's in There: Rethinking (?) Intelligence Preparation of the Battlefield in Megacities/Dense Urban Areas" by Richard L. Wolfel, Amy Krakowka Richmond, Mark Read and Colin Tansey. Excerpt: The complexity of the modern city has been a key conclusion in most Army research surrounding military operations in megacities. This complexity is based on three fundamental concepts of the modern city. First, modern cities are multidimensional. Second, cities are interconnected through globalization. Third, cities are uncontrollable.

(7) "Megacities and Dense Urban Environments: Obstacle or Opportunity" by Dawn A. Morrison and Colin D. Wood. Excerpt: Current military thinking tends to present the megacity and dense urban environment as challenging, intimidating, and as a source of anxiety for military commanders who contemplate its operational environment. While megacities and dense urban environments are challenging and complex, we argue that the unique characteristics of these environments offer many opportunities and leveraging points that future U.S. military forces can use to their advantage to conduct successful military operations.

(8) "Megacities: The Good, the Bad, and the Ugly" by Russell W. Glenn. Excerpt: Today's armed forces and those accompanying their security efforts worldwide have no more conducted major operations in a megacity – those urban areas in excess of ten million population – than have they participated in a nuclear war. Fortunately, however – and unlike the case with the officers above – recent experience and history's lessons from undertakings in cities short of the ten million mark have much to offer.

(9) "Megacity Madness" by Gustav A. Otto and AJ Besik. Excerpt: The paper outlines a few ways to think about and analyze a megacity and make recommendations to prepare for operations in such an environment. The recommendations herein could not all encompassing, and likely never will be. It is an introduction by which a person or organization may consider the myriad of issues regarding a megacity, that when combined become vexing if not a wicked problem.

(10) "Operational Environment Implications of the Megacity to the U.S. Army" by Darryl Ward. Excerpt: Depending on the statistical reference, there are between 23 and 30 megacities in the world. Statistical numbers vary primarily due to different interpretations of metropolitan limits and surrounding areas. However, regardless of how megacities are quantified, trends within the global operational environment (herein referred as the "OE") indicate that the number of urban areas will continue to rise.

(11) "Qualitative Analysis Concept in Support of Force 2025 and Beyond (F2025B) Maneuvers" by Joel Lawton and John Hoven. Excerpt: The use of qualitative analysis

within the Army intelligence community can help remedy certain capability gaps in obtaining locally nuanced information. Reliance on quantitative driven surveys and methods such as PMESII-PT (Political, Military, Economic, Social, Infrastructure, Information, Physical Environment, and Time) and ASCOPE (Area, Structures, Capabilities, Organizations, People, and Events) questionnaires for understanding tactical information works largely from a hypothesis-driven approach which can ignore pertinent information (e.g., unknown-unknowns).

(12) "Using the Internet of Things to Gain and Maintain Situational Awareness in Dense Urban Environments and Megacities" by Alfred C. Crane and Richard Peeke. Excerpt: It may prove beneficial to leverage the internet of things (IOT) in order to provide our Soldiers, Sailors, Airmen and Marines the decisive advantage needed to fight and win future armed conflicts. It can be anticipated that connected devices such as game consoles, "baby monitors" (1) and "that smart meter (that) knows when you're home and what electronics you use when you're there" (2), for example, will be prolific in the future operating environment. With this in mind, the joint force will have opportunities to use these devices to gain and maintain situational awareness in a mega city or dense urban environment.

Section 4, Freedom of Movement and Protection: This section includes published articles from Small Wars Journal that we received from the call for papers. The section will explore issues, concepts, and capabilities as they relate to future land forces gaining freedom of movement or protection in megacities or dense urban areas in 2025 and beyond. Featured articles include:

(1) "U.S. Army Megacity Operations: Enduring Principles and Innovative Technologies" by Frank Prautzsch. Excerpt: By 2050, urbanization will arguably be the most consequential event in the history of mankind. Out of every 100 children born at that time, 57 will be Asian, and 22 will be African. The spectrum of operations spanning non-combat and combat missions in the face of natural or adversarial threats, makes preparation a multi-dimensional problem requiring significant attention and forethought

(2) "Unmanned Systems in Support of Future Medical Operations in Dense Urban Environments" by Nathan Fisher and Gary R. Gilbert. Excerpt: the growing planned use of unmanned systems (UMS) and robotics on the future battlefield affords both great opportunities and challenges to far future medical operations, especially in Dense Urban Areas. UMS could serve as a force multiplier for medical operations in future environments as their capabilities continue to evolve and mature to include providing medical logistics support, aid in the delivery of telehealth/teleconsultation to the point of care, and provide opportunities for expedited casualty evacuation.

Section 5, Expeditionary Operations: This section includes published articles from Small Wars Journal that we received from the call for papers. The section will explore issues, concepts, and capabilities as they relate to future land forces conducting expeditionary operations in megacities or dense urban areas in 2025 and beyond. Featured articles include:

(1) "A Revolution in Military Affairs (RMA) versus "Evolution": When Machines are Smart Enough!" by Tom Keeley. Excerpt: There is a general perception that the Operational Environment (OE) will "evolve" as technology evolves at an incremental rate: smaller, cheaper, faster… The "evolution" term is used throughout the Mad Scientist call to action. But there have been revolutions or significant paradigm shifts that have transformed the military in the past.

(2) "TRAuma Care In a Rucksack (TRACIR), a Disruptive Technology Concept" by Jan Berkow and Ron Poropatich. Excerpt: Trauma care in future military environments will require medical technological innovations for an integrated force with the attributes and capabilities to mitigate risks and maximize clinical effectiveness in an Anti-Access, Area Denial (A2/AD) insurgency scenario.

(3) "Assessing Physiological Response to Toxic Industrial Chemical Exposure in Megacities" by Danielle L. Ippolito. Excerpt: Noninvasive or minimally invasive screening methods could enable early intervention, treatment, and informed decision making to optimize force readiness. Mapping biomolecular patterns of adverse health effects represents a promising solution to the complex problem of assessing health effects after exposure to mixtures of different chemicals and /or pollutants and aggregated exposure effects over time.

(4) "How to Hold or Take a Big City — Seven Lines of Effort" by Geoff Demarest. Excerpt: An American armed force smaller than, say, that used in Sadr City, Baghdad might well achieve victory in a future urban environment. Regardless of the size and sophistication of the opposing force, the lines of effort for success in taking or holding a city can be placed in basically the same seven proposed categories.

(5) "Integrated Global Health Surveillance and Response through Multi-Source Technologies" by Paul O. Kwon. Excerpt: Since 1980, one to three new human infections have been identified annually. These Emerging Infectious Diseases (EIDs) impact social, political, economic and environmental arenas.

(6) "Pain Management: Maintaining the Force" by Marcie Fowler and Laura L. McGhee. Excerpt: Combat injuries can result in severe acute pain, and options for pain control on the battlefield are currently limited. There is a need for improved pain control on the battlefield, as well as in higher echelons of casualty care. Initial pain control can increase patient comfort and aid in evacuation from the point of injury.

Section 6, Future Training Challenges: This section includes published articles from Small Wars Journal that we received from the call for papers. The section will explore issues, concepts, and capabilities as they relate to future land forces training for or in megacities or dense urban areas in 2025 and beyond. Featured articles include:

(1) "Man, Computer, and Special Warfare" by Patrick Duggan. Excerpt: Man-machine teaming is inexorable and Special Warfare needs a blueprint to transform along with it. With every passing day, our hyper-connected landscape spawns a new class of threats more technologically evolved than the last.

(2) "Research and Vision for Intelligent Systems for 2025 and Beyond" by Brett Piekarski, Brian Sadler, Stuart Young, William Nothwang and Raghuveer Rao. Excerpt: This paper examines the research challenges and ways we can augment that vision to enable even more capable systems and a larger impact on future operations through collective heterogeneous systems that exhibit distributed awareness, intelligence, adaptable and resilient controls and behaviors, and operational complexity.

(3) "Technical Challenges for Simulation and Training in Megacities" by Jon Watkins and Chuck Campbell. Excerpt: Megacities, urban areas with populations over 10 million people, are of growing importance to the military, and thus are of growing importance to training. It is critical for Modeling and Simulation (M&S) applications to represent those environments and situations which are inherently unusual or difficult to train live.

Acknowledgements

TRADOC G-2 would like to thank all of our partners and contributing authors who wrote papers in response to our call for papers in early 2016. There are many individuals and organizations who made contributions to the TRADOC G-2 Mad Scientist Megacities and Dense Urban Areas event where we cannot mention them all. We would principally like to acknowledge the efforts of:

ASU Research Enterprise (ASURE) for their willingness to co-sponsor the conference, logistical support, coordination, analytical support, and much more. Specifically, Dr. Fran Zenzen, Chris Fortunato, Jim Russell, and Jennifer Van Paris were instrumental in the success of the conference. We cannot thank the diligence and support of these individuals enough.

Small Wars Journal (SWJ) and their Editor in Chief, Dave Dilegge for their willingness to publish approximately 25 Mad Scientist related articles. The success of the call for paper and their impact on the concepts and capabilities communities would have not been possible without the support of SWJ. We encourage readers to visit their site at: http://smallwarsjournal.com/.

All of the authors and presenters who, most on their own time and expense, made the Mad Scientist event a success. We received more than 35 submissions as part of the call for papers and hosted more than 20 speakers during the conference at ASU. Each of these individuals played a critical role in helping the Army explore the distinctive challenges of future land forces operating in megacities and dense urban areas.[10]

Continuous Engagement

To get involved with TRADOC G-2's Mad Scientist Initiative we encourage all readers to join our All Partners Access Network (APAN) webpage at: https://community.apan.org/wg/tradoc-g2/mad-scientist/. Our APAN site is designed around the notion that Mad Scientist is a global, virtual "marketplace of ideas," enabling obscure sources/outsiders to collaborate with the Army so as to bring in new ideas via a credible, fair, and transparent process. Therefore, it is open to the public, without requiring DoD credentials for access. The site also contains information on future events and contains articles, papers, videos, and related content from all past events.

[10] For a complete list of conference presenters, please visit the TRADOC G-2 Mad Scientist Megacities and Dense Urban Areas APAN page at: https://community.apan.org/wg/tradoc-g2/mad-scientist/m/mdua

SECTION 1: "Army Operation in Megacities and Dense Urban Areas"

A Mad Scientist Perspective": This section includes an article written for ICoE's Military Intelligence Bulletin (MIPB) titled, "Army Operation in Megacities and Dense Urban Areas: A Mad Scientist Perspective." The article was written by TRADOC G-2 personnel, Joel Lawton, Matthew Santaspirt, Michael Crites, and Major Lori Shields. The article will be published during 4th Quarter FY16 (PB 34-16-3). The article details the complexities of land forces operating in megacities and dense urban areas (DUAs) and how they are exacerbated by geopolitical factors, proliferation of advanced technologies, terrain, demographics, and a potential mix of state, non-state, and hybrid actors. It also details the Mad Scientist Megacities and Dense Urban Areas conference and defines specific concepts and capabilities that future land forces will need to operate in megacities and dense urban areas.

Army Operations in Megacities and Dense Urban Areas:

A Mad Scientist Perspective

By:

Joel Lawton, Matthew Santaspirt, and Michael Crites

Edited by: Ms. Lori Shields

Vignette: Calling in the Note

On December 7, 2041 the superpower creditor nation, Red, sees an opportunity to ascend to the position of premier superpower in the world. Red calls for payment of all debts from superpower debtor nation, Blue. The same day, Red successfully seizes the Tokyo Stock Exchange with an attack in cyber space.

Acceding to Red's demands, Blue begins selling off assets in all foreign stock exchanges. This action, combined with the threat of cyber-attack from Red, throws all markets into turbulence with the exception of White's market, which is within one megacity-state (island) in south Asia. This one market owes its stability to an elite division of cyber defense troops that successfully defeats Red's cyber-attack.

Red uses all the wealth gained from Blue to accelerate economic development of Africa, including feeding, clothing, housing, and medically treating Africa's impoverished masses. Red's information warfare campaign wins approval of global mass media.

The center of world trade, within Blue boundaries, barely survives a cyber-attack from Red. With the danger mounting, Blue requests a detachment of cyber defense troops from White. White sends a regiment in exchange for ground warfare protection from Blue.

Red determines that controlling the global economy (by uniting its own two stable major markets with the Tokyo market and the White market when captured), can be accomplished with minimum bloodshed, maximum metal carnage, and localized environmental destruction in White. The key to a Red victory involves defeating Blue's vaunted robotic forces. The key to a Blue victory involves killing Red's human leadership. These factors place Blue at a distinct disadvantage in public affairs, propaganda, and information war. Blue forces moving to deployment must fight demonstrators at home.

Red moves a proxy army into attack positions on the ground north of White and a proxy navy in the South China Sea because only a physical seizure on the ground can gain control of the White stock market intact. Blue lands three armored divisions on the ground in White composed of 25 percent armored humans and 75 percent robots. Blue establishes a massive air base in White with air forces composed primarily of drones with only a small percent of command aircraft manned by human pilots. Humans are all leaders while robots are all non-rates. The reverse 75-25 composition characterizes the opposing Red forces. Red gains public sympathy by exposing more humans to combat, thus strengthening its information warfare position.

The White megacity-state's electronic warfare envelope extends forty kilometers in every direction from the White Stock Exchange. Military units of any attacker cannot communicate with each other inside the electronic warfare umbrella except by using ancient technology like land line, or at sea, flag and light signals or underwater cable. White's stock market sits four kilometers north of the shoreline. Geography makes an *amphibious landing the most likely method of attack, compared with the challenge of fighting infantry through forty kilometers of dense urban area without communications.*

Any alliance of Red with Green (superpower with proxies of criminal gang armies) or Black (regional hegemon with religious militia proxies) represents the most dangerous threat course facing Blue-White.

Mad Scientist Megacities and Dense Urban Areas Synopsis:

As in the opening vignette, the complexities of land forces operating in megacities and dense urban areas (DUAs) are exacerbated by geopolitical factors, proliferation of advanced technologies, terrain, demographics, and a potential mix of state, non-state, and hybrid actors. Urban areas are centers of commerce, transportation, politics and perhaps most importantly large portions of a nation's population. The Army has over time developed concepts, doctrine, tactics, techniques and procedures for operating in them. Such as Army Tactics, Techniques, and Procedures (ATTP) 3-06.11, "Combined Arms Operations in Urban Terrain," recognizes the importance of the Army being proficient in conducting urban operations, "urban operations are among the most difficult and challenging missions" and goes on to propose ways to "plan, prepare, and execute offensive, defensive, and stability operations."[1] However, preparing to conduct operations in a megacity or DUA presents a worst case scenario for the Army and Joint Force. Challenges are multifaceted and numerous. Future Army forces will have to conduct diverse mission sets not only in complex terrain, but against hybrid threats, contested areas, and huge numbers of noncombatants with embedded malicious actors and potentially against enemy overmatch technologies.

The types of tasks that the Army may be required to perform in megacities or in DUAs include: Non-combatant evacuation; humanitarian assistance disaster relief (HA/DR) missions; raids; deny adversary objectives; counter weapons of mass destruction operations; conduct military engagement and security cooperation; provide a global stabilizing presence; provide support to civil authorities, and counter-terrorism/counterinsurgency missions.[2] Urban operations doctrine currently considers large cities to have populations from 100,000 to 20 million, where the Army will have to prepare to conduct operations in varying scale, scope, range, and in any Operational Environment (OE).[3] Preparation does not imply intent or desire to operate in these environments, but current trends in urbanization increases the possibility for the Army and the Joint Force to have to conduct operations in megacities and DUAs.

One of the unique aspects of megacities, examined aside from less populous DUAs, is that they are economically interconnected to global systems. At the strategic or national level, megacities are “inextricably linked to global economic prosperity… warrant[ing] significant attentions across all tenets of national power.”[4] Some cities, take New York City (NYC) for example, exceed some nation states in gross domestic product and flow of commerce. A crisis in a city such as NYC can have global implications. During September 11, 2001, global trade markets lost incalculable amounts of money. Losses to NYC itself exceeded $95 billion, the insurance industry lost more than $40 billion, and another $92 billion was lost to jobs and the economy as a direct result.[5] Megacities may hold the world's concentration of commerce, goods, services, exchange of ideas and information inherent in the aggregation of the best and brightest of a nation in close contact. The problem is that not all of these cities are as resilient (the population's ability to adapt, overcome, or respond to emergency) to crisis as others.[6] The Army, Joint Force, and global community must be prepared to react and protect these economic powerhouses. Therefore, the Army should similarly be prepared to operate in DUAs (i.e., cities with populations less than 10 million), but further be able to respond to the scale and scope of a megacity in order to protect the world's flow and exchange resources and finances throughout global markets.

The Mad Scientist Initiative:

As a learning organization, the U.S. Army routinely studies the global environment to think, learn, analyze, and implement changes to its doctrine, training, and capabilities. Mad Scientist is a U.S. Army Training and Doctrine Command (TRADOC) G-2 initiative organized around themes, problem sets, and challenges the Army expects to face in the future OE. Mad Scientist enables continuous dialogue between the Joint military, international partners, academia, policy institutions, and private sector organizations to assist the Army in exploring the evolution of the OE through the year 2050. Furthermore, Mad Scientist examines the effects of technology in the far future OE to inform near-term capability investments. Mad Scientist supports this through exploring innovative ways to improve the effectiveness of the future force to ensure it can accomplish a diverse set of missions throughout the full range of military operations (ROMO) - to include operating in megacities and DUAs.

Building upon previous work, to include a 2015 report completed by the Chief of Staff of the Army (CSA) Strategic Studies Group on megacities, TRADOC G-2 partnered with Arizona State University (ASU) Foundation, the ASU Research Enterprise (ASURE) and the Intelligence Center of Excellence (ICoE) to conduct a Mad Scientist conference (21-22 April 2016, with a focus on "Megacities and Dense Urban Areas in 2025 and Beyond."). This event was critical in supporting megacity and DUAs concept and capability development. The conference was used as a venue to validate assumptions or propose concepts to interested academic, material developer, and Joint communities. Speakers at this event included senior military leadership, ASU professors, engineers, and other world renowned experts. In order to ensure that the presenters were subject matter experts in their respective fields of study, a call for papers was conducted during the selection process.

The event was organized around four overarching problem sets for future land forces operating in megacities or DUAs. These problem sets additionally served as the conference's objectives: 1) *gain situational understanding,* 2) *enable future force freedom of movement and access,* 3) *conduct expeditionary operations,* 4) and *mitigate future training challenges*. These problems sets were generally defined and were used as a basis to explore concepts and capabilities to match the complexities of these environments.

Megacity and Dense Urban Areas Problem Sets and Event Objectives:

(1) *Gain Situational Understanding*: Megacities are defined as population centers with ten million or more residents.[7] Currently, 55% of the world's population

lives in urban areas and 13% live in some 24 megacities.[8] [9] By 2025 there will be nearly 40 megacities throughout the world, posing challenges to some host nation governments to "effectively deal with their explosive growth and maintain security."[10] Globalization, domestic cultural shifts, the ubiquitous flow of information, pervasiveness of criminal networks, and social or ethnic demographic pressures will further obfuscate clear geographic separation between inhabitants.[11]

Dense populations, critical infrastructure, and the proliferation of technologies that operate within the electromagnetic spectrum pose many challenges to future forces. Army forces will not be able to rely on a "template or checklist of reconnaissance targets to reveal the nature" of a city.[12] Stressors, networks of people, lines of communication, flow of commerce, and the capacity (resilience) for a city to overcome challenges will vary throughout a single city. Intelligence Preparation of the Battlefield (IPB) will have to evaluate a variety of operational data layers that incorporates "multiple dimensions simultaneously (surface, subsurface, air, space, cyber, information, etc.) to achieve required effects."[13] Intelligence frameworks must adapt interactively to "complex operational environments, like dense urban areas, using both urban operational data layers and city as a system context and perspectives."[14]

The identification and securing of structures or infrastructure may not be easy within a megacity or DUA. Forces may have to operate within larger structures, sub-terrain, or hundreds of feet up within a building. The Army will have to consider how to employ and integrate networks of sensors with socio-cultural data, leverage multiple collection means, to develop methods that identify these areas.

Every DUA or megacity should be considered "unique and must be understood within its own historical, cultural, local, regional, and international context."[15] Ergo, the Army will examine how to achieve situational understanding under conditions it will have to operate within.

(2) *Enable Future Force Freedom of Movement and Access*: Current doctrine presupposes that Army ground forces will have complete control over "the location and circumstance of its next engagement."[16] This prediction assumes that Army task organization, formations, and execution of those mission sets will be adequate in any environment. The potential for large-scale HA/DR missions, the "dichotomy of threat conjoined with growing criticality will produce a complex security environment," and the resources to sustain operations in population centers exceeding 10 million people will challenge Mission Command and Army planners.[17] The Army will have to consider how to organize its forces to unique situations, varied missions, and rapidly changing tactical conditions.

Megacities and DUAs will be frequently "challenged by threats to their stability" that could require an Army intervention.[18] In circumstances where the Army must commit air or ground forces, the complexity of a dynamic threat may pose unforeseen risk to, for example, Soldier and vehicle protection. A one-size fits all approach to armor and protection systems may not suffice to defend against a host of potential threats in densely populated areas.

Further, both conventional and hybrid threats may employ a host of capabilities that can include: chemical, biological, radiological, nuclear, and explosive abilities; armor and anti-armor capabilities; improvised explosive devices; air and anti-air capabilities; directed energy weapons; personal armor defeating small arms rounds, and a multitude of other advanced and conventional military technologies employed by non-state, state-sponsored hybrid, and state actors.[19] “There is no silver bullet, no magic material, or countermeasure” that will protect all Army units, vehicles, and Soldiers.[20] The Army will have to explore new modular protection systems; new personal armor; moveable or adjustable armor; augmenting or replacing forces with robotics, artificial intelligence, and other technologies that can “dynamically respond to threats, rapidly reacting to changes in the threat picture.”[21]

It must too take in account how to manage or protect large population centers through: defense support to civil authorities, security cooperation activities, large-scale operations, protecting critical infrastructure, isolating combatives from the general population, and being able to provide rapid HA/DR response.[22] [23] The Army must consider the integration of Special Operation Forces to develop capable formations designed to operate in a diverse and dynamic OE. Therefore, the Army must find solutions to enable freedom of movement and access through developing capabilities that efficaciously balance protection with mobility and lethality.

(3) *Conduct Expeditionary Operations*: Expeditionary forces operate as an agile, integrated, and rapidly deployable force, able to conduct a wide range of operations, from peacetime to high-end forcible entry operations. Expeditionary operations are decentralized in nature requiring adaptive Mission Command in order to project power across all warfare domains. The Army Operating Concept (AOC) defines expeditionary maneuver as the rapid deployment of forces, "positioned forward… [to] respond and resolve crises, defeat enemies, establish security, and consolidate gains." [24] In order to conduct expeditionary operations within megacities and DUAs, the Army will have to consider new size, weight, and power applications; invest in new vertical lift abilities, and the synchronization "of capabilities critical to accomplish the mission."[25]

In order for the Army to achieve sustained expeditionary operations across a ROMO, solutions must focus on the integration of the Army's unique capabilities with Naval Expeditionary Forces over four specific areas: 1) The forward deployment of expeditionary forces—forces will have to shape the OE, be actively prepared to defuse a crisis, and defeat adversaries. 2) Sea basing operations—forces will have to use the sea as a base from which to conduct the full ROMO and provide sustained logistical support to forward deployed forces. Currently, around 40% of the world's population lives near coastlines and "population density in coastal areas will continue to increase in the future."[26] Sea basing allows Naval Forces to physically 'be there' but be off shore. Sea basing will allow the Army, Navy and Marine Corps Forces to strengthen international partnerships and ensure access to critical regions while reducing visibility and dependence on land bases. With Naval Forces controlling the sea, expeditionary forces are capable of presenting the adversary with a mobile and multi-dimensional threat. 3) Scalability of forces—expeditionary forces need to provide scalable units and capability for crisis response, up to and including forcible entry operations deep into the enemy territory. This allows commanders to tailor force footprints to evolving conditions, composite forward and merge rapidly deploying forces into a unified force scaled to the mission. The scalability of forces will also require decentralized Mission Command solutions. 4) Integration—the Army will need to integrate institutional and operational capabilities, with unified actions partners, to execute Joint Combined Arms Operations.[27] Each of these focus areas require new concepts and capabilities to support the Army in sustained expeditionary operations in megacities and DUAs.

(4) *Mitigate Future Training Challenges*: The Army will have to seek new or innovative ways to train the future force to conduct land, sea, air, cyber, and space operations in megacities and DUAs. For example, "the Army-at-large must expand the training of younger and young officers and noncommissioned officers to include the fundamental concepts that enable design methodologies" for solving complicated tactical problems in these environments.[28] Building military operations in urban terrain training (MOUT) centers "is impractical to impossible to fully recreate [for] megacities (like we do with MOUT sites) or to get access to real-world cities for live training."[29] The Army will have to consider ways for Soldiers to think critically about their environments and how to adapt to the complexities in these terrains. For the reason that the Army cannot fully reconstruct the scale and scope of megacities and DUAs, it will have to

consider technology enabled solutions such as virtual reality, immersive gaming, and modeling and simulation.

Event Themes and Insights

The Mad Scientist conference focused on megacities and DUAs in 2025 and Beyond was conducted in April of 2016 in conjunction with ASU Foundation, ASURE, and ICoE. Through presentations by subject matter experts on various megacity or DUA related issues, open discussion, and attendee discourse, we were supplied with insights, technological solutions, and issues to consider as they relate to the event's four core objectives.[30]

Gain Situational Understanding: In order to effectively operate in a megacity or DUA, the Army needs to understand the environment – physical terrain as well as human terrain.[31] In the era of ubiquitous information, intelligence can be derived from a myriad of open-source channels. For instance, through the mapping of geo-located tweets, future forces can gain a picture of where incidents are occurring (e.g., natural disaster, terrorist attack; etc.), what areas are access denied, and what type of aid is needed. Further, all of this information can be received, updated in real time, and coupled with full motion video from networked traffic cameras that are already emplaced throughout cities.[32] This type of information gathering and analysis can save time, fuel, and, most importantly, lives through early alerts and optimal route planning. Further, this type of technology is already available and will only become more accurate in the future.

Future forces would also benefit from High Resolution 3D mapping that not only represents the physical terrain found in the area of operations, but also the history.[33]

Organizing the data in space as well as time will provide increased situational understanding that allows the Soldier to recognize and appreciate how the past relates to the present.[34] A terrain map augmented with cyber-social geography and historical events that is laid out spatially and temporally would afford the Soldier with a full suite of tools to achieve mission objectives in a megacity or DUA without being hindered by cultural or social obstacles.

Enable Future Force Freedom of Movement and Access: Megacities and DUAs impose unique restrictions on access to the battlefield due to the density of tall buildings and people, as well as the use of subterranean transportation and infrastructure. With that, the use of smaller unmanned vehicles will be crucial in the future fight. Evacuating personnel will be of vital importance, and unmanned vehicles may be able to do so in denied areas. If evacuation is untenable, and treatment is needed right away, Soldiers could use an unmanned vehicle that is remotely operated. An unmanned system outfitted with sensors and video link would allow medical personnel to diagnose and administer treatment to a victim from a safe distance.[35] To fully realize this idea, the Army could take a system of systems approach to the matter.[36] That is, a suite of biometric sensors working in conjunction with an unmanned vehicle to diagnose and evacuate victims from the crisis area to a medical center where autonomous medical treatment can be administered while under the observation of a human (either in person or via video link).[37] [38]These highly integrated teams will set the Army apart from our adversaries and provide overmatch.

Conduct Expeditionary Operations: When forces are deployed abroad, the challenge will lie in fully understanding the geography as well as the formal and informal social networks. Cities in which the Army is likely to operate in the future will have geographical indicators that will be invisible to those unfamiliar to the region.[39]

In the field, Soldiers could take advantage of virtual humans to aid in face-to-face interactions and interviews, as well as assist in decision making.[40] A human-machine hybrid will outperform either a group of humans working together or a computer working independently. These virtual humans could help to interface with the local populations and increase the amount and accuracy of information received compared to a system that used only humans.[41] Being able to effectively use the local population as a resource will prove invaluable.

Mitigate Future Training Challenges: One of the unique characteristics of a megacity is its sheer size and density. Because of this, the Army will have a significant challenge in accurately representing a megacity or DUA, both physically and virtually, that provides a realistic training environment.

On the virtual side, current modeling and simulation capabilities simply cannot address all the complexities and details that an urban metropolis contains.[42] [43] The future megacity or DUA will have thousands of buildings, and in the megacity with more than 10 million people, and miles of infrastructure (both underground and aboveground). Complicating things further, the interior layout of each building is of vital importance and must be known and mapped out to be of benefit in a training environment.

Perhaps most importantly, each megacity will be distinctly different from every other megacity or DUA. This means that creating and training in a virtual model of NYC may not adequately prepare Army forces for operating in a city like Lagos, for example. In order to build a capability for the future force, the Army will have to identify and incorporate only those parts of a megacity or DUA that will matter. Simulations can be used to compartmentalize a city and experiment on certain pieces to determine what parts are of operational significance.[44]

As stated in the ‘expeditionary operations’ section, the barriers between humans and computers are lowering and machines and people are beginning to merge.[45] A human-machine hybrid will outperform either a group of people working together, or a computer working independently. It is crucial to take advantage of this improvement, but we must start now to train our forces on how to act in concert with machines.[46] Virtual humans (computers that act autonomously and mimic human behavior) have been proven to elicit more honest responses from human subjects and were even reported to make subjects feel more comfortable and open than a real person.[47] This technology would prove very useful in training our Soldiers on person to person interactions and interviews. It could potentially improve the efficiency and effectiveness of Army training while offering potential cost savings by way of being mostly virtual

Way Forward:

The complexities, challenges, and unique environments that megacities and DUAs pose to future land forces may require new concepts, capabilities, training, and doctrine.[48] The Army must seek new efficient and effective science and technology solutions accompanied with innovative training methods and supporting doctrine in order to operate in these environments.

The four overarching problem sets that Mad Scientist examined – situational understanding, future force freedom of movement and access, expeditionary operations, and training – are emblematic of most Army, academic, and subject matter expert concerns for future land forces operating in megacities and DUAs. These focus areas will require Army and Joint innovation champions to advance elements of our capabilities, training, education, and leader development. Partnerships between the DoD and academia, as well as the greater materiel development communities, will have to be codified and championed by senior DoD leadership to be successful. Using Mad Scientist as a venue and vehicle to explore outside perspectives on this problem set, the Army and Future Force will be able to augment its current approach to "Combined Arms Operations in Urban Terrain."

Currently, the Maneuver Center of Excellence (MCoE) and ICoE are leading the Army in concepts and capabilities dealing with the megacity and DUAs problem sets. For instance, MCoE has established an Urban Training Detachment at Fort Hamilton, NYC and is working in collaboration with ICoE to implement megacity OE characteristics at Combat Training Centers.[49] The Mad Scientist initiative, ASU Research Foundation, ASURE, and ICoE have informed an Army Capabilities Integration Center (ARCIC) white paper to the CSA that addresses megacity environments, future Army operations in megacities, and required capabilities for those environments.[50] Finally, ICoE in partnership with ASURE is reviewing doctrine to implement new procedures, processes, and methods to conduct IPB in megacities and DUAs.

Disclaimer: *The views and opinions in this article are those of authors' which were derived from insights captured from the 21-22 April Mad Scientist conference. Therefore, the opinions may not be reflective of any DoD or USG agency.*

Acknowledgements: TRADOC G-2 would like to thank ASU Research Foundation and ASURE for their partnership, support, and collaboration during the Megacities and Dense Urban Areas conference. We would also like to thank all the presenters, attendees, and the online community for their participation. Lastly, a special thanks to *Small Wars Journal*, particularly Dave Dilegge, for helping us with our call for papers and for publishing more than 25 articles.

[1] *Combined Arms Operations in Urban Terrain.* Headquarter, Department of the Army. ATTP 3-06.11, xii. 10 June 2011.
[2] *The U.S. Army Operating Concept: Win in a Complex World 2020-2040.* TRADOC Pamphlet 525-3-1, 9. 31 October 2014.
[3] *Combined Arms Operations in Urban Terrain.* Headquarter, Department of the Army. ATTP 3-06.11, xii. 10 June 2011.
[4] "The Megacity: Operational Challenges for Force 2025 and Beyond." Army Chief of Staff's Future Study Plan, Unified Quest 14. 2014.
[5] "How much did the September 11 terrorist attack cost America?" Institute for the Analysis of Global Security. (2004). http://www.iags.org/costof911.html.
[6] "Megacities and the United States Army: Replicating the Home Field Advantage." Chief of Staff of the Army, Strategic Studies Group Cohort III, July 2015, 87, 107, 153-154, 248, 263, 359.
[7] Kotkin, Joel, et al. 2014. "The Problem with Megacities." Chapman University, Center for Demographics and Policy, 7.
[8] Ibid, 7.
[9] "The Megacity: Operational Challenges for Force 2025 and Beyond." Army Chief of Staff's Future Study Pan, Unified Quest 14. 2014.
[10] COL Marc Harris, et al. 2014. "Megacities and the United States Army: Preparing for a Complex and Uncertain Future." Chief of Staff of the Army, Strategic Studies Group. June, 3
[11] Moser, Caroline and Cathy McLlwaine. 2014. "Editorial: New frontiers in twenty-first century urban conflict and violence." International Institute for Environment and Development (IIED). Vol 26, 2. 2 October, 336.

[12] COL Marc Harris, et al. 2014. "Megacities and the United States Army: Preparing for a Complex and Uncertain Future." Chief of Staff of the Army, Strategic Studies Group. June, 11.
[13] "The Megacity: Operational Challenges for Force 2025 and Beyond." Army Chief of Staff's Future Study Pan, Unified Quest 14. 2014.
[14] Hedges, William. 2016. "An Analytic Framework for Operations in Dense Urban Areas." Small Wars Journal. 11 March. http://smallwarsjournal.com/jrnl/art/an-analytic-framework-for-operations-in-dense-urban-areas.
[15] COL Marc Harris, et al. 2014. "Megacities and the United States Army: Preparing for a Complex and Uncertain Future." Chief of Staff of the Army, Strategic Studies Group. June, 11.
[16] Ibid, 4.
[17] Ibid, 5.
[18] Ibid, 5.
[19] Lawton, Joel and Philip Serpico. 2015. "Net Assessment: Threats to Future Army Acquisitions." Small Wars Journal. 10 October. http://smallwarsjournal.com/jrnl/art/net-assessment-threats-to-future-army-acquisitions.
[20] Scharre, Paul and Alexander Velez-Green. 2015. "Adaptive and Cooperative Protection: New Force Concepts for U.S. Army Ground Vehicles." Center for a New American Security. October, 4.
[21] Ibid, 4.
[22] Disasters are distinguished as slow onset and rapid onset events. Slow onset disasters are "slowly emerging disasters whose ongoing process is discovered, often years or even decades into the disaster" (2010). Rapid disasters have "a clear initiating event" and "marks" the start of an event (2010). Ref: Cline, Rebecca J., W., Heather Orom, Lisa Berry-bobovski, Tanis Hernandez, C. B. Black, Ann G. Schwartz, and John C. Ruckdeschel. 2010. Community-level social support responses in a slow-motion technological disaster: The case of Libby, Montana. American Journal of Community Psychology 46, no. 1-2: 1-18, http://search.proquest.com/docview/746555622?accountid=8289.
[23] "The U.S. Army Operating Concept: Win in a Complex World 2020-2040." TRADOC Pamphlet 525-3-1, 30 October 2014. 16.
[24]Ibid, 7.
[25] Ibid, 7.
[26] "What percentage of the American population lives near the coast?" National Oceanic and Atmospheric Administration (NOAA), 29 February 2016. http://oceanservice.noaa.gov/facts/population.html.
[27] Derived from conversations with Mad Scientist support staff, participants at the 21-22 April 2016 conference, and MAJ Lori Shields, Strategic Communications, TRADOC G2.
[28] "Megacities and the United States Army: Replicating the Home Field Advantage." Chief of Staff of the Army, Strategic Studies Group Cohort III, July 2015, 36.
[29] Watkins, John and Chuck Campbell. 2016. "Technical Challenges for Simulation and Training in Megacities." Small Wars Journal. 12 February. http://smallwarsjournal.com/jrnl/art/technical-challenges-for-simulation-and-training-in-megacities.
[30] Most insights were derived from speaker presentations at the 21-22 April 2016 Mad Scientist "Megacities/DUA" conference. For a list of the presenters and their topics, please visit the Mad Scientist, All Partners Access Network (APAN) website for agenda, speaker presentations, videos, and biographies. The site can be found at: https://community.apan.org/wg/tradoc-g2/mad-scientist/p/mc.
[31] Insight provided by conference speaker, Abe Usher, HumanGeo Group.
[32] Insight provided by conference speaker, Frank Prautzsch, Velocity Technology Partners LLC.
[33] Insight provided by conference speaker, Dr. Chris Tucker, Map Story.
[34] Ibid.
[35] Insight provided by conference speaker, Mr. Nathan Fisher, The Geneva Foundation.
[36] Insight provided by conference speaker, Dr. Brett Piekarski, Army Research Laboratory.
[37] Insight provided by conference speaker, Frank Prautzsch, Velocity Technology Partners LLC.
[38] Insight provided by conference speaker, Dr. George Poste, ASU.
[39] Insight provided by conference speaker, Dr. Russel Glenn, Australian National University.

[40] Insight provided by conference speaker, Dr. William Swartout, USC.
[41] Insight provided by conference speaker, Dr. Brett Piekarski, Army Research Laboratory.
[42] Insight provided by conference speakers, Dr. Fran Zenzen, ASU Research Enterprise and John Watkins, Dignitas Technologies LLC.
[43] Insight provided by conference speaker, Dr. Amy Krakowka-Richmond, USMA.
[44] Insight provided by conference speakers, Dr. Fran Zenzen, ASU Research Enterprise and John Watkins, Dignitas Technologies LLC.
[45] Insight provided by conference speaker, Dr. William Swartout, USC.
[46] Insight provided by conference speaker, COL (Ret.) Kevin Felix, The Roosevelt Group.
[47] Ibid.
[48] Insight provided by conference speaker, BG John Kem, Army University.
[49] Insight provided by conference speaker, CW4 Dennis Castellanos, MCoE.
[50] Report at time of this article is currently in staffing and review. Report title, “U.S. Army White Paper for Urban Operations in Megacities: 2020-2040.” Army Capabilities Integration Center.

SECTION 2: MITRE Report

This section is a comprehensive report developed by the MITRE Corporation. The report provides an overview of capability and technology ideas generated through the Mad Scientist Megacities initiative that address challenges posed by megacities and dense urban areas. Data for this report was captured from the Mad Scientist Megacities and Dense Urban Areas event, Megacity publications, and a Mad Scientist technology survey. Material generated through these forums is examined from the perspective of four primary Megacity Objectives (Situational Understanding, Freedom of Movement and Protection, Expeditionary Operations, and Future Training Challenges).

U.S. Army TRADOC G-2 Mad Scientist Megacities and Dense Urban Areas Initiative: Data Collection and Analysis

David N. Farrell

Dr. Megan Ward

Sponsor: U.S. Army TRADOC G-2

Department No.: J62D

Contract No.: W56KGU-15-C-0010

Project No.: 0716A92D-OE

Document No: MP160330

Location: Hampton, VA

This page intentionally left blank.

Mad Scientist: Megacities and Dense Urban Areas Compendium Section 2

Executive Summary

This report provides an overview of technologies, capabilities, and challenges identified through the Training and Doctrine Command (TRADOC) G-2 Mad Scientist (MS) initiative addressing megacity and dense urban area (DUA) challenges for 2025 and beyond.

MS is a TRADOC G-2 initiative organized around themes, problem sets, and challenges the Army expects to face in the future Operational Environment (OE) that allows for continuous learning, adaptation, innovation, and broader engagement in problem solving. Dialogue between Joint military, international partners, academia, policy institutions, and private sector organizations will help the Army explore the evolution of the OE in support of the Campaign of Learning, 2025 Maneuvers, science and technology (S&T) investments, and capability development for the Army. MS is exploring innovative ways to improve the effectiveness of the future force to ensure it can accomplish a diverse set of missions throughout the full range of military operations (ROMO) - to include operating in megacities and DUAs.

By 2050, 60% of the world's population is expected to reside in cities. Adversaries are increasingly moving to environments where U.S. advantages in detection, standoff, and precision firepower may be constrained. Further, the potential for Army involvement within cities may be exacerbated by global challenges including: liberal trade and economic coordination; climate change; nuclear proliferation; responsibility to protect, and failing states and ungoverned areas. The types of tasks that the Army may be required to perform in a megacity or in DUAs include: Non-combatant evacuation; humanitarian assistance disaster relief (HADR) missions; raids; deny adversary objectives; counter weapons of mass destruction operations; conduct military engagement and security cooperation; provide a global stabilizing presence; provide support to civil authorities, and counter terrorism/counterinsurgency missions. Megacity and DUA environments present a number of challenges that the Army must prepare for and address if it will be successful in future missions. However, military forces are unprepared for future combat in these environments.

To address this gap in U.S. military capabilities, TRADOC G-2, in collaboration with Arizona State University Research Enterprise (ASURE), Army Capabilities Integration Center (ARCIC), and the Army's Intelligence Center of Excellence (ICoE), focused on four primary objectives that align to Army Warfighting Challenges (AWFCs) as part of a MS Megacities Initiative with the objective that no U.S. Army soldier is at a disadvantage in an urban environment. The four primary megacity objectives are:

1) **Situational Understanding:** What emerging concepts and capabilities will enable Intelligence Preparation of the Battlefield (IPB); Intelligence Surveillance and Reconnaissance (ISR) capabilities; Mission Command Systems; electronic warfare (EW), and a human, demographic, and cultural understanding within megacities and dense urban areas (AWFC #1)?

2) **Freedom of Movement and Protection:** What emerging concepts and capabilities will enable access and freedom of movement in, above (buildings and airspace), below (sub-terrain), and around megacities? What new capabilities for Decentralized Urban Logistics can improve sustainment efficacy in urban areas? What will protect vehicles and Soldiers, while enabling freedom of movement, from multitude of advanced and conventional military technologies as well as environmental threats (AWFC #16)?
3) **Expeditionary Operations:** What emerging concepts and capabilities will enable expeditionary maneuver; evolve Army Health Support of Operations; enhance the ability to manage or influence large population centers, and offer solutions for achieving partner interests and strategic objectives throughout a range of military operations (during peace and combat operations; AWFC #12)?
4) **Future Training Challenges:** What emerging technologies and capabilities must the Army explore and adopt in order to realistically represent the complexities of a megacity to a training audience (home station and Combat Training Centers) allowing the development of cohesive teams that thrive in ambiguity, austerity, or chaos within the Operational Environment of 2025 and Beyond (Human Dimension Strategy Strategic Objective #2; AWFC #8).[1]

Through efforts such as a Megacities and Dense Urban Areas in 2025 and Beyond Conference that MS cohosted with ASURE and ICoE, an online MS technology survey, and a call for academic publications on megacities and DUAs, the MS Megacities Initiative encouraged dialogue and idea generation to support greater understanding of the future megacity and DUA OEs and underlying capability and technology needs.

This report provides an overview of the results of this MS Megacities Initiative. Data was captured from the Megacities and Dense Urban Areas in 2025 and Beyond Conference presentations and discussions, academic publications, and MS technology survey. Material generated through these forums was examined and findings are reported below from the perspective of the four primary megacity objectives, highlighting excerpts from MS contributors.[2]

The MS Megacities Initiative successfully addressed all four of the megacities objectives, finding that the growing complexity of the OE and more lethal opponents enabled by technology and connectivity will require advanced situational understanding and a system of systems approach to enable decisions making. To successfully operate in increasingly dense and complex environments the Army will

[1] Lawton, Joel and Grubbs, Lee, "Information Paper: Mad Scientist Conference: Megacities and Dense Urban Areas."

[2] MS contributors defined as: Any contributor of insights provided through the MS Megacity Initiative, including Megacities and Dense Urban Areas in 2025 and Beyond Conference presenters, authors of academic publications submitted in response to the MS call for papers on megacities and DUAs, contributors of ideas to the online MS technology survey, and participants discussing megacities and DUAs in the Megacities and Dense Urban Areas in 2025 and Beyond Conference virtual chat room or Twitter page.

rely on understanding and modeling interactions between human and physical systems and should leverage innovative sources of information and big data analytics for situational understanding. The Army will need to integrate expert knowledge with collective intelligence and growing sensor data and explore new analytic frameworks and innovative emerging technologies. The fundamental role of situational understanding in future Army operations is reflected by the results of the MS Megacities Initiative where this topic was the predominant theme.

With a focus on technologies to enable access and freedom of movement, MS contributors began to address the Freedom of Movement and Protection megacity objective. The Army can leverage the vertical features of megacities and DUAs environments, lessons learned from domestic emergency response and evacuation research, and technology advancements in unmanned systems to address some of these challenges to freedom of movement and protection.

To address the Expeditionary Operations megacity objective, a number of technologies were identified with potential to support medical operations in megacities and DUAs, including medical evacuation and care in the field. An intelligence model to support unified action, an operational planning framework for densely populated urban areas, and the use of virtual humans were proposed to enhance situational understanding, planning, and interactions with local populations for expeditionary operations.

The Army will have to continue to explore innovative training methods, new, interdisciplinary curriculums, evolving perspectives that embrace complexity, flexibility, and originality, and advanced technology solutions that can immerse soldiers into megacity environments to address future training challenges.

In addition to addressing topics related to the 4 primary megacity objectives, MS contributors also underscored the importance of trying to attain U.S. objectives without having to engage in and deploy military forces to a megacity or DUA.

Although a number of concepts and capability/technology ideas were generated through the MS Megacities Initiative, this work has only begun to address the complexity of megacities and DUAs. A concerted effort to continue to address this topic, to include: ensuring situational understanding remains incorporated into the TRADOC S&T Needs for the Warfighter; leveraging the TRADOC critical thinking enterprise to focus on megacities and DUAs from the system of systems perspective; exploring the utility of various proposed analytic frameworks; further examining the human component of megacities and DUAs, including informal social networks and governance structures; pilot programs to leverage and integrate diverse data sets; exploring collaboration methods to further engage additional interdisciplinary subject matter experts; and addressing concepts and capabilities to avoid military engagement in megacities and DUAs when possible will further build on the success of the MS Megacities Initiative.

Introduction: Megacities Initiative for Collaboration and Idea Generation

Mad Scientist (MS) is a Training and Doctrine Command (TRADOC) G-2 initiative organized around themes, problem sets, and challenges the Army expects to face in the future Operational Environment (OE) for the far future (2040-2050). MS allows for continuous learning, adaptation, innovation, and broader engagement in problem solving. Dialogue between Joint military, international partners, academia, policy institutions, and private sector organizations will help the Army explore the evolution of the OE in support of the Campaign of Learning, 2025 Maneuvers, S&T investments and capability development for the Army. MS is exploring innovative ways to improve the effectiveness of the future force to ensure it can accomplish a diverse set of missions throughout the full range of military operations (ROMO) - to include operating in megacities and Dense Urban Areas (DUAs).

By 2050, 60% of the world's population is expected to reside in cities. Adversaries are increasingly moving to environments where U.S. advantages in detection, standoff, and precision firepower may be constrained. Further, the potential for Army involvement within cities may be exacerbated by global challenges including: liberal trade and economic coordination; climate change; nuclear proliferation; responsibility to protect, and failing states and ungoverned areas. The types of tasks that the Army may be required to perform in a megacity or in DUAs include: Non-combatant evacuation; humanitarian assistance disaster relief (HADR) missions; raids; deny adversary objectives; counter weapons of mass destruction operations; conduct military engagement and security cooperation; provide a global stabilizing presence; provide support to civil authorities, and counter terrorism/counterinsurgency missions. Megacity and DUA environments present a number of challenges that the Army must prepare for and address if it will be successful in future missions. However, military forces are unprepared for future combat in these environments.

To address this gap in U.S. military capabilities, TRADOC G-2, in collaboration with Arizona State University Research Enterprise (ASURE), Army Capabilities Integration Center (ARCIC), and the Intelligence Center of Excellence (ICoE), focused on four primary objectives that align to Army Warfighting Challenges (AWFCs) as part of a MS Megacities Initiative with the objective that no U.S. Army soldier is at a disadvantage in an urban environment. The four primary megacity objectives are:

1) **Situational Understanding:** What emerging concepts and capabilities will enable Intelligence Preparation of the Battlefield (IPB); Intelligence Surveillance and Reconnaissance (ISR) capabilities; Mission Command Systems; electronic warfare (EW), and a human, demographic, and cultural understanding within megacities/dense urban areas (AWFC #1)?
2) **Freedom of Movement and Protection:** What emerging concepts and capabilities will enable access and freedom of movement in, above (buildings and airspace), below (sub-terrain), and around megacities? What new

capabilities for Decentralized Urban Logistics can improve sustainment efficacy in urban areas? What will protect vehicles and Soldiers, while enabling freedom of movement, from multitude of advanced and conventional military technologies as well as environmental threats (AWFC #16)?

3) **Expeditionary Operations:** What emerging concepts and capabilities will enable expeditionary maneuver; evolve Army Health Support of Operations; enhance the ability to manage or influence large population centers, and offer solutions for achieving partner interests and strategic objectives throughout a range of military operations (during peace and combat operations; AWFC #12)?

4) **Future Training Challenges:** What emerging technologies and capabilities must the Army explore and adopt in order to realistically represent the complexities of a megacity to a training audience (home station and Combat Training Centers) allowing the development of cohesive teams that thrive in ambiguity, austerity, or chaos within the Operational Environment of 2025 and Beyond (Human Dimension Strategy Strategic Objective #2; AWFC #8).[3]

The MS Megacities Initiative provided multiple forums for collaboration and idea generation, including the Megacities and Dense Urban Areas in 2025 and Beyond Conference, an online MS technology survey, and a call for academic publications on megacities and DUAs, to support understanding of the future OE and underlying capability and technology needs.

This report provides an overview of the results of this MS Megacities Initiative. Data was captured from the MS Megacities and Dense Urban Areas Conference presentations and discussions, academic publications, and MS technology survey. Material generated through these forums was examined and findings are reported below from the perspective of the four primary megacity objectives (Situational Understanding, Freedom of Movement and Protection, Expeditionary Operations, and Future Training Challenges), highlighting excerpts from MS contributors.[4] This report does not provide a comprehensive review of all megacity-related concepts, challenges, and needs but instead, provides an overview of the key megacity concepts and ideas generated through the MS Megacities Initiative.

Megacities and Dense Urban Areas in 2025 and Beyond Conference

On 21-22 April, 2016, MS cohosted an event with ASURE and ICoE designed to examine complexities of future land forces operating in megacities and DUAs. This Megacities and Dense Urban Areas in 2025 and Beyond Conference examined how future forces will gain situational understanding; obtain freedom of movement and

[3] Lawton, Joel and Grubbs, Lee, "Information Paper: Mad Scientist Conference: Megacities and Dense Urban Areas."

[4] MS Contributor defined as: Any contributor of insights provided through the MS Megacity Initiative, including Megacities and Dense Urban Areas in 2025 and Beyond Conference presenters, authors of academic publications submitted in response to the MS call for papers on megacities and DUAs, contributors of ideas to the online MS technology survey, and participants discussing megacities and DUAs in the Megacities and Dense Urban Areas in 2025 and Beyond Conference virtual chat room or Twitter page.

access; improve the ability to conduct expeditionary operations; and address future training challenges. Over 140 participants attended from the military, academia, and industry with nearly 40% from outside the Army. The Megacities and Dense Urban Areas Conference also included a virtual component with over 500 individuals participating through web streaming, a chat room, and Twitter - #madsci16 (See Appendix 2 for list of speakers and presentations).

Mad Scientist Technology Survey
An online technology survey (available at https://survey.max.gov/818145) was used to capture input on capability and technology ideas that could impact the OE and U.S. forces. Contributors were asked to provide a title and description of their capability/technology idea and to rate their idea across several applicable categories; specifically, eight Levels of Effort (LOEs), six Technology Imperatives, 20 Army Warfighting Challenges (AWFCs) and four megacities objectives. Contributors representing academia, government, and industry submitted 63 capability/technology ideas that were applicable to the megacity and dense urban environment topic (identified by contributor through a survey question asking if their nominated idea is “applicable to megacities/dense urban environments”).

Megacity and DUA Academic Publications
In 2015, TRADOC G-2 put out a call for papers that address one or more of the four primary megacity objectives. 34 academic publications on megacities and DUAs submitted in response to this call for papers were reviewed and categorized based on the extent to which they addressed one or more of the 4 megacity objectives (primarily or somewhat addressed one or more megacity objectives; see Appendix 3: Methodology for details).

The following section presents some general themes and challenges identified from insights gathered from the MS Megacities Initiative. These general themes and challenges include broad, recurring topics relevant across multiple megacity objectives. This section sets the stage for subsequent sections containing a more detailed review of insights categorized by the 4 megacity objectives.

General Themes and Challenges

A megacity is the un-consumable elephant; the number of bites needed to address all of its requirements would far exceed any coalition's capabilities.[5]

The likelihood that the U.S. Army will have to operate in megacities and DUAs is increasingly probable and these environments present a number of challenges that the Army must prepare for and address if it will be successful in future missions.[6][7] Major cities "grow together" forming regions of dense populations that stretch hundreds of kilometers and can encompass over 100 million people. [8] These dense urban environments are extremely complex: modern cities are multidimensional (subterranean, surface, and vertical); cities are interconnected through globalization, social media, and modern methods of communication/information dissemination; cities are difficult to control.[9] Each megacity will be unique in its complexity and numerous characteristics will complicate and differentiate these environments (demographics, infrastructure, public health and disease, technologies, connectivity and social media, and warfare groups).

The multitude of forces that will constantly impact the OE in megacities and DUAs will be important considerations as the Army develops capabilities to operate in these environments. Key megacity and DUA drivers include demographics (people), natural resources (water, oil, land), and globalization (interconnectivity).[10] The human factor will remain a crucial element as the military prepares to engage in megacities and DUAs, especially as the future becomes increasingly populated by a new species defined as "homo sapiens sapiens.net". This new species will live their lives persistently linked to their supercomputer smartphones and connected to a global virtual network. How this new species learns, communicates, and is influenced will be a key area of focus in the megacities and DUA domain.[11] Future Army forces will have to conduct missions against state, non-state, and hybrid threats surrounded by dense populations of noncombatants. Through the MS Megacities Initiative, MS contributors provided insights into a number of additional challenges the future Army will face in megacities and DUAs.

Challenges the Army Will Face in Megacities and DUAs Include:

- Rapid growth in urban areas will produce more demand on the infrastructure and flow systems, more waste, and increased urban density.[12]

[5] Glenn, Russell Dr., "Megacities: The Good, the Bad, and the Ugly."
[6] Hedges, William CSM (Ret.), "An Analytical Framework for Operations in Dense Urban Terrain."
[7] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."
[8] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."
[9] Wolfel, Richard, et al., "It's in There: Rethinking(?) Intelligence Preparation of the Battlefield in Megacities/Dense Urban Areas."
[10] Ward, Darryl, "Operational Environment Implications of the Megacity to the US Army."
[11] Crow, Michael Dr., "Welcome Remarks, Day 1." Megacities/DUA Conference Presentation.
[12] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."

- A major challenge of megacities is density (data, people, and infrastructure).[13]
- The lack of a clearly demarcated boundaries for the area of operations will be problematic.[14] The Army will have to consider the rural and regional areas around megacities as well as the world-wide implications of operations within megacities.[15]
- The proliferation of advanced weaponry coupled with the rapid digital spread of information and ideology, allows anyone to be a threat, and will lead to growing instability in many parts of the world.[16]
- Changing infrastructure, subcultures, and places to "hide in plain sight" present a particular challenge to data gathering."[17]
- Megacities are more susceptible to natural and manmade disasters when in close proximity to large bodies of water. Extreme water events caused by floods, hurricanes, typhoons, and tsunamis will exacerbate life threatening situations in areas of increased urbanization.[18]
- Urban vertical and subterranean warfare significantly complicate Army operations, freedom of movement, and force protection.[19][20]
- Disease in megacities can result in catastrophic, global outcomes. Infectious disease will interface with urbanization, impacting military missions (e.g. warfare, humanitarian missions, and force protection). Rapid growth of dense urban areas in developing countries will continue to push people into environments that put them in greater contact with animal reservoirs of disease. Denial, fear, misinformation, decontamination, and disposal are among the many factors future military forces may have to contend with.[21]

The Army is Not Prepared to Operate in Megacities
The complexity and uniqueness of megacities will greatly impact the Army's thinking and future capabilities to operate in these environments.[22] Megacities and DUAs may pose the most significant security challenge in future decades, one for which the U.S. is not well prepared to counter.[23] In addition to the inherent complexities of a megacity, non-state actors have turned to complex urban terrains to avoid confronting superior Western military forces and to compensate for their inferior

---

[13] Rose, James "Greg", "Army Panel on Megacities." Megacities/DUA Conference Presentation.
[14] Wolfel, Richard PhD et al., "It's in There: Rethinking(?) Intelligence Preparation of the Battlefield in Megacities/Dense Urban Areas."
[15] Glenn, Russell Dr., "Megacities: The Good, The Bad, and The Ugly." Megacities/DUA Conference Presentation.
[16] Richmond, Todd, "The Innovation Spectrum - Exploring Left of Boom."
[17] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."
[18] Ward, Darryl, "Operational Environment Implications of the Megacity to the US Army."
[19] Prautzch, Frank, "U.S. Army Mega City Operations: Enduring Principles and Innovative Technologies." Megacities/DUA Conference Presentation.
[20] Ward, Darryl, "Operational Environment Implications of the Megacity to the US Army."
[21] Poste, George Dr., "Health Innovation for Dense Urban Areas." Megacities/DUA Conference Presentation.
[22] Glenn, Russell Dr., "Megacities: The Good, the Bad, and the Ugly."
[23] Kozloski, Robert, "Power Through Stability."

military capabilities.[24] These adversaries will continue to expand into dense urban areas to hide among the population and it will become more difficult to effectively fight enemies using conventional military weapons.[25] [26] [27] With Western military technology and training designed for more open environments, current military operating procedures and perspectives may not be adequate to overcome the challenges of megacities. [28] [29] The U.S. Army still relies heavily on traditional methods of individual (scout, leader observation, etc.) as well as platform (imagery and intelligence) observation, two-dimensional mapping, and population surveying that may no longer be sufficient.[30]

According to Dr. Douglas Ollivant, the U.S may not have been fighting first tier opponents for the last 15 years, leaving our military forces unprepared for future combat.[31] Advanced opponents, known as hybrid warriors, are significantly closing the gap between state and non-state forces and they are enabled by technology and connectivity. Dr. Douglas Ollivant noted that by 2050, hybrid warrior groups will be operating in a megacity and DUA environments.[32] However, current models focus on non-hybrid warrior-like opponents.[33]

The expansive area and density of megacities and DUAs are likely to prohibit traditional military models of overpowering, isolating, and controlling populations in these environments.[34] Consequently, U.S. military forces will have to increase their emphasis on influencing populations and narratives in megacity and DUA environments.[35] Adaptability will also be key in understanding and operating in these complex environments. Each megacity is unique and continuously evolving, therefore there will not be a single solution for how to understand, operate in, and train for a megacity or DUA environment but a number of possible solutions that are situationally dependent.[36] This complexity will require an interdisciplinary, collaborative approach to address the megacities problem.[37] Determining routines and patterns in megacity systems will necessitate data compilation and analysis beyond what is currently available to the Army today.[38] Big data analytics will become a necessity as new sources of data, including social media, are leveraged to enable insights through an examination of aggregate behaviors collective

---

[24] Glenn, Russell Dr., "Megacities: The Good, the Bad, and the Ugly."
[25] Kozloski, Robert, "Power Through Stability."
[26] Quintas, Leopold BG et al., "Welcome Remarks." Megacities/DUA Conference Presentation.
[27] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."
[28] Morrison, Dawn A. and Wood, Colin D., "Megacity and Dense Urban Environments: Obstacles or Opportunity?"
[29] Glenn, Russell Dr., "Megacities: The Good, the Bad, and the Ugly."
[30] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."
[31] Ollivant, Douglas Dr., "Hybrid Warfare in Urban Environment." Megacities/DUA Conference Presentation.
[32] Ollivant, Douglas Dr., "Hybrid Warfare in Urban Environment." Megacities/DUA Conference Presentation.
[33] Ollivant, Douglas Dr., "Hybrid Warfare in Urban Environment." Megacities/DUA Conference Presentation.
[34] Glenn, Russell Dr., "Megacities: The Good, the Bad, and the Ugly."
[35] Prautzch, Frank, "U.S. Army Mega City Operations - Enduring Principles and Innovative Technologies."
[36] Glenn, Russell Dr., "Megacities: The Good, The Bad, and The Ugly." Megacities/DUA Conference Presentation.
[37] Kem, John BG, "Welcome Remarks." Megacities/DUA Conference Presentation.
[38] Glenn, Russell Dr., "Megacities: The Good, the Bad, and the Ugly."

intelligence.[39] A system of systems approach to this analysis was a common theme discussed by MS contributors to support situational understanding, for future unmanned systems that support military missions, and for biosurveillance for force protection and outbreak response.[40] [41] [42] [43] [44]

Shifting Army Doctrine

Megacity and DUA environments are not an entirely new challenge, therefore, the Army should avoid creating completely new paradigms and instead, draw on the past to innovate instead of invent.[45] [46] However, these challenging environments will still require shifts in Army doctrine and methods. The need for more megacity-specific doctrine (discussed in greater detail in subsequent sections) is needed in a number of areas, including:[47]

- **Adoption of a city as a system perspective** will require adaptation of a significant portion of Army doctrine resulting in an urban analytic framework tailored to address the operational data layers found within urban centers, their environmental dynamism, and their state of connectedness.[48]
- The dynamic nature of urban environments demands an **expansion of traditional Intelligence Preparation of the Battlefield (IPB) thinking.** IPB often fails to gain sight of the dynamics between the components of problems within an interactively complex system and is not conducive to an interactively complex OE.[49] The basic definition of IPB often does not take into account how the variables explaining DUAs are increasingly interconnected, offers little instruction on how to address a complex, multidimensional environment, and provides little operational advice or examples.[50]
- Megacities research needs to better **address the likelihood of more lethal competitors**. Current mental models are stuck on none-hybrid warrior-like opponents.[51]

---

[39] Dixon, Robert COL, “Bringing Big Data to War in Mega-Cities.”
[40] Morrison, Dawn A. and Wood, Colin D., “Megacity and Dense Urban Environments: Obstacles or Opportunity?”
[41] Kwon, Paul O. LTC, “Integrated Global Health Surveillance and Response through Multi-Source Technologies.”
[42] Poste, George Dr., “Health Innovation for Dense Urban Areas.” Megacities/DUA Conference Presentation.
[43] Fisher, Nathan, “Unmanned Systems in Support of Future Medical Operations in Dense Urban Environment.” Megacities/DUA Conference Presentation.
[44] Piekarski, Brett Dr., “Research and Vision for Intelligent Systems for 2025 and Beyond.” Megacities/DUA Conference Presentation.
[45] Glenn, Russell Dr., “Megacities: The Good, The Bad, and The Ugly.” Megacities/DUA Conference Presentation.
[46] Prautzch, Frank, “U.S. Army Mega City Operations: Enduring Principles and Innovative Technologies.” Megacities/DUA Conference Presentation.
[47] Glenn, Russell Dr., “Megacities: The Good, the Bad, and the Ugly.”
[48] Hedges, William CSM (Ret.), “White Paper: An Analytic Framework for Operations in Dense Urban Areas.”
[49] Hedges, William CSM (Ret.), “White Paper: An Analytic Framework for Operations in Dense Urban Areas.”
[50] Wolfel, Richard PhD et al., “It’s in There: Rethinking(?) Intelligence Preparation of the Battlefield in Megacities/Dense Urban Areas.”
[51] Ollivant, Douglas Dr., “Hybrid Warfare in Urban Environment.” Megacities/DUA Conference Presentation.

- Changes in doctrine to enable the **development of knowledge experts in megacities** is needed where personnel are assigned to monitor cities.[52]
- Greater **emphasis on strategically supporting, manipulating and/or undermining the flows, infrastructure, and systems of the megacity** as opposed to current emphasis on kinetic, military tasks.[53]
- The Army must change its thinking to **focus more on rigorous big data-driven analysis**, instead of relying largely on the same reductionist models that limit holistic thinking.[54]
- The Army must **change its attitude towards cyberwarfare** and innovate new ideas and concepts for warfare.[55]
- A shift in how medical data is defined, stored, captured, visualized, and shared is needed for more easily transportable semi-autonomous and autonomous Tactical Combat Casualty Care capabilities to support future missions. This will require a **paradigm shift in the practice of operational medicine** from an "art" that employs subjective measures to assess and treat, to a "science" based on employing objective quantifiable measures.[56]
- **Faster technological iteration and adaptation** is needed as opposed to large, long-term development, acquisition, and sustainment programs. Smaller, faster, and more flexible systems to supplement, or supersede, existing weapons and other systems with rapid prototyping, small automated production runs, remote software updates, and development and deployment to upgrade a soldier's tools in months or weeks will be needed.[57]

Frameworks Proposed

In addition to proposing specific technology ideas, a number of MS contributors proposed broader frameworks that may help the Army shift its perspective and analytic approach towards megacities and DUAs, including:

- Hardware/software/outcomes framework of analysis for urban areas to conceptualize the issues in a megacity.[58]
- **Operationalized megacity framework** for assessing the integrated system quality of each megacity for purposes of projecting the effects of military operations in that environment.[59]

---

[52] Zenzen, Fran Dr., "Frameworks for Future Challenges: Understanding Dense Urban Terrain." Megacities/DUA Conference Presentation.

[53] Morrison, Dawn A. and Wood, Colin D., "Megacity and Dense Urban Environments: Obstacles or Opportunity?"

[54] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."

[55] Duggan, Patrick COL et al., "Army Panel on Megacities." Megacities/DUA Conference Presentation.

[56] Berkow, Jan and Poropatich, Ron COL(R), "TRAuma Care in a Rucksack (TRACIR) - A Disruptive Technology Concept."

[57] Richmond, Todd, "The Innovation Spectrum - Exploring Left of Boom."

[58] Otto, Gustav and Besik, AJ, "Megacity Madness."

[59] Morrison, Dawn A. and Wood, Colin D., "Megacity and Dense Urban Environments: Obstacles or Opportunity?"

- **Complexity theory and ESA framework** to facilitate the rapid understanding of complex populations in a way that can be communicated across large organizations and leveraged to conduct operations that are more effective.[60] [61]
- **Urban analytic framework** to address the operational data layers found within urban centers and the relationships between different parts of the environment and understanding the cumulative effects of these interactions. This analytic framework supports development of courses of action (COA) for operations occurring in dense urban areas.[62] [63]
- **An intelligence model to better support unified action** involving the U.S. Army's Regionally Aligned Forces (RAF) and associated joint, interagency, intergovernmental, and multinational partners (JIIM) to extend and accelerate intelligence in Unified Land Operations (ULO) through more collective network engagement practices and joint targeting processes.[64]
- **An operational planning framework for urban operations** in relation to densely populated urban geography with seven lines of effort.[65]
- **The cyber-enabled Special Warfare (CE-SW) pyramid** advances a conceptual framework to align technology, tools, and tactics for a new contemporary cyber-enabled Special Warfare practice.[66]

The following section provides a more detailed examination of the insights provided by MS Contributors categorized by the four primary megacity objectives.

[60] Pike, Tom, Long, Nick, and Alexander, Perry, "Understanding Nations: New Ideas to Analyze Foreign States."
[61] Pike, Tom MAJ and Brown, Eddie MAJ, "Populations as Complex Adaptive Systems: A Case Study of Corruption in Afghanistan."
[62] Hedges, William CSM (Ret.), "White Paper: An Analytic Framework for Operations in Dense Urban Areas."
[63] Hedges, William CSM (Ret.), "An Analytical Framework for Operations in Dense Urban Terrain." Megacities/DUA Conference Presentation.
[64] Morris, Victor R., "Tailoring Intelligence and Analytic Support to Regionally Aligned and Multinational Forces - Collective Network Identification and Engagement Requirements for Unified Action Partners."
[65] Demarest, Geoff, "How to Hold or Take a Big City - Seven Lines of Effort."
[66] Duggan, Patrick COL, "Man, Computer, and Special Warfare."

Alignment of Contributor Insights to Megacity Objectives

Situational Understanding

What emerging concepts and capabilities will enable Intelligence Preparation of the Battlefield (IPB); Intelligence Surveillance and Reconnaissance (ISR) capabilities; Mission Command Systems; electronic warfare (EW), and a human, demographic, and cultural understanding within megacities/dense urban areas?

Overview

The growing complexity of the OE and more lethal opponents enabled by technology and connectivity require advanced situational understanding to enable decision making. The fundamental role of situational understanding in future Army operations is reflected by the results of the MS Megacities Initiative, where this topic was the predominant theme.

- Situational understanding was a major topic of discussion throughout the April 2016 Megacities and Dense Urban Areas in 2025 and Beyond Conference.
- 90% of megacity academic publications and ideas submitted to the MS technology survey addressed the Situational Understanding megacity objective. This megacity objective was addressed the most by academic publications and ideas submitted to the MS technology survey.
- 71% of ideas submitted to the MS technology survey addressed AWFC #1: Develop Situational Understanding. The was the most addressed AWFC by ideas submitted to the MS technology survey.
- The majority of ideas proposed through the technology survey by contributors affiliated with Academia (86%) and Government (87%) addressed the Situational Understanding megacity objective. 100% of ideas submitted by contributors affiliated with Industry or "Other" addressed Situational Understanding.

(See the Qualitative Summary of Data section below for more details about data alignment to megacity objectives and AWFCs).

To successfully operate in increasingly dense and complex environments, the Army will rely on understanding and modeling interactions between human and physical systems. Increased urbanization will create both challenges and opportunities, requiring new sources of information and big data analytics that the Army can leverage for situational awareness and intelligence operations. The Army will need to integrate expert knowledge with collective intelligence that aggregates disparate and dense data sources such as cyber-social geography and growing sensor data. The Army must explore and leverage new analytic frameworks and innovative emerging technologies while applying a system of systems perspective to megacities and DUAs for predictive capabilities and rapid decision making.

Challenges and Opportunities

A number of challenges to data gathering and situational understanding were highlighted by MS contributors. The dynamic and complex character of megacities presents a particular challenge to intelligence operations. Consequently, the Army will have to move beyond relying heavily on traditional methods of observation, mapping, and population surveying and approaches that emphasize discrete problem sets and well-defined regions. [67] [68] Although these methods were sufficient, understanding how well traditional intelligence methods are suited to provide situational understanding in megacities and DUAs will inform the development of new processes and technologies.[69] [70] For example:

- Dr. Richard Wolfel et al. highlighted that the basic definition of IPB often does not take into account how the variables explaining dense urban areas are increasingly interconnected, offers little instruction on how to address the complex, multidimensional environment, and provides little operational advice or examples.[71]
- According to CSM (Ret) William "Bill" Hedges, IPB often fails to gain sight of the dynamics between the components of problems within an interactively complex system and is not conducive to these complex OEs.[72]
- An expansion of traditional IPB thinking is needed to account for how megacity and DUA variables are interconnected in these complex systems.[73] [74]

MS contributors highlighted the importance of understanding the human terrain in megacities and DUAs. People are a critical factor to consider when analyzing these environments, however, an in-depth understanding of populations is not always part of military megacity preparation. [75] [76] The interaction between infrastructure and the human terrain further complicates situational understanding, especially as individuals change dimensions from the subterranean through the vertical dimensions of megacities.[77] Understanding the spatial and temporal patterns of daily life can enable modeling and forecasting of population movement, behavior, and reaction

---

[67] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."
[68] Wolfel, Richard PhD et al., "It's in There: Rethinking(?) Intelligence Preparation of the Battlefield in Megacities/Dense Urban Areas."
[69] Wolfel, Richard PhD et al., "It's in There: Rethinking(?) Intelligence Preparation of the Battlefield in Megacities/Dense Urban Areas."
[70] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."
[71] Wolfel, Richard PhD et al., "It's in There: Rethinking(?) Intelligence Preparation of the Battlefield in Megacities/Dense Urban Areas."
[72] Hedges, William CSM (Ret.), "White Paper: An Analytic Framework for Operations in Dense Urban Areas."
[73] Wolfel, Richard PhD et al., "It's in There: Rethinking(?) Intelligence Preparation of the Battlefield in Megacities/Dense Urban Areas."
[74] Hedges, William CSM (Ret.), "White Paper: An Analytic Framework for Operations in Dense Urban Areas."
[75] Morrison, Dawn A. and Wood, Colin D., "Megacity and Dense Urban Environments: Obstacles or Opportunity?"
[76] Otto, Gustav and Besik, AJ, "Megacity Madness."
[77] Wolfel, Richard PhD et al., "It's in There: Rethinking(?) Intelligence Preparation of the Battlefield in Megacities/Dense Urban Areas."

within the megacity environment to facilitate military operations.[78] In addition to the human terrain, several other considerations important for situational understanding in megacities and DUAs were identified by MS contributors including:

- **Infrastructure:** Characteristics and quality of infrastructure within a megacity.[79]
- **Integration:** The degree to which an environment is highly or loosely integrated.[80]
- **Invisible geographies**: Awareness of "invisible geographies" where seen and unseen features (ex: cultural forces, religious systems, old and new infrastructure) intersect.[81]
- **Weather:** Megacity and DUAs can be heavily influenced by microscale weather conditions that can differ significantly from block to block, especially in areas near large bodies of water. Current capabilities cannot accurately represent these rapidly changing and complex microclimates. Military operations will require comprehensive weather support, including accurate information about these microclimates, as well as a better understanding of the different ways weather may impact friendly forces, noncombatants, and adversaries. Future weather-related research to improve weather prediction capabilities should include:[82]
    - Understanding atmospheric processes in megacities and DUAs.
    - Understanding battlefield sensor performance.
    - Advanced development of microscale weather models.
    - New weather related decision aids that include prediction of human domain conditions based on weather combined with reactions of a population to military operations.
- **Disease and Biosurveillance:** Disease in megacities can result in catastrophic, global outcomes. It is important to consider the nature of disease threats as megacities become more prevalent and how this may impact stability, humanitarian needs, military missions, and force protection. Surveillance and accurate diagnosis is key to addressing global biosecurity threats.[83]

[78] Morrison, Dawn A. and Wood, Colin D., "Megacity and Dense Urban Environments: Obstacles or Opportunity?"
[79] Morrison, Dawn A. and Wood, Colin D., "Megacity and Dense Urban Environments: Obstacles or Opportunity?"
[80] Morrison, Dawn A. and Wood, Colin D., "Megacity and Dense Urban Environments: Obstacles or Opportunity?"
[81] Fin, Ed Dr., "Stories and Visions for a Better Future." Megacities/DUA Conference Presentation.
[82] Knapp, David, Randall, Robb, and Staley, Jim, "Atmospheric Impacts and Effects Predictions and Applications for Future Megacity and Dense Urban Area Operations."
[83] Poste, George Dr., "Health Innovation for Dense Urban Areas." Megacities/DUA Conference Presentation.

Unique characteristics of megacities and DUAs also offer opportunities the Army can leverage to address the Situational Understanding megacity objective.[84] [85] For example, Dr. Russell Glenn noted that a trained and educated population can provide situational understanding to increase the chance of early detection (e.g. disease events) and interdiction. Larger, dense areas also tend to offer a breadth and depth of information that may not be available elsewhere, such as demographic and cell phone data useful for tracking events.[86] [87]

Potential Data Sources

Enormous amounts of data about a city and its population is now readily available and MS contributors identified a number of potential sources of intelligence as well as analytic concepts to support situational understanding of megacities and DUAs, including:[88]

- **Internet of Things (IOT):** The Army can leverage the internet of things (IOT) for situational understanding in megacities and DUAs. Data obtained from connected devices, personal electronic devices, and deployed unmanned systems could be combined to create a real-time 3D model of a building, including the interior. This information could identify occupants in the building to increase force protection and reduce the risk of civilian casualties. Additionally, the military can access traffic and security cameras in combination with other devices for situational understanding outside buildings and throughout a city. This reservoir of data can be collected and analyzed and changes in these systems can be observed in real time as data streams are updated continuously. Most importantly, this could be accomplished with a minimal military presence in the city itself.[89] [90]
- **Collective Intelligence:** Collective intelligence exploits available information, such as social media data, for situational understanding and predictive capabilities in complex environments. Individual pieces of information can be aggregated into a meaningful whole to provide valuable insight about a population's behaviors.[91] Included in this are proxy variables, pieces of information that can provide situational understanding about seemingly

[84] Morrison, Dawn A. and Wood, Colin D., "Megacity and Dense Urban Environments: Obstacles or Opportunity?"
[85] Glenn, Russell Dr., "Megacities: The Good, The Bad, and The Ugly." Megacities/DUA Conference Presentation.
[86] Glenn, Russell Dr., "Megacities: The Good, the Bad, and the Ugly."
[87] Glenn, Russell Dr., "Megacities: The Good, The Bad, and The Ugly." Megacities/DUA Conference Presentation.
[88] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."
[89] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."
[90] Crane, Alfred and Peeke, Richard LTC, "Using the Internet of Things to Gain and Maintain Situational Awareness in Dense Urban Environments and Mega Cities."
[91] Usher, Abe, "Addressing the Challenges of the Human Terrain in 2050." Megacities/DUA Conference Presentation.

unrelated events.[92] The convergence of distributed sensor networks with social media data will further strengthen the utility of collective intelligence.[93] [94] Human review, intuition, and knowledge in conjunction with systems to baseline human biases are needed for effective data interpretation.[95]

- **Cyber-Social Geography:** According to Dr. Chris Tucker, the physical terrain is only one important dimension of geography in dense urban environments. Digital neighborhoods must be overlaid with physical neighborhoods using High Resolution 3D mapping to visualize the cyber-social geography of a megacity for situational understanding. It is also important to organize all data, warfighting functions, and narratives in space and time. [96]
- **Science Fiction and Storytelling:** Science fiction and storytelling provide a shared language for foresight, strengthens resilience, and provides a tool to examine and understand complicated challenges. Science fiction and storytelling are inexpensive and allow for extrapolation and integration from different fields of study to explore a broader space.[97]
- **Biometrics:** Biometrics is the process of recognizing an individual based on measurable anatomical, physiological, and behavioral characteristics.[98] Biometrics-enabled intelligence can contribute to the discovery of unknown potential adversaries and characterize their level of potential threat to U.S. interests.[99] Integrated intergovernmental production and sharing is required for biometric enabled intelligence to accurately identify known or suspected adversaries living amongst a larger population.[100]
- **Autonomous Vehicles:** Autonomous vehicles can provide rapid situational understanding about unfamiliar environments as military forces are deployed to these locations.[101] Swarms of unmanned ground/air microvehicles could be equipped with weather sensors to dramatically improve currently

[92] Usher, Abe, "Addressing the Challenges of the Human Terrain in 2050." Megacities/DUA Conference Presentation.
[93] Usher, Abe, "Addressing the Challenges of the Human Terrain in 2050." Megacities/DUA Conference Presentation.
[94] Richmond, Todd, "The Innovation Spectrum - Exploring Left of Boom."
[95] Usher, Abe, "Addressing the Challenges of the Human Terrain in 2050." Megacities/DUA Conference Presentation.
[96] Tucker, Chris Dr., "Emerging Geographical Tools to Understand Dense Urban Areas." Megacities/DUA Conference Presentation.
[97] Fin, Ed Dr., "Stories and Visions for a Better Future." Megacities/DUA Conference Presentation.
[98] Morris, Victor R., "Enhancing Intergovernmental Counter-Terrorism and Identity Discovery Capabilities through Identity and Biometric Enabled Intelligence."
[99]Morris, Victor R., "Enhancing Intergovernmental Counter-Terrorism and Identity Discovery Capabilities through Identity and Biometric Enabled Intelligence."
[100] Morris, Victor R., "Enhancing Intergovernmental Counter-Terrorism and Identity Discovery Capabilities through Identity and Biometric Enabled Intelligence."
[101] Piekarski, Brett Dr., "Research and Vision for Intelligent Systems for 2025 and Beyond." Megacities/DUA Conference Presentation.

inadequate local weather condition sensing.[102] MS contributors also discussed the utility of microdrone "flocks" (large number of self-propelled microdrones) for surveilling and collecting information in megacities and DUAs.[103] Small drones equipped with high resolution cameras and other sensors can be used to relay information about buildings, their occupants, and human activities.[104] [105]

- **Man/Machine Teaming**: Man/machine teaming in the future could feature adaptive, intelligent data streams that project information forward to military forces based on their requests or anticipated needs.[106]
- **Modeling and Simulation (M&S)**: A critical capability to support Complex IPB is the development of a Complex IPB Agent Based Model (ABM) application. This application would model the interaction of different groups, based on analyst inputs, to see if certain population behaviors are more likely. This capability could allow analysts and decision makers to adjust variables to assess possible impacts on population behavior, providing a powerful option exploration tool.[107]

Analysis and Decision Making

As noted above, megacities and DUAs produce enormous quantities of data and analysts are just beginning to learn how to use that information in innovative ways.[108] Given the amount of readily available data, the Army must develop practical methods to exploit this exploit this data.[109] However, the Army currently lacks the resources, expertise, and approaches to fully investigate and exploit the reservoir of information available.[110] Big data analytics, knowledge management, and decision-making tools will be needed to process these large and diverse data sets.[111] Decision makers will have to decide how best to use the information produced by these analytic systems, therefore, better decision making at all levels is a critical component of big data analytics.[112] [113] Virtual humans may provide one method for improving decision making. A virtual human, acting as part of a decision team can increase introspection and bring forward a vast quantity of knowledge to inform decision

---

[102] Knapp, David, Randall, Robb, and Staley, Jim, "Atmospheric Impacts and Effects Predictions and Applications for Future Megacity and Dense Urban Area Operations."
[103] Bitterman, Alex Phd and Carlo, Richard, Prof, "Flocking Phones & Drones: Three-Dimensional, Real-Time, Mapping of Dense Urban Environments Using Off-the-Shelf Microdrone, Smartphone, and Point-Cloud Technology."
[104] Bitterman, Alex Phd and Carlo, Richard, Prof, "Flocking Phones & Drones: Three-Dimensional, Real-Time, Mapping of Dense Urban Environments Using Off-the-Shelf Microdrone, Smartphone, and Point-Cloud Technology."
[105] Insights provided by MS contributors.
[106] Richmond, Todd, "The Innovation Spectrum - Exploring Left of Boom."
[107] Brown, Eddie MAJ and Pike, Tom MAJ, "Complex IPB."
[108] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."
[109] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."
[110] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities,"
[111] Crane, Alfred and Peeke, Richard LTC, "Using the Internet of Things to Gain and Maintain Situational Awareness in Dense Urban Environments and Mega Cities."
[112] Insights provided by MS contributors.
[113] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."

making.[114] [115] In the future machines may have the ability to remove humans completely from decision making, however, in the near term humans will likely have to create policies that control the decision making behavior of machines.[116] For example, Knowledge Enhanced Electronic Logic (KEEL) technology allows humans to package policies to control the behavior of battlespace systems and devices. KEEL is an enabling technology that makes it easy to package human judgment and reasoning skills (expertise) into machines.[117]

System of Systems Perspective

Analyzing megacities from a system of systems approach can improve situational understanding and enable more robust decision making. This approach was a common theme among a number of MS contributors and multiple concepts and frameworks to enable analysis and understanding of megacities and DUAs from this system of systems perspective were proposed, including:

- Megacities exist as a system of systems and should be considered as a convergence of factors such as people, external influence, and infrastructure. How integrated and functional these systems will largely determine the success and livability of the environment. Dawn Morrison and Colin Wood provided an outline of an operationalized megacity framework useful in assessing the integrated system quality of each megacity to better understand the future military operational environment. Strategically supporting, manipulating and/or undermining the flows, infrastructure and systems of a megacity environment as a whole itself may transform what was previously viewed as intimidating complexity into a sophisticated, integrated, and manageable system of systems. By focusing on the integrated system of systems inherent to the megacity and fully understanding the population, future U.S. military forces will be more capable of successfully operating in a megacity.[118] [119]
- Megacities are highly complex, adaptive, interconnected networks of networks that cannot be controlled but can be influenced. It is therefore critical to understand how to influence the trajectory of megacities and how to anticipate their responses, requiring a sophisticated analysis of the networks embedded within and between urban systems. It is useful to focus on resilience to shocks, a critical and fundamental attribute of complex systems. Quantifying resilience is required for comparative analyses and critical to planning interventions, evaluating options, and anticipating responses. Quantifying the

---

114 Swartout, William Dr., "Virtual Humans as Centaurs." Megacities/DUA Conference Presentation.
115 Felix, Kevin COL (ret.), "Army Panel on Megacities." Megacities/DUA Conference Presentation.
116 Keeley, Tom, "A Revolution in Military Affairs (RMA) versus 'Evolution' - When Machines Are Smart Enough."
117 Keeley, Tom, "A Revolution in Military Affairs (RMA) versus 'Evolution' - When Machines Are Smart Enough."
118 Morrison, Dawn A. and Wood, Colin D., "Megacity and Dense Urban Environments: Obstacles or Opportunity?"
119 Insights provided by MS contributors.

dynamics and features of these networks is key to understanding both their resilience and that of the complex systems they govern.[120]

- From this system of systems perspective, Gustav Otto and AJ Besik outlined a way to think about a megacity like a computer through the combination of software, hardware and outcomes. This hardware/software/outcomes framework of analysis for megacities can be used to conceptualize the issues in a megacity.[121]
- IPB steps are not conducive to understanding the dynamics between interactively complex systems. Therefore, a relevant urban analytic framework in support of framing, mapping, and developing courses of action (COA) for operations occurring in megacities was proposed. This analytic framework is specifically tailored to accommodate a city's system of diversity and provides a structure that incorporates urban operational data layers and city as a system context and perspectives. The overarching concept behind this framework is alignment with systems thinking, focusing attention on the relationships between different parts of the environment and working to understand the cumulative effects of these interactions. Adoption of this city as a system perspective will require adaptation of a significant portion of Army doctrine. This framework involves framing the OE, mapping urban problem systems, moving from describing the problem to how to influence it via identification of Environment Centers of Gravity (E-COGS), and developing and analyzing courses of action (COA) designed to affect the E-COG.[122]
- Complex adaptive systems or complexity theory was developed to identify the underlying laws governing complex systems and provides an effective lens to understand the true nature of a nation, its behavior, and the dynamics that can emerge within.[123] Incorporating complexity-based components into systems analysis can enable the military to analyze and convey the complexity of the urban and social environments, improving operational understanding, visualization, description, and assessment.[124] The Emergent States Assessment (ESA) is an analytic tool that leverages complexity theory to support decision makers in Counterinsurgency and Stability Operations and can also be used to understand megacities. The ESA method offers an analytic framework that facilitates the rapid understanding of complex populations in a way that may be communicated across large organizations and leveraged to conduct operations that are more effective. The ESA framework defines, analyzes, and assesses a population by the complex

[120] Shutters, Shade T., Herche, Wes, and King, Erin, "Anticipating Megacity Responses to Shocks: Using Urban Integration and Connectedness to Assess Resilience."
[121] Otto, Gustav and Besik, AJ, "Megacity Madness."
[122] Hedges, William CSM (Ret.), "White Paper: An Analytic Framework for Operations in Dense Urban Areas."
[123] Pike, Tom, Long, Nick, and Alexander, Perry, "Understanding Nations: New Ideas to Analyze Foreign States."
[124] Brown, Eddie MAJ, "Conveying the Complex: Updating U.S. Joint Systems Analysis Doctrine with Complexity Theory."

adaptive system terms of fitness landscape, agent fitness, agent response profile, building blocks, identity tags, and emergent phenomena.[125]

- Surveillance and accurate diagnosis is key to addressing global biosecurity threats. Biosecurity in complex environments will require a systems based approach and a complex web of surveillance, education, and interactive communications, otherwise known as "network of networks". [126] [127] A series of global biosurveillance systems exist but better integration of these systems is needed, such as an Integrated Global Health Surveillance and Response Program, for military planning and operations, and disease response and prevention.[128] [129]

[125] Pike, Tom MAJ and Brown, Eddie MAJ, "Populations as Complex Adaptive Systems: A Case Study of Corruption in Afghanistan."
[126] Kwon, Paul O. LTC, "Integrated Global Health Surveillance and Response through Multi-Source Technologies."
[127] Poste, George Dr., "Health Innovation for Dense Urban Areas." Megacities/DUA Conference Presentation.
[128] Poste, George Dr., "Health Innovation for Dense Urban Areas." Megacities/DUA Conference Presentation.
[129] Kwon, Paul O. LTC, "Integrated Global Health Surveillance and Response through Multi-Source Technologies."

Freedom of Movement and Protection

What emerging concepts and capabilities will enable access and freedom of movement in, above (buildings and airspace), below (sub-terrain), and around megacities? What new capabilities for Decentralized Urban Logistics can improve sustainment efficacy in urban areas? What will protect vehicles and Soldiers, while enabling freedom of movement, from multitude of advanced and conventional military technologies as well as environmental threats (e.g., water, sanitation, air pollution; etc.)?

Overview

The complexity of megacities and DUAs present a number of unique and dynamic challenges to military access, freedom of movement, and force protection. MS contributors began to address aspects of the Freedom of Movement and Protection megacity objective with a focus on technologies to enable access and freedom of movement.

- Freedom of Movement and Protection was the second most addressed megacity objective by academic publications and ideas submitted to the MS technology survey.
- 72% of megacity academic publications and ideas submitted to the MS technology survey addressed the Freedom of Movement and Protection megacity objective.
- 24% of ideas submitted to the technology survey addressed AWFC #16: Set the Theater, Sustain Operations, and Maintain Freedom of Movement (aligned to the Freedom of Movement and Protection megacity objective). This was the 9th most addressed AWFC by ideas submitted to the technology survey.
- Freedom of Movement and Protection was the second most addressed megacity objective by technology survey contributors affiliated with Industry (88%) and Government (82%) and the third most addressed by Academia (64%). 100% of ideas submitted by contributors affiliated with Industry or “Other” addressed this objective.

(See the Qualitative Summary of Data section below for more details about data alignment to megacity objectives and AWFCs).

Factors discussed by MS contributors that complicate freedom of movement and force protection include more capable opponents, complex infrastructure (especially subterranean and vertical dimensions), and dense populations that will complicate humanitarian missions. The Army can leverage the vertical features of these environments, lessons learned from domestic emergency response and evacuation research, and technology advancements in unmanned systems to address some of these challenges.

Challenges and Opportunities

As noted previously, the Army will face advanced opponents enabled by technology and connectivity in conjunction with complex, dense infrastructure spanning multiple dimensions (e.g. subterranean, surface, supersurface, air, cyber) and greater exposure to disease and toxic industrial chemicals and materials that will further complicate freedom of movement and force protection.[130] [131] [132] For example, controlling fires will be difficult due to the presence of buildings, smoke and smog, and reflections from building surfaces degrading vision and laser designation and opponents will increasingly exploit subterranean domains to avoid detection and targeting.[133] However, these same challenges may also present opportunities for the Army to leverage megacity and DUA infrastructure to its advantage by using the vertical space:[134]

- The greatest advantage resides in exploiting the vertical space inherent in all urban centers.
- New technological approaches to securing the vertical space, providing greater stand-off from explosives, and options for aerial refit would greatly improve military operations in megacities and DUAs.
- Current technological advances in net zero basing systems could be developed to ensure a fully contained and controlled environment within a skyscraper.
- Distributed high ground basing throughout the megacity would allow for greater command and control of the environment through extended visual over watch.
- Exploiting the vertical space would also entail greater use of unmanned systems.

Unique restrictions imposed by megacities and DUAs on military access and movement will require greater use of unmanned systems.[135] These systems could be a force multiplier and improve the effectiveness and reach of soldiers in complex urban environments.[136] [137] Further, in addition to advancements in personal protective gear, unmanned systems could also be used to carry out missions in contaminated environments to limit soldier exposure to disease and toxic industrial

---

130 Ollivant, Douglas Dr., "Hybrid Warfare in Urban Environment." Megacities/DUA Conference Presentation.
131 Ippolito, Danielle PhD, "Assessing Physiological Response to Toxic Industrial Chemical Exposure in Megacities."
132 Poste, George Dr., "Health Innovation for Dense Urban Areas." Megacities/DUA Conference Presentation.
133 Glenn, Russell Dr., "Megacities: The Good, the Bad, and the Ugly."
134 Morrison, Dawn A. and Wood, Colin D., "Megacity and Dense Urban Environments: Obstacles or Opportunity?"
135 Fisher, Nathan, "Unmanned Systems in Support of Future Medical Operations in Dense Urban Environment." Megacities/DUA Conference Presentation.
136 Piekarski, Brett Dr. et al., "Research and Vision for Intelligent Systems for 2025 and Beyond."
137 Insights provided by MS contributors.

chemicals and materials.[138] Currently, unmanned systems focus is primarily on the development of individual system technologies, however, MS contributors emphasized the need for a system of systems approach and unmanned/human teaming.[139] [140] [141] Highly distributed, collaborative heterogeneous teams of unmanned systems integrated with humans, sensor data, and information from knowledge bases will provide opportunities for overmatch. The following are some key considerations for unmanned systems identified by MS contributors:[142] [143] [144]

- Greater research focus is needed on how to integrate varying levels of autonomy and intelligence across spatially and temporally distributed singular systems, small teams, and swarm behavior under one robust and adaptable command and control architecture.[145]
- Future military intelligent systems must make decisions on their own at rates beyond which a human can control them.
- Distributed intelligence, the opportunity of unmanned systems to learn from one another, is required.[146]
- The development and use of numerous individual systems at low price points will enable the exploration of behaviors that are prohibitive in more expensive systems. Failure of some of these lower cost platforms may benefit the collective whole through distributed intelligence.[147]
- The Army must plan for resiliency when faced with a loss of systems and communications. Resiliency is critical for intelligent systems, yet very difficult to model, analyze, and put into practice.[148] [149]
- Commercial approaches can inform military unmanned system development but will not completely meet military needs because commercial devices are

---

[138] Ippolito, Danielle PhD, "Assessing Physiological Response to Toxic Industrial Chemical Exposure in Megacities."
[139] Fisher, Nathan, "Unmanned Systems in Support of Future Medical Operations in Dense Urban Environment." Megacities/DUA Conference Presentation.
[140] Piekarski, Brett Dr. et al., "Research and Vision for Intelligent Systems for 2025 and Beyond."
[141] Piekarski, Brett Dr., "Research and Vision for Intelligent Systems for 2025 and Beyond." Megacities/DUA Conference Presentation.
[142] Piekarski, Brett Dr., "Research and Vision for Intelligent Systems for 2025 and Beyond." Megacities/DUA Conference Presentation.
[143] Piekarski, Brett Dr. et al., "Research and Vision for Intelligent Systems for 2025 and Beyond."
[144] Fisher, Nathan, "Unmanned Systems in Support of Future Medical Operations in Dense Urban Environment." Megacities/DUA Conference Presentation.
[145] Piekarski, Brett Dr. et al., "Research and Vision for Intelligent Systems for 2025 and Beyond."
[146] Piekarski, Brett Dr. et al., "Research and Vision for Intelligent Systems for 2025 and Beyond."
[147] Piekarski, Brett Dr. et al., "Research and Vision for Intelligent Systems for 2025 and Beyond."
[148] Piekarski, Brett Dr. et al., "Research and Vision for Intelligent Systems for 2025 and Beyond."
[149] Insights provided by MS contributors.

not created for or working in unstructured, austere environments (e.g. rubble, underground, hostile environments).[150]

Lessons learned from domestic emergency response and large-scale urban evacuation operations may provide insights that inform operation planning and missions to manage and protect large populations. For example:[151]

- Evacuation planning ideally requires both multi-modal transportation (multiple travel modes) and intermodal transportation (travel involving connections between two or more travel modes in a single trip). Multi-modal transportation provides travel options to accommodate diverse and uncertain needs, including long-distance evacuations with limited road space, vehicles, and fuel.
- Establishing lines of communication between emergency officials and the population will be a necessity, however, there are often communication barriers (e.g. language, access, locating people, cooperation).
- It may be possible to recruit the local community to assist with the movement of supplies and goods and to conduct evacuations of buildings, neighborhoods, districts, cities, or metropolitan regions.

[150] Piekarski, Brett Dr., "Research and Vision for Intelligent Systems for 2025 and Beyond." Megacities/DUA Conference Presentation.
[151] Hess, Daniel Baldwin PhD, "Large-Scale Mass Evacuation in Metropolitan Areas: Improving Coordination for Multi-Modal Transport."

Expeditionary Operations

What emerging concepts and capabilities will enable expeditionary maneuver; evolve Army Health Support of Operations; enhance the ability to manage or influence large population centers, and offer solutions for achieving partner interests and strategic objectives throughout a range of military operations (during peace and combat operations)?

Overview

The expansive area and density of megacities and DUAs are likely to prohibit traditional military models of overpowering, isolating, and controlling in these environments.[152] Although MS contributors began to address methods to engage in and influence these environments, there was an emphasis on Army Health Support, including medical evacuation and care in the field.

- Expeditionary Operations was the third most addressed megacity objective by academic publications and ideas submitted to the MS technology survey.
- 71% of megacity academic publications and ideas submitted to the MS technology survey addressed the Expeditionary Operations megacity objective.
- 24% of ideas submitted to the technology survey addressed AWFC # 12: Conduct Joint Expeditionary Maneuver and Entry Operations (aligned to the Expeditionary Operations megacity objective). This was the 8th most addressed AWFC by ideas submitted to the technology survey.
- Expeditionary Operations was the third most addressed objective by technology survey contributors affiliated with Academia (50%) and the least addressed by Government (66%). 100% of ideas submitted by contributors affiliated with Industry or “Other” addressed this objective.

(See the Qualitative Summary of Data section below for more details about data alignment to megacity objectives and AWFCs).

A number of technologies were identified with potential to improve medical operations in megacities and DUAs. Additionally, an intelligence model to support unified action, an operational planning framework for densely populated urban areas, and the use of virtual humans were proposed to enhance situational understanding and planning for expeditionary operations and interactions with local populations.

Challenges and Opportunities

As a result of the unique restrictions imposed by current and future megacities and DUAs, such as pervasive and easily concealed adversaries, limited access and freedom of movement, and increased evacuation times, future medical operations could be limited or unavailable. [153] MS contributors discussed a number of potential

[152] Glenn, Russell Dr., “Megacities: The Good, the Bad, and the Ugly.”
[153] Fisher, Nathan and Gilbert, Gary, “Unmanned Systems in Support of Future Medical Operations in Dense Urban Environments.”

technologies to address limitations in medical support to military forces operating in megacity and DUA environments, with an emphasis on a shift to unmanned technologies.[154] [155] For example, in megacity environments, smaller aircraft with greater freedom of movement and advanced navigation will be needed for medical support.[156]

- An emerging capability in future unmanned vehicles is multifunctional systems that can be reconfigured to accommodate different payloads. Multifunctional unmanned systems can be leveraged to improve medical support to military operations, including peacetime humanitarian support missions in megacities and DUAs.[157] [158] [159]
- Unmanned vehicles can improve far forward casualty care or can be used for rapid medical evacuation.[160] [161]
- The quality of the interface provided for interactions between medical personnel and the unmanned system is an important consideration. It is particularly important for a field medic to interact efficiently with unmanned systems providing medical support due to the cognitive and physical demands of actively caring for a casualty.[162]

Autonomous and semi-autonomous Tactical Combat Casualty Care (TCCC) capabilities can also support future expeditionary operations. [163] The “Trauma Care in a Rucksack” concept addresses current deficiencies in combat casualty care through a novel approach that overcomes the use of subjective physiologic signs and symptoms used to assess and treat patients. This subjective practice is also an obstacle towards semi-autonomous and autonomous Tactical Combat Casualty Care (TCCC) solutions. A set of proposed disruptive technology building blocks create a

---

[154] Fisher, Nathan and Gilbert, Gary, “Unmanned Systems in Support of Future Medical Operations in Dense Urban Environments.”
[155] Morrison, Dawn A. and Wood, Colin D., “Megacity and Dense Urban Environments: Obstacles or Opportunity?”
[156] Fisher, Nathan and Gilbert, Gary, “Unmanned Systems in Support of Future Medical Operations in Dense Urban Environments.”
[157] Fisher, Nathan and Gilbert, Gary, “Unmanned Systems in Support of Future Medical Operations in Dense Urban Environments.”
[158] Poste, George Dr., “Health Innovation for Dense Urban Areas.” Megacities/DUA Conference Presentation.
[159] Insights provided by MS contributors.
[160] Fisher, Nathan and Gilbert, Gary, “Unmanned Systems in Support of Future Medical Operations in Dense Urban Environments.”
[161] Fisher, Nathan, “Unmanned Systems in Support of Future Medical Operations in Dense Urban Environment.” Megacities/DUA Conference Presentation.
[162] Fisher, Nathan and Gilbert, Gary, “Unmanned Systems in Support of Future Medical Operations in Dense Urban Environments.”
[163] Berkow, Jan and Poropatich, Ron COL(R), “TRAuma Care in a Rucksack (TRACIR) - A Disruptive Technology Concept.”

paradigm shift in how medical data is defined, stored, captured, visualized, and shared to enable more semi-autonomous and autonomous TCCC solutions.[164]

Multiple unique considerations must also be taken into account when planning for and implementing medical care strategies in Megacities and DUAs to include IPB to understand the medical needs of both combatants and civilians.[165] As megacities and dense urban environments continue to grow in number and population size, service members will likely be exposed to a greater number of infectious diseases and toxic chemicals and materials. For example, a review and evaluation of recent literature identified the top 30 megacity chemical threats. [166]

- A literature review indicated that most megacity threats were related to air quality, physical injuries, chemical/radiation exposure, water quality, and infectious diseases.
- A review of the top 30 megacity chemical threats identified acute lung injury and/or acute respiratory distress syndrome as the most significant threats to soldiers in these environments.

Given these threats, an Integrated Global Health Surveillance and Response Program of surveillance, education, and interactive communications (a "network of networks") will be particularly important for supporting expeditionary operations and Army Health Support of Operations.[167] Additionally, far forward diagnostic devices for detection of emerging health effects from exposure to chemicals can inform triage during exposure events and treatment and return-to-duty decisions.[168] However, ruggedization and miniaturization of biomarker diagnostic devices pose significant challenges and require further research and testing to develop this capability.[169]

Enabling Expeditionary Operations

The expansive area and density of megacities and DUAs are likely to prohibit traditional military models of overpowering, isolating, and controlling in these environments.[170] Consequently, U.S. military forces will have to learn to influence instead of trying to overwhelm and control megacity and DUA environments.[171] Moving forward, it will become increasingly important to try to isolate only portions of a megacity or DUA depending on what is deemed most important (e.g. based on

---

[164] Berkow, Jan and Poropatich, Ron COL(R), "TRAuma Care in a Rucksack (TRACIR) - A Disruptive Technology Concept."
[165] Fowler, Marcie PhD and McGhee, Laura MAJ, "Pain Management: Maintaining the Force."
[166] Ippolito, Danielle PhD, "Assessing Physiological Response to Toxic Industrial Chemical Exposure in Megacities."
[167] Kwon, Paul O. LTC, "Integrated Global Health Surveillance and Response through Multi-Source Technologies."
[168] Ippolito, Danielle PhD, "Assessing Physiological Response to Toxic Industrial Chemical Exposure in Megacities."
[169] Ippolito, Danielle PhD, "Assessing Physiological Response to Toxic Industrial Chemical Exposure in Megacities."
[170] Glenn, Russell Dr., "Megacities: The Good, the Bad, and the Ugly."
[171] Prautzch, Frank, "U.S. Army Mega City Operations - Enduring Principles and Innovative Technologies."

function, critical infrastructure, or "other-governed" areas).[172] It will be critical to identify specific communities and formal and informal types of social networks in growing populations that offer the greatest promise for supporting or impeding Army objectives.[173] [174] Insight into alternative governance structures and how to interface with them will be crucial to effective operations.[175] The ability to call upon expert knowledge already in place or rapidly acquired in a region of interest, in partnership with collective intelligence, can enhance the ability to manage or influence large population centers.[176] [177] [178]

Analytic frameworks and virtual humans were proposed by MS contributors to enhance the Army's ability to manage or influence large population centers. For example, a proposed operational planning framework for densely populated urban geography includes seven lines of effort (Maintain and improve advantage in anonymity; Maintain and improve advantage in competitive distances; Control service flows; Control convocation spaces; Progressively reduce enemy sanctuary space; Pursue the *mens rea*; and Punish the enemy) and twelve research categories aligned to the seven lines of effort on which to focus for situational understanding of large urban areas.[179] A proposed intelligence model tailored to support unified action involving the Army's Regionally Aligned Forces (RAF) and partners consists of nine components which extend intelligence and analytic support through collective network engagement and joint targeting processes. All nine components of the model correlate to specific parts of the RAF's mission involving comprehensive approaches to understanding areas of responsibility, interoperability training, collaborative planning, and execution of regional partnered missions during the initial phases of the overall operation planning phases.[180]

Additionally, virtual humans can aid in interactions, language translation, and interviews with local populations to improve the Army's ability to leverage local knowledge.[181] [182] [183] Virtual humans are able to use verbal and non-verbal communication to interact naturally with real people who may feel more comfortable

---

[172] Glenn, Russell Dr., "Megacities: The Good, The Bad, and The Ugly." Megacities/DUA Conference Presentation.
[173] Glenn, Russell Dr., "Megacities: The Good, the Bad, and the Ugly."
[174] Krakowka-Richmond, Amy Dr., "Army Panel On Megacities." Megacities/DUA Conference Presentation.
[175] Insights provided by MS contributors.
[176] Zenzen, Fran Dr., "Frameworks for Future Challenges: Understanding Dense Urban Terrain." Megacities/DUA Conference Presentation.
[177] Usher, Abe, "Addressing the Challenges of the Human Terrain in 2050." Megacities/DUA Conference Presentation.
[178] Insights provided by MS contributors.
[179] Demarest, Geoff, "How to Hold or Take a Big City - Seven Lines of Effort."
[180] Morris, Victor R., "Tailoring Intelligence and Analytic Support to Regionally Aligned and Multinational Forces - Collective Network Identification and Engagement Requirements for Unified Action Partners."
[181] Swartout, William Dr., "Virtual Humans as Centaurs." Megacities/DUA Conference Presentation.
[182] Swartout, William Dr., "Virtual Humans as Centaurs."
[183] Insights provided by MS contributors.

and be more willing to reveal sensitive information.[184] [185] Virtual humans could provide critical situational understanding while promoting communication and developing relationships with local populations in support of expeditionary operations.

Future Training Challenges

What emerging technologies and capabilities must the Army explore and adopt in order to realistically represent the complexities of a megacity to a training audience (home station and Combat Training Centers) allowing the development of cohesive teams that thrive in ambiguity, austerity, or chaos within Operational Environment of 2025 and Beyond?

Overview

Training challenges will require the Army to build advanced technical capabilities and leverage interdisciplinary collaboration to understand and address complex megacity problems.[186] MS contributors proposed innovative training methods and curriculums with a focus on technologies to realistically represent the complexities of a megacity or DUA for training

- Future Training Challenges was the least addressed megacity objective by academic publications and ideas submitted to the MS technology survey.
- 63% of megacity academic publications and ideas submitted to the MS technology survey addressed the Future Training Challenges megacity objective.
- 37% of ideas submitted to the technology survey addressed AWFC #8: Enhance Realistic Training (aligned to the Future Training Challenges megacity objective). This was the 2nd most addressed AWFCs by ideas submitted to the technology survey.
- Future Training Challenges was the second most addressed objective by technology survey contributors affiliated with Academia (71%) and the least addressed by Government (66%). 100% of ideas submitted by contributors affiliated with Industry or "Other" addressed this objective.

(See the Qualitative Summary of Data section below for more details about data alignment to megacity objectives and AWFCs).

The Army should continue to explore innovative training methods, new, interdisciplinary curriculums, evolving perspectives that embrace complexity, flexibility, and originality, and advanced technology solutions that can immerse soldiers into a megacity environment for future training.

[184] Swartout, William Dr., "Virtual Humans as Centaurs." Megacities/DUA Conference Presentation.
[185] Swartout, William Dr., "Virtual Humans as Centaurs."
[186] Felix, Kevin COL (ret.), "Army Panel on Megacities." Megacities/DUA Conference Presentation.

Challenges and Opportunities

A Complex Adaptive Learning System

The Army will have to evolve into a complex adaptive learning system of "Master Learners" who embrace complexity and innovation.[187] [188] [189] To start, the Army should develop leaders and instructors who are open to new training methods and curriculums, understand and mitigate generation gaps in learning styles, and are exposed to megacity and DUA environments as often as possible. [190] [191]

Interdisciplinary curriculums in applicable fields such as urban planning, social science, the science of cities, big data analytics, and cyber warfare will accelerate institutional learning.[192] [193] [194] [195] [196] For example, cyberwarfare capabilities can vastly improve military success, therefore, the Army's perspective on cyberwarfare must evolve to greater prioritize this topic for training.[197] [198] COL Patrick Duggan proposed the cyber-enabled Special Warfare (CE-SW) pyramid, a conceptual framework to align technology, tools, and tactics to strengthen Special Warfare capabilities and man-machine teaming to counter future threats. The CE-SE pyramid begins at the base with cyber-technology skills, education, and training, which are the foundation for this framework.[199] [200]

Modeling and Simulation

Advanced technologies will play a critical role in training for future OEs.[201] Training with virtual humans can improve soldier interactions with local populations and Modeling and Simulation (M&S) can immerse soldiers into unfamiliar environments.[202] A key observables from a lecture based pilot course in megacities was a need for students to be immersed in a megacity environment for effective training.[203] However, the Army will be significantly challenged to accurately develop a physical megacity or DUA for training given the size and complexity of these environments. M&S has the potential to both enhance training and provide opportunities for experimentation to evaluate tactical and strategic options, allow for iterative training, and determine what parts of an environment are of operational

[187] Crow, Michael Dr., "Welcome Remarks, Day 1." Megacities/DUA Conference Presentation.
[188] Krakowka-Richmond, Amy Dr., "Army Panel On Megacities." Megacities/DUA Conference Presentation.
[189] Felix, Kevin COL (ret.), "Army Panel on Megacities." Megacities/DUA Conference Presentation.
[190] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."
[191] Insights provided by MS contributors.
[192] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."
[193] Duggan, Patrick COL, "Man, Computer, and Special Warfare."
[194] Insights provided by MS contributors.
[195] Iwanski, Jeremy J. SSG, "The U.S. Military and Megacities/Dense Urban Areas."
[196] Glenn, Russell Dr., "Megacities: The Good, the Bad, and the Ugly."
[197] Iwanski, Jeremy J. SSG, "The U.S. Military and Megacities/Dense Urban Areas."
[198] Duggan, Patrick COL et al., "Army Panel on Megacities." Megacities/DUA Conference Presentation.
[199] Duggan, Patrick COL et al., "Army Panel on Megacities." Megacities/DUA Conference Presentation.
[200] Duggan, Patrick COL, "Man, Computer, and Special Warfare."
[201] Insights provided by MS contributors.
[202] Swartout, William Dr., "Virtual Humans as Centaurs." Megacities/DUA Conference Presentation.
[203] Castellanos, Dennis CW4, Army Panel on Megacities." Megacities/DUA Conference Presentation.

significance.[204] [205] [206] [207] [208] For example, Early Synthetic Prototyping (ESP) explores ways for end users to test, iterate, and manipulate ideas in a virtual prototyping environment.[209] ESP can track not only what a user does but also how and why.[210] This technology has applications for idea generation, M&S enhancement, and training evaluation and improvement. However, accurately representing megacities and DUAs for M&S is particularly challenging.[211] For example:

- The greatest challenge in modeling dense urban areas is modeling human behavior and capabilities and interactions between human and physical systems.[212] [213]
- To maintain an accurate representation of the environment, automated collection of continuous data sources is needed.[214]
- Increased urban density compounds the complexity of relationships between infrastructure components. M&S applications will require a higher density of data for megacities.[215]
- Megacities are inherently intricate in terms of how people interact with them, including complex effects on entities, secondary effects, implied or expected behaviors, and multi-dimensional context. Some of these effects must be represented in M&S for effective and realistic training.[216]
- Greater urban density results in an increase in non-specific environment features known as "clutter". Currently, clutter is often minimized in M&S but in megacities, clutter will play an important role in operations. These features will differ based on location and these unique characteristics must be

[204] Watkins, Jon, "Challenges with Representing the Megacity Environment in Simulations." Megacities/DUA Conference Presentation.
[205] Shutters, Shade T., Herche, Wes, and King, Erin, "Anticipating Megacity Responses to Shocks: Using Urban Integration and Connectedness to Assess Resilience."
[206] Otto, Gustav and Besik, AJ, "Megacity Madness."
[207] Zenzen, Fran Dr., "Frameworks for Future Challenges: Understanding Dense Urban Terrain." Megacities/DUA Conference Presentation.
[208] Felix, Kevin COL (ret.), "Army Panel on Megacities." Megacities/DUA Conference Presentation.
[209] Richmond, Todd, "The Innovation Spectrum - Exploring Left of Boom."
[210] Richmond, Todd, "The Innovation Spectrum - Exploring Left of Boom."
[211] Watkins, Jon and Campbell, Chuck, "Challenges with Representing the Megacity Environment in Simulation."
[212] Zenzen, Fran Dr., "Frameworks for Future Challenges: Understanding Dense Urban Terrain." Megacities/DUA Conference Presentation.
[213] Insights provided by MS contributors.
[214] Zenzen, Fran Dr., "Frameworks for Future Challenges: Understanding Dense Urban Terrain." Megacities/DUA Conference Presentation.
[215] Watkins, Jon and Campbell, Chuck, "Challenges with Representing the Megacity Environment in Simulation."
[216] Watkins, Jon and Campbell, Chuck, "Challenges with Representing the Megacity Environment in Simulation."

represented for visual relevancy. This diversity requires increased flexibility in how data is represented.[217]

- Buildings will be large, close together, and will often require both interior and subterranean representation. Subterranean environments represent particular risks to soldiers due to factors such as collapse, access, and air flow. Currently, subterranean environments and building interiors are underrepresented in M&S. [218]
- Transportation networks will be increasingly complex, requiring representation of roadways, railways, water ways, and subways, to include transitioning from above to below ground.[219]
- Weather can greatly impact Army operations, however, Army simulations currently have minimal representation and modeling of weather.[220]
- Currently, M&S technologies cannot address all the details of a complex environment, therefore, defining what types of data are important for megacity M&S is critical for success.[221] [222]
- To replicate future megacity environments, M&S must accurately reflect various types munitions such as stun guns, mood-altering gasses, and other temporarily incapacitating capabilities to train for military engagement, security cooperation, and deterrence[223]

Alternative options proposed by MS contributors to offset some of the challenges of accurately representing megacities and DUAs in M&S include conducting exercises in real urban terrain environments, leveraging the expertise of movie and video production companies with experience in coordinating activities in urban environments to create real-life vignettes, and preparing soldiers to be resilient, flexible, and skilled in the analytic capabilities to quickly assess and respond in unfamiliar environments.[224]

Avoiding Megacities and DUAs

---

[217] Watkins, Jon and Campbell, Chuck, "Challenges with Representing the Megacity Environment in Simulation."
[218] Watkins, Jon and Campbell, Chuck, "Challenges with Representing the Megacity Environment in Simulation."
[219] Watkins, Jon and Campbell, Chuck, "Challenges with Representing the Megacity Environment in Simulation."
[220] Watkins, Jon and Campbell, Chuck, "Challenges with Representing the Megacity Environment in Simulation."
[221] Watkins, Jon and Campbell, Chuck, "Challenges with Representing the Megacity Environment in Simulation."
[222] Watkins, Jon, "Challenges with Representing the Megacity Environment in Simulations." Megacities/DUA Conference Presentation.
[223] Ward, Darryl, "Operational Environment Implications of the Megacity to the US Army."
[224] Insights provided by MS contributors.

In addition to addressing topics related to the 4 primary megacity objectives, MS contributors also underscored the importance of trying to attain U.S. objectives without having to engage in and deploy military forces to a megacity or DUA.[225]

- According to Robert Kozloski, a non-lethal strategy could allow the U.S. to achieve national policy goals without incurring the risks of traditional military actions. This could include a broader application of information operations, early intervention, non-lethal force and weapons, and directed energy systems.[226]
- Gustav Otto and AJ Besik suggested a pilot group of professionals to develop cross-functional tactics, techniques, and practices to deal with uncertain scenarios before they become problems to be more effective at advancing non-escalating solutions in a megacity or DUA environment.[227]
- As noted above, a proposed intelligence model tailored to support unified action involving the Army's Regionally Aligned Forces (RAF) and partners can enhance steady-state activities and shaping operations to dissuade and deter potential adversaries while strengthening relationships with partners and allies.[228]

[225] Insights provided by MS contributors.
[226] Kozloski, Robert, "Power Through Stability."
[227] Otto, Gustav and Besik, AJ, "Megacity Madness."
[228] Morris, Victor R., "Tailoring Intelligence and Analytic Support to Regionally Aligned and Multinational Forces - Collective Network Identification and Engagement Requirements for Unified Action Partners."

Quantitative Summary of Data

Technology Survey Data

Data collected from 34 academic publications submitted in response to a 2015 TRADOC G-2 call for papers and 63 ideas submitted to an online technology survey were analyzed to assess how ideas aligned to the 4 primary megacity objectives and the 20 AWFCs (see Appendix 4 for further analysis of alignment to eight Levels of Effort (LOEs) and six Technology Imperatives). All 4 megacity objectives were addressed by submitted academic publications and ideas submitted to the technology survey and all 20 AWFCs were addressed by ideas submitted to the technology survey. Situational understanding was the predominant topic addressed in both academic publications and ideas submitted through the technology survey.

- The Situational Understanding megacity objective was addressed the most out of all 4 objectives by submitted academic publications and ideas submitted through the technology survey.
- The 2 AWFCs addressed the most by ideas submitted through the technology survey were aligned with the Situational Understanding and Future Training Challenges megacity objectives.

Alignment to Megacity Objectives

All 4 megacity objectives were addressed by the MS Megacity Initiative. Although academic publications and ideas submitted to the technology survey address all 4 objectives, ideas predominantly addressed the Situational Understanding megacity objective. The Future Training Challenges objective was addressed the least.

Figure 1: Number of academic publications and survey ideas that address one or more of the 4 megacity objectives. Heat map colors determined by a scale of lowest (yellow) to highest (green) values.

	Primary Megacity/DUA Objectives			
	1. Situational Understanding	2. Freedom of Movement and Protection	3. Expeditionary Operations	4. Future of Training
Total number of academic publications (34 papers reviewed) and ideas submitted to the technology survey (63 ideas) that address one or more of the 4 primary megacity/DUA objectives (either primarily or somewhat address)	88	70	69	61

Academic Publication Alignment to Megacity Objectives

34 academic publications were reviewed to determine how they align to one or more of the primary megacity objectives and to what extent they address those objectives (primarily address, somewhat address, or do not address). When possible, these ratings were determined by the publication authors. When authors did not provide ratings, an independent reviewer read and rated the paper based on the content of the publication. Papers addressed all 4 megacity objectives. Papers predominantly addressed the Situational Understanding objective and the Future of Training objective was addressed the least.

Figure 2: Number of academic publications (34 total) that address one or more of the 4 megacity objectives. Heat map colors determined by a scale of lowest (yellow) to highest (green) values.

	Primary Megacity/DUA Objectives			
	1. Situational Understanding	**2. Freedom of Movement and Protection**	**3. Expeditionary Operations**	**4. Future of Training**
Total number of academic publications (34 papers reviewed) that address one or more of the 4 primary megacity/DUA objectives (either primarily or somewhat address)	32	20	21	15

Figure 3: Extent academic publications (34 total) addressed one of more of the 4 megacity objectives (number of publications that primarily address, somewhat address, or do not address the focus areas). Heat map colors determined by a scale of lowest (yellow) to highest (green) values.

Degree to which academic publications (34 papers reviewed) address the primary megacity/DUA objectives.	**1. Situational Understanding**	**2. Freedom of Movement and Protection**	**3. Expeditionary Operations**	**4. Future of Training**
Primarily addresses an objective	20	3	9	4
Somewhat addresses an objective	12	17	12	11
Does not address an objective	2	14	13	19

Alignment of Ideas Submitted to Technology Survey to Megacity Objectives

Contributors submitted 63 capability/technology ideas that were applicable to the megacity and DUA topic (identified by idea contributor through a survey question asking if their nominated idea is "applicable to Megacities/Dense Urban Environments"). Idea contributors were asked to rate the alignment of their idea to one or more of the primary megacity objectives and rate to what extent ideas address those objectives (primarily address, somewhat address, or do not address). Ideas addressed all 4 megacity objectives. Ideas predominantly addressed the Situational Understanding objective and the Future of Training objective was addressed the least. Idea contributors were also asked to rate how recent their idea is (Established, Emerging, New). The majority of ideas were rated as emerging.

Figure 4: Number of ideas submitted to the technology survey (63 total) that address one or more of the 4 megacity objectives. Heat map colors determined by a scale of lowest (yellow) to highest (green) values.

	Primary Megacity/DUA Objectives			
	1. Situational Understanding	**2. Freedom of Movement and Protection**	**3. Expeditionary Operations**	**4. Future of Training**
Total number of ideas submitted to the technology survey (63 ideas) that address one or more of the 4 primary megacity/DUA objectives (either primarily or somewhat address)	56	50	48	46

Figure 5: Extent ideas submitted to the technology survey (63 total) address one of more of the 4 megacity objectives (number of ideas that primarily address, somewhat address, or do not address the focus areas). Heat map colors determined by a scale of lowest (yellow) to highest (green) values.

	Primary Megacity/DUA Objectives			
Degree to which ideas submitted (63 ideas) to the technology survey address the primary megacity/DUA objectives.	**1. Situational Understanding**	**2. Freedom of Movement and Protection**	**3. Expeditionary Operations**	**4. Future of Training**
Primarily addresses an objective	41	21	22	22
Somewhat addresses an objective	15	29	26	24
Does not address an objective	7	13	15	17

Figure 6: How recent are the ideas submitted to the technology survey (Established, Emerging, New)?

How recent is the capability/technology idea (63 ideas)	Number of ideas submitted to the technology survey
Established: **Existing technologies (i.e. well researched; in use through practical applications for at least 12 months) that will be used in new ways**	24
Emerging: **Technology is currently under research and/or development, although not yet used in practical application**	33
New: **Technology was discovered within the last 12 months. Although new, it is currently used in practical application.**	6

In addition to the 4 megacities objectives, ideas submitted to the technology survey were rated based on their alignment to one or more of the 20 AWFCs (See Appendix 4 for AWFC definitions). Idea contributors were also asked in the survey to provide an influence rating for maintaining overmatch for their idea (Ratings: None, Minimal, Moderate, Significant, and Extremely valuable; see Appendix 4 for more details on influence values and definitions).

All AWFCs were addressed by the ideas submitted to the technology survey. The majority of ideas address AWFC #1: Develop Situational Understanding with 32 of those ideas rated as either extremely or significantly valuable. Four AWFCs are aligned to the 4 megacity objectives (identified by AWFCs in the grey boxes in the table). The majority of submitted ideas that address AWFCs are aligned to the Situational Understanding and Future Training Challenges objectives (AWFCs #1 and #8). Additionally, ideas specific to the megacities/DUA topic addressed AWFCs that are not currently aligned to the 4 megacities objectives. For example, approximately 37% of ideas submitted addressed AWFC #9: Improve Soldier, Leader and Team Performance (3rd highest AWFC addressed) and 35% of ideas addressed AWFC #2: Shape the Security Environment (4th highest AWFC addressed).

Figure 7: Number of ideas submitted to the technology survey that address one or more of the 20 AWFCs and alignment to 4 primary megacities objectives (grey boxes). Heat map colors determined by a scale of lowest (yellow) to highest (green) values. AWFCs ordered from highest to lowest number of ideas.

AWFCs	Number of ideas submitted to technology survey (63 total ideas) that address one or more AWFCs	Alignment to Primary Megacities/DUA Objectives
1: Develop Situational Understanding	45	Situational Understanding
8: Enhance Realistic Training	23	Future Training
9: Improve Soldier, Leader and Team Performance	23	Future Training
2: Shape the Security Environment	22	
10: Develop Agile and Adaptive Leaders	19	Future Training
13: Conduct Wide Area Security	17	Force Protection and Movement
19: Exercise Mission Command	16	
12: Conduct Joint Expeditionary Maneuver and Entry Operations	15	Expeditionary Operations
16: Set the Theater, Sustain Operations, and Maintain Freedom of Movement	15	Force Protection and Movement
3: Provide Security Force Assistance	14	
6: Conduct Homeland Operations	14	
4: Adapt the Institutional Army	12	Future Training
5: Counter Weapons of Mass Destruction	11	
15: Conduct Joint Combined Arms Maneuver	11	Force Protection and Movement
14: Ensure Interoperability and Operate in a Joint, Interorganizational, and Multinational Environment	9	
20 Develop Capable Formations	9	Expeditionary Operations
11: Conduct Air-Ground Reconnaissance	8	Situational Understanding
18: Deliver Fires	7	
7: Conduct Space & Cyber Electromagnetic Operations & Maintain Communications	6	
17: Integrate Fires	6	

Affiliation of MS Contributors

Contributors representing academia, government, and industry submitted ideas to the technology survey. The majority of ideas were submitted by contributors identified as Government, followed by Academia and Industry. Contributors who identified as "Other" listed "nonprofit" and "DoD" as their affiliation.

Figure 8: Number of ideas submitted by contributors affiliated with academia, government, industry, or "other"

Affiliation of technology survey contributors (63 ideas)	Number of ideas submitted to the technology survey
Academic	14
Government	38
Industry	8
Other	3

The number of ideas that address one or more of the 4 megacities objectives by each affiliation type were collected from the ratings provided through the technology survey. Because total number of ideas submitted differ based on affiliation type, the following ratings are reported as the percent of ideas when examining affiliation.

All affiliations addressed all 4 megacities objectives. The majority of ideas proposed by contributors affiliated with Academia (86 % of 14 ideas) and Government (87% of 38 ideas) addressed the Situational Understanding objective. All Industry ideas (100% of ideas) addressed Situational Understanding, Expeditionary Operations, and Future Training. Ideas proposed by contributors affiliated with "Other" addressed all megacity objectives.

Figure 9: The percent of ideas submitted to the technology survey that address one or more of the 4 megacities objectives by affiliation type. Heat map colors determined by a scale of 0 (yellow) to 100% (green).

	Primary Megacity/DUA Objectives			
Affiliation of technology survey contributors (63 ideas)	**1. Situational Understanding**	**2. Freedom of Movement and Protection**	**3. Expeditionary Operations**	**4. Future of Training**
Academic (14 ideas)	86	64	50	71
Government (38 ideas)	87	82	79	66
Industry (8 ideas)	100	88	100	100
Other (3 ideas)	100	100	100	100

A number of AWFCs were also addressed by all affiliations. The majority of ideas proposed by contributors affiliated with Academia, Government, and Industry addressed AWFC #1: Develop Situational Understanding (aligned to Situational Understanding megacity objective). The majority of ideas submitted by the "Other" affiliation addressed AWFC #1: Develop Situational Understanding (aligned to Situational Understanding megacity objective), AWFC #9: Improve Soldier, Leader and Team Performance, and AWFC #13: Conduct Wide Area Security Ideas.

Out of the 4 AWFCs that align to the 4 megacity objectives (grey boxes in Figure 10), only the AWFC aligned to the Expeditionary Operations megacity objective was not addressed by all affiliations: ideas submitted by contributors affiliated with Academia and an "Other" affiliation did not address AWFC #12: Conduct Joint Expeditionary Maneuver and Entry Operations.

Academia focused the most on AWFC #1: Develop Situational Understanding (64% of 14 ideas; aligned to Situational Understanding megacity objective), followed by AWFC #8: Enhance Realistic Training (50% of 14 ideas; aligned to Future Training Challenges megacity objective), and AWFC #9: Improve Soldier, Leader and Team Performance (43% of 14 ideas). Several AWFC were not addressed (6 AWFCs), including the AWFC aligned to the Expeditionary Operations megacity objective (AWFC #12: Conduct Joint Expeditionary Maneuver and Entry Operations) and 5 AWFC were barely addressed (10% or less of ideas).

Government affiliated ideas focused the most on AWFC #1: Develop Situational Understanding (74% of 38 ideas; aligned to Situational Understanding megacity objective), AWFC #2: Shape the Security Environment (39% of 38 ideas), and AWFC #12: Conduct Joint Expeditionary Maneuver and Entry Operations (37% of 38 ideas; aligned to Expeditionary Operations megacity objective). All AWFC were addressed by contributors associated with Government with several AWFCs barely addressed (10% or less ideas; 5 AWFCs). Contributors affiliated with Government had the highest number of ideas, possibly explaining why more AWFCs were addressed by this group.

Industry-affiliated contributors focused the most on AWFC #1: Situational Understanding (75% of 8 ideas; aligned to Situational Understanding megacity objective), AWFC #8: Enhance Realistic Training (50% of 8 ideas; aligned to Future Training Challenges megacity objective); and AWFC #2: Shape the Security Environment (38% of 8 ideas). AWFC #14: Ensure Interoperability and Operate in a Joint, Interorganizational, and Multinational Environment was the only AWFC not addressed by Industry.

Contributors identified as an “Other” affiliation focused the most on AWFC #1: Situational Understanding (67% of 3 ideas; aligned to Situational Understanding megacity objective) as well as on two AWFCs not associated with the 4 megacity objectives: AWFC #9: Improve Soldier, Leader and Team Performance (67% of 3 ideas); and AWFC #13: Conduct Wide Area Security Ideas (67% of 3 ideas). 8 AWFCs were not addressed by contributors with an “Other” affiliation.

Figure 10: Percentage of ideas submitted to the technology survey that address one or more of the 20 AWFCs by affiliation type. Alignment of AWFCs to 4 primary megacities objectives indicated by the grey boxes. Heat map colors determined by a scale of 0 (yellow) to 100% (green).

	Affiliation of technology survey contributors (63 ideas)			
AWFCs	Academic (14 ideas)	Government (38 ideas)	Industry (8 ideas)	Other (3 ideas)
1: Develop Situational Understanding	64	74	75	67
2: Shape the Security Environment	21	39	38	33
3: Provide Security Force Assistance	21	21	25	33
4: Adapt the Institutional Army	7	21	25	33
5: Counter Weapons of Mass Destruction	14	21	13	0
6: Conduct Homeland Operations	29	24	13	0
7: Conduct Space & Cyber Electromagnetic Operations & Maintain Communications	0	11	13	33
8: Enhance Realistic Training	50	29	50	33
9: Improve Soldier, Leader and Team Performance	43	34	25	67
10: Develop Agile and Adaptive Leaders	29	32	25	33
11: Conduct Air-Ground Reconnaissance	7	16	13	0
12: Conduct Joint Expeditionary Maneuver and Entry Operations	0	37	13	0
13: Conduct Wide Area Security	14	29	25	67
14: Ensure Interoperability and Operate in a Joint, Interorganizational, and Multinational Environment	7	18	0	33
15: Conduct Joint Combined Arms Maneuver	0	26	13	0
16: Set the Theater, Sustain Operations, and Maintain Freedom of Movement	7	32	13	33
17: Integrate Fires	0	13	13	0
18: Deliver Fires	0	13	13	33
19: Exercise Mission Command	21	26	25	33
20: Develop Capable Formations	7	18	13	0

In addition to ideas that address one of the 4 megacity objectives or 20 AWFCs, additional ideas categorized as “Other” were also submitted by survey contributors, including:

Government ideas that contributors identified as addressing topics "other" than the 4 megacities objectives:

- Intelligence Preparation of the Battlefield
- Visualization of region
- Phase 0 operations to prevent deployed forces
- Reconstitution operations
- 3d operations and common operating picture
- Maneuvering within the mega city from the soldier perspective
- Specialty UAVs
- Broadband over Power lines
- Non-Lethal Weapons
- Weapons effect and physics based modeling
- Agile, compact, layered synthetic environment representation
- Future training challenges
- Environmental awareness

Industry ideas that contributors identified as addressing topics "other" than the megacities objectives:

- Complex urban areas war games
- Experimentation
- Detailed exercises that get into the nuts and bolts of how maneuver intends to operate differently in cities
- Human dimension
- Networks
- Mission command systems
- Command and control
- COA development
- Package judgment and reasoning into systems throughout the command and control hierarchy

Ideas from "Other" affiliations that contributors identified as addressing topics "other" than the megacities objectives:

- Smarter access and egress from urban environments

Virtual Contributors

The Megacities and DUA conference also included over 500 individuals participating virtually through web streaming, a chat room, and Twitter: #madsci16. Chatroom and Twitter discussions were captured and an initial analysis of this data was conducted using a qualitative data analysis tool to identify the 100 most frequent terms used by participants for insight into predominant discussion topics. Based on this analysis, as visualized in the word cloud below, “training”, “human”, “hybrid”, “change”, “cultural”, “tech”, and “terrain” are among some of the more frequently used terms (See Appendix 4 for separate word clouds for the chat room and Twitter discussions)

Figure 11: 100 most frequent terms from the Megacities/DUA conference chat room and Twitter discussions.

Conclusion

Ideas for innovative concepts, technologies, data sources, and analytic and training methods are beginning to address the unique challenges that megacities and DUAs pose to future Army forces. Through the MS Megacities Initiative, all four of the primary megacities objectives were addressed by MS contributors from across government, academia, and industry.

The fundamental role of situational understanding in future Army operations is reflected by the results of the MS Megacities Initiative where this topic was the predominant theme. Advanced situational understanding and a system of systems approach is required to enable decision making in increasingly dense and complex environments. Understanding and modeling interactions between human and physical systems, innovative data sources, big data analytics, new analytic frameworks, expert knowledge integrated with collective intelligence, and emerging technologies can support situational understanding. The Army can leverage the vertical features of megacities and DUAs environments, lessons learned from domestic emergency response and evacuation research, and technology advancements in unmanned systems to address some challenges to freedom of movement and protection. A number of technologies have potential to support medical operations in megacity and DUAs, including for medical evacuation and care in the field. An intelligence model to support unified action, an operational planning framework for densely populated urban areas, and the use of virtual humans may support expeditionary operations. To address future training challenges, the Army will have to continue to explore innovative training methods, new, interdisciplinary curriculums, evolving perspectives that embrace complexity, flexibility, and originality, and advanced technology solutions that can immerse soldiers into megacity environments. In addition to addressing topics related to the 4 primary megacity objectives, MS contributors also underscored the importance of trying to attain U.S. objectives without having to engage in and deploy military forces to a megacity or DUA.

Although a number of concepts and capability/technology ideas were generated through the MS Megacities Initiative, this work has only begun to address the complexities of megacities and DUAs. A concerted effort to continue to address this topic, to include the following steps, will further build on the success of the MS Megacities Initiative.

- Ensure Situational Understanding remains incorporated into TRADOC Science and Technology (S&T) Needs for the Warfighter.
- Leverage the TRADOC critical thinking enterprise to focus on megacities and DUAs from the system of systems perspective.
- Leverage experimentation and exercise venues to explore the utility of various proposed analytic frameworks for future operational use.

- Continue to focus research, training, and modeling and simulation on the human component of megacities and DUAs, including informal social networks and governance structures, for situational understanding, freedom of movement and force protection, expeditionary operations.
- Initiate pilot programs to leverage diverse megacity data sets and integrate them with mission command and intelligence for decision making.
- Explore innovative collaboration methods to continue to engage additional interdisciplinary subject matter experts from social sciences, creative arts, public policy and administration, data analysis, the arts and humanities, and urban planning.
- Develop concepts and capabilities to attain U.S. objectives without having to engage in and deploy military forces to megacities and DUAs when possible.

Appendix 1: Sources

Berkow, Jan, and Poropatich, Ron COL(R). "TRAuma Care in a Rucksack (TRACIR) - A Disruptive Technology Concept." Center for Military Medicine Research - University of Pittsburgh, n.d.

Bitterman, Alex Phd, and Carlo, Richard, Prof. "Flocking Phones & Drones: Three-Dimensional, Real-Time, Mapping of Dense Urban Environments Using Off-the-Shelf Microdrone, Smartphone, and Point-Cloud Technology." Center for Architecture & Remote Sensing, SUNY Alfred State College of Technology, 2016.

Brown, Eddie MAJ. "Conveying the Complex: Updating U.S. Joint Systems Analysis Doctrine with Complexity Theory." School of Advanced Military Studies, U.S. Army Command and General Staff College, February 2013.

Brown, Eddie MAJ, and Pike, Tom MAJ. "Complex IPB." Self Published, 2016.

Castellanos, Dennis CW4, "Army Panel on Megacities." Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 21, 2016.

Crane, Alfred, and Peeke, Richard LTC. "Using the Internet of Things to Gain and Maintain Situational Awareness in Dense Urban Environments and Mega Cities." Army Capabilities Integration Center, 2016.

Crow, Michael Dr., "Welcome Remarks, Day 1." Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 21, 2016.

Demarest, Geoff. "How to Hold or Take a Big City - Seven Lines of Effort." U.S. Army Foreign Military Studies Office, n.d.

Dixon, Robert COL. "Bringing Big Data to War in Mega-Cities." War on the Rocks, January 19, 2016. http://warontherocks.com/2016/01/bringing-big-data-to-operations-in-mega-cities/.

Duggan, Patrick COL, "Army Panel on Megacities." Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 21, 2016.

Duggan, Patrick COL. "Man, Computer, and Special Warfare." Small Wars Journal, January 4, 2016. http://smallwarsjournal.com/jrnl/art/man-computer-and-special-warfare.

Felix, Kevin COL (RET.), "Army Panel on Megacities." Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 21, 2016.

Fin, Ed Dr. “Stories and Visions for a Better Future.” Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 21, 2016.

Fisher, Nathan. “Unmanned Systems in Support of Future Medical Operations in Dense Urban Environment.” Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 22, 2016.

Fisher, Nathan, and Gilbert, Gary. “Unmanned Systems in Support of Future Medical Operations in Dense Urban Environments.” Small Wars Journal, February 4, 2016. http://smallwarsjournal.com/jrnl/art/unmanned-systems-in-support-of-futuremedical- operations-in-dense-urban-environments.

Fowler, Marcie PhD, and McGhee, Laura MAJ. “Pain Management: Maintaining the Force.” United States Army Institute of Surgical Research, 2016.

Glenn, Russell Dr. “Megacities: The Good, The Bad, and The Ugly.” Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 22, 2016.

Glenn, Russell Dr. “Megacities: The Good, the Bad, and the Ugly.” Australian National University, April 2016.

Greco, Thomas DISE. “Day 1 Closing Remarks.” Closing Remarks presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 21, 2016.

Greco, Thomas DISE, Phillips, Gary E. DISL, and Hutchinson, Kira Dr. “Day 2 Opening Remarks.” Welcome presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 22, 2016.

Hedges, William CSM (Ret.). “An Analytical Framework for Operations in Dense Urban Terrain.” Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 21, 2016.

Hedges, William CSM (Ret.). “White Paper: An Analytic Framework for Operations in Dense Urban Areas.” U.S. Army Intelligence Center of Excellence, September 28, 2016.

Hess, Daniel Baldwin PhD. “Large-Scale Mass Evacuation in Metropolitan Areas: Improving Coordination for Multi-Modal Transport.” University of Buffalo, State University of New York, January 16, 2016.

Ippolito, Danielle PhD. “Assessing Physiological Response to Toxic Industrial Chemical Exposure in Megacities.” U.S. Army Center for Environmental Health Research, 2016.

Iwanski, Jeremy J. SSG. “The U.S. Military and Megacities/Dense Urban Areas.” Self Published, 2016.

Kem, John BG, “Welcome Remarks.” Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 21, 2016.

Krakowka, Amy Dr., “Army Panel on Megacities.” Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 21, 2016.

Keeley, Tom. “A Revolution in Military Affairs (RMA) versus ‘Evolution’ - When Machines Are Smart Enough.” Compsim, March 2015.

Knapp, David, Randall, Robb, and Staley, Jim. “Atmospheric Impacts and Effects Predictions and Applications for Future Megacity and Dense Urban Area Operations.” Army Research Lab & U.S. Army Intelligence Center, n.d.

Kozloski, Robert. “Power Through Stability.” Marine Corps Gazette, September 2014.

Kwon, Paul O. LTC. “Integrated Global Health Surveillance and Response through Multi-Source Technologies.” Self Published, 2016.

Lawton, Joel and Grubbs, Lee, “Information Paper: Mad Scientist Conference: Megacities and Dense Urban Areas.” December 2015.

Morrison, Dawn A., and Wood, Colin D. “Megacity and Dense Urban Environments: Obstacles or Opportunity?” Self Published, 2016.

Morris, Victor R. “Enhancing Intergovernmental Counter-Terrorism and Identity Discovery Capabilities through Identity and Biometric Enabled Intelligence.” Self Published, 2016.

Morris, Victor R. “Tailoring Intelligence and Analytic Support to Regionally Aligned and Multinational Forces - Collective Network Identification and Engagement Requirements for Unified Action Partners.” Self Published, 2016.

Ollivant, Douglas Dr. “Hybrid Warfare in Urban Environment.” Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 21, 2016.

Otto, Gustav, and Besik, AJ. “Megacity Madness.” Self Published, 2016.

Piekarski, Brett Dr. “Research and Vision for Intelligent Systems for 2025 and Beyond.” Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 22, 2016.

Piekarski, Brett Dr., Sadler, Brian, Young, Stuart, and Nothwang, William. “Research and Vision for Intelligent Systems for 2025 and Beyond.” U.S. Army Research Laboratory, 2016.

Pike, Tom, Long, Nick, and Alexander, Perry. "Understanding Nations: New Ideas to Analyze Foreign States." *InterAgency Journal* 6, no. 3 (September 2015): 47–56.

Pike, Tom MAJ, and Brown, Eddie MAJ. "Populations as Complex Adaptive Systems: A Case Study of Corruption in Afghanistan." Small Wars Journal, August 26, 2011.

Poste, George Dr. "Health Innovation for Dense Urban Areas." Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 21, 2016.

Prautzch, Frank. "U.S. Army Mega City Operations: Enduring Principles and Innovative Technologies." Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 22, 2016.

Prautzch, Frank. "U.S. Army Mega City Operations - Enduring Principles and Innovative Technologies." Self Published, 2016.

Quintas, Leopold BG, Kem, John S. BG, Crow, Michael M. Dr., and Greco, Thomas DISE. "Welcome Remarks." Welcome presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 21, 2016.

Richmond, Todd. "The Innovation Spectrum - Exploring Left of Boom." University of Southern California Institute for Creative Technologies, 2016.

Rose, James "Greg", "Army Panel on Megacities." Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 21, 2016.

Shutters, Shade T., Herche, Wes, and King, Erin. "Anticipating Megacity Responses to Shocks: Using Urban Integration and Connectedness to Assess Resilience." Arizona State University, 2016.

Swartout, William Dr. "Virtual Humans as Centaurs." Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 22, 2016.

Swartout, William Dr. "Virtual Humans as Centaurs." University of Southern California Institute for Creative Technologies, 2016.

Tucker, Chris Dr. "Emerging Geographical Tools to Understand Dense Urbane Areas." Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 22, 2016.

Usher, Abe. "Addressing the Challenges of the Human Terrain in 2050." Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 21, 2016.

Ward, Darryl. “Operational Environment Implications of the Megacity to the U.S. Army.” TRADOC G-2, March 2016.

Watkins, Jon. “Challenges with Representing the Megacity Environment in Simulations.” Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 22, 2016.

Watkins, Jon, and Campbell, Chuck. “Challenges with Representing the Megacity Environment in Simulation.” Dignitas Technologys and Edge Wise Technologies, February 11, 2016.

Wolfel, Richard PhD, Krakowka, Amy Dr., Read, Mark COL, and Tansey, Colin MAJ. “It’s in There: Rethinking(?) Intelligence Preparation of the Battlefield in Megacities/Dense Urban Areas.” United States Military Academy, 2016.

Zenzen, Fran Dr. “Frameworks for Future Challenges: Understanding Dense Urban Terrain.” Information Briefing presented at the TRADOC G-2 Mad Scientists 2016: Megacities and Dense Urban Areas in 2025 and Beyond, Tempe, AZ, April 22, 2016.

Appendix 2: List of Mad Scientist Megacities Initiative Contributors

Table 1: Mad Scientists Contributors

NAME	ORGANIZATION	IDEA CONTRIBUTION (S)	SOURCE
BG LEOPOLD QUINTAS	DIRECTOR, CONCEPT DEVELOPMENT AND LEARNING DIRECTORATE, TRADOC	WELCOME/OPENING REMARKS	CONFERENCE PRESENTATION
BG JOHN S. KEM	PROVOST, ARMY UNIVERSITY, DEPUTY COMMANDANT, U.S. ARMY COMMAND AND GENERAL STAFF COLLEGE	WELCOME/OPENING REMARKS	CONFERENCE PRESENTATION
DR. MICHAEL M. CROW	PRESIDENT, ARIZONA STATE UNIVERSITY	WELCOME/INNOVATION AND EDUCATION	CONFERENCE PRESENTATION
DR. GEORGE POSTE	CHIEF SCIENTIST AND REGENT'S PROFESSOR, ARIZONA STATE UNIVERSITY	"HEALTH INNOVATION FOR DENSE URBAN AREAS"	CONFERENCE PRESENTATION
MR. ABE USHER	CHIEF TECHNOLOGY OFFICER, HUMANGEO GROUP,	"ADDRESSING THE CHALLENGES OF THE HUMAN TERRAIN IN 2050"	CONFERENCE PRESENTATION
DR. DOUGLAS OLLIVANT	ARIZONA STATE UNIVERSITY, FUTURE OF WAR SENIOR FELLOW	"HYBRID WARFARE IN URBAN ENVIRONMENTS"	CONFERENCE PRESENTATION
COL PATRICK DUGGAN	STRATEGIC LANDPOWER TASK FORCE, SOCOM	ARMY PANEL ON MEGACITIES	CONFERENCE PRESENTATION
COL (RET.), KEVIN FELIX	SENIOR CONSULTANT, THE ROOSEVELT GROUP	ARMY PANEL ON MEGACITIES	CONFERENCE PRESENTATION
DR. AMY KRAKOWKA-RICHMOND	ASSOCIATE PROFESSOR OF GEOGRAPHY, USMA	ARMY PANEL ON MEGACITIES	CONFERENCE PRESENTATION
CW4 DENNIS CASTELLANOS	COMMANDER'S ACTION GROUP, MANEUVER CENTER OF EXCELLENCE (MCOE)	ARMY PANEL ON MEGACITIES	CONFERENCE PRESENTATION
MR. JAMES "GREG" ROSE	DIRECTOR, CAPABILITY DEVELOPMENT INTEGRATION DIRECTORATE (CDID) ICOE	ARMY PANEL ON MEGACITIES (MODERATOR)	CONFERENCE PRESENTATION
CSM (RET) WILLIAM "BILL" HEDGES	LNO, INTELLIGENCE & INFORMATION WARFARE DIRECTORATE & ICOE	"AN ANALYTIC FRAMEWORK FOR OPERATIONS IN DENSE URBAN AREAS"	CONFERENCE PRESENTATION
DR. ED FINN	FOUNDING DIRECTOR OF THE CENTER FOR SCIENCE AND THE IMAGINATION AND ASSISTANT PROFESSOR, ARIZONA STATE UNIVERSITY	STORIES AND VISIONS FOR A BETTER FUTURE	CONFERENCE PRESENTATION
DR. FRAN ZENZEN	ASURE CHIEF OPERATING OFFICER, ARIZONA STATE UNIVERSITY	"FRAMEWORKS FOR FUTURE CHALLENGES: UNDERSTANDING DENSE URBAN AREAS"	CONFERENCE PRESENTATION

NAME	ORGANIZATION	IDEA CONTRIBUTION (S)	SOURCE
DR. RUSSELL GLENN	ASSOCIATE PROFESSOR, STRATEGIC AND DEFENCE STUDIES CENTRE, AUSTRALIAN NATIONAL UNIVERSITY	"MEGACITIES: THE GOOD, THE BAD, AND THE UGLY"	CONFERENCE PRESENTATION
MR. NATHAN FISHER	PROJECT MANAGER, MECHANICAL ENGINEER AND ROBOTICIST, THE GENEVA FOUNDATION	"UNMANNED SYSTEMS IN SUPPORT OF FUTURE MEDICAL OPERATIONS IN DENSE URBAN ENVIRONMENTS"	CONFERENCE PRESENTATION
DR. WILLIAM SWARTOUT	DIRECTOR OF TECHNOLOGY, USC INSTITUTE FOR CREATIVE TECHNOLOGIES	"VIRTUAL HUMANS AS CENTAURS"	CONFERENCE PRESENTATION
MR. FRANK PRAUTZSCH	PRESIDENT, VELOCITY TECHNOLOGY PARTNERS LLC	"U.S. ARMY MEGA CITY OPERATIONS: ENDURING PRINCIPLES AND INNOVATIVE TECHNOLOGIES"	CONFERENCE PRESENTATION
MR. JON WATKINS	FOUNDER AND CHIEF OPERATING OFFICER, DIGNITAS TECHNOLOGIES LLC	"CHALLENGES WITH REPRESENTING THE MEGACITY ENVIRONMENT IN SIMULATIONS"	CONFERENCE PRESENTATION
DR. BRETT PIEKARSKI	CHIEF OF THE MICRO & NANO MATERIALS & DEVICES BRANCH, ARMY RESEARCH LABORATORY	"RESEARCH AND VISION FOR INTELLIGENT SYSTEMS FOR 2025 AND BEYOND"	CONFERENCE PRESENTATION
DR. CHRIS TUCKER	CHAIRMAN AND CEO, MAP STORY	EMERGING GEOGRAPHICAL TOOLS TO UNDERSTAND DENSE URBAN AREAS	CONFERENCE PRESENTATION
MR. THOMAS GRECO	TRADOC DCS G-2	OPENING REMARKS CONFERNCE SUMMATION	CONFERENCE PRESENTATION
MR. GARY PHILLIPS	TRADOC G-2 SENIOR INTELLIGENCE ADVISOR	DAY 1 INSIGHTS	CONFERENCE PRESENTATION
DR. KIRA HUTCHINSON	TRADOC G-29	ADMINISTRATIVE REMARKS	CONFERENCE PRESENTATION
COL LEE GRUBBS	DEPUTY, TRADOC G-2	DAY 2 INSIGHTS	CONFERENCE PRESENTATION
LTG KEVIN MANGUM	DEPUTY COMMANDING GENERAL, TRADOC	CONFERENCE SUMMATION AND CLOSING REMARKS	CONFERENCE PRESENTATION
KIRA HUTCHINSON	TRADOC G2	COMPLEX IPB; METAL FOAM THAT OBLITERATED BULLETS; POINT OF DEMAND WATER PRODUCTION; DATA DRIVEN DECISION MAKING TOOL	ELECTRONIC SURVEY
WILLIAM THEUER	AFCEA AK	DISTRIBUTED MOBILITY AND TEAMS	ELECTRONIC SURVEY
BRIAN SWEENEY	PLANETRISK, INC	DISCRETE GLOBAL GRID (DDG)	ELECTRONIC SURVEY
CARRIE MEZA	NAVY EXPEDITIONARY WARFARE	AUTONOMOUS SYSTEMS	ELECTRONIC SURVEY
RICHARD WOLFEL	U.S. MILITARY ACADEMY	SOCIAL MEDIA MAPPING	ELECTRONIC SURVEY
RICHARD KNAPP	USAACE QAO	CROWDSOURCING INTELLIGENCE	ELECTRONIC SURVEY
TOM KEELEY	COMPSIM LLC	KNOWLEDGE ENHANCED ELECTRONIC LOGIC - KEEL TECHNOLOGY	ELECTRONIC SURVEY
CHRISTOPHER EDWARDS	AWG	SWARM DRONE MEGACITY MAPPING	ELECTRONIC SURVEY

NAME	ORGANIZATION	IDEA CONTRIBUTION (S)	SOURCE
DAVID CONNELL	DEFENCE RESEARCH & DEVELOPMENT CANADA	SOCIAL BOTS	ELECTRONIC SURVEY
GEOFF DEMAREST	FMSO	GENOME ENGINEERING	ELECTRONIC SURVEY
SCOTT GORIC	ARMY	ROBOTICS OPTICS	ELECTRONIC SURVEY
SEAN	NGIC	MACHINE EMOTIONAL INTELLIGENCE	ELECTRONIC SURVEY
RUSS GLENN	ANU	KEY INDIVIDUAL RECOGNITION TOOL	ELECTRONIC SURVEY
ANTHONY GARNER	ARCIC/CDLD/ FUTURE WARFARE DIVISON	MUMT	ELECTRONIC SURVEY
CHRISTOPHER EDWARDS	AWG	TACTICAL VIRTUAL HUMAN ASSISTANT	ELECTRONIC SURVEY
JUNE CROWE	IIA	AGGREGATION OF OPEN SOURCE INFORMATION	ELECTRONIC SURVEY
RANDALL HILL	USC INSTITUTE FOR CREATIVE TECHNOLOGIES	VIRTUAL / AUGMENTED REALITY VIRTUAL HUMANS	ELECTRONIC SURVEY
BOB DIXON	U.S. ARMY	THINKING URBAN WARRIOR	ELECTRONIC SURVEY
MARK STALZER	CALTECH	BIOWEAPON NUCLEAR THREAT HUMAN INTELLECTUAL THREATS	ELECTRONIC SURVEY
BRIAN GRUCHACZ	RDECOM ARDEC	RAPID VACCINE FABRICATION AND DEPLOYMENT	ELECTRONIC SURVEY
GEOFF DEMAREST	FMSO	GROUND SHAPING	ELECTRONIC SURVEY
JON WATKINS	DIGNITAS TECHNOLOGIES	CONCEPTUALIZATION & PROTOTYPE THROUGH VIRTUAL SIMULATION	ELECTRONIC SURVEY
WILLIAM HEDGES	I2WD/ICOE (LNO)	AN ANALYTIC FRAMEWORK FOR DENSE URBAN AREAS	ELECTRONIC SURVEY
CHRISTIAN FORTUNATO	ASURE	SYSTEMS ENGINEERING AND MODELING	ELECTRONIC SURVEY
LLOYD BROWN	ASURE	MEGACITY INTEGRATED MODEL	ELECTRONIC SURVEY
JIM RUSSELL	ASURE	LEARNING: FROM TRAINING TO EDUCATION	ELECTRONIC SURVEY
MARK WALLACE	USAICOE CONCEPTS	GOVERNMENT CONSULTANT FOR FUTURE INTELLIGENCE	ELECTRONIC SURVEY
JIM RUSSELL	ASURE	URBAN OPERATIONS ARE "NORMAL" OPERATIONS	ELECTRONIC SURVEY
JESSE COOK	USMC	GRAPHENE	ELECTRONIC SURVEY
MARGARET LOPER	GEORGIA TECH RESEARCH INSTITUTE	MACHINE TO MACHINE TRUST	ELECTRONIC SURVEY
ROBERT E SMITH	U.S. ARMY TANK AUTOMOTIVE RD&E CENTER	MEGACITY "MASTER LEARNER" VIRTUAL WORLD VERTICAL FIGHTING VEHICLE/ PLATFORM	ELECTRONIC SURVEY
JESSE COOK	USMC	FAO/RAO ANTHROPOLOGIST	ELECTRONIC SURVEY

NAME	ORGANIZATION	IDEA CONTRIBUTION (S)	SOURCE
FRANK PRAUTZSCH	VELOCITY TECHNOLOGY PARTNERS LLC	GRAPHENE	ELECTRONIC SURVEY
ROBERT MCMURTRIE	ICOE/ TRADOC CAPABILITY MANAGER- TERRESTRIAL AND IDENTITY	IDENTITY BASED TECHNOLOGIES	ELECTRONIC SURVEY
WILLIAM GOTHARD	U.S. ARMY SPECIAL OPERATIONS COMMAND	FEMTOSECOND LASER	ELECTRONIC SURVEY
LOGAN MATHESEN	ASURE	LIVEHOODS COMMUNITY IDENTIFIER	ELECTRONIC SURVEY
DYLAN FARLEY	COLLEGE OF WILLIAM AND MARY	SUBTERRANEAN MAPPING SYSTEM	ELECTRONIC SURVEY
THOMAS MCMURTRIE	TRAC-WSMR	PROVINCIAL RECONSTRUCTION TEAM CAPABILITY FOR REGIONALLY ALIGNED FORCES	ELECTRONIC SURVEY
LTC MELVIN D. JUAN	NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY	GEOSPATIAL INFORMATION & SERVICES	ELECTRONIC SURVEY
NATHAN FISHER	TATRC	UNMANNED AIR SYSTEMS FOR MEDICAL OPEATIONS	ELECTRONIC SURVEY
RANDALL HILL	USC INSTITUTE FOR CREATIVE TECHNOLOGIES	SOCIAL SIMULATION	ELECTRONIC SURVEY
PETER PALMER	GDMS	EDGE INNOVATION NETWORK	ELECTRONIC SURVEY
BRIAN GRUCHACZ	RDECOM- ARDEC	INSTANT NEGATIVE TRENDING ALERTS	ELECTRONIC SURVEY
DAVID FORDYCE	U.S. ARMY RESEARCH LABORATORY	URBAN ENVIRONMENT CHARACTERIZATION	ELECTRONIC SURVEY
DANIELLE L. IPPOLITO	USACEHR	FIELDABLE DETECTION CARTRIDGE FOR MOLECULAR INDICATORS OF EXPOSURE AND ADVERSE HEALTH EFFECTS; EHARM: ELECTRONIC HEALTH ASSESSMENT AND RISK MANAGEMENT TOOL FOR ASSESSING PHYSIOLOGICAL RESPONSE TO TOXIC INDUSTRIAL CHEMICAL EXPOSURE	ELECTRONIC SURVEY
ALLISON WIN	TRADOC	MAD SCIENTIST SME	ELECTRONIC SURVEY
JULIO DE LA CRUZ	ARL HRED ATSD	CHIEF ENGINEER FOR SNE	ELECTRONIC SURVEY
FREDERICK SAPP	TRADOC SWO	AUTONOMOUS SYSTEMS	ELECTRONIC SURVEY
CHRISTOPHER TUCKER	THE MAPSTORY FOUNDATION	MAPSTORY.ORG	ELECTRONIC SURVEY
DR. STEVEN FUNK	U.S. ARMY AFRICA	MACHINE REAL TIME VERBAL TRANSLATOR	ELECTRONIC SURVEY
DENNIS CASTELLANOS	MCOE	LEADER DEVELOPMENT AND TRAINING	ELECTRONIC SURVEY
DAVID KNAPP	ARMY RESEARCH LABORATORY	ATMOSPHERIC CHARACTERIZATION AND PREDICTION	ELECTRONIC SURVEY
FRAN ZENZEN	ASU RESERACH ENTERPRISE	CONSOLIDATED CITY MODELS	ELECTRONIC SURVEY
ANGELA HOISTION	TRADOC/USAICOE TCM-FOUNDATION	VISUAL RESPONSIVE / ARTIFICIAL INTELLIGENCE INTERACTIVE SOFTWARE	ELECTRONIC SURVEY

NAME	ORGANIZATION	IDEA CONTRIBUTION (S)	SOURCE
BRIAN KETTLER	LOCKHEED MARTIN ADVANCED TECHNOLOGY LABS	EXPEDITIONARY MODELING OF MEGACITIES	ELECTRONIC SURVEY
BERKOW, JAN AND POROPATICH, RON COL(R)	U.S. ARMY	"TRAUMA CARE IN A RUCKSACK (TRACIR) - A DISRUPTIVE TECHNOLOGY CONCEPT."	PAPER SUBMISSION
BITTERMAN, ALEX PHD AND CARLO, RICHARD, PROF	CENTER FOR ARCHITECTURE & REMOTE SENSING, SUNY ALFRED STATE COLLEGE OF TECHNOLOGY	"FLOCKING PHONES & DRONES: THREE-DIMENSIONAL, REAL-TIME, MAPPING OF DENSE URBAN ENVIRONMENTS USING OFF-THE-SHELF MICRODRONE, SMARTPHONE, AND POINT-CLOUD TECHNOLOGY."	PAPER SUBMISSION
BROWN, EDDIE MAJ AND PIKE, TOM MAJ	U.S. ARMY	"COMPLEX IPB."	PAPER SUBMISSION
BROWN, EDDIE MAJ	U.S. ARMY	"CONVEYING THE COMPLEX: UPDATING U.S. JOINT SYSTEMS ANALYSIS DOCTRINE WITH COMPLEXITY THEORY."	PAPER SUBMISSION
CRANE, ALFRED AND PEEKE, RICHARD LTC	U.S. ARMY	"USING THE INTERNET OF THINGS TO GAIN AND MAINTAIN SITUATIONAL AWARENESS IN DENSE URBAN ENVIRONMENTS AND MEGA CITIES."	PAPER SUBMISSION
DEMAREST, GEOFF	FMSO	"HOW TO HOLD OR TAKE A BIG CITY - SEVEN LINES OF EFFORT."	PAPER SUBMISSION
DIXON, ROBERT COL	U.S. ARMY	"BRINGING BIG DATA TO WAR IN MEGA-CITIES."	PAPER SUBMISSION
DUGGAN, PATRICK COL	U.S. ARMY	"MAN, COMPUTER, AND SPECIAL WARFARE."	PAPER SUBMISSION
FISHER, NATHAN AND GILBERT, GARY	U.S. ARMY	"UNMANNED SYSTEMS IN SUPPORT OF FUTURE MEDICAL OPERATIONS IN DENSE URBAN ENVIRONMENTS."	PAPER SUBMISSION
FOWLER, MARCIE PHD AND MCGHEE, LAURA MAJ	U.S. ARMY	"PAIN MANAGEMENT: MAINTAINING THE FORCE."	PAPER SUBMISSION
GLENN, RUSSELL DR.	AUSTRALIAN NATIONAL UNIVERSITY	"MEGACITIES: THE GOOD, THE BAD, AND THE UGLY."	PAPER SUBMISSION
HEDGES, WILLIAM CSM (RET.),	U.S. ARMY	"WHITE PAPER: AN ANALYTIC FRAMEWORK FOR OPERATIONS IN DENSE URBAN AREAS."	PAPER SUBMISSION
HESS, DANIEL BALDWIN PHD	UNIVERSITY OF BUFFALO, STATE UNIVERSITY OF NEW YORK	"LARGE-SCALE MASS EVACUATION IN METROPOLITAN AREAS: IMPROVING COORDINATION FOR MULTI-MODAL TRANSPORT."	PAPER SUBMISSION
IPPOLITO, DANIELLE PHD	U.S. ARMY	"ASSESSING PHYSIOLOGICAL RESPONSE TO TOXIC INDUSTRIAL CHEMICAL EXPOSURE IN MEGACITIES."	PAPER SUBMISSION
IWANSKI, JEREMY J. SSG	U.S. ARMY	"THE U.S. MILITARY AND MEGACITIES/DENSE URBAN AREAS."	PAPER SUBMISSION
KEELEY, TOM	COMPSIM	"A REVOLUTION IN MILITARY AFFAIRS (RMA) VERSUS 'EVOLUTION' - WHEN MACHINES ARE SMART ENOUGH."	PAPER SUBMISSION
KNAPP, DAVID, RANDALL, ROBB, AND STALEY, JIM	U.S. ARMY	"ATMOSPHERIC IMPACTS AND EFFECTS PREDICTIONS AND APPLICATIONS FOR FUTURE	PAPER SUBMISSION

NAME	ORGANIZATION	IDEA CONTRIBUTION (S)	SOURCE
		MEGACITY AND DENSE URBAN AREA OPERATIONS.”	
KOZLOSKI, ROBERT	USMC	“POWER THROUGH STABILITY.”	PAPER SUBMISSION
KWON, PAUL O. LTC	U.S. ARMY	“INTEGRATED GLOBAL HEALTH SURVEILLANCE AND RESPONSE THROUGH MULTI-SOURCE TECHNOLOGIES.”	PAPER SUBMISSION
MORRISON, DAWN A. AND WOOD, COLIN D.	U.S. ARMY	“MEGACITY AND DENSE URBAN ENVIRONMENTS: OBSTACLES OR OPPORTUNITY?”	PAPER SUBMISSION
MORRIS, VICTOR R.	U.S. ARMY	“ENHANCING INTERGOVERNMENTAL COUNTER-TERRORISM AND IDENTITY DISCOVERY CAPABILITIES THROUGH IDENTITY AND BIOMETRIC ENABLED INTELLIGENCE.”	PAPER SUBMISSION
MORRIS, VICTOR R.	U.S. ARMY	“REVISING ATTACK THE NETWORK (ATN) AND DEFEAT THE DEVICE (DTD) C-IED LINES OF OPERATION: 21ST CENTURY THREATS AND NATO INTEROPERABILITY.”	PAPER SUBMISSION
MORRIS, VICTOR R.	U.S. ARMY	“TAILORING INTELLIGENCE AND ANALYTIC SUPPORT TO REGIONALLY ALIGNED AND MULTINATIONAL FORCES - COLLECTIVE NETWORK IDENTIFICATION AND ENGAGEMENT REQUIREMENTS FOR UNIFIED ACTION PARTNERS.”	PAPER SUBMISSION
OTTO, GUSTAV AND BESIK, AJ	DOD	“MEGACITY MADNESS.”	PAPER SUBMISSION
PIEKARSKI, BRETT DR. ET AL.	U.S. ARMY	“RESEARCH AND VISION FOR INTELLIGENT SYSTEMS FOR 2025 AND BEYOND.”	PAPER SUBMISSION
PIKE, TOM, LONG, NICK, AND ALEXANDER, PERRY	U.S. ARMY	“UNDERSTANDING NATIONS: NEW IDEAS TO ANALYZE FOREIGN STATES.”	PAPER SUBMISSION
PIKE, TOM MAJ AND BROWN, EDDIE MAJ	U.S. ARMY	“POPULATIONS AS COMPLEX ADAPTIVE SYSTEMS: A CASE STUDY OF CORRUPTION IN AFGHANISTAN.”	PAPER SUBMISSION
PRAUTZCH, FRANK	VELOCITY TECHNOLOGY PARTNERS LLC	“U.S. ARMY MEGA CITY OPERATIONS - ENDURING PRINCIPLES AND INNOVATIVE TECHNOLOGIES.”	PAPER SUBMISSION
RICHMOND, TODD	UNIVERSITY OF SOUTHERN CALIFORNIA INSTITUTE FOR CREATIVE TECHNOLOGIES	“THE INNOVATION SPECTRUM - EXPLORING LEFT OF BOOM.”	PAPER SUBMISSION
SHUTTERS, SHADE T., HERCHE, WES, AND KING, ERIN	ARIZONA STATE UNIVERSITY	“ANTICIPATING MEGACITY RESPONSES TO SHOCKS: USING URBAN INTEGRATION AND CONNECTEDNESS TO ASSESS RESILIENCE.”	PAPER SUBMISSION
SWARTOUT, WILLIAM DR.	UNIVERSITY OF SOUTHERN CALIFORNIA INSTITUTE FOR CREATIVE TECHNOLOGIES	“VIRTUAL HUMANS AS CENTAURS.”	PAPER SUBMISSION
WARD, DARRYL	FMSO	“OPERATIONAL ENVIRONMENT IMPLICATIONS OF THE MEGACITY TO THE U.S. ARMY.”	PAPER SUBMISSION

NAME	ORGANIZATION	IDEA CONTRIBUTION (S)	SOURCE
WATKINS, JON AND CAMPBELL, CHUCK	DIGNITAS TECHNOLOGYS AND EDGE WISE TECHNOLOGIES	"CHALLENGES WITH REPRESENTING THE MEGACITY ENVIRONMENT IN SIMULATION."	PAPER SUBMISSION
WOLFEL, RICHARD PHD ET AL.	USMA	"IT'S IN THERE: RETHINKING(?) INTELLIGENCE PREPARATION OF THE BATTLEFIELD IN MEGACITIES/DENSE URBAN AREAS."	PAPER SUBMISSION

Appendix 3: Methodology

1) Developed a protocol to collect and asses the results of the Mad Scientist (MS) Megacities Initiative.
2) Collected the results of the MS Megacities Initiative
   - Collected insights about megacities and DUAs from academic publications submitted in response to a 2015 TRADOC G-2 call for papers.
   - Collected insights from the April 2016 MS Megacities and Dense Urban Areas Conference presentations and discussions, including virtual chat room and Twitter discussions.
   - Collected data from the online technology survey (ideas; submitter affiliations; ratings aligning ideas to the 4 primary megacity objectives, LOEs, AWFCs, and Technology Imperatives; ratings about how recent ideas are and level of influence of the idea).
3) Analyzed the results of the MS Megacities Initiative to address extent to which proposed megacity capability and technology ideas address the 4 megacity objectives.
   - Authors of submitted academic publications and independent reviewers read and rated submitted papers based on how well they addressed one or more of the 4 megacity objectives. For each of the 4 megacity objectives, a paper was given a:
     - Score of 2 if the paper primarily addressed a megacity objective (the major focus of the paper addresses a megacity objective).
     - Score of 1 if the paper somewhat addressed a megacity objective (information addressing a megacity objective was not the major focus of the paper).
   - Attended the Megacities and Dense Urban Areas Conference and collected relevant data:
     - Collected notes on presentations and discussions. Insights were then categorized into the 4 megacity objectives.
     - Virtual discussions (chat room and Twitter) we collected, sanitized (names and irrelevant information removed) and analyzed using NVivo 11, a qualitative data analysis tool, to identify the 100 most frequent terms (3 letters or more) used in the discussions.
   - Performed a quantitative summary of the collected data from the online technology survey (ideas; submitter affiliations; ratings aligning ideas to the 4 primary megacity objectives, LOEs, AWFCs, and Technology Imperatives; ratings about how recent ideas are and level of influence of the idea) to assess how ideas aligned to megacity objectives, LOEs, AWFCs, and Technology Imperatives.
4) Developed a technical report with the results of the MS Megacities and Dense Urban Areas Conference, with specific recommendations to the TRADOC plan.

Appendix 4: Additional Data Analysis Results

Survey Data

Data collected from 63 ideas submitted to an online technology survey were analyzed to assess how ideas aligned to eight Levels of Effort (LOEs) and six Technology Imperatives.

Figure 12: Number of ideas submitted to the technology survey (63 total) that address one or more of the 8 LOEs. Heat map colors determined by a scale of lowest (yellow) to highest (green) values.

	8 Lines of Effort (LOEs)								
	LOE1: Mobile Protected Platforms	LOE2: Improved Lethality and Effects	LOE3: Logistics Optimization	LOE4: Aviation	LOE5: Cyber Electromagnetic Activities	LOE6: Accelerated Data to Decision	LOE7: Human Performance Enhancement	LOE8: Robotics	Number of "Other" ideas not aligned to LOEs
Number of ideas submitted to the technology survey (63 ideas) that address one or more of the 8 LOEs	3	5	3	1	1	18	14	5	13

Figure 13: The percent of ideas submitted to the technology survey that address one or more of the 8 LOEs by affiliation type. Heat map colors determined by a scale of 0 (yellow) to 100% (green).

	8 LOEs								
Affiliation of technology survey contributors (63 ideas)	**LOE1: Mobile Protected Platforms**	**LOE2: Improved Lethality and Effects**	**LOE3: Logistics Optimization**	**LOE4: Aviation**	**LOE5: Cyber Electromagnetic Activities**	**LOE6: Accelerated Data to Decision**	**LOE7: Human Performance Enhancement**	**LOE8: Robotics**	**Other**
Academic (14 ideas)	0	0	0	0	0	43	29	7	21
Government (38 ideas)	8	11	8	3	3	29	18	11	11
Industry (8 ideas)	0	13	0	0	0	13	13	0	63
Other (3 ideas)	0	0	0	0	0	0	67	0	33

8 Lines of Effort (LOEs):

LOE1: Mobile Protected Platforms: To enable a globally-responsive force that is rapidly deployable, through the use of lighter materials, and novel protection systems, to protect against kinetic and non-kinetic future threats. These vehicles will be augmented by unmanned vehicles and unmanned aerial systems.

LOE2: Improved Lethality and Effects: The Army requires munitions, platforms, and mission command systems that enable the detection, identification and engagement of threats with precise, scalable and tailorable effects, both kinetic and non-kinetic, in a contested environment.

LOE3: Logistics Optimization: In order to have an expeditionary capability to fight in a contested environment, the Army must increase logistical efficiencies, increase unit self-sufficiency, and decrease demands.

LOE4: Aviation: The future Army requires aviation assets with extended reach, increased lethality and increased responsiveness, capable of operating in all environments and conditions.

LOE5: Cyber Electromagnetic Activities: Commanders and staffs must integrate and synchronize cyberspace operations, electromagnetic spectrum management operations and related capabilities in a contested environment.

LOE6: Accelerated Data to Decision: The future demands our Soldiers be empowered with situational awareness and understanding to make rapid decisions by accelerating the flow of information to the point of need at the speed of war.

LOE7: Human Performance Enhancement: The Army must maximize the return on its most critical resource. The future requires that Soldiers who have enhanced cognitive, physical and socio-cultural skills in order to be effective in the complex environment in which they will operate."

LOE8: Robotics: The Army needs affordable, interoperable, and autonomous unmanned systems to engage integrated manned-unmanned teaming and serve as force multipliers across all echelons and war fighting functions. Artificial intelligence capabilities will be critical to empower unmanned systems and serve as decision aids.

Figure 14: Number of ideas submitted to the technology survey (63 total) that address one or more of the Technology Imperatives and the influence ratings for maintaining overmatch. Heat map colors determined by a scale of lowest (yellow) to highest (green) values.

Technology Imperatives	Number of ideas submitted to technology survey (63 total ideas) that address one or more Technology Imperatives	Influence Rating: Extremely valuable	Influence Rating: Significant	Influence Rating: Moderate	Influence Rating: Minimal	Number of ideas with an influence rating of extremely valuable or significant
Grow Adaptive Leaders, Optimize Human Performance	30	10	11	8	1	21
Maximize Demand Reduction and Improve Reliability	4	0	3	1	0	3
Maintain Overmatch	26	8	5	13	0	13
Continuous Upgrade, Protect and Simplify the Network	10	3	3	3	1	6
Enhance Expeditionary Capabilities	27	5	14	7	1	19
Medical Science	7	2	5	0	0	7

Influence Rating for Maintaining Overmatch

- None: Will likely not provide any additional value relative to current capabilities in this area.
- Minimal: Will likely provide minimal (1-25%) improvement over current capabilities. Although limited and/or indirectly related, it may provide slight contributions to future progress in this area.
- Moderate: Will likely provide moderate (26-50%) improvement over current capabilities. Not critical, but notably relevant; it will have noticeable contributions towards future progress in this area.
- Significant: Will likely provide significant (51-75%) improvement over current capabilities. A highly noticeable and important component of future progress in this area.
- Extremely Valuable: Will likely provide game-changing (76-100%) improvement over current capabilities. Critical to future progress in this area; it may become a dominant and/or transformative technology to this area.

Figure 15: The percent of ideas submitted to the technology survey that address one or more of the Technology Imperatives by affiliation type. Heat map colors determined by a scale of 0 (yellow) to 100% (green).

	Technology Imperatives					
Affiliation of technology survey contributors (63 ideas)	Grow Adaptive Leaders, Optimize Human Performance	Maximize Demand Reduction and Improve Reliability	Maintain Overmatch	Continuous Upgrade, Protect and Simplify the Network	Enhance Expeditionary Capabilities	Medical Science
Academic (14 ideas)	57	7	43	21	21	7
Government (38 ideas)	39	8	39	13	50	11
Industry (8 ideas)	50	0	63	25	50	13
Other (3 ideas)	100	0	0	0	33	33

Technology Imperatives:

- Grow Adaptive Leaders, Optimize Human Performance: Improve experience, judgment, endurance and interaction, and maximize the human potential.
- Maximize Demand Reduction and Improve Reliability: Field technologies that extend equipment life cycles, improve reliability, availability, and maintainability, while maintaining or increasing performance.
- Maintain Overmatch: Counter emerging threats and challenges in the strategic environment, particularly increased adversary investments in, and access to knowledge and technology, to retain and improve core Army operational advantages, particularly in the areas of mobility, lethality, protection, intelligence, and mission command.
- Continuous Upgrade, Protect and Simplify the Network: Improve the information environment in which our Soldiers operate, while ensuring resilience and reducing the complexity and fragility of the network, to empower leaders at the lowest levels with relevant combat information that provides a high degree of situational understanding and greater interoperability with joint, interagency, and multinational partners and capabilities.
- Enhance Expeditionary Capabilities: Retain core Army operational advantages, while increasing global, operational, and tactical mobility, overall protection, augmented with enhanced survivability, and discriminant lethality,

to improve Army global responsiveness and ability to protect forces, conduct forcible and early entry, and transition rapidly to offensive operations to ensure access and seize the initiative while offsetting emerging enemy capabilities.

- Medical Science: Seeks means to improve soldier resiliency, enable quicker physical and mental healing, enable smoother integration of our warriors back into society, and improve the quality of life for the Soldier.

Figure 16: Number of ideas submitted to the technology survey (63 total) that address one or more of the 20 AWFCs and the influence ratings for maintaining overmatch. Heat map colors determined by a scale of lowest (yellow) to highest (green) values.

AWFCs	Number of ideas submitted to technology survey (63 total ideas) that address one or more AWFCs	Alignment to Primary Megacities/DUA Objectives	Influence Rating: Extremely valuable	Influence Rating: Significant	Influence Rating: Moderate	Influence Rating: Minimal	Number of ideas with an influence rating of extremely valuable or significant
1: Develop Situational Understanding	45	Situational Understanding	16	16	12	1	32
8: Enhance Realistic Training	23	Future Training	7	8	7	1	15
9: Improve Soldier, Leader and Team Performance	23	Future Training	7	7	7	2	14
2: Shape the Security Environment	22		6	9	7	0	15
10: Develop Agile and Adaptive Leaders	19	Future Training	8	6	5	0	14
13: Conduct Wide Area Security	17	Force Protection and Movement	5	5	4	3	10
19: Exercise Mission Command	16		3	7	4	2	10
12: Conduct Joint Expeditionary Maneuver and Entry Operations	15	Expeditionary Operations	5	4	6	0	9
16: Set the Theater, Sustain Operations, and Maintain Freedom of Movement	15	Force Protection and Movement	3	6	6	0	9
3: Provide Security Force Assistance	14		4	6	4	0	10
6: Conduct Homeland Operations	14		2	6	5	1	8
4: Adapt the Institutional Army	12	Future Training	3	5	3	1	8
5: Counter Weapons of Mass Destruction	11		3	6	2	0	9
15: Conduct Joint Combined Arms Maneuver	11	Force Protection and Movement	2	4	3	2	6
14: Ensure Interoperability and Operate in a Joint, Interorganizational, and Multinational Environment	9		2	3	3	1	5
20 Develop Capable Formations	9	Expeditionary Operations	2	2	3	2	4
11: Conduct Air-Ground Reconnaissance	8	Situational Understanding	1	4	3	0	5
18: Deliver Fires	7		2	2	3	0	4
7: Conduct Space & Cyber Electromagnetic Operations & Maintain Communications	6		1	2	3	0	3
17: Integrate Fires	6		2	1	2	1	3

20 Army Warfighting Challenges (AWFCs):

1. Develop Situational Understanding: How to develop and sustain a high degree of situational understanding while operating in complex environments against determined, adaptive enemy organizations.
2. Shape the Security Environment: How to shape and influence security environments, engage key actors, and consolidate gains to achieve sustainable security outcomes in support of Geographic and Functional Combatant Commands and Joint requirements.
3. Provide Security Force Assistance: How to provide security force assistance to support policy goals and increase local, regional, and host nation security force capability, capacity, and effectiveness.
4. Adapt the Institutional Army: How to maintain an agile institutional Army that ensures combat effectiveness of the total force, supports other services, fulfills DoD and other agencies' requirements, ensures quality of life for Soldiers and families, and possesses the capability to surge (mobilize) or expand (strategic reserve) the active Army.
5. Counter Weapons of Mass Destruction: How to prevent, reduce, eliminate, and mitigate the use and effects of weapons of mass destruction (WMD) and chemical, biological, radiological, nuclear, and high yield explosives (CBRNE) threats and hazards on friendly forces and civilian populations.
6. Conduct Homeland Operations: How to conduct homeland operations to defend the Nation against emerging threats.
7. Conduct Space and Cyber Electromagnetic Operations and Maintain Communications: How to assure uninterrupted access to critical communications and information links (satellite communications [SATCOM], positioning, navigation, and timing [PNT], and intelligence, surveillance, and reconnaissance [ISR]) across a multi-domain architecture when operating in a contested, congested, and competitive operating environment.
8. Enhance Realistic Training: How to train Soldiers and leaders to ensure they are prepared to accomplish the mission across the range of military operations while operating in complex environments against determined, adaptive enemy organizations.
9. Improve Soldier, Leader, and Team Performance: How to develop resilient Soldiers, adaptive leaders, and cohesive teams committed to the Army professional ethic that are capable of accomplishing the mission in environments of uncertainty and persistent danger.
10. Develop Agile and Adaptive Leaders: How to develop agile, adaptive, and innovative leaders who thrive in conditions of uncertainty and chaos and are capable of visualizing, describing, directing, and leading and assessing operations in complex environments and against adaptive enemies.

11. Conduct Air-Ground Reconnaissance: How to conduct effective air-ground combined arms reconnaissance to develop the situation rapidly in close contact with the enemy and civilian populations.
12. Conduct Joint Expeditionary Maneuver and Entry Operations: How to project forces, conduct forcible and early entry, and transition rapidly to offensive operations to ensure access and seize the initiative.
13. Conduct Wide Area Security: How to establish and maintain security across wide areas (wide area security) to protect forces, populations, infrastructure, and activities necessary to shape security environments, consolidate gains, and set conditions for achieving policy goals.
14. Ensure Interoperability and Operate in a Joint, Interorganizational, and Multinational Environment: How to integrate joint, interorganizational, and multinational partner capabilities and campaigns to ensure unity of effort and accomplish missions across the range of military operations.
15. Conduct Joint Combined Arms Maneuver: How to conduct combined arms air-ground maneuver to defeat enemy organizations and accomplish missions in complex operational environments.
16. Set the Theater, Sustain Operations, and Maintain Freedom of Movement: How to set the theater, provide strategic agility to the joint force, and maintain freedom of movement and action during sustained and high tempo operations at the end of extended lines of communication in austere environments.
17. Integrate Fires: How to coordinate and integrate Army and JIM fires in combined arms, air-ground operations to defeat the enemy and preserve freedom of action across the range of military operations.
18. Deliver Fires: How to deliver fires to defeat the enemy and preserve freedom of action across the range of military operations.
19. Exercise Mission Command: How to understand, visualize, describe, and direct operations consistent with the philosophy of mission command to seize the initiative over the enemy and accomplish the mission across the range of military operations.
20. Develop Capable Formations: How to design Army formations capable of rapidly deploying and conducting operations for ample duration and in sufficient scale to accomplish the mission.

Virtual Contributors

The Megacities and DUA conference also included over 500 individuals participating virtually through web streaming, a chat room, and Twitter. Chat room and Twitter discussions were captured and an initial analysis of this data was conducted using a qualitative data analysis tool to identify the 100 most frequent terms used by participants for insight into predominant discussion topics.

Figure 17: 100 Most Frequent terms from Twitter (#madsci16) discussion.

Figure 18: 100 Most Frequent terms from chat room discussion.

Appendix 5: Terms of Reference

Term	Definition
Air dimension	The area above the ground usable by aircraft and aerial munitions. In urban areas, airspace is broken up by man-made structures of different heights and densities in addition to the irregularities in natural terrain. This produces an "urban canyon" effect that can adversely impact operations. Urban canyons often cause higher wind speeds with unpredictable wind direction and turbulence that can cause some munitions to miss their targets (increasing risk for both collateral damage and friendly fire) and significantly increase risks for rotary wing operations near the surface. (JP 3-06)
Area of operations	An area defined by the commander that is large enough to accomplish the mission and protect the force. It also identifies the operational environment as a composite of the conditions, circumstances, and influences that affect the employment of capabilities and bear on the decisions of the commander. (JP 3-0) The problem in the modern dense urban environment is that the Operational Environment, including the area of operations, often extends much further than in the past. (Wolfel, Krakowka Richmond, Read, Tansey)
Army Health Support of Operations	Related to medical civil-military operations; all military health-related activities in support of a joint force commander that establish, enhance, maintain or influence relations between the joint or multinational force and host nation, multinational governmental and nongovernmental civilian organizations and authorities, and the civilian populace in order to facilitate military operations, achieve United States operational objectives, and positively impact the health sector. (JP 4-02)
Army Warfighting Challenges (AWFCs)	The Army uses the AWFC analytical framework to focus prioritized efforts on first-order enduring military challenges and as the organizing construct to lead future force development. AWFCs are enduring first-order

	problems, the solutions to which improve the combat effectiveness of the current and future force. The AWFC methodology integrates near- (today to 2020), mid- (2020 to 2030), and far-term (2030 to 2040 and beyond) modernization efforts for the Army. (ARCIC)
Big data analytics	The strategy of analyzing large volumes of data, or big data. This big data is gathered from a wide variety of sources, including social networks, videos, digital images, sensors, and sales transaction records. The aim in analyzing all this data is to uncover patterns and connections that might otherwise be invisible, and that might provide valuable insights about the users who created it. Through this insight, businesses may be able to gain an edge over their rivals and make superior business decisions. (Technopedia)
Biosurveillance	the process of gathering, integrating, interpreting, and communicating essential information related to all-hazards threats or disease activity affecting human, animal, or plant health to achieve early detection and warning, contribute to overall situational awareness of the health aspects of an incident, and to enable better decision-making at all levels. (White House: National Strategy for Biosurveillance).
Biometrics	The process of recognizing an individual based on measurable anatomical, physiological, and behavioral characteristics. (JP 2-0)
Biosecurity	measures that are taken to stop the spread or introduction of harmful organisms to human, animal and plant life. The measures taken are a combination of processes and systems that have been put in place by bioscience laboratories, customs agents and agricultural managers to prevent the use of dangerous pathogens and toxins. (Medicalnet)
Catastrophic Event	Any natural or man-made incident, including terrorism, which results in extraordinary levels of mass casualties, damage, or disruption severely affecting the population,

	infrastructure, environment, economy, national morale, and/or government functions.(JP 3-28)
Civil Defense	All those activities and measures designed or undertaken to: a. minimize the effects upon the civilian population caused or which would be caused by an enemy attack on the United States; b. deal with the immediate emergency conditions that would be created by any such attack; and c. effectuate emergency repairs to, or the emergency restoration of, vital utilities and facilities destroyed or damaged by any such attack. (DOD)
Course of Action (COA)	1. Any sequence of activities that an individual or unit may follow; 2. A scheme developed to accomplish a mission; 3. A product of the course-of-action development step of the joint operation planning process. Also called COA. (JP 5-0)
Cyber/Information dimension	Part of cyber space; domain characterized by the use of electronics and the electromagnetic spectrum to store, modify, and exchange data via networked systems and associated physical infrastructures. (Joint Cyberspace Operations Lexicon)
Dense urban areas (DUAs)	Represent densely developed territory, encompassing residential, commercial, and other non-residential urban land uses in which social and economic interactions occur. (U.S. Census).
Distributed Awareness	Infers that the systems perceive the environment and gathers information from many different sources to provide situational awareness for the individual platform as well as the collective system. (Piekarski, Sadler, Young, and Nothwang)
Distributed Intelligence	Infers that the individual and collective system can reason about the constantly changing local and collective situational awareness and the local and overall mission objectives to make predictions about future and real-time adaptations and decisions to optimize operations based on that future. (Piekarski, Sadler, Young, and Nothwang)

Environment Centers of Gravity (E-COGS).	E-COGS are those accumulators/nodes and flows that appear to play a more central role in the viability and functionality of the system. E-COGs are the critical elements that truly enable the system to function to the degree required in order to fulfill its inherent system and city objective(s). (William "Bill" Hedges)
Expeditionary	The ability to deploy task-organized forces on short notice to austere locations, capable of conducting operations immediately upon arrival. (TP 525-3-1)
Expeditionary Maneuver	The rapid deployment of task-organized combined arms forces able to transition quickly and conduct operations of sufficient scale and ample duration to achieve strategic objectives. (TP 525-3-1)
Exterior and interior space	What is visible from outside buildings or subsurface areas, and the significant range of people, infrastructure, and activity that occurs unseen in the interior of those structures. (JP 3-06)
Flock	Group of artificially intelligent microdrones (defined as the size of an apple or smaller) that could provide a constant stream of swarm data about a specific building, neighborhood, or city. Exhibited by birds, fish, bacteria, and insects, flocking is best described as the collective motion of a large number of self-propelled entities notable because it typically does not involve any central coordination of the individual player entities. (Bitterman and Carlo)
Health Surveillance	The regular or repeated collection, analysis, archiving, interpretation, and distribution of health-related data used for monitoring the health of a population or of individuals, and for intervening in a timely manner to prevent, treat, or control the occurrence of disease or injury, which includes occupational and environmental health surveillance and medical surveillance subcomponents. (JP 4-02)
Human Dimension	The cognitive, physical, and social components of Soldier, Army Civilians, leader, and organizational development and performance essential to raise, prepare, and

	employ the Army in unified land operations. (TP 525-3-7)
Human Environment	Information about the physical security, cultural narratives, economic security, ideology and belief systems, authority figures, and organizations relevant to major social groups in the area under study comprises the human environment. This information may come from open source, unclassified collection and is referenced geospatially, relationally, and temporally to enable the creation of various maps or views of the human dynamics in areas where the joint force has committed resources. Information on social groups and their interests, beliefs, leaders, and the drivers of individual and group behavior is needed to conduct effective operations in urban environments. (JP 3-06)
Human Factors Dimension	The physical, cultural, psychological, and behavioral attributes of an individual or group that influence perceptions, understanding, and interactions. (JP 2-0)
Integrated Financial Operations	The integration, synchronization, prioritization, and targeting of fiscal resources and capabilities across United States departments and agencies, multinational partners, and nongovernmental organizations against an adversary and in support of the population. (JP 1-06)
Intelligence Preparation of the Battlefield (IPB)	The analytical methodologies employed by the Services or joint force component commands to reduce uncertainties concerning the enemy, environment, time, and terrain. (JP 2-01.3)
Internet of Things (IOT)	a computing concept that describes a future where every day physical objects will be connected to the Internet and be able to identify themselves to other devices. The term is closely identified with RFID as the method of communication, although it also may include other sensor technologies, wireless technologies or QR codes. (Technopedia)

Interorganizational	Elements of U.S. government agencies; state, territorial, local, and tribal agencies; foreign government agencies; intergovernmental, nongovernmental, and commercial organizations. (Does not include forces.) (TP 525-3-1)
Interorganizational Coordination	The interaction that occurs among elements of the DOD, engaged U.S. government agencies; state, territorial, local, and tribal agencies; foreign military forces and government agencies; intergovernmental and nongovernmental organizations. (JP 3-08)
Joint Urban Operations	Joint operations planned and conducted on, or against objectives within a topographical complex and its adjacent natural terrain, where man-made construction or the density of population are the dominant features. Also called JUOs. (JP 3-06)
Mad scientist (MS) contributors	Any contributor of insights provided through the MS Megacity Initiative, including, Megacities and DUAs Conference presenters, authors of academic publications submitted in response to the MS Megacities call for papers, contributors of ideas to the online MS technology survey, and participants discussing megacities and DUAs in the Megacities and DUAs Conference virtual chat room or Twitter page.
Megacity	A metropolitan area whose population exceeds 10 million people (United Nations; U.S. National Intelligence Council).
Military Civic Action	Programs and projects managed by United States forces but executed primarily by indigenous military or security forces that contribute to the economic and social development of a host nation civil society thereby enhancing the legitimacy and social standing of the host nation government and its military forces. (JP 3-57)
Modeling and Simulation	The discipline that comprises the development and/or use of models and simulations; the use of models, including

	emulators, prototypes, simulators, and stimulators, either statically or over time, to develop data as a basis for making managerial or technical decisions. The terms "modeling" and "simulation" are often used interchangeably, but simulation generally executes models over time, space, events, or other processes. (DOD M&S Glossary)
Multinational	Between two or more forces or agencies of two or more nations or coalition partners. (JP 5-0)
Operational Adaptability	The ability to shape conditions and respond effectively to changing threats and situations with appropriate, flexible, and timely actions. (TP 525-3-1)
Operational Environment	A composite of the conditions, circumstances, and influences that affect the employment of capabilities and bear on the decisions of the commander. Also called Operational Environment. (JP 3-0)
Religious Advisement	The practice of informing the commander on the impact of religion on joint operations to include, but not limited to: worship, rituals, customs, and practices of U.S. military personnel, international forces, and the indigenous population; as well as the impact of military operations on the religious and humanitarian dynamics in the operational area. (JP 1-05)
Sociocultural Factors	The social, cultural, and behavioral factors characterizing the relationships and activities of the population of a specific region or operational environment. (JP 2-01.3)
Space Dimension	The environment corresponding to the space domain, where electromagnetic radiation, charged particles, and electric and magnetic fields are the dominant physical influences, and that encompasses the earth's ionosphere and magnetosphere, interplanetary space, and the solar atmosphere. (JP 3-59)
Special Warfare	Execution of activities that involve a combination of lethal and nonlethal actions taken by a specially trained and educated force that has a deep understanding of

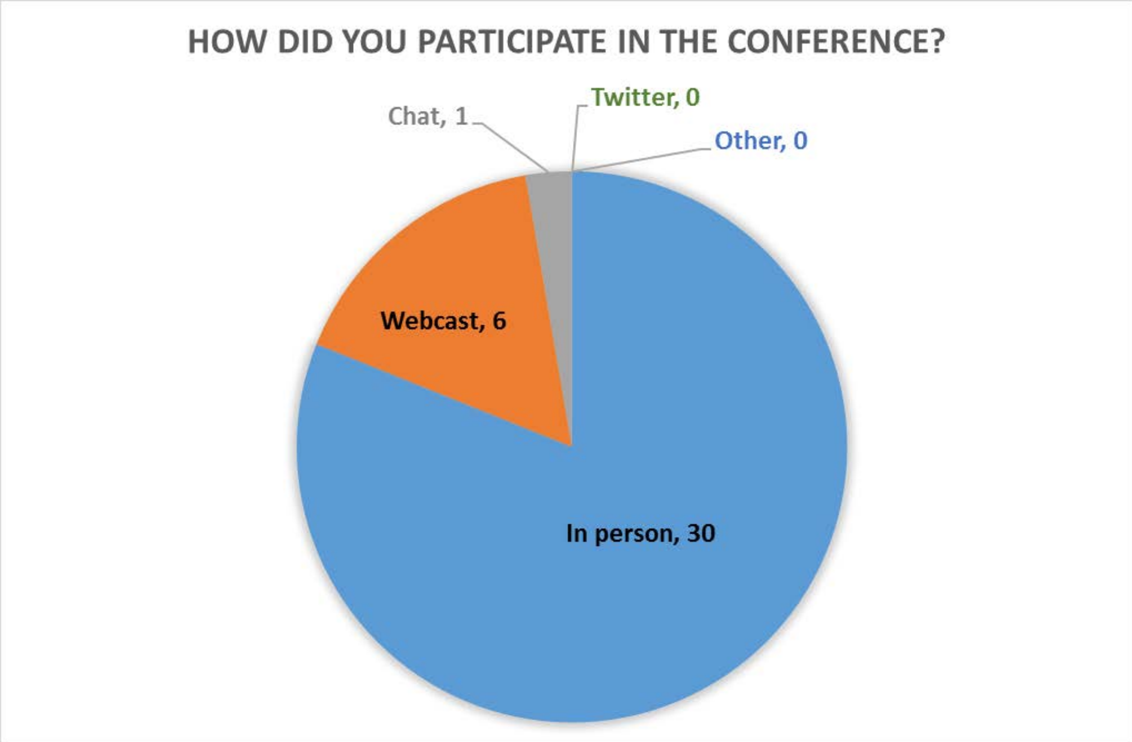
	cultures and foreign language, proficiency in small-unit tactics, and the ability to build and fight alongside indigenous combat formations in a permissive, uncertain, or hostile environment; includes "special operations forces conducting combinations of unconventional warfare, foreign internal defense, and/or counterinsurgency through and with indigenous forces or personnel. (ADP 3-05)
Stability Mechanism	The primary method through which friendly forces influence civilians to attain conditions that support establishing a lasting, stable peace. (ADRP 3-0)
Subsurface dimension	Areas below ground level that consist of sewer and drainage systems, subway tunnels, utility corridors, or other subterranean spaces. These areas can be used for cover and concealment, movement, and engagement, but their use requires intimate knowledge of the area. (JP 3-06)
Supersurface dimension	Roofs and upper floors of buildings, stadiums, towers, or other structures that can be used for movement, maneuver, observation, firing positions, or other advantage. (JP 3-06)
Surface dimension	Include exterior ground-level areas of streets and roads, parks and fields, and any other exterior space. These surface areas follow the natural terrain and are themselves broken up by man-made features. (JP 3-06)
System of systems	A system-of-interest whose system elements are themselves systems; typically, these entail large scale inter-disciplinary problems with multiple, heterogeneous, distributed systems. (INCOSE)
Technology Imperatives	Focusing mechanism to ensure U.S. Army S&T efforts to align with future capability needs. They were the top down element that complimented the TRADOC Centers of Excellence functional oriented S&T needs. We use this as a means to advise materiel developers so they can make informed decision regarding technology efforts under

	their care that use Army S&T dollars. (TRADOC)
Uncertain Environment	Operational environment in which host government forces, whether opposed to or receptive to operations that a unit intends to conduct, do not have totally effective control of the territory and population in the intended operational area. (JP 3-0)
Urban Triad	The three elements that compose the urban environment: complex man-made physical terrain, a population of significant size and density, and an infrastructure. (JP 3-06)
Virtual humans	Embodied, autonomous computer agents that look and behave like people. They use verbal and non-verbal communication to interact naturally with real people. Recently, we have seen ways in which a virtual human may outperform either real people or inanimate systems alone People may feel more comfortable interacting with a virtual human and may feel less judged and more willing to reveal more sensitive information to a virtual character. At the same time a virtual human can use gestures that work at a more subliminal level to encourage people to open up. (Dr. William Swartout)
Virtual Reality	The effect created by generating an environment that does not exist in the real world. Usually, a stereoscopic display and computer-generated three-dimensional environment gives the immersion effect. The environment is interactive, allowing the participant to look and navigate about the environment, enhancing the immersion effect. Virtual environment and virtual world are synonyms for virtual reality; Virtual Reality (Wearable) includes a participant using a Helmet-Mounted Display to experience an immersive representation of a computer-generated simulation of a virtual world. In this case, the user does not view the real world and is connected to the computer rendering the scene with a cable, typically allowing about 3-4 meters of movement. (DOD M&S Glossary)

Appendix 6: Administrative Survey Results

Responses to a conference feedback survey from Megacity and DUA Conference participants (total of 36 responses):

Figure 19: Number of people who participated in the Megacities and Dense Urban Areas Conference in person or through the webcast, chat, Twitter, or other (total of 36 responses).



Survey Question: What did you like about the conference?	
Conference Content: Informative, diverse topics; good content; good selection of experts	• Great briefs • Great speakers, • Distinguished presenters. • Wide array of subject matter • The topics were diverse, well presented and the majority were related directly to the topic. • I thought many of the speakers were compelling and interesting. The breadth of participants helped reduce some of the parochial Army views of the world. • Wide variety of speakers from different organizations provided different perspectives. • Very informative in decomposing the problem space. • The variety of relevant topics covered under the MgC and DUA theme was eye opening. • Great selection of presenters with a wide range of expertise from technology to strategy and to narratives. This is the key part of the Mad

	Scientists series bringing in real expertise and linking experts. • Informed speakers. • Excellent speakers and a wide variety of experts. • Excellent speakers and content. • I learned quite a bit about the state of some technologies, things about which I had been unaware. • A great selection of speakers and the ability for me to ask questions in chat mode and have a discussion on the topic "real time" • Conference brought together a knowledgeable group of researchers and military practitioners to discuss the emerging concepts in Dense Urban Areas/Megacities. Many of the presenters were excellent and provided a fresh perspective on this difficult emerging challenge. • Good overview talks. • The material presented was relevant to the challenges described by existing works and studies (i.e. AOC, SSG, RAND) geared at future military operations in a Megacity through 2050. The primary objectives laid out in the MS info paper linked exactly to the themes/presentations throughout the two-day event, and ultimately proved in the out brief the realistic, clear (and necessary) path forward. The "so what" was there! • Speakers were interesting. • Wide variety of speakers and topics. • A great lineup of presentations. Enjoyed the online presentations leading up to the event as well. Great use of supporting IT resources. • The topics and the speakers • Some good thinkers presented challenging briefs that got me thinking. • The presenters were well qualified and the talks were relevant to the megacity operational environment. I came away stimulated by a number of different talks and ideas from the conference. • Great gathering of the top minds addressing DoD future Megacity issues • The topics were very interesting and at a good length. • I think this MS workshop did a good job of highlighting the challenge in the DUA/MC space.
Networking Opportunities – Great opportunity for networking.	• Good opportunity for expanding one's network. • Great networking • Connecting with people who are open and interested in new approaches. • excellent networking opportunities

	• The conference provided a great networking opportunity within this important and increasingly important area of interest. • Opportunity to meet and talk to some creative people face-to-face.
Administration: Well organized; good format of presentations and Q&A sessions; lunches provided; helpful pre-conference material; helpful and effective virtual component.	• Very well organized • I enjoyed the presentation format and the ability to ask questions of each presenter. • It was professionally executed in a superb venue. Provided lunches were great • great venue and agenda • The conference was well organized. • Great conference and very engaging speakers. I liked the open dialog and the variety of presentations. • Excellent facilities and accommodations. • The venue was well laid out and everything was convenient. The luncheons were delicious. • ASU did a terrific job hosting this and the provided lunch was much appreciated. The briefings were, in general, interesting. • Definitely one of the better conferences I have been to in recent years. • Good pacing and timing for presentations and Q&A sessions. Very glad multi-speaker sessions were limited (to one), got more good information from the TED talk-style presentations than the single panel session. • Networking breaks were a great length of time. • The organization of the conference was perfect from what I could tell. Everything was easy, on time, comfortable. I know that having that be the case for me means that a number of people had been exerting themselves mightily and I appreciate it very much. • I think the pre-conference preparation with the Small Wars Journal articles, the APAN connection and the email notices and advice from Joel Lawton were all useful and welcome. I've been to a conference or two, and this one rates at the top in terms of admin painlessness and theme focus. • I love the arrangements provided by our host, Arizona State University--the hotel recommendations and accommodations, ease of transportation (walking distance) from hotel to conference, excellent conference establishment with a comfortable conference room, snacks and refreshments, and variety of lunch options, and the wonderful staff that put together a well-run conference.

	• I have perfect comms from my computer at work. easy to use and great platform for getting all the data I needed remotely. • Format was good. • Very well run • Excellent organization and venue. ASU and TRADOC personnel were all helpful, gracious, and hospitable. The ice breaker was well done. The opportunity to ask questions was excellent. • The ASURE and ASU team worked well with the Army • The webcast worked well. • Overall, the conference was well put together. The conference center was a perfect locale. The refreshments/lunch provided by ASU were top notch and a surprise (given DoD restrictions on providing such things). • Again, it could not have been better administered, and I got much out or it. • I loved this conference and hope to participate next year. I have several ideas for potential talks from my institute -- USC Institute for Creative Technologies. • Phenomenal event! Best one since my assignment at ARCIC
Survey Question: What can be improved?	
Administration: More discussion; collaboration, Q&A time needed; timing of conference was problematic; virtual audience had difficulty seeing slides easily.	• Need to be able to zoom the slides - can't see the slides and the chat at the same time • Conference running late on Friday that requires travel is less than ideal. Sessions on Wednesday and Thursday would have helped. But this is a minor consideration. • Timing. Start the conference one day earlier so that it can be wrapped up by Friday at noon for ease of travel. • Include some small group break out sessions with individual presenters for a more informal question and answer period. • It would be great to have a form or forum where people can sign up to collaborate on projects. Although the networking during breaks was useful, having more guided collaboration and joint idea sharing would be beneficial. Something as simple as a survey where people submit quickly "I can help on BLANK project doing etc., my contact info is as follows". • Shorten the agenda; too long for a given day. • Scheduling the conference for the middle of the week rather than at the end of the week. Significant

	number of people left at lunch on Friday, which is not fair for presenters on Friday afternoon. • There wasn't enough time for questions of the presenters and you could not always get to them during breaks and the social periods. • Also, as a result of the long plenary speakers list, the occasions for sitting and exchanging were reduced. A couple more round-table chats would have been nice. At a conference with such interesting folk I think I get more listening to conversation over meals than I do listening to a podium talk. • I was a fish in a sea as the only person representing my organization. Being new to the Mad Scientist conference, BREAKOUT SESSIONS would help myself in a less formal setting, talk to others about what my organization does, and maybe add to the megacites discussion and perhaps lead to more "mad" ideas from the scientists attending the conference. • More interaction with panel and more people asking questions to challenge some of premises proposed. • Hard question. I personally have no issues or complaints thus far, and would only add that the community of interest (with TRADOC G2 as lead) not lose momentum, and possibly look at establishing a MS OPT type structure to allow precise management of follow-on activity and traceability to concept/capability development, S&T investment influence, and the full JIM (Joint, Interagency, multi-national) role and responsibility. • So, next time I'd be interested in more discussion time perhaps a lot more, than what was afforded this time. • Calling the meeting a "conference" presents significant regulatory restrictions on attendance by DAC personnel. I probably will not be able to attend the Georgetown MS Conference, because I did not receive enough advance notice to begin the paperwork (I've been told at least 120 day lead time). Suggest calling it a "seminar" or "workshop" instead of "conference". • More time for discussion in small group settings • The one recommended hotel that I could get into with the government rate (Moxie) was 30 minute walk away, and no rental car authorized. • Shorter presentations to allow for more diversity in topics and increase the number of presenters. Poster sessions could also address this issue. • more speakers

	• Need to show the slides for those watching virtually longer. There was not enough time to read the slides or see what the speaker was referring to. Conference was not at an ideal time for those on the East coast. • Only some of the sessions have been posted on YouTube. Would be very helpful if Titles included speaker names and contact information. Or perhaps include the Agenda with links to the published videos on APAN. • Maybe the remainder of the videos remain to be posted. Maybe an email to everyone attending with the agenda with links to individual videos. • Would also be of value to have a list of attendees with special interest areas, so direct communication could be established. • Get a bigger venue next year with more speakers with varied backgrounds and experiences... • chat screen inside of "video" screen would be better
Conference Content: Greater diversity of speakers and topics; more speakers; greater speaker/audience interaction and debate; some content redundant and not clearly connected to megacities; some megacity topics not adequately addressed; need more discussion on solutions; speakers should focus more on the future verse current capabilities; unclear how presentations all tied together.	• Include fast-feedback qualitative analytic methods. These are designed specifically for problems that the conference speakers identified as difficult or impossible with their quantitative models (ill-defined contexts, unique contexts, contexts that are completely unpredictable except in respect, etc.). • A few presented topics had little or no specific connection to megacities. In the end, all talks were stimulating and eye opening, so I believe that is fine. • I was a little disappointed to see who did NOT present, especially RDECOM's MATDEV WG. This is not TRADOC's fault, of course, but I wonder if it might have helped to seek out bigger activities like that and try to twist their arm. • Include presenters, and participants contact information and links to presentation slides as an end of conference data point or as a follow on email link to all participants. • I would liked to have seen more senior maneuver, aviation and fires participation. It was good that CW4 Castellanos attended. LTG Mangum was good to see on day 2. • Discussion on implementing or driving decisions based on Mad Scientist conferences. • For this being described as a "megacity" conference, there were a number of speakers whose content only peripherally related to the challenges of operating in, with, and through a megacity. The speaker discussing the implications

	of cyber warfare, for example, addressed cyber in a megacity almost as an afterthought. • More on solutions being developed • We need to continue to emphasize to our presenters that Mad Scientists is about the future. They should address the time period between 2030-2050. Outlining current research and development is great but then the presenter should take a leap forward. • Some of the presentations were not MegaCity related and were a little tough to tie into the conference topic. • The megacity challenge and future environment was covered in depth, but the "so what" was a bit lacking. I would have liked to have seen the AWFC linked to capability gaps and requirements. • There was no military problem statement to focus the discussion. The various briefs while interesting had little connective tissue. It was clear some are using the megacity topic as a convenient topic to latch on to for possible funding purposes. • The military problem is key to the whole Army discussion about this operational challenge. Fact is the Army doesn't at present know what the problem is so a logical start point might be to revisit the SSG conclusions AND get some relevant historical input from the Combat Studies Institute and others. The SSG was not a definitive end state but rather a start point. At the end of the day operations in megacities are about combat every other operation is a lesser problem. The precise nature of that combat is still unknown and THAT needs to be better defined before "solutions" are trotted out. Also need to do some work to narrow the set of megacities we're potentially concerned about - I don't much care about western of allied megacities; the Army problem will be locations that are generally closed and hostile to us and that we don't have ready access to in PH 0. That's a big deal for the Intel community in trying to help set conditions in PH 0 for subsequent joint force operations. • Would have liked to have a visual map of some sort that tied all of the presentations together to address the overall conference theme. Additionally, noticed that some critical topics were a little light in content, i.e. DOD rebalance to Pacific, cyber defense/offense/mitigation, operational energy, etc. • A few too many of the speakers were on the stage for cheerleading and spreading wonder dust. There was no need for anyone to say the world has

	cities, is going to have more of them or we should do something in response. Also not much of a need for anyone to say how great their organization is. When you put leadership on the stage that's what your going to get. OK, some of that is always overhead to get buy-in and pay the bills, but this conference exceeded on that score. • Realizing that this is an emerging topic, their seemed to be a very weak link between some of the invited talks and megacities. Given the status of the problem (MEGACITIES), I am wondering why more emphasis is not being focused on defining the simple urban areas cities between 500K and 9.9M! At this point, research that can inform the DUA/MC problem space about indicators, MOEs and MOPs to begin the process of understanding there applicability to the DUA/MC space and provide a baseline for exploring the effects of scale and emergent behavior/properties in a DUA/MC. • By the end of the second day some of the talks felt a bit redundant -- too much time defining what a megacity is and what problems are associated with one and not enough time suggesting possible approaches the Army can take to mitigate the risks and deal with the challenges. Other than Swartout and the ARL scientist in robotics, it was a little light on technology. • The majority of speakers were from ASU, which I understand since they were hosting. However, for other academics in the audience, it came across as TRADOC is partnered only with ASU and there are no opportunities to participate in this research. • More involvement from other Services. • Invite foreign attendees. • I was looking for more give and take, back and forth discussion, debate, etc between the speakers and the general audience, and within the general audience. • There needs to be much better problem definition and subsequent focus/relevance of presenters. Anyone who thinks the Army has this megacity problem clearly defined and is on a coherent path is sadly mistaken. My take away is that our effort is scattershot at best and that until we have a much better idea of what we are trying to address - and why - this will remain unfocused. It's the difference between basic research and applied research. • The schedule was filled with a little too much lectern and not enough table. To me, if we are going to spend the money to physically travel (and suffer the admin consequences) then the payoff is

	in face-to face exchanges. With that in mind, a conference schedule might be better designed that maximizes small-group and personal conversation opportunities and minimizes plenaries. Bottom line, though: great event. • If possible, the focus on viable research approaches that would link the research community with military practitioners would be a useful follow-on to this MS workshop. • Some of the discussion sessions were abbreviated. I think a more robust interactive (with the audience) session is needed. • Most presentations were very interesting. However, the modeling and simulation time slot could have been better served by paper only, and the presentation used for another aspect of mega-cities/dense urban environments.

Survey Question: Were the discussion sessions sufficient (1-5; 5 is the highest rating)?: Average score: 4.0

Survey Question: Do you plan on attending subsequent Mad Scientist Conferences?

Yes: 33

No: 3

- My focus area now is on complex dense urban areas. So, I doubt that I will attend future Mad Scientist sessions.
- Absolutely and the community of interest being built out is a critical point of departure for Army futurists.
- Future Mad Sci: answer is really "maybe" depending on focus and getting beyond show and tell.
- My organization was mainly interested in the megacities/dense urban area discussion and how we can contribute to the overall success of it. If there are subsequent MS conferences that needs geospatial-intelligence information and services, then yes I will participate in the future.

SECTION 3: Situational Awareness

This section includes published articles from Small Wars Journal that we received from the call for papers. The section will explore issues, concepts, and capabilities as they relate to future land forces gaining situational understanding in megacities or dense urban areas in 2025 and beyond.

- "An Analytic Framework for Operations in Dense Urban Areas"
  by William Hedges

- "Anticipating Megacity Responses to Shocks : Using Urban Integration and Connectedness to Assess Resilience"
  by Shade T. Shutters, Wes Herche and Erin King

- "Atmospheric Impacts and Effects Predictions for Applications for Future Megacity and Dense Urban Area Operations"
  by David Knapp, Robb Randall and Jim Staley

- "Complex IPB"
  by Tom Pike and Eddie Brown

- "Identity and Biometrics Enabled Intelligence (BEI) Sharing for Transnational Threat Actors"
  by Victor R. Morris

- "It's in There: Rethinking (?) Intelligence Preparation of the Battlefield in Megacities/Dense Urban Areas"
  by Richard L. Wolfel, Amy Krakowka Richmond, Mark Read and Colin Tansey

- "Megacities and Dense Urban Environments: Obstacle or Opportunity"
  by Dawn A. Morrison and Colin D. Wood

- "Megacities: The Good, the Bad, and the Ugly"
  by Russell W. Glenn

- "Megacity Madness
  by Gustav A. Otto and AJ Besik

- "Operational Environment Implications of the Megacity to the U.S. Army"
  by Darryl Ward

- "Qualitative Analysis Concept in Support of Force 2025 and Beyond (F2025B) Maneuvers"
  by John Hoven and Joel Lawton

- "Using the Internet of Things to Gain and Maintain Situational Awareness in Dense Urban Environments and Megacities"
  by Alfred C. Crane and Richard Peeke

An Analytic Framework for Operations in Dense Urban Areas

By ***William Hedges***

Originally published in Small Wars Journal on 11 March 2016

Available online at: http://smallwarsjournal.com/jrnl/art/an-analytic-framework-for-operations- in-dense-urban-areas

Introduction

The U.S. Army Operating Concept, (AOC) *Win in a Complex World*, "provides the intellectual foundation and framework for learning and for applying what we learn to future force development under Force 2025 and Beyond.[i] The AOC focuses on important questions; this paper provides a relevant framework supporting how we go about attempting to answer two of the questions presented within the AOC: "what is the environment we think Army forces will operate in, and what is the problem we are trying to solve?" [ii] Both of these questions and potential resolution thereof are key to how we continue to tackle Army Warfighting Challenge #1, developing and sustaining a high degree of situational understanding against determined, adaptive threats. The AOC provides due consideration to anticipated threats and the future operating environment (OE) by outlining five characteristics of the future operating environment with likely significant impact on land force operations:

(1)*Increased velocity and momentum of human interaction and events;*

(2)*Potential for overmatch;*

(3)*Proliferation of weapons of mass destruction*;

(4)*Spread of advanced cyberspace and counter-space capabilities;*

(5)*Demographics and operations among populations, in cities, and in complex terrain.*[iii]

Though the latter characteristic is the most compelling, it is important to note that the other future OE characteristics would indeed be exacerbated by the conditions found in dense urban areas (DUA). This paper provides a relevant analytic framework in support of framing, mapping, and developing courses of action (COA) for operations occurring in DUA today and in the future.

Background I – Dense Urban Areas

Discussion regarding DUA-oriented environments usually center on the roughly 28 megacities on the planet today. However, the increasing global pace of urbanization is not confined to just a megacities issue or perspective; recent United Nations studies portend a 60% population surge in urban areas by 2030. [iv] Despite the scale and complexity of the world's megacities, there are almost 850 cities with populations between 500k and 9.9m – in essence, "middleweight" cities[v] that also represent interactively complex operating environments. Environments which may feature a dense and diverse population mix; further complicated by the potential for loose integration[vi], a multitude of networks, and potentially volumes of big data[vii] that present noteworthy challenges for information collection, much less its parsing, characterization, and understanding.

According to the National Intelligence Council's *Global Trends 2030: Alternative* Worlds, precipitous changes in world demographics are expected to perpetuate significant changes, or megatrends, in the world's diplomatic, economic, and military power.[viii] Such change may undoubtedly lead to a potentially volatile and uncertain security environment where US interests and related national security concerns are increasingly vulnerable to a variety of actors and a range of threats.[ix] In accepting that cities/dense urban areas represent the nexus of the megatrends alluded to above, the potential for US forces to operate in DUA is significant today and increasingly probable in both the near and far terms. Which presents the following questions, how do US forces develop critical situational understanding of such environments, and what would constitute a viable analytic framework for developing and placing that understanding into relevant and applicable context?

Background II – IPB: A Dated Methodological Approach

For the better part of four decades, Army intelligence has tackled operational challenges via an approach known as Intelligence Preparation of the Battlefield (IPB), which was embedded within the Military Decision-making Process (MDMP). Even though the Army has revised a great deal of its doctrine and associated tactics, techniques, and procedures in an effort to adapt to an evolving OE landscape, our situational understanding largely remains anchored to IPB's role as a MDMP catalyst for all environments. IPB's orientation is towards linear engagement areas and a specific threat methodology and model. It is essentially reductionist and quantitative in nature, still supportive of a structurally complex OE; but, often fails to gain sight of the dynamics between the components of problems within an interactively complex system. The dense urban area problem approach must be qualitatively focused and employ diverse heuristics[x] lines of effort rather than the rigidity invoked by the IPB analytic framework. [xi]

The products for each step of IPB are not conducive to an interactively complex OE. These products fail to adequately unify the different elements found within the OE while seeking alignment to a threat or system of opposition[xii] picture. One pointed example associated with the IPB construct, lies with the challenge of incorporating religion as an operational data layer specific to an OE. Presently, an analytic team focusing on a religious-themed impact – central to operational planning, would focus on the operational variables captured within a given city's OE assessment (note though that doctrinally, religion at present is not represented as a "stand-alone" variable). Such a religious-themed search (within PMESII- PT[xiii], F-ASCOPE[xiv], SWEAT-MSO[xv], DIMEFIL[xvi], and even METT-TC[xvii] analysis) would potentially yield multiple and disparate religious informational elements, which is to be expected. However, the IPB construct does not afford a clear step for tying together several "like" elements into a single operational data layer and illustrating or modeling the relationship of that system upon other systems (IPB does not accommodate "modelling" until step 3 and that step/model is threat-centric).

The relevance of the example above highlights a significant gap within the IPB framework/process and the inability to truly support comprehensive mission analysis and problem framing, especially for the multitude of data layers found in DUA. Though religion is often citied within an OE assessment, there is little conduit via IPB to truly discern analytic value. In IPB, there exists the potential for such data to be "not considered" since it may be interpreted as having little to no value in either describing the threat or the threat COA. This example highlights another IPB-related challenge. How the Army doctrinally captures relevant operational variables is potentially problematic given that a very relevant operational variable like religion (or perhaps even tribal/familia factors) is buried within our PMESII-PT or F- ASCOPE snapshots despite the data point that religion continues to emerge as a dominant theme for a multitude of current and perhaps future operating environments.[xviii] IPB's role and suitability as a MDMP catalyst, directed towards an interactively complex environment focused on a city-system environmental challenge or a hybrid warfare[xix]-oriented system of opposition – remains questionable.

An Urban Analytic Framework: City as a System

Dense urban areas represent the higher nexus of interactively complex operating environments. The IPB process' end-state provides an inadequate degree of situational understanding for such complex environs given its inherent threat-oriented slant versus a city as a system or all-encompassing environmental perspective. Adoption of this city as a system perspective will require adaptation of a significant portion of our Army doctrine and thus, lead to an urban analytic framework tailored to address the operational data layers found within urban centers, their environmental dynamism, and their state of connectedness. [xx]

One such urban analytic structure has been developed by CAERUS Associates, championed by the Combatting Terrorism Technical Support Office (CTTSO),[xxi] and has been applied by elements within the special operations community. The overarching concept behind this framework is alignment with systems thinking, focusing attention on the relationships between different parts of the environment and working to understand the cumulative effects of these interactions.[xxii]

The CTTSO analytic framework certainly offers dividends as well as potential shortcomings. "Shoehorning" another analytic framework into IPB should not be the first objective. Instead, the Army should be focused on: the capture of the DUA's operational data layers; the display or modeling of those data layers; determination and analysis of city system Environmental Centers of Gravity (E-COG); the potential impact on friendly or threat/ systems of opposition COA; and the impact or urban consequences of friendly/threat COAs upon the city systems. All of these objectives should be contained within an analytic framework dedicated to understanding interactively complex and adaptive operating environments (i.e. DUA).

Creating a Tailored Urban Analytic Framework

The creation of a tailored urban analytic framework would build upon the merits of the CTTSO/CAERUS construct and incorporate additional elements essential to both development of a pertinent intelligence- oriented model and relevant support to Army staff action planners during the course of MDMP. Such a framework would stand-alone; and be the primary analytic process that develops situational understanding for DUA.

Such a framework could potentially look much like the following:

I. Frame the Urban Operational Environment

- Identify Operational Data Layers (ODL)
  - ✓ Baseline alignment w/ PMESII + SWEAT-MSO + PT operational variables
  - ✓ Graduated process should encompass F-ASCOPE variables
  - ✓ F-ASCOPE incorporates "city as a system" analytic characteristics/descriptors
- Describe effects/impact of systems-oriented ODL on the OE (POS & NEG)
  - ✓ Capture of city system current/"steady state"
  - ✓ City system resiliency descriptors
- Describe effects/impact of systems-oriented ODL on -
  - ✓ Friendly forces, threat forces or systems of opposition in both conventional operation's context and hybrid warfare context

II. Map Urban Problem Systems

- Identify problem systems & associated elements (specific OE context)
  - ✓ F-ASCOPE primary orientation potentially aligned to METT-TC dependent on mission/phase/echelon
- Conceptually map problem system (city-system-specific "flow" assessment)
  - ✓ Incorporates data central to understanding complex adaptive systems
  - ✓ Development of system-specific situation/event-like templates
- Geospatially map problem system
- Cultivate understanding (role, impact, & effects) of problem system

III. Develop & Analyze Urban COAs

- Identify city-system E-COGs
  - ✓ System COG determination based on Critical Factors Analysis (CC/CR/CV)
  - ✓ Determination of system flow impact on other city-systems
- Develop COAs
  - ✓ "Urban Consequences" rationale incorporated w/in MDMP
- Analyze COAs
  - ✓ Potential impact on friendly & threat or system of opposition COAs
  - ✓ Impact of friendly & threat COAs on city system(s)
  - ✓ Determine COA acceptability criterion
- Validate understanding of the problem system(s)

Figure 1. Proposed Urban Analytic Framework Framing the Urban Operational Environment

I. Frame the Urban Operational Environment

- Identify Operational Data Layers (ODL)
  - ✓ Baseline alignment w/ PMESII + SWEAT-MSO + PT operational variables
  - ✓ Graduated process should encompass F-ASCOPE variables
  - ✓ F-ASCOPE incorporates "city as a system" analytic characteristics/descriptors
- Describe effects/impact of systems-oriented ODL on the OE (POS & NEG)
  - ✓ Capture of city system current/"steady state"
  - ✓ City system resiliency descriptors
- Describe effects/impact of systems-oriented ODL on -
  - ✓ Friendly forces, threat forces or systems of opposition in both conventional operation's context and hybrid warfare context

Figure 2. Framing the Urban Operational Environment

This first step is an initial assessment construct of a city's operational environment. It represents an assessment of existing OE conditions developed from both operational and mission variable analysis within the commander's area of operations, the area of influence, and the area of interest. This assessment is integral to planning and facilitating friendly force operations. The data visualization capture should provide for an initial city/system modeling construct, illustrating individual components within each city system, leading to the ability to display a layered (system upon system) operational view.

Before we can begin to frame the problem we must first understand the components of the potential problem system, therefore it begins with identifying the operational data layers associated with a specific urban environment. Note that historical application of IPB towards DUA usually resulted in a limited operational data layer perspective (i.e. three layers: terrain, weather, and the threat); yet, urban OEs (e.g. megacities and "middleweight" cities) will likely involve a multitude of diverse data layers.

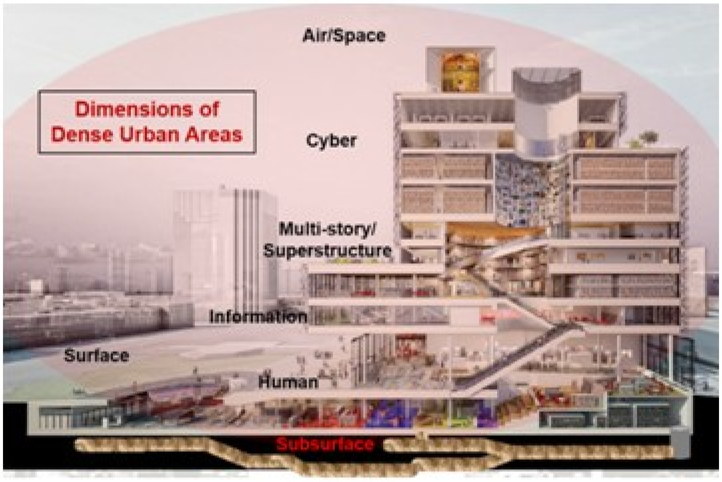


Figure 3.

Characterization or context of how the data applies assists the process of identifying relevant urban area data layers. Figure 3 captures the common themes related to the dimensions often associated with DUA, [xxiii] and in effect, guides the "fit" of a data layer within the urban OE.

Using Figure 3 as a general guide, an initial analysis of population, infrastructure, and physical environment variables (described within the CAERUS framework as the Urban Triad[xxiv]) would yield critical insight to the operational data layers relevant to a given DUA (See Appendix: "Select examples of operational data layers within Dense Urban Areas." The cited examples are reflective of an initial PMESII + SWEAT-MSO + PT analysis.)[xxv]

Further maturation of these initially identified data layers will be required in which F-ASCOPE context, particularly the "flow" or relationship aspect, is geared towards a "city as a system" perspective, and thus lay the groundwork for both individual system and system-on-system interaction analysis.[xxvi] Each systems' perspective should continue to evolve, leading to a description of the positive and negative effects/impacts of the systems- oriented operational data layers on the OE from a holistic standpoint.[xxvii] The overarching objective is to capture the city systems' status currently or from a "steady state" standpoint.[xxviii] The resultant capture should include additional descriptors of each systems' resident capabilities which enable achieving or maintaining a degree of resiliency against internal or external forces/factors/variables.

This urban OE framing concludes with a transition from our examination of the city systems as federated entities, to one in which an analytic team then describes the effects/impact of systems-oriented data layers on friendly and threat forces, the latter of which may be addressed as systems of opposition[xxix] in order to achieve both a conventional and a hybrid warfare context.

Mapping Urban Problem Systems

II. Map Urban Problem Systems

- Identify problem systems & associated elements (specific OE context)
  - ✓ F-ASCOPE primary orientation potentially aligned to METT-TC dependent on mission/phase/echelon
- Conceptually map problem system (city-system-specific "flow" assessment)
  - ✓ Incorporates data central to understanding complex adaptive systems
  - ✓ Development of system-specific situation/event-like templates
- Geospatially map problem system
- Cultivate understanding (role, impact, & effects) of problem system

Figure 4. Mapping Urban Problem Systems

Mapping the urban problem system elaborates on the problem through system map visualization. Transferring this knowledge to a map/picture supports the identification of key accumulators/nodes and flows integral to the problem system itself and our understanding of the system in general. This mapping process assists key input to:

- Friendly forces concept of operation;
- Running intelligence estimate;
- Development, evaluation, and refinement of priority intelligence requirements;
- Facilitating the initial scoping of a unit's intelligence collection plan.

Whereas the initial urban OE framing is largely a strategic and operational undertaking (e.g. geographic combatant command aligned to corps and divisions), the mapping of the urban problem system step may largely fall to BCTs and below. In tactical echelons, F-ASCOPE evaluation and subsequent analysis[xxx] would be aligned with the applicable METT-TC variables, dependent upon specific mission, operational phase context, and the respective operationally engaged echelon. This mapping step should incorporate data central to understanding complex adaptive systems, essentially alluding to global graph[xxxi] utilization; human domain mapping; human social culture behavior modeling; and emergent state phenomena.[xxxii]

A definitive by-product of framing the urban OE, specifically the analysis of the relevant operational data layers and their systems' orientation, yields select identification of those problem systems along with their associated sub-elements (see Figure 5[xxxiii]).

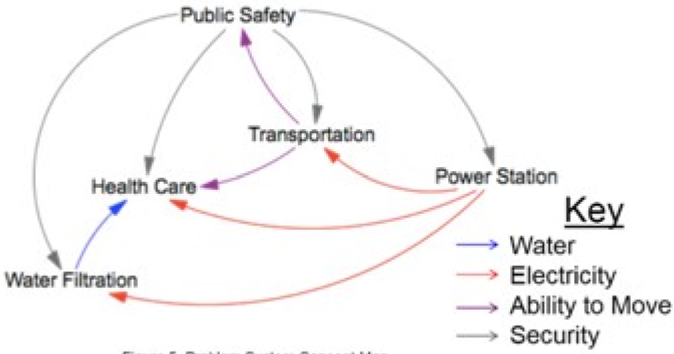


Figure 5. Problem System Concept Map

Concept Mapping is a key component of problem framing and is linked to TRADOC PAM 525-5-500,"Commander's Appreciation and Campaign Design," 200).

As the concept and geospatial mapping functions come together (See Figure 6 on following page) the data therein is critical towards enabling an analytic team the means to convert system patterns of operations (to include systems of opposition) to graphics. This visualization may take on a form similar to elements within the present IPB process in which situation and event-like templates are generated; thereby illustrating system and city key "terrain," potential/necessary objectives, named areas of interest, target areas of interest, and associated decision points.

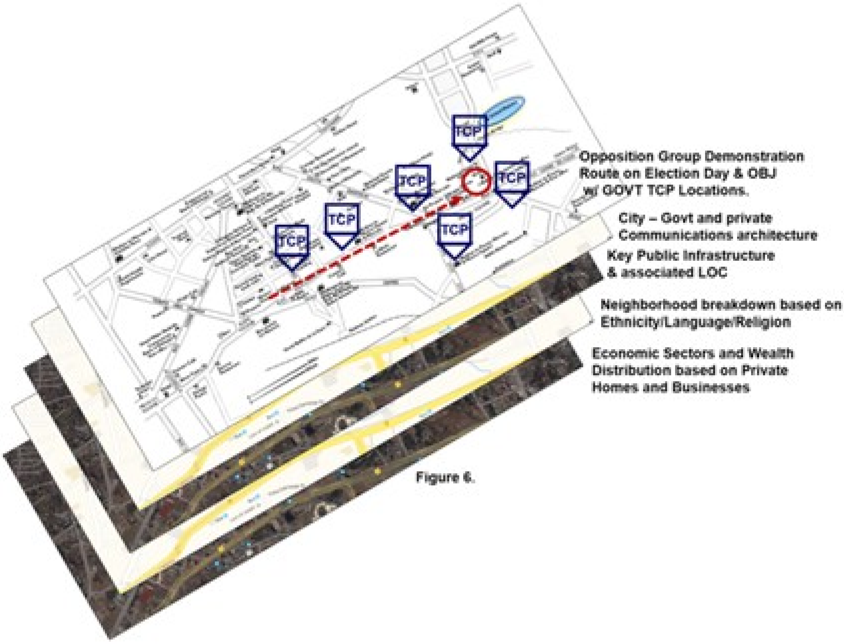


Figure 6 (above) is an example of the Urban OE visualization discussed on the previous page. In this figure's example, significant operational data layer examples (culled from the examples presented in the Appendix) were combined and framed in a visual array for a select portion of a city in support of a specific event.

In sum, mapping the urban problem system embodies a visual representation of the elements of the problem and their relationships. This step is an integral element towards truly facilitating and cultivating a deeper understanding of each system's role, impact, and effects. This step illustrates and affords:

- General understanding (and simplification) for how disparate parts of the system interconnect and interact to produce emergent phenomena and provides a visual means supporting systematic study of system parts.[xxxiv]
- Structural diagramming showing directional flows of resources and the connections between accumulators/nodes (based on the initial F-ASCOPE analysis). This diagramming technique results in a visual track of resource flow(s) through the problem system while building a holistic picture of the system(s) within the OE.[xxxv]
- Understanding how the population, infrastructure, and key actors relate to the physical terrain. This in turn aids in revealing the territorial logic shaping the spectrums of behavior[xxxvi] of the key actors within the urban OE and potentially puts a face to each of the city's operational data layers. [xxxvii]

Fruition of the latter comment above is intrinsic to a maneuver commander's vision and intent as well as the unit's urban battlespace (or engagement) management. Analysis and subsequent data mapping should answer several significant questions relevant to friendly force operations, strategies, and objectives – contributing to the commander's understanding of system/city (urban) metabolism.

Developing & Analyzing Urban COAs

III. Develop & Analyze Urban COAs

- Identify city-system E-COGs
  - ✓ System COG determination based on Critical Factors Analysis (CC/CR/CV)
  - ✓ Determination of system flow impact on other city-systems
- Develop COAs
  - ✓ "Urban Consequences" rationale incorporated w/in MDMP
- Analyze COAs
  - ✓ Potential impact on friendly & threat or system of opposition COAs
  - ✓ Impact of friendly & threat COAs on city system(s)
  - ✓ Determine COA acceptability criterion
- Validate understanding of the problem system(s)

Figure 7. Develop & Analyze Urban COAs

This framework then moves from describing the problem to how to influence it[xxxviii] via identification of Environment Centers of Gravity (E-COGS). E-COGS are those accumulators/nodes and flows that appear to play a more central role in the viability and functionality of the system. E-COGs are the critical elements that truly enable the system to function to the degree required in order to fulfill its inherent system and city objective(s). E-COG identification may be aided by the location of potential E-COG within a city's overall systems diagram, the potential E-COG's centrality (degree of accumulators/nodes and flows interaction) and its loop positioning (where a closed sequence of causes and effects occurs) [xxxix]

E-COG application extends traditional COG analysis from one that is adversary centric to one that embraces a systems-supportive environmental perspective. E-COG analysis resides within the premise that population, infrastructure, and the physical environment all provide resources to both friendly forces and systems of opposition as well as all those who rely on the city's systems for well-being, sustainment, and progress. There may be multiple E-COGs "in play" at the same time within the same DUA, with each or a combination thereof, extremely susceptible to change over time.

The key to E-COG application is giving each system found within the population, infrastructure, or environment (e.g. water, energy, communications systems, etc.) greater context or depth by stating the objective(s) of each of those entities (as opposed to a "threat intent" in traditional COG analysis).
Alignment of an objective to a system enables tailored application of current COG or critical factors analysis using critical capabilities, critical requirements, and critical vulnerabilities descriptions, rendering a more refined intelligence portrait of system interaction and the impact on the DUA. E-COG identification, partnered with relevant critical factors analysis provides an important conceptual link between framing the environment, identifying and characterizing the problem systems,[xl] and creating a model[xli] that incorporates the elements/systems therein.

E-COG identification within the problem(s) system(s) remains key towards developing tentative courses of action (COA) designed to affect the E-COG and thus achieve a friendly force desired end-state.[xlii] Select examples of related system/E-COG-related friendly COAs may center around degradation of the E-COG to deny resources to a system of opposition or a clearly defined threat entity;[xliii] and reinforcement of an E-COG in order to ensure that that E-COG functions and contributes positively to the system users.[xliv]

This framework enhances the operations planning staff's ability to determine COA acceptability criterion specific to DUA through an urban consequences rationale developed within MDMP.[xlv] Urban consequences COA considerations may also be assisted by using imaginative advanced structure analytic techniques (e.g. outside-in thinking and morphological analysis[xlvi]) to forecast how the COA may affect other not-yet-analyzed systems.[xlvii] This process may also serve as a check against baseline system-on- system effects analysis, in which a relationship outcome may not be sufficiently captured or the relationship effects are now unfavorable to friendly force operations.

Preparing for the AOC's Future Operating Environment

DUA require an analytic framework specifically tailored to accommodate a city's system diversity. The analytic framework presented provides a structure that incorporates urban operational data layers and city as a system context and perspectives. It is a catalyst towards addressing AOC questions like "what is the environment we think Army forces will operate in, and what is the problem we are trying to solve?" The potential for US forces to operate in DUA remains significant today and in the far term given the global pace of urbanization and the world's megatrends involving more complex diplomatic, economic, and military power. These trends are largely population-centric, and thus urban centric. As the Army's potential OE landscape continues to evolve, so must the Army's doctrinal framework, processes, and applications evolve as well. This framework is representative of our human domain[xlviii] efforts (e.g. data collection and analysis) in understanding the human interface resident within DUA; it is an education enabler that prepares the Army for the "unknown."[xlix] It complements the Army's human dimension[l] educational effort as well, guiding both situational understanding and the knowledge acquisition necessary for managing and influencing an Army team (and those within the human domain) through a potentially challenging and relatively unknown problem set. Gaining further insight to the dynamics between the components of problems within a decidedly complex urban system and the potential for hybrid warfare therein will not be easy; but, it must be a requirement. Development of situational understanding for dense urban areas remains a critical component of Army planning; such understanding demands relevant context and a framework appropriate for content application.

Appendix

Select operational data layers examples found within Dense Urban Areas.

The following examples are grouped or nested within an overarching concept (e.g. human geography) and shaped initially by the appropriate dense urban area dimensional perspective (see Figure 3 on page 9):

- Human geography of the "cityscape" (Human/Cyber/Information/Surface)
  - ❑ Ethnicity/Language/Religion
  - ❑ Social groups and organizations
  - ❑ Select demographic group patterns of life capture
  - ❑ Attitudes; social networking near-term sentiment analysis
  - ❑ Health & medical
  - ❑ Significant events

- Relative degree of urbanization & associated demographics (Human/Cyber/Information/Surface)
  - ❑ Geospatial visualization of dense urban core and peri-urban
  - ❑ Distributions of wealth (wealthy core vs. poor core & poor periphery (geospatial graphic representation))
  - ❑ Familia/tribal pockets; relationships, ideology influencers
  - ❑ Demographic dependencies on government or armed groups
  - ❑ Grievances; Identified coping mechanisms; opportunities to create resiliency
  - ❑ Identification of what one knows of the "social state," group or population movement (human condition mapping)

- Analysis of urban inflow & outflows (Human/Cyber/Information/Surface/sub-surface)
  - ❑ Sewage, Water, Electricity, Academia, Trash, Medical, Safety, Food
  - ❑ Demographic/social movement (Dense urban core to peri-urban areas & peri-urban areas to dense urban core)
  - ❑ Traffic and commuter patterns (Road/rail/pedestrian/maritime/air)
  - ❑ Wealth and economic distribution patterns, means of economic control and infrastructure controls (Define "elite, middle-class, and poor" based on present conditions)
  - ❑ International trade flows into/from city (incl. Air and sea ports/other (rail/ground))

- Economics (Human/Cyber/Information)
  - ❑ Basis and state of financial capital
  - ❑ Type/flow of commodities and remittance
  - ❑ Potential for stabilizing effects of illicit economies
  - ❑ Unemployment; rates, socio-economic aspects of affected divisions w/in general population

- Systems of opposition (Human/Cyber/Information)
  - ❑ Identification, description, and their core interests
  - ❑ Opposition methods, span, and degree of control
  - ❑ System rivals/allies (active/potential)
  - ❑ Level of demonstrated or potential access to advanced lethal/military technologies available to the system of opposition
  - ❑ Population's reliance/dependence on the system (security, aid, conflict resolution, social rule, financial assistance) and impact on terms of support/acceptance of the system's authority or influence

- Security controls/overwatch mechanisms (Human/Cyber/Information)
  - ❑ Government security forces; degree of presence, influence, and control
  - ❑ Internet and social media penetration; government internet policy
  - ❑ Identification of political/military influencers
  - ❑ Population's reliance/dependency on the city government (admin services, property rights, conflict resolution, social welfare/aid, education, and health) and impact on terms of support/acceptance of the government's authority or influence

- Other "Actors" (not identified/discovered above) (Human/Cyber/Information)
  - ❑ Local administration (governance, military, law enforcement)
  - ❑ Religious/Business/labor
  - ❑ Illicit network "leads" or commodities providers
  - ❑ Hostile actors (not otherwise captured w/in system of opposition; e.g. gangs)

End Notes

[i] "The US Army Operating Concept," TRADOC Pamphlet 525-3-1 (Oct 14), i (Foreword).
[ii] Ibid. iii (Preface).
[iii] Ibid. 11-12.
[iv] "The US Army Operating Concept," TRADOC Pamphlet 525-3-1 (Oct 14), 12.
[v] "Readiness in an Urban Era: Implications for the US Army," Strategic Initiatives Group – Lyceum, School of Advanced Military Studies (SAMS), Ft. Leavenworth, KS (May 15), i.
[vi] US Army Chief of Staff' Strategic Studies Group (Megacities), "*A Proposed Framework for Appreciating Megacities: A US Army Perspective,"* Small Wars Journal (Apr 2014), 2. System typology often featuring decentralized and informal systems, low quality infrastructure, and unregulated flow capacity.
[vii] Luciano Florida, *"The Fourth Technological Revolution,"* Oxford, UK, Oxford University Press (May 2014), 14-15.
[viii] National Intelligence Council, *Global Trends 2030: Alternative Worlds* (Washington DC: Office of the Director of National Intelligence (2012), ii.
[ix] SAMS, "Readiness in an Urban Era: Implications for the US Army," 1.

[x] Heuristics are strategies using readily accessible, though loosely applicable, information to control (or steer) problem solving.
[xi] "Commander's Appreciation and Campaign Design," TRADOC Pamphlet 525-5-500 (Jan 2008), 6.
[xii] Understanding the Threat as a System of Opposition," David Pendall, COL, USA, White Paper (Jan 2014), 4.
[xiii] Political, Military, Economic, Sociological, Infrastructure, Information – Physical Environment & Time. "Brigade Combat Team Intelligence Techniques," ATP-2-19.4 (FM 2-19.4) (Feb 2015), 1-3.
[xiv] Flow – Area, Structures, Capabilities, Organizations, People & Events. ATP 2-19.4, B-21.
[xv] Sewage, Water, Energy, Academics, Trash – Medical, Safety, & Other Considerations. "Engineer Reconnaissance," FM 3-34.170 (Mar 2008), 6-14.
[xvi] Diplomatic, Information, Military, Economic, Financial, Intelligence, and Law Enforcement. Vulnerability Analysis Workbook, Understanding the Threat, Vol 1, US Army Asymmetric Warfare Group, Ft. Meade MD (Jun 2008), v.
[xvii] Mission, Enemy, Terrain & Weather, Troops & Support Available – Time Available & Civil Considerations. ATP 2-19.4, 1-3.
[xviii] Re-scoping how the Army views and applies applicable operational variables to a problem set like dense urban areas, could significantly add data dimensions not presently considered for urban-related mission analysis.

[xix] Frank Hoffman, LtCol, USMCR (Ret.), "The Janus choice: Defining today's multifaceted conflict," Armed Forces Journal (Oct 2009). Combat operations characterized by the simultaneous and adaptive employment of a complex combination of conventional weapons, irregular warfare, terrorism and criminal behavior to achieve political objectives.
[xx] "City as a System, Analytic Framework," Version 1.0, CAERUS Associates and the Combatting Terrorism Technical Support Office, Alexandria, VA (Jun 2015), 1.
[xxi] CTTSO was established in 1999 by the Assistant Secretary of Defense for Special Operations/Low- Intensity Conflict. It is charged with providing a forum for interagency and international users to discuss mission requirements to combat terrorism, prioritize requirements, fund and manage solutions, and deliver capabilities.
[xxii] "City as a System, Analytic Framework," 1.
[xxiii] There exists minute differences for representing the dimensions of the urban landscape between various DoD entities as part of the dense urban area community of interest.
[xxiv] "City as a System, Analytic Framework," 25-26. The CAERUS/CTTSO Urban Triad Paradigm conceptually borrows from Joint Publication 3-06, "Joint Urban Operations," and contributes significantly towards defining the unique features of urban environments. This paradigm is represented by population (PMESII),

infrastructure (SWEAT-MSO), and physical environment and time (as a latter sub-set of PMESII-PT application.
[xxv] "Dense Urban Areas & Megacities Challenge," Brief to US Army Intelligence Center of Excellence representatives, Dr. Rolf Halden, Arizona State University Research Enterprise (ASURE), Phoenix, AZ (24 Sep 15), slide 19. Multi-variable consideration creates multiple lines of information ingest, protects against data gaps, and thus better informs follow-on mapping and modeling efforts.
[xxvi] David J. Kilcullen, "*The City as a System: Future Conflict and Urban Resilience,"* The Fletcher Forum of World Affairs, VOL 36:2 (Summer 2012), 36.
[xxvii] Capture and analysis of negative effects/impacts regarding urban operational data layers is key to informing friendly COA development. There may be circumstances in which the effects of a city-related system are so adverse that an environmentally imposed condition like area anti-access/area denial is present.
[xxviii] Comparing/contrasting current city steady-state with a desired future state, based on the urban OE's operational data layers analysis and a Commander's guidance/mission analysis will also require a structured analytic outline (see DIA & CIA structured analytics regarding diagnostic techniques, argument mapping, and contrarian techniques).
[xxix] Pendall, (Jan 2014), 4.
[xxx] Identification of critical city system flows may not be readily apparent to a planning staff via F- ASCOPE regarding a dense urban OE's effects on operations and the implications therein. This contention is reinforced by the CAERUS framework's apt descriptors of accumulators and nodes as related, yet hardly interchangeable concepts. These terms may require doctrinal re-visit in light of the critical application of F-ASCOPE in support of dense urban terrain analysis.
[xxxi] A global graph is a scalable, operational environment-specific database that identifies, stores, and updates the relationships between hundreds of thousands to millions of entities. The relationships between entities are stored as fusion triples, i.e., as object-predicate-object. Future analytic teams would employ algorithms and artificial intelligence means to discover and explore not only those entities and relationships that are obviously relevant to their unit's mission; but more important, to discover and track those entities which were not previously known to the unit. Global graphs are foundational and fundamental to all future analytics, to understanding threat and non-threat networks of people, places, procedures, and underlying motivations, and perhaps most importantly, to understanding complex operational environments as complex adaptive systems.
[xxxii] Tom Pike and Eddie J. Brown, "*Populations as Complex Adaptive Systems: A Case Study of Corruption in Afghanistan,"* Small Wars Journal (Aug 2011), 3.
[xxxiii] "City as a System, Analytic Framework," Brief to US Army Intelligence Center of Excellence, CAERUS Associates and the Combatting Terrorism Technical Support Office, Alexandria, VA (14 Jul 2015), slide 16.

[xxxiv] "City as a System, Analytic Framework," 30.
[xxxv] Ibid. 30-31.
[xxxvi] "Dense Urban Areas & Megacities Challenge," Brief, Dr. Rolf Halden, ASURE, terminology discussion.
[xxxvii] "City as a System, Analytic Framework," 35.
[xxxviii] Ibid. 37.
[xxxix] Ibid. 39.
[xl] Ibid. 38.
[xli] Comparison between two or more dense urban OEs will likely yield contrasting elements or system- specific-interaction differences; therefore, model-linked experimentation efforts may require a very specific dense urban OE test subject and scenario in order to adequately convey and capture the resultant impact of a critical variable upon the other resident systems within the OE.
[xlii] "City as a System, Analytic Framework," 41.
[xliii] Ibid.
[xliv] Ibid.

[xlv] Ibid. 42. Urban operational consequences are not presently captured within MDMP as part of step 4 (COA Analysis – War Game) and step 5 (COA Comparison). A planning staff may need to return to the urban OE framing and mapping steps in order to re-assess how the friendly/threat COAs will impact the system-specific operational data layers.
[xlvi] Richards J. Heur Jr., and Randolph H. Pherson, "*Structured Analytic Techniques for Intelligence Analysis,"* Washington, DC, CQ Press – Division of SAGE (2011), 108.
[xlvii] City as a System, Analytic Framework," 42.
[xlviii] Totality of the physical, cultural, psychological, and social environments that influence human behavior to the extent that the success of any military operation or campaign depends on the application of unique capabilities that are designed to influence, fight, and win in population-centric conflicts.
[xlix] Thomas E. Ricks, *"The Generals,"* New York, NY, Penguin Press (2012), 346. The author's context was in relation to *"FM 100-5: Operations,"* in which that document was categorized as ". . . emphasized training, which prepares soldiers for the known, far more than education, which prepares them to deal with the unknown."
[l] Cognitive, physical, and social (CPS) components of Soldier, civilian, leader, and organizational development and performance essential to raise, prepare, and employ the Army in unified land operations.

Anticipating Megacity Responses to Shocks: Using Urban Integration and Connectedness to Assess Resilience

*By **Shade T. Shutters, Wes Herche and Erin King***

Originally published in Small Wars Journal on 26 February 2016

Available online: http://smallwarsjournal.com/jrnl/art/anticipating-megacity-responses-to-shocks-using-urban-integration-and-connectedness-to-asse

Introduction

Over half of humanity now lives in cities, a proportion rising to 80% by 2100 [1]. With this rapid demographic shift has come a new type of geographical entity – the megacity [2]. Typically defined as an urbanized area with at least 10 million residents, 28 megacities exist in the world today – almost 10 times as many as the three that existed in 1970. And nearly 40 of these massive human agglomerations will exist just 10 years from now. In parallel with this trend is a diffusion of world power from traditional hegemonic states to networks of diverse types of actors, including non-state entities such as megacities [3].

The rapid emergence of these dense urban areas has led to their prominent role in recent U.S. operations, with urban warfare being an integral part of allied efforts in both Iraq and Afghanistan. Operations in Fallujah, Iraq in 2005 were described as, "the heaviest urban combat Marines have been involved in since Hue City in Vietnam in 1968," [4]. In Afghanistan, a resurgent Taliban has concentrated its attacks on dense urban areas, forcing Afghan security forces into an urban warfare front for which they are ill- prepared [5]. Indeed, Iraq's recent announcement that it will construct a reinforced wall to surround Baghdad illustrates the ever increasing emphasis of megacities and their security.

Given these recent experiences and prevailing trends there is clearly a need for a deeper understanding of dense urban environments at this unprecedented scale [6, 7]. What, if anything, fundamentally differentiates megacities from other cities? How does a contemporary military force confront an urban system of such immensity? While current military doctrine extends to urban operations, the sheer size of current megacities is beyond the scope of that doctrine. A recent report by the Chief of Staff of the Army's Strategic Studies Group [8] summarizes the gaps in our understanding of megacities and the potential implications for national security.

The report states that megacities "create a complex security environment which will challenge policy makers and military planners" and that megacities will be the strategic key in future U.S. military interventions. This presents a paradox for strategic planning and operations, framing urban warfare as a "wicked problem" [9-

11]. By their nature, complex systems such as megacities cannot be controlled in a traditional military sense, but they can be influenced [12]. It is critical then to understand exactly how to influence the trajectory of these cities and how to anticipate their responses to that influence.

Urban Resilience

A primary objective of better understanding of megacities is to enable a proper evaluation of alternative tactical and strategic options. It is virtually impossible to evaluate a scenario for intervening in a megacity without the ability to anticipate the megacity's response. And the magnitude and nature of a city's response to intervention is intimately related to the city's resilience.

Thus, we focus in this paper on a critical and fundamental attribute of megacities, and indeed of all complex systems – their resilience to shocks [13]. How well can a megacity respond to a shock? How long will that response take? What are its vulnerabilities and weaknesses? What policy interventions can affect its resilience? Quantifying that resilience is a crucial prerequisite for comparative analyses, for assessing the impact of policies, and for planning both strategic and tactical options. It is also central to anticipating whether a disrupted urban environment will eventually recover from a shock or transition into a haven for violent extremists.

Connectedness, integration, and interdependence

Ideally, our understanding of megacities, or any dense urban environment would include a theoretically- grounded, quantification of resilience, which many experts claim is virtually impossible to create [14, 15]. Analysts are thus forced to derive simplistic qualitative notions of resilience. This has led to a prevailing view asserting that tightly connected, highly integrated cities are the most resilient to shocks [16, 8, 17]. Cities such as London and New York, this view claims, will recover from shocks much more readily than the likes of Lagos or Dhaka.

This concept of integration or connectedness and its relation to resilience is sufficiently accepted so that it was used as the basis for the CSA's proposed megacity typology (Figure 1). As Harris et al [8] conclude:

> *Highly integrated systems are characterized by strong formal and informal relationships among its component parts. These relationships manifest as highly ordered hierarchical structures with formalized procedures and norms, and open communication among its various parts. Highly integrated systems are inherently stable, show high degrees of resilience (ability to absorb change) and manage growth in a relatively controlled manner.*
>
> *Loosely integrated systems, on the other hand, lack many of the formal relationships that keep highly integrated systems stable. Weak control and communications systems, and lack of consistent rules for interaction amongst component parts lead to low resilience and unregulated growth. This growth, in turn, contributes more component parts that aren't formally integrated into the system, creating a downward spiral of instability.*

The assertion that higher connectedness of a system increases that system's resilience comes largely from the engineering concepts of robustness and redundancy [18-20], where designed networks and engineered systems must be crafted to withstand shocks [17]. The rationale is that if one part of a system fails, higher connectivity enables the rapid replacement of resources and the uninterrupted flow of information through the system.

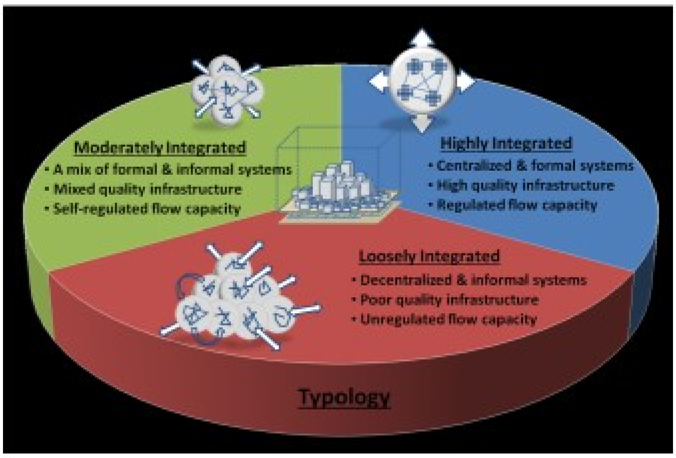


Figure 1: A typology of megacities defined by the level of a city's integration (from [8] p. 14).

Yet this prevailing view is not the only one. A contrary view, outlined in the seminal tome *Panarchy* [21] and originating in ecology-related fields, asserts that highly connected and integrated systems become brittle and susceptible to cascading failures [22, 23]. To better illustrate this counter view, we present a simple organismic analogy to cities.

An analogy from biology

Let us consider an illuminating analogy from the animal kingdom. Though this vantage point will be new to most readers, it is important to understand that an animal is a collection of numerous individual cells: individuals that communicate with each other, coordinate activities, carry out diverse functional tasks, change their behavior in response to their environment, regulate themselves, and depend on one another for survival. In other words, just like a city, an animal is nothing less than a complex adaptive social system [24].

Biologists typically place animals along a continuum of internal complexity with humans at one end (most complex) and sponges at the other (least complex). The human body is made of nearly 200 different types of cells, which form a highly integrated hierarchy of interconnected tissues, organs, and dynamic systems. These systems and their components show an incredible degree of self-regulation, feedback controls, interdependency, redundancy, and defense capabilities. On the other hand sponges have no tissues, no organs, no systems at all, and are composed of only four types of cells. Thus under virtually any conceived scale of integration, connectedness, or interdependency, humans are far above sponges.

But which is more resilient? Consider the shock of discharging a firearm into both a human and a sponge. In humans a small area of localized damage can trigger a series of cascading system failures culminating in the collapse of the entire system and the death of the individual. And the sponge? Some of its cells would die but the system overall would be largely unaffected. With minimal integration between damaged areas and the rest of the animal, unaffected parts continue to function as if nothing had happened. In fact, a sponge can be subjected to chemical or mechanical stresses that virtually disintegrate the animal into a mass of unconnected cells and those cells will soon reconstitute into a single animal. Given this example it is difficult to argue that the highly integrated and hierarchical society of cells forming a human body is more resilient than a lowly sponge. Can the analogous social systems of cities be so different?

Recent empirical evidence

Partly to reconcile this apparent contradiction over the role of connectedness, a recent study attempted to craft a quantitative and anticipatory metric of urban resilience. Using massive government datasets on the economies of U.S. cities, Shutters et al [25] developed a quantitative measure of a city's "tightness" or level of economic integration. Using this metric the authors found that, following the shock of the 2007- 2009 "Great Recession," U.S. cities with tightly integrated economies actually had the largest percentage drops in several measures of economic performance. In addition, the highly integrated cities took longer to return to their pre-shock performance levels. In other words, the most integrated cities were the *least* resilient to this global economic shock.

Yet the authors of this study caution that resilience is likely very nuanced and contextual. Factors such as the type of shock, its geographical extent, its duration, etc., will ultimately determine what is and is not a resilient megacity. For instance, a disaster befalling a specific U.S. port city may have cascading impacts on the U.S. economy, but the nature of this geo-specific shock is likely quite different than the global economic shock described above. In any regard, clarifying the impact of increasing connectedness is paramount in today's world of increasing globalization and interdependency [26].

The Key to Urban Resilience

Thus far we have established that understanding the resilience of megacities is critical to planning interventions, evaluating options, and anticipating responses, but that typical thinking about urban resilience is both naïve and conflicted. So what is the way forward?

We believe the key to understanding urban resilience can be summarized in one word – networks. To appreciate this assertion we must first accept that cities are complex adaptive systems. They exhibit emergent properties, evolutionary dynamics, and non-linear responses. But more importantly, cities, like all complex systems, are composed of a network of interacting parts and subsystems. Complex urban systems are virtually defined as a multiplex of interacting complex networks [27-29].

Indeed, modern urban centers, and particularly megacities, are no longer isolated fortresses, but large, highly complex interconnected networks of networks. Those networks include transportation, financial, resource distribution, sewer and water infrastructure, electricity, communication and data, economic trade, social networks, and others. These networks can best be conceptualized as "Level 2" socio-techno systems under the Allenby and Sarewitz [30] framework of technologies and emergent technological systems that have co-evolved as integral parts of human beings and societies. Networks like traffic conduits and electrical delivery can be mapped through physical inspection, including remote sensing. On the other hand, financial and social networks, for example, require tools such as social media analytics and data mining. Still others, such as economic interdependence networks, require careful analysis with tools from information theory and other advanced techniques [31].

Quantifying the dynamics and topological features of these networks is key to understanding both their resilience and that of the complex systems they govern [31-33, 25]. This includes analyzing the diversity of networks embedded in dense urban systems. Thus the tasks at hand include at least two major agendas:

(1) determining how the different networks comprising a city are affected by various shocks, and (2) generating the high quality data needed to inform models of urban resilience for developing nation megacities, where current data availability is limited.

Conclusion

Given current global trends in population growth, urbanization, and power dynamics, megacities and other dense urban environments will continue to grow in strategic importance . Thus, it is critical that we enhance our understanding these complex systems. This understanding will require embracing a complex adaptive systems framework focused on the networks that comprise urban systems.

In particular, assessing multiple policy and tactical options requires the ability to anticipate how a megacity will respond to intervention or shocks; and those responses are a function of the resilience of an urban system. Thus, the imperative is to better understand urban resilience, theoretically ground its assertions, and rigorously quantify it for enhanced decision making. We assert that the best way to accomplish these goals is through sophisticated analysis of the multitude of networks embedded within (and existing between) urban systems.

End Notes

1. United Nations Population Fund (2007). *State of the world population 2007: Unleashing the Potential of Urban Growth*. United Nations, New York.

2. Dobbs, R. (2010). *Prime Numbers: Megacities*. Foreign Policy Magazine 181:132-135.

3. National Intelligence Council (2012). *Global Trends 2030: Alternative Worlds*. Office of the Director of National Intelligence, Washington, DC.

4. Garamone, J. (2005). *ScanEagle Proves Worth in Fallujah Fight*. DoD News 11-Jan-2005, available at http://archive.defense.gov/news/newsarticle.aspx?id=24397.

5. Smith, J. (2015). *Battle for Kunduz Draws Afghans into Urban Warfare*. Stars and Stripes Oct. 13, 2015, available at http://www.stripes.com/news/battle-for-kunduz-draws-afghans-into-urban-warfare-1.373072.

6. Adamson, W. G. (2015). *Megacities and the US Army*. Parameters: The US Army War College Quarterly 45(1):45-54.

7. Felix, K. M. and F. D. Wong (2015). *The Case for Megacities*. Parameters: The US Army War College Quarterly 45(1):19-32.

8. Harris, M., R. Dixon, N. Melin, D. Hendrex, R. Russo, and M. Baily (2014). *Megacities and the United States Army: Preparing for a complex and uncertain*

future. Office of the Chief of Staff of the Army, Strategic Studies Group, Arlington, Virginia, USA.

9. Rittel, H. W. J. and M. M. Webber (1973). *Dilemmas in a general theory of planning*. Policy Sciences 4(2):155-169.

10. Camillus, J. C. (2008). *Strategy as a wicked problem*. Harvard Business Review 86(5):98.

11. Bebber, R. (2015). *The Wicked Problem of War*. MOC Warfighter, U.S. Naval War College 5, available at https://www.usnwc.edu/mocwarfighter/Article_M.aspx?ArticleID=40.

12. Clark, A. (1999). *Leadership and Influence: The Manager as Coach, Nanny and Artificial DNA*. Pages 47-66 *in* J. Clippinger, editor. The biology of business: De-codeing the natural laws of Enterprise. Jossey-Bass, San Francisco.

13. Kilcullen, D. (2012). *The City as a System: Future Conflict and Urban Resilience*. The Fletcher Forum of World Affairs 36(2 Summer 2012):19-39.

14. Walker, B. and D. Salt (2012). *Resilience Practice: Building Capacity to Absorb Disturbance and Maintain Function*. Island Press, Washington, DC.

15. USAID (2013). *The Resilience Agenda: Measureing Resilience in USAID, Technical Note 1866*. United States Agency for International Development, Washington, DC.

16. Norton, R. J. (2003). *Feral Cities*. Naval War College Review 56(4):97-106.

17. Sterbenz, J. P. G., D. Hutchison, E. K. Çetinkaya, A. Jabbar, J. P. Rohrer, M. Schöller, and P. Smith (2014). *Redundancy, diversity, and connectivity to achieve multilevel network resilience, survivability, and disruption tolerance*. Telecommunication Systems 56(1):17-31.

18. Pavard, B., J. Dugdale, N. B.-B. Saoud, S. Darcy, and P. Salembier (2008). *Underlying concepts in robustness and resilience and their use in designing socio-technical systems*. Pages 127-142 *in* E. Hollnagel, C. P. Nemeth, and S. Dekker, editors. Resilience engineering perspectives: Remaining sensitive to the possibility of failure. Ashgate Publishing, Burlington, Vermont, USA.

19. Smith, P., D. Hutchison, J. P. G. Sterbenz, M. Scholler, A. Fessi, M. Karaliopoulos, C. Lac, and B. Plattner (2011). *Network Resilience: A Systematic Approach*. Ieee Communications Magazine 49(7):88-97.

20. Krupa, M. B., F. S. C. III, and A. L. Lovecraft (2014). *Robustness or resilience? Managing the intersection of ecology and engineering in an urban Alaskan fishery*. Ecology and Society 19(2):17.

21. Gunderson, L. H. and C. S. Holling, editors. (2002). *Panarchy:*

understanding transformations in human and natural systems. Island Press, Washington, DC.

22. Kauffman, S. A. (1993). *The Origins of Order: Self-Organization and Selection in Evolution*. Oxford University Press, New York.

23. Dorner, D. (1996). *The logic of failure: recognizing and avoiding error in complex situations*. Metropolitan Books, New York.

24. Maynard Smith, J. and E. Szathmáry (1997). *The major transitions in evolution*. Oxford University Press, New York.

25. Shutters, S. T., R. Muneepeerakul, and J. Lobo (2015). *Quantifying urban economic resilience through labour force interdependence*. Palgrave Communications 1(201510):1-7.

26. Ward, D. (2016). *Operational Environment Implications of the Megacity to the US Army*. Small Wars Journal 12(2):02-Feb-2016.

27. Craven, P. and B. Wellman (1973). *The Network City*. Sociological Inquiry 43(3-4):57-88.
28. Batty, M. (2013). *The New Science of Cities*. MIT Press, Cambridge, Massachusetts.
29. Neal, Z. P. (2013). *The connected city: How networks are shaping the modern metropolis*. Routledge, New York, NY.

30. Allenby, B. and D. Sarewitz (2011). *The techno-human condition*. MIT Press, Cambridge, Massachusetts, USA.

31. Ulanowicz, R. E., S. J. Goerner, B. Lietaer, and R. Gomez (2009). *Quantifying sustainability: Resilience, efficiency and the return of information theory*. Ecological Complexity 6(1):27-36.

32. Buldyrev, S. V., R. Parshani, G. Paul, H. E. Stanley, and S. Havlin (2010). *Catastrophic cascade of failures in interdependent networks*. Nature 464(7291):1025-1028.

33. Parshani, R., S. V. Buldyrev, and S. Havlin (2010). *Interdependent Networks: Reducing the Coupling Strength Leads to a Change from a First to Second Order Percolation Transition*. Physical Review Letters 105(4):048701.

Atmospheric Impacts and Effects Predictions and Applications for Future Megacity and Dense Urban Area Operations

*By **David Knapp, Robb Randall and Jim Staley***

Originally published in Small Wars Journal on 22 March 2016

Available online at: http://smallwarsjournal.com/jrnl/art/atmospheric-impacts-and-effects-predictions-and-applications-for-future-megacity-and-dense-

Introduction

By 2030 it is expected that more than 60% of the world's population will live in dense urban centers and the majority of these Megacity/Dense Urban Areas are/will be in complex terrain environments.

Consequently, weather conditions within these dense urban and complex terrain (DUCT) environments will influence a greater populace and can negatively influence military operations, community services, and overall situational understanding needed for Intelligence Preparation of the Battlefield (IPB) and Intelligence, Surveillance, and Reconnaissance (ISR). Extreme weather conditions will impact DUCT areas often already overstressed by uncontrolled growth and a degraded public infrastructure. Unique weather conditions experienced within the DUCT will highlight, and even magnify, weather sensitivities affecting threat, civilian populations, and DoD weapons systems and operations. Current state-of-the-science atmospheric sensing, characterization, and forecasting capabilities cannot accurately represent the rapidly changing and complex atmospheric processes in a DUCT environment. Therefore, innovative and disruptive solutions are required to revolutionize locally fine-tuned weather support for DUCT operations, information critical to IPB and ISR needs. If localized urban and complex terrain domain weather conditions can be accurately sensed, characterized, and predicted, such information will be a force multiplier for local commanders tasked with leading operations in these multifaceted and intricate domains.

Local Duct Weather Concerns Impacting Operations

There are a variety of atmospheric environment concerns that must be addressed to improve the potential for success in a Megacity/DUCT battlefield. A few examples of topics that must be addressed by current and future atmospheric scientists are below:

- DUCT Winds: The local complex terrain (natural and man-made urban sprawl, etc.), can significantly influence near-surface wind patterns across just a few city blocks. Unpredicted wind funneling between, around, and over buildings can lead to small unmanned aerial system failure, inaccurate dispersion plume predictions (chemical, biological, smoke, etc., coupled with consequence management), and many other related environmental impacts and effects issues for warfighters in such domains. Significant research and development efforts are needed to determine such microscale wind effects within unique DUCT environments.

- Severe weather concerns: Flooding, drought, excess heat/cold, precipitation, and wind influences in each particular Megacity can be drastically different from day to day, hour to hour, and from one section of the Megacity to another. Questions regarding what the populace does during expected severe weather events and how best to militarily influence or control civilians during such events must be addressed. Equally important are questions regarding how best to address the need for new decision support applications to aid military planners through mission execution in such extreme weather conditions. Decision tools addressing how the severe weather effects food, communications, fuel, and service distribution, for both military and civilian operations, can enhance leadership's decision toolset for planning and execution.

- Battlefield sensor performance: The often complex and varied local weather conditions within a DUCT domain can wreak havoc on battlefield sensor performance. Since sensors are influenced by not only target, but also background signatures, the complex and oftentimes densely packed structures of the urban environment together with heating and cooling changes, precipitation, and atmospheric aerosol concentrations impact infrared and acoustic sensors and performance.

- Scientific work needed: The spatial resolution of fine-scale atmospheric prediction models must be continuously improved and validated for accurate predictions in difficult DUCT domains. What weather spatial resolution is required to effectively address DUCT weather effects? How often should fine-scale DUCT atmospheric prediction models be run to adequately depict the environment? This information and answers to the questions noted are critical for accurate microscale weather prediction model performance. Additionally, specific weather sensing requirements within the DUCT need to be addressed, insofar as determining ideal numbers, types, placement, etc., to insure weather prediction models are initialized using the most recent and accurate local conditions possible. These sensing advances will provide data to enhance the understanding of Megacity atmospheric processes critical to improving the underlying physics and dynamics of microscale atmospheric models tailored to such domains.

Specific Operational Challenges Within Megacity Domains

1. Military units deploying within a DUCT domain are likely to operate in small teams conducting short duration missions. These teams will often execute different types of missions within city blocks of each other. The DUCT environment can be heavily influenced by microscale weather conditions which are often significantly different from one block to the next.

2. Most DUCT environments are located near significant bodies of water (lakes, rivers, littoral), which further influence micro-climates associated with these high humidity and valley terrain areas.

3. Aviation operations will likely be a preferred method of mission execution. Wind, cloud ceiling, visibility, precipitation, buildings, wires, communication towers, and urban terrain objects such as large signs and billboards within the DUCT domain will significantly influence all aviation operations.

4. Weather conditions within the DUCT domain effect threat operations just as they do friendly force operations. Determining the weather impact differences between friendly and threat forces can significantly contribute to the DUCT battlefield commander's IPB knowledge base. Other related challenges relate to weather's impact on concealment of operations for both friendly and threat forces.

5. Weather sensing and atmospheric characterization capabilities are lacking within DUCT environments. Reliable weather forecasting capabilities (weather forecast models) require local weather observations as input to accurately characterize current/initial atmospheric conditions. Sufficient numbers of weather observations enable meaningful mission watch. Mission watch provides operational commanders a real-time weather picture of the Area of Operations (AO) during mission execution. Effective weather "mission watch" provides atmospheric monitoring of choke points, avenues of approach and even military objectives within the AO.

6. Lastly, addressing environmental intelligence for autonomous systems in Megacities, swarms of unmanned ground/air micro-vehicles could be equipped with weather sensors to dramatically improve currently inadequate local weather condition sensing and thus improve the accuracy of local DUCT atmospheric prediction models.

Needed Solutions: Weather Technologies to Change Warfare for Decision Makers at All Echelons

Looking ahead at the Megacity/DUCT battlefields of 2030 and beyond, there is an overwhelming need to revolutionize the science of atmospheric sensing, characterizing, and predicting local conditions in DUCT environments. The Battlefield Environment Division at Army Research Laboratory (ARL), in conjunction with research partners across the DoD, academia, and civilian public and private arenas, will be using a combination of existing very fine-scale resolution (microscale) meteorological tower arrays, unmanned system-hosted existing/emerging sensor technologies, and optimized sensor placement strategies to include crowdsourcing techniques to sense and characterize DUCT atmospheric domains. Applying sensor data and characterization improvements (separately and combined) to novel, forward-deployed microscale Nowcasting ("pocket modeling") technology hosted on computationally complex but extremely efficient General Purpose Graphics Processing Units (GPGPU) and smaller portable devices such as warfighter-hosted communications platforms is the way of the future for DUCT operational weather forecasting.

Observed data must be used to verify/validate the atmospheric modeling weather forecast improvements as related to value-added to the DUCT warfighter, showing how improved localized weather forecasts significantly enhance warfighter operations. Applying all such fine-scale technology improvement lessons learned to advanced automated state-of-the-science decision tools focused on predicting attrition rates from operations in adverse DUCT weather conditions will be one critical result this long-term effort. Thus, Megacity battlefield commanders will be provided with a full picture of predicted atmospheric effects and impacts on local operations, including expected losses due to hazardous weather. Pocket modeling (focused local atmospheric prediction technology hosted on personal communications devices), crowdsourcing sensed data, and GPGPU advances for atmospheric prediction computing are just a few of the disruptive technologies to be used as the capability to run a complex terrain atmospheric model is pushed to the lowest echelons in the battlefield which will positively affect current DoD processes. Development of deployable hardware and software system prototypes for weather effects intelligence and decision tools for DUCT environments is the planned culmination of ARL's work on meteorological sensor arrays, microscale atmospheric prediction systems, and unmanned system and atmospheric sensing platform resources to reach these technological goals.

There are a number of critical steps being addressed to move the science forward as the needed technological advances are developed:

- Perform research to understand atmospheric processes in DUCT environments. Effective weather sensing and atmospheric characterization of the AO will optimize mission execution by providing essential input to weather forecast models. This improves forecast accuracy and therefore confidence in planning and execution of all military operations; forecast accuracy improvements mean a safer operating environment for military and civilian personnel, with few, if any, weather surprises. Weather sensing in DUCT domains also provides critical, real-time situational awareness supporting current operations. A comprehensive understanding of current atmospheric conditions enables the commander's full utilization of the AO, in both time and space, allowing for the selection of tactics, weapons, and targets based, at least in part, on atmospheric conditions. Accurate and timely weather observations are a true force multiplier, protecting military and civilian operations from the uncertainty of mission-limiting weather conditions.

- Advanced development of microscale models. Develop DUCT fine-scale operational local atmospheric modeling capabilities suitable for forecast center and forward-deployed implementation on the smallest computational platforms possible. Such capabilities will support both operational theater forecast centers as well as the lowest battlefield echelons with on-scene local atmospheric predictions. These forecasts will have the capability to ingest the most current, locally-sensed atmospheric data. Local forward-deployed atmospheric modeling capabilities will ensure timely weather forecast updates to Megacity commanders and decision-makers down to actionable Soldier levels. Today, precise prediction of local weather events is limited by the resolution of currently fielded weather forecast modeling capabilities and the availability of weather observations.Improving the resolution of weather predictions, especially in the complex terrain of a Megacity, requires a significant increase in the number of weather observations and optimized placement of weather sensors in the domain to initialize the weather predictions. Research will consider the value of remotely-sensed observations (e.g. satellite, radar, etc) as input to these improved forecast model capabilities. Weather sensing capabilities, combined with better model physics, will significantly improve the weather forecast accuracies within an urban environment. Additionally, developing forward-deployed and frequently updated small "pocket" computer platform atmospheric modeling capabilities, providing data to on-board weather decision tools will significantly enhance the local timeliness and accuracy of microscale DUCT weather predictions.
- New weather related decision aids include sensor performance tools for multiple modalities, including acoustic, infrared, radar, and seismic. Urban routing tools must account for manned and unmanned ground and aerial vehicles. Decision aid development must include applications supporting a prediction of human domain conditions based on weather and climate combined with and including populace reactions to military operations. DUCT-focused ensemble probabilistic predictions will produce forecast confidence output for decision support tools of high interest and use by military commanders and decision makers within the Megacity.

Summary

Weather conditions significantly influence military operations within Megacity DUCT operational domains. Confident execution of military operations demand comprehensive weather support at spatial and temporal resolutions that accurately depict microclimates found in every DUCT environment. These weather conditions effect all aspects of the geospatial environment within the Megacity.

Increased resolution and accuracy of deployed weather support products is crucial, especially so in the DUCT environment. Effective weather sensing, atmospheric characterization and prediction will optimize mission execution by providing critical, real-time situational awareness supporting future operations as well as providing essential input to weather forecast models and decision support tools. This improves forecast accuracy and confidence in planning and execution of all military operations. Forecast accuracy improvements mean a safer operating environment for military and civilian personnel.

This disruptive-based approach ensures DoD DUCT battlefield Commanders will have a full picture of predicted atmospheric effects and impacts on DUCT operations, including expected losses due to hazardous weather. The work highlighted in this paper will optimize our understanding and application of crucial weather conditions within the Megacity operations as future urban operating environments become the norm.

Complex IPB

By **Tom Pike and Eddie Brown**

Originally published in Small Wars Journal on 24 March 2016

Available online at: http://smallwarsjournal.com/jrnl/art/complex-ipb

> *The right perspective makes hard problems easy while the wrong perspective makes easy problems hard.*
>
> -- Scott Page

The last 15 years of conflict have shown the difficulty in understanding the internal dynamics of a foreign population. Understanding these internal dynamics, however, is essential to implementing policies and taking action to influence the foreign population's behavior in pursuit of U.S. goals. The U.S. Government must improve its capability to rapidly analyze foreign populations and the need for this capability will only increase as megacities, with their incredibly complex population systems become more numerous. Unfortunately, the challenge is not only finding effective approaches to understand foreign populations but also finding approaches that can integrate assessments from a Battalion Intelligence Officer all the way to a strategic level agency. This integration is necessary to synchronize the efforts of the large and likewise complex U.S. Government. Acknowledging these daunting challenges demands the U.S., and in particular Army intelligence, work to find and apply improved analytic frameworks for foreign population analysis.

Intelligence Preparation of the Battlefield (IPB) provides a strong nucleus to develop new frameworks, but must evolve past its force on force focus to an approach that analyzes multiple groups competing within a population. The integration of new concepts from complex adaptive system theory provides rigorously tested concepts many of which have already been incorporated into common analytic software—such as Analyst Notebook, Palantir, and others—to cope with the problems of Yemen, Somalia, Iraq, Syria, and elsewhere. Complexity based approaches have also been the core of strategic assessments which have influenced the highest levels of government. The challenge is to operationalize these approaches so intelligence analysts, at all levels, can gain an understanding that leads to synergistic policy and action. A critical capability to support this evolution of IPB is the development and integration of Agent Based Models. Agent based Models, a proven tool of complex adaptive systems, can provide staffs and decision makers an option exploration tool to help them visualize possible effects of their policies and actions.

Using IPB as the nucleus and integrating concepts from complex adaptive systems theory generates Complex IPB. Complex IPB is the next generation of IPB and has the potential to dramatically improve foreign population analysis as well as improve U.S. ability to influence foreign populations.

> **IPB**
>
> Define the Area of Operations
>
> Describe environmental effects
>
> Evaluate the threat
>
> Evaluate threat courses of action

> **Complex IPB**
>
> Define the Area of Operations
>
> Describe fitness landscape effects
>
> Evaluate the major groups
>
> Evaluate major groups' courses of action
>
> Asses the groups interaction
>
> Evaluate population behavior

The strength of IPB is its underlying logic. A reasonable prediction of threat behavior can be made by analyzing the situation combined with an assessment of the threat's capability. This logic is evident by reviewing the four steps of IPB. Step one is to define the operational environment. This is a description of the area of operations' significant characteristics that can influence friendly or threat courses of action. Step two is to describe the environmental effects on operations, for example a densely forested swamp would be severely restricted or no-go terrain. Together, these two steps are the constants, which the threat has little ability to change. Step three is evaluate the threat.[1] This is the threat's capability, through the context of the terrain and weather effect. What is the range of the threat's weapons and what is the threat's vehicles ability to negotiate the terrain accounting for the weather? What knowledge does the threat have in constructing IEDs? How easily is the threat able to move through the population without interdiction by local authorities? The conventional threat must choose different courses of action in a desert than in a jungle, while the insurgent threat must alter how it plants IEDs based on how freely it can move and its capacity to construct them. This is the simple elegance of IPB. The given situation and the threat's capability limits what they can and cannot do. This situation leads to the fourth step, evaluate threat courses of action, a reasonable prediction of what actions the threat can take reduced by the environmental and capability constraints.[2] These courses of action or hypotheses are then confirmed or denied through the implementation of a collection plan. The predictions of threat behavior allows friendly forces to maximize the limited capability of their limited collection assets to determine what course of action the threat adopted and how they are adapting. This logic can be applied not only to threat forces but also to groups in foreign populations. To understand how to do this it is useful to first examine the decision making of an individual.

The choices of an individual sitting within a population socio-cultural-political-ecosystem (fitness landscape for short) are constrained by the same general logic which IPB uses to analyze a threat force. When a person wakes up they will make decisions to generally maximize their situation. This individual confronts a fitness landscape which has an impact on what action the individual may take. This is similar to the terrain analysis and effects in IPB but with the added layers- politics, economics, social, information, infrastructure, environment and possibly more. The individual also has a capability (or fitness function) such as a profession, education, ethnic group, savings or family connections. A person survives or thrives based on their fitness function and its ability to extract resources from the fitness landscape. This simple dynamic is prevalent across time and space. In the 1980s, while the country faced a horrific insurgency from the Shining Path, a group from the Institute of Liberty and Democracy wanted to see how long it would take a person to set up a two-person sewing machine shop in a shanty town of Lima, Peru. It took more than 1800 hours, which when accounting for access to the government offices was more than 300 days and cost 32 times the monthly minimum wage.[3] When similar studies where done in Peru on everything from marriage licenses to property transfers the results were the same staggering obstacles.[4] The implications were clear, Peruvians in Lima's shanty towns were not joining the legal economy because the bureaucracy was such a daunting obstacle, severe no-go terrain, that it was impossible for them to do so. The government began to reform this situation and these reforms were seen as a crucial in defeating the Shining Path insurgency. In a lecture at the National Defense University, Dr. David Kilcullen described the choice for many Afghans working to find resolution to a dispute. If they went to the local Afghan Government official they would be beaten up and no action would be taken. If they went to the Taliban they could expect at least some sort of predictable, albeit harsh justice.[5] Many individuals therefore choose to ask the Taliban for justice, since at least there was a chance of resolution of their issue. The dynamic is the same as a threat commander making decisions in IPB, an individual has a capability to face the situation and from this develops courses of action.

The challenge then becomes analyzing hundreds to millions of people and their decisions instead of one threat unit. At first glance, this challenge seems overwhelming. Fortunately, complex adaptive systems have a property called emergence. Just as a threat unit is made up of a number of individuals but can be viewed as a single entity due to the military structure, emergence has a similar effect without the requirement of a centralized command structure.[6] Large groups of people will make the same decision without a centralized decision making process. This phenomenon is evident in the recent conflicts, where different tribes, ethnic groups and individuals decided to support either the insurgency or the government. Although each group or individual may have had different motives for their decision when these micro- decisions aggregated together the result was either the strengthening or weakening of the insurgency.

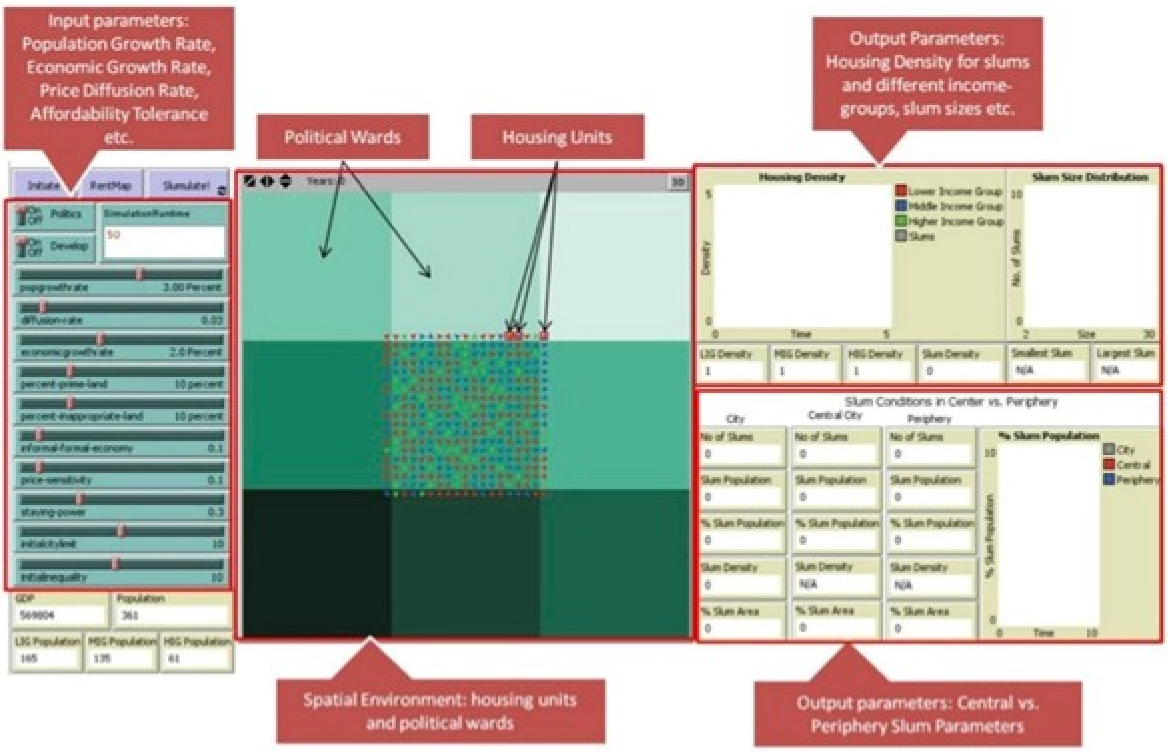
Thanks to the property of emergence analysts, can look at groups of people and view them as a cohesive whole. Analysts do not need to understand each person, instead they can identify the key groups within a population and use the same IPB logic to try and predict these groups' courses of action by analyzing their situation and capability. Unlike IPB where the terrain is a constant, however, groups can actively shape the fitness landscape they are negotiating.

Arguably, the reason a fitness landscape of cultural, economic, social and other dynamics even exists is because it is the result of the interaction of lots of individuals and groups, who are negotiating it each day. The idea that each group contributes to the shape of the fitness landscape means different groups may be able to radically alter it. This is a significant difference from IPB as the threat, cannot turn a desert into a jungle, turn a machine gun into a tank, or make a secure radio suddenly compatible with a newly arrived foreign partner. Coalition actions in Iraq clearly demonstrate how a group can significantly change the fitness landscape of a population. Prior to the Iraqi invasion of 2003, being a Ba'athist in the Iraqi fitness landscape provided an avenue of approach to jobs and security. After the invasion the coalition made contentious decisions to bar Ba'athist members[7] which immediately and dramatically altered this terrain. Instead of having an avenue of approach, Ba'athist's now faced no-go terrain when trying to get government jobs or security. Unfortunately, these same individuals, were the people in the country who had many critical capabilities from technical knowledge of the infrastructure to organizational understanding of the government. This decision had cascading effects throughout the rest of the coalition's time in theater, with many arguing this decision drove key Iraqi leaders to the insurgency.[8] The Coalition dramatically reshaped the fitness landscape, but at the same time they had to negotiate the new landscape they created. Groups within a population have the ability to influence the fitness landscape which shapes the situation of the population every day and subsequently influences decisions. Evaluating group courses of action uses the same reasoning underlying IPB, however, the groups being analyzed have greater ability to shape the situation.

Evaluating group courses of action then leads to the next step of Complex IPB, assessing the groups' interaction. This step is effectively wargaming from the Military Decision Making Process (MDMP). Each group will be making decisions to maximize their situation and outcompete any perceived rivals. They will adjust their courses of action based on what their rivals are doing. Having multiple groups increases the complexity of what one is analyzing. For example, if there is an insurgency, with a government group, an insurgent group, and three more major groups (a total of five groups) in the population each with the three possible courses of action, there are 125 possible combinations. This challenge can be simplified as the possible behavior of concern will likely only have a few categories. Despite this large number of different combinations the effect of these combinations will still fall into four broad categories. The insurgency may be (1) expanding and gaining legitimacy (groups supporting the insurgents), (2) contracting and losing legitimacy (groups supporting the government), (3) is in a stalemate with neither the government nor insurgency gaining ground, or (4) an alternate group is rising up to take power from the government and insurgency. In addition, most of the combinations may fall into only one or two categories. This allows analysts to generalize the combinations and focus on those combinations leading to or away from US objectives.

The interaction of the groups and the courses of action they pursue leads to the population's behavior. This statement is significant because it fundamentally defies the Westphalian tradition, and the default view, of viewing foreign states as a single entity. Instead, foreign populations are more like ecosystems, where the various groups are in a delicate equilibrium and the government is only one part, albeit an important part, of the functioning of that ecosystem. Evaluating the population behavior is an assessment of the interaction of major groups within that population as they pursue courses of action. These interactions may result in an unstable state, a dictatorial regime, or an emerging democracy. Critically, this dynamic is scalable, whether the population is a village, a province, a nation, or a region of the world. Allowing analysts at all levels to use a common approach to understand the population of concern. The behavior of the population is a result of the interactions of the groups within it at all levels. This assessment of the population's behavior is also the culmination of Complex IPB. Applying the Complex IPB framework will provide decisions makers a better understanding of the internal dynamics which are driving the populations' behavior; this understanding should allow leaders to take more effective action and better synergize the instruments of power to achieve U.S. Objectives.

Applying the Complex IPB framework to population analysis will improve the situational understanding of any population in any environment, this understanding can be further enhanced through the development and integration of Agent Based Modeling tools into the analytic and decision making processes. The primary tool to model complex adaptive systems is Agent Based Models (ABM) As Agent Based Models are unfamiliar to many readers please see the embedded graphic or if you would prefer a video **please follow this link**. The model the graphic below portrays is very relevant to Dense Urban Areas as it is a model of slum formation. On the left of the picture are the input parameters, which allows users to manipulate variables and see the impact of adjusting these variables. The output parameters are different ways of measuring the models behavior to provide insight into what is happening.



Graphic One: "Slums provide shelter for nearly one third of the world's urban population, most of them in the developing world. Slumulation represents an agent-based model which explores questions such as i) how slums come into existence, expand or disappear ii) where and when they emerge in a city and iii) which processes may improve housing conditions for urban poor.[9]

ABMs have already proven effective in analyzing and informing policy on everything from foreign population behavior to the US electric grid to leadership in organizations.[10] ABMs are proven tools which takes the perspective of the agents. An agent is a discrete entity with its own behavior and own goals. In the context of the Complex IPB framework, agents would represent the major groups and their internal variations. These agents then interact with each other. The fitness landscape is the terrain in which they interact. These interactions then produce a possible emergent behavior of the population. This emergent behavior is the U.S. objective. Are the groups supporting the insurgency or the government? Does the fitness function of one group allow it to gain dominance over the system undermining the democratic institutions? ABMs allow for the adjustment of variables within a group's fitness function or a manipulation of the fitness landscape. In the application, the action of the analyst may be to adjust the size of the money variable for a group's fitness function or adjust a variable of the fitness landscape to represent a change in the government process which may result in restrictive terrain becoming an avenue of approach for a previously excluded group. As the adjustments are made the analysts, staffs and decision makers would be able to see how multiple changes at different points in the system may affect the interaction of the groups and the subsequent behavior of the population. From this course of action development they then may adjust how money is dispersed to influence the power of competing fitness functions, help pass new laws to provide access to previously excluded groups, and/or focus on attacking a different part of the insurgent network. A Complex IPB agent based model application will provide analysts, staffs and decision makers an option exploration tools that gives them insights into how the different groups may react to U.S. policy and actions.

ABM and its integration into decision making processes does face hurdles for implementation. The first hurdle is "can a generic model be created that any analyst can set specifically enough to analyze the local problem set or will an Army element need to be created to build models specific to a Brigade Combat Team (BCT) and their particular problem?" In other words, can a universal application be created that is both effective and user-friendly enough that analysts can apply it to their local situation whether in humanitarian missions in Africa or active insurgencies in South Asia. Or, will a group of experts need to do the coding and formulas necessary for a realistic model to be created that analysts can further adjust to the specific situation of the local area. If a group of experts is needed to support ABM model, it cannot be experts working in isolation instead it must be a symbiotic relationship with the BCT forward, where the entities are working as a team to further refine and update the model so staffs can employ it to achieve their objectives. The second hurdle is these models will only ever give a probabilistic outcome and will have to be run multiple times to see what behavior has the highest probability. This is a reflection of reality and it often creates some computing challenges. The nature of the model, its complexity and the austerity of the environment will determine what is feasible. Even if Complex IPB must be completed in analog, it will still provide an improved understanding of the situation. ABMs enhance the approach they do not replace it. The third hurdle is the need to federate production when conducting a campaign. The analysis of a village will have an impact on the analysis of a region, which will have an impact on the analysis of the country. From step one, any plan to integrate ABM into decision making must look at how to link these ABMs together. National action has a local impact and local events can have a national impact. ABM can and must serve as a catalyst to help synchronize whole of government efforts when influencing the behavior of a foreign population. ABM is a powerful tool which must accompany Complex IPB and be integrated into decision making processes whether MDMP for a BCT or discussions by the National Security Council.

The foundation of IPB is a strong and powerful logic. Understanding a threat's situation and its capability within the given situation allows for a reasonable prediction of that threat's behavior. This same logic can be applied to most people who are fighting each day to maximize their situation. The property of emergence allows analysts to focus on the main groups of the population instead of trying to understand the millions of people who may be in the area of operations. Complex IPB then follows the same initial steps as IPB, but with a focus on groups and an incorporation of the more dynamic fitness landscape (the cultural, social, economic, information, government terrain): (1) Define the Area of Operations, (2) Describe the Fitness Landscape effects, (3) Evaluate the major groups (4) Evaluate major group courses of actions. Complex IPB must then add an additional two steps. (5) Assess the groups interaction and (6) Evaluate population behavior. These two steps follow logically from the base of IPB. Complex IPB can then be enhanced through development and application of a Complex IPB Agent Based Model application. Although its development and implementation faces some hurdles, ABMs are a proven tool, which can provide analysts, staffs and decision makers the ability to explore numerous options and combinations of options and visually see the possible effects. Complex IPB is the natural evolution of IPB and has the potential to improve analysis and influence of foreign populations.

End Notes

[1] Headquarters, Department of the Army, Army Techniques Publication 2-01.3, *Intelligence Preparation of the Battlefield*, (November 2014), 1-1-1-4

[2] Ibid, 1-1-1-4

[3] Hernando De Soto, *The Other Path: The Economic Answer to Terrorism*, (New York: Basic Books, 1989), xxi-xxxiv

[4] Ibid

[5]David Kilcullen, "Counterinsurgency," (lecture, Afghanistan-Pakistan Foundation Course, National Defense University, October 6, 2009)
[6]*Understanding Complexity*, taught by Scott E. Page, Lecture 6

[7] *FRONTLINE: The Lost Year in Iraq,* (October 17, 2006)

http://www.pbs.org/wgbh/pages/frontline/yeariniraq/ (accessed May 26th, 2014)

[8] Ibid

[9] Patel, A., Crooks, A.T. and Koizumi, N,. "Slumulation: an Agent-based Modeling Approach to Slum Formation", (2012), http://www.css.gmu.edu/Slums/PatelCrooksKoizumi_Slumulation.pdf, (accessed 27 February 2016).

[10] Joshua Epstein, *Generative Social Science: Studies in Agent-Based Computational Modeling*, (Princeton Unversity Press, 2007)

Identity and Biometrics Enabled Intelligence (BEI) Sharing for Transnational Threat Actors

By ***Victor R. Morris***

Originally published in Small Wars Journal on 22 March 2016

Available online at: http://smallwarsjournal.com/jrnl/art/identity-and-biometrics-enabled-intelligence-bei-sharing-for-transnational-threat-actors

Global Terrorism Trend Summary

According to the 2015 Global Terrorism Index, excluding Turkey, Europe accounted for 21 percent of all foreign fighters in 2014. Half of the foreign fighters are from neighboring Middle-East and North Africa (MENA) countries and an additional four percent are from Turkey [1]. Unfortunately, France has the distinction of being Europe's leading exporter of jihadis, nearly 1,600 out of a continental total of over 5,000, according to government figures. Despite the government's efforts after the Charlie Hebdo attacks in January to block and prevent citizens from leaving for the war zone, the pace of departures has remained essentially unchanged [2]. Furthermore, Belgium has sent more young men and women per capita than anywhere in the West and another global terrorism trend asserts that private citizens are increasingly the targets of terrorist attacks. Deaths of private citizens increased by 172 percent between 2013 and 2014 compared to the total number of deaths which rose 80 percent [3]. In light of recent events in Europe and the contemporary operating environment, terrorist activity and associated political violence will continue to have direct and indirect effects on European security.

This article outlines initiatives to enhance international identity operations and intelligence product sharing, which are the result of compliant biometric data capture, transmission and intelligence fusion among intergovernmental law enforcement and military organizations to identify threats. The proposed initiatives describe what is required within international biometric cycles and frameworks once an interoperable and compliant environment has been established. These initiatives support threat network pattern and predictive analysis, personality based engagement and identity dominance attempts in all of the operational environment's domains and systems; specifically the human domain in population centric conflicts. The overall goal of these initiatives is in support of operations involving the identification of threat actors from the civilian population.

Intergovernmental Organizations: INTERPOL, Europol, NATO, OSCE and Frontex

First, it is necessary to outline the organizations mentioned above. This article focuses on the following organizations and the criticality of sharing identity intelligence: International Criminal Police Organization (INTERPOL), European Police Office (Europol), North Atlantic Treaty Organization (NATO), Organization for Security Co-operation in Europe (OSCE) and External Borders (Frontex). The United States Army European Command (EUCOM) and United States Army Intelligence and Security Command (INSCOM) are not discussed in detail, but are integral military and national organizations responsible for unified combatant command, scientific and technical intelligence (S&T) and general military intelligence. The National Ground Intelligence Center (NGIC), Defense Forensics and Biometrics Agency (DFBA) and FBI's Next Generation Identification (NGI) system are also currently at the forefront of identity intelligence and interoperability programs and operations at the inter-agency and international levels. The NGI organization model of bringing relevant parties and databases together serves as an effective real-world example of international cooperation involving Identity Intelligence [4]. Additionally, the Secure Identity and Biometrics Association (SIBA), International Organization for Migration (IOM) and United Nations are not discussed in detail, but play a vital role in identity management policy and practice. The UN Security Council facilitates peacekeeping operations which currently involve biometrics support to humanitarian operations involving asylum seekers [5].

First, INTERPOL was established as the International Criminal Police Commission (ICPC) in 1923 and is currently an intergovernmental organization facilitating international police cooperation headquartered in Lyon, France. As of 2015, it is composed of 190 countries and is the second largest political organization after the United Nations in terms of international representation. Some of INTERPOL's work involves counter threat financing, money laundering and corruption. This international organization also functions as a network of criminal law enforcement agencies from different countries, facilitating administrative liaison among the law enforcement agencies of the member countries and providing communications and database assistance. A new program of activity in development within INTERPOL's Chemical and Explosive Terrorism Prevention Unit is discussed later as an example of multi-agency information sharing and international activity.

Next, Europol is the law enforcement agency of the European Union. The agency's origin stems from earlier intergovernmental networks created after several terrorist acts, notably the hostage taking and subsequent massacre during the 1972 Olympic Games in Munich. Currently, the organization is headquartered in The Hague and has a staff of 912 regular police officers and 185 liaison officers, as well as personnel seconded from national law enforcement organizations. EUROPOL's capabilities and requirements are related to INTERPOL with regard to criminal intelligence, counterterrorism, counter organized crime operations, cyber-crime, security cooperation, and immigration services. The investigative processes are enabled by information exchange, intelligence analysis, expertise and training. Lastly, EUROPOL is currently adapting and evolving to counter the global terrorism threat. Building on existing activities, Europol launched the European Counter Terrorist Centre (ECTC) on 1 January 2016 as a platform by which Member States can increase information sharing and operational coordination, focusing on foreign terrorist fighters, the trafficking of illegal firearms and terrorist financing. Member States will provide counter-terrorism experts to the ECTC to form an enhanced cross-border investigation support unit, capable of providing quick and comprehensive support to the investigation of major terrorist incidents in the European Union [6]. Additionally, Europol's Scanning, Analysis and Notification (SCAN) Team provides EU national authorities with an additional strategic organized crime (OC) product which involves early warning notices of new organized crime threats.

Thirdly, the North Atlantic Treaty Organizations (NATO) also called the North Atlantic Alliance is an intergovernmental military alliance based on the North Atlantic Treaty signed on 4 April 1949. NATO's main organizational headquarters is in Brussels, Belgium where NATO's secretary general also resides. NATO's operational headquarters is located in Mons, Belgium where NATO's Supreme Allied Commander of the nations also resides. Belgium is one of the 28 member states across North America and Europe. An additional 22 countries participate in NATO's Partnership for Peace program, with 15 other countries involved in institutionalized dialogue programs. Within NATO there are a myriad of concepts, organizations and departments which deal solely with counterterrorism. NATO's military concept for defense against terrorism (MC 472) serves as the primary reference for this section and identifies four different roles for military operations for Defense Against Terrorism (DAT): anti-terrorism defensive measures, consequence management, counter terrorism offensive measures, and military cooperation [7]. The military cooperation Concept states that NATO must harmonize its procedures and efforts with civil authorities within nations in order to maximize its effectiveness against terrorism. The four roles also support the Programme of Work for Defense Against Terrorism which involve: incident management, force protection/survivability, and network engagement related biometrics. Additionally, all of the aforementioned capabilities and requirements associated with INTERPOL and EUROPOL directly integrate and overlap with emerging network identification and engagement concepts involving: counter- terrorism/defense against terrorism, counter transnational criminal organizations, counter cyber threats, and counter piracy.

These concepts addresses threat networks from a regional and transnational perspective and simultaneously support strategic activities that enable network engagement within a Joint Operational Area (JOA). Lastly, it is important to note, that informing processes like NATO Human Network Analysis and Support to Targeting (HNAT) and Attack the Networks (AtN) now called Network Engagement (NE) are integrated into existing planning processes (OPP, JOPP, MDMP, and TLPs) and support systems analysis and engagement of friendly, neutral, unknown and threat actors in complicated multi-dimensional operational environments.

Next, the Organization for Security and Co-operation in Europe (OSCE) is the world's largest security- oriented intergovernmental organization. The origins can be traced to the 1975 conference on Security and Co-operation in Europe (CSCE) held in Helsinki, Finland. The OSCE is concerned with early warning, conflict prevention, **crisis management**, post-conflict rehabilitation and border monitoring. The organization includes 57 participating states in Europe, northern and central Asia and North America. For the purposes of this article, the focal point for the OSCE involves the Politico-Military or first dimension. The OSCE takes a comprehensive approach to the politico-military dimension of security and seeks to enhance military security by promoting greater openness, transparency and co-operation. Key security aspects involve arms control, border management, combating terrorism, conflict prevention, military reform, policing and implementation [8]. The OSCE also looks at human rights issues in relation to counter- terrorism which is an important point when it comes to ethical concerns and privacy by design initiatives regarding biometric capture, transmission, sharing and storage.

Lastly, Frontex from the French Frontières Extérieures or external borders is an agency of the European Union which was established in 2004 to manage the cooperation between national border guards securing its external borders. Frontex operations aim to detect and stop illegal immigration, human trafficking and terrorist infiltration which has significant implications for NATO’s interdependent purpose for biometrics operations involving threat identification. The agency is currently seated in Warsaw, Poland. The official missions and tasks include: promoting, coordinating and developing European border management in line with the EU fundamental rights charter, which the concept of Integrated Border Management. Activity areas are: joint operations, training, risk analysis, research, rapid response capability, information systems and information sharing, and cooperation with non-European Union countries [9]. The most important functions with regard to this assessment include intelligence, associated pattern and predictive analysis, and sharing. Risk analysis is the starting point for all Frontex activities, from joint operations through training to research studies. The agency collates data from member states, EU bodies, and all-source intelligence within and beyond Europe’s borders. Furthermore, to analyze the data, Frontex has its own risk analysis model called the common integrated risk analysis model or CIRAM. CIRAM enables the assessment of the relative risks posed by different threats and was developed in close consultation with member states, and is applicable both at EU and national level. Lastly, Frontex has established a community called the Frontex Risk Analysis Network (FRAN) that links the intelligence networks of individual European countries with pan-European organization. This provides the framework for sharing knowledge and producing analytical and strategic reports on the current state of play at the external borders as well as for the production of the Semi-Annual and Annual Risk Analysis documents and other, tailored, risk-analysis products [10]. Frontex is pioneering controlled personal data processing, interoperability, intelligence and information sharing involving patterns and trends in irregular migration and cross-border criminal activities at the external borders. In order to cope with the current security environment, this organization must continue to evolve and fuse identity and all-source intelligence at existing situation centers, while acting as the central point of contact for international organizations like INTERPOL and Europol.

All-source Intelligence Critical Components: Identity and Biometric Enabled Intelligence (BEI)

Based on the above discussion, it is apparent there is a significant amount of commonality, interoperability, and privacy consideration with regard to de-compartmentalizing similar counter-terrorism campaigns. What is not apparent involves the importance of the intelligence process and sharing of Identity Intelligence as a result of privacy enhancing technological frameworks throughout the aforementioned organizations. In order understand the associated capability gaps, a concise understanding of biometrics, intelligence products and identity intelligence is required. First, biometrics is the process of recognizing an individual based on measurable anatomical, physiological, and behavioral characteristics. A biometric is a measureable physical characteristic or personal behavioral trait used to recognize the identity or verify the claimed identity of an individual [11]. Furthermore, Identity Intelligence is one of the eight categories of intelligence products and a vital component of all-source intelligence analysis and fusion. The categories overlap and the same intelligence and information can be used in each of the categories. From a joint doctrinal perspective, Identity Intelligence or “I2” can be defined as: results from the fusion of identity attributes (biologic, biographic, behavioral, and reputational information) and other information and intelligence associated with those attributes collected across all intelligence disciplines. I2 utilizes enabling intelligence activities, like biometrics-enabled intelligence (BEI), forensics enabled intelligence (FEI), cyber enabled intelligence (CEI) and document and media exploitation (DOMEX), to discover the existence of unknown potential threat actors by connecting individuals to other persons, places, events, or materials, analyzing patterns of life, and characterizing their level of potential threats to US interests [12] . BEI is a core complimentary intelligence capability and is the information associated with and/or derived from biometric signatures and the associated contextual information. A key result of BEI involves the positive identification of a specific person and/or matching of an unknown identity to a place, activity, device, component or weapon. A broader definition of identity intelligence highlights it as a component of NATO's overall security intelligence [13]. This definition accurately describes 21st century warfare executed through espionage, sabotage, subversion and terrorism, as well as against loss or unauthorized disclosure. Though doctrinally sound, the definitions alone do not capture the enrollment, identification or verification functions that begins with tactical level "raw" biometric capture, transmission, identification, all-source intelligence fusion, and identity intelligence product development. Intelligence sharing drives key leader's decision-making which facilitates international deliberate and dynamic targeting and prosecution efforts.

Identity Intelligence Interoperability Assessment, Implications and Way Ahead

The NATO Standardization Agreement 4715: Biometrics Data, Interchange, Watchlisting and Reporting was initiated in 2009 and published in 2013, and currently accounts for policy and technical gaps involving European Organizations with regard to biometric interoperability and encryption. Biometric Encryption (BE) is a vital requirement of interoperability programs and involves the employment and sharing of "untraceable biometrics" technologies that seek to translate the biometric data provided by the user. In this case, a unique biometric template is not created or contained. NATO's Communication and Information (NCI) Agency and associated coordination groups are pioneering automated biometric identification systems and authoritative sources with "game-changing" privacy by design concepts involving an encrypted biometric "ping 'n ring" positively pave the way for regulated biometrics data transmission and sharing. In summary, the "ping 'n ring" concept involves anonymous biometric data queries which when matched in certain databases yield a reference number and point of contact for follow- on bilateral action (user centric based on privacy by design principles). With that being said, the greater gap involves the deliberate fusion of biometric enabled intelligence, all-source intelligence and sharing resulting in an "I know all about you and your associations" situation. Another beneficial aspect of this sharing is the mutual trust and relationships that are developed, which leads to more proactive dissemination of biometric enabled intelligence products and updates on a regular and routine basis (proactive not reactive). Homegrown terrorism involving "known and unknown wolves" and/or "Lone Mujahid" and "Lone Jihad Legion"[14] are the main perpetrators of terrorist activity in the West. Seventy per cent of all deaths from terrorism in the West since 2006 were by lone wolf terrorists with the rest being unknown or group attacks by more than three attackers [15]. Although, Islamic fundamentalism was not the main cause of terrorism in the West during the last nine years, the current situation involving DAESH [16] will likely shift the statistics for the foreseeable future and become the main cause. Another indirect effect of DAESH's paramilitary extremist state operations and terror campaigns involves emboldening human-trafficking and smuggling networks oriented towards refugees fleeing Syria and Iraq which are a direct effect of DAESH and an authoritarian regimes. The migrant and refugee situation also pose security related concerns for Europe for a variety of reasons. The point of this article is not to discuss the migrant crisis, but to highlight the importance of tactical multi-modal biometric capture, identification, verification and sharing to accurately identify potential threats and violent extremist network affiliations through Identity Intelligence. The pre-emptive identification of individual cell members may demonstrate non-linear change involving local, connected, associated cells and materiel. This involves the disproportional inputs of interdicting one cell member which results in exponential (non-linear) outputs involving the exploitation of personnel and materiel for intelligence value, tactical and operational gain.

Intergovernmental Identity Intelligence Lessons Learned, Best Practices and Solutions

In order to capture biometric data, get results from a database(s) (identify-threat, verify-friendly or store), and accelerate rule of law proceedings, greater effort needs to be placed on BEI fusion and sharing between military and law enforcement organizations. Due to the global nature of the threat, law enforcement agencies cannot go at this alone and require support from military organizations to track and identify threats and vice versa. The aforementioned assessment is evident from Operations Iraqi and Enduring Freedom's evidence based operations, warrant based targeting and rule of law lines of operations and effective governance lines of effort. Both operations utilized biometric and forensic enabled intelligence and a robust library of biometric signatures to non-lethally remove insurgents from the battlefield through prosecution in host nation court. These efforts involved inter-agency cooperation and non-lethal engagement of unknown, friendly, neutral and threat networks in a dynamic operational environment. The same concepts and implications should be applied to on-going operations like Ukraine's Anti-terrorist Operation (ATO) and French led Operation Barkhane in the five-state Sahel region (G5 Sahel) for the same mid to long term effects involving current targeting, exploitation for prosecution and interdiction of foreign fighters. Currently, Program TEAL, whose name is the result of combining blue law enforcement and green military, is a new program of activity in development and is associated with INTERPOL's Chemical and Explosive Terrorism Prevention Unit [17]. In summary, the activities involve multi-agency and cross-jurisdictional CIED teams, coordination of information sharing, and sub-projects targeting people and devices. Project Watchmaker is one of the sub-projects and involves identifying, locating and prosecuting terrorists involved in the manufacture and use of IEDs and other explosives.INTERPOL is also intensifying efforts to support and encourage national, regional and international efforts to monitor and prevent Foreign Terrorist Fighters (FTFs).

In order to be successful a new project needs to be developed which captures key components of intelligence fusion and sharing from all organizations and integrates them into one concept or integrated concepts. The concept which is included in all operational phases needs to involve the following components: Interagency European Biometrics Center of Excellence (CoE), EU Border Assistance Mission support, border management and technical intelligence (TECHINT) systems integration into ping and ring architecture, dedicated BEI analytical cells in existing civil-military fusion centers, access, training and production of Identity Intelligence products (immediate, current and strategic), and recurrent vetting. BEI products and resources include, but are not limited to: Biometric Match Reports (BMR), Biometric Enabled Watch Lists (BEWL), Biometric Intelligence Analytic Report (BIAR), Biometric Named Areas of Interest (BX NAI), Single Source Biometric Reports (SSBR), tracking intelligence and prosecution support packages. Core tasks associated with this concept involve: identifying, locating, and prosecuting terrorists affiliated with collective violent extremist organizational (VEO) activities across a trans-regional spectrum. The decisive point here involves accurately identifying returning foreign fighters at points of entry (coming in) and during criminal or miscellaneous encounters with law enforcement (already in) through biometric identification and other sources of intelligence.

Conclusion

In conclusion, real world solutions involving intergovernmental production and sharing of biometric enabled intelligence as a means to accurately identify dynamic and adaptive known or suspected terrorists living amongst the population are imperative to collective European security. BEI and I2 are the capabilities and means required to strip anonymity from the enemy and must be developed and better shared throughout our international military and law enforcement organizations. A more integrated intergovernmental framework is required in order to facilitate a holistic and visibly controlled approach to Identity and biometric enabled intelligence. “The deadliest attackers have a background in jihadi warfare.” [18]

References and End Notes

1. The Global Terrorism Index 2015 is the third edition and provides a comprehensive summary of the key global trends and patterns in terrorism over

the last 15 years with an emphasis on 2014. It is produced by the Institute for Economics and Peace. The GTI is based on data from the Global Terrorism database which has codified over 140,000 terrorist incidents. In 2014 the total number of deaths from terrorism increased by 80 per cent when compared to the prior year. This is the largest yearly increase in the last 15 years.

2. thejournal.ie: http://www.thejournal.ie/more-than-1200-europeans-returned-isis-islamic-state- 2452426-Nov2015/
3. The Global Terrorism Index 2015.
4. Defense One. Jihadi John and the Future of the Biometrics Terror Hunt. FBIs growing collaboration with the Department of Defense. The FBI's system is called the Next Generation Identification, or NGI. It includes photos, aliases, and physical characteristics and, of course, fingerprints. Today, it's completely interoperable with the military's Automated Biometric Identification System, or ABIS, and the Department of Homeland Security's Automated Biometric Identification System, or IDENT. The center also works with the State Department and allied law enforcement agencies around the world. http://www.defenseone.com/technology/2015/02/jihadi-john-and-future-biometrics-terror- hunt/106263/.
5. Tracking Refugees With Biometrics: More Questions Than Answers: http://warontherocks.com/2016/03/tracking-refugees-with-biometrics-more-questions-than- answers/
6. Europol. https://www.europol.europa.eu/content/ministers-commit-reinforcing-europol%E2%80%99s-counter-terrorism-capabilities
7. MC 472: http://www.nato.int/cps/en/natohq/topics_69482.htm
8. OSCE What we do: http://www.osce.org/what
9. Frontex, Mission and tasks, intelligence and operations: http://frontex.europa.eu/about- frontex/origin/
10. Frontex, Mission and tasks, intelligence and operations: http://frontex.europa.eu/about- frontex/origin/
11. ADRP 2-0, 4-65. ADRP 2-0 Unclassified Public Release; unlimited distribution
12. Joint Intelligence (JP 2-0), I-20. Unclassified
13. Allied Joint Publication 2 (AJP 2), 3-13. NATO Unclassified
14. AQAP's English Language Inspire Magazine 13 (2014) describes economic target categories, open front and Lone Jihad Legions. Open Source Jihad (OSJ) is also outlined as a resource for "Muslims" to train at home instead of risking dangerous travel abroad.
15. The Global Terrorism Index 2015. Terrorism in Western Countries.
16. Term. DA'ISH is the Arabic acronym for "The Islamic State in Iraq and the Sham" Al-Sham is the historic region of Syria or Greater Syria. "DAESH" is a play on words (Daes) and has a derogatory connotation involving trampling, bigotry and discord. The terrorist para-state takes offense to this term which is the reason for greater use in the Arab world and West.
17. INTERPOL Chemical and Explosive Terrorism Prevention Unit Programme TEAL UN CCW Meeting Geneva 10 April 2015. Project Watchmaker: UNSCR 2178-

Foreign Terrorist Fighters (FTF) INTERPOL to intensify efforts. Project TIDE- Technical Information Data Exchange links to Project Watchmaker. http://www.unog.ch/80256EDD006B8954/(httpAssets)/ CD096873D6067394C1257E23007603F2/$file/12+INTER

18. The journal .Petter Nesser, a senior researcher at the Norwegian Defence Research Establishment http://www.thejournal.ie/more-than-1200-europeans-returned-isis-islamic-state-2452426- Nov2015/.

It's in There: Rethinking (?) Intelligence Preparation of the Battlefield in Megacities/Dense Urban Areas

*By **Richard L. Wolfel, Amy Krakowka Richmond, Mark Read and Colin Tansey***

Originally published in Small Wars Journal on 2 March 2016

Available online at: http://smallwarsjournal.com/jrnl/art/it%E2%80%99s-in-there-rethinking- intelligence-preparation-of-the-battlefield-in-megacities-dense-urb

The complexity of the modern city has been a key conclusion in most Army research surrounding military operations in megacities/dense urban areas. This complexity is based on three fundamental concepts of the modern city. First, modern cities are multidimensional (subterranean, surface and vertical). Second, cities are interconnected through globalization, social media and modern methods of communication/information dissemination. Third, cities are uncontrollable due to increased connectivity, rise of black market/informal economy, ineffective government control of slums and the rise of vulnerability in significant portions of the city. As the US Army considers the challenges of operating in dense urban areas, leadership requires a basic understanding of the operating environment. In such a complex environment, understanding the multidimensional, interconnected and uncontrollable elements in complex environments using traditional approaches of situational awareness, which emphasize discrete problem sets and well-defined regions, is problematic at best.

Intelligence sections provide a basic understanding of the operating environment. Military intelligence (MI) Concepts, such as Intelligence Preparation of the Battlefield (IPB), Areas, Structures, Capabilities, Organizations, People and Events (ASCOPE), Sewage, Water, Electricity, Academics, Trash, Medical, Safety, and Other Considerations (SWEAT-MSO), and Political, Military, Economic, Social, Information, Infrastructure, Physical Environment, and Time (PMESII-PT), have been used extensively within the MI community for decades in order to provide a snapshot of the operating environment. Before we go off and try to develop, or find the next new "it" concept, or gadget, we need to step back and critically evaluate what currently exists. How do traditional intelligence methods help inform situational awareness in dense urban environments? Where do these methods fall short? These gaps then become areas where new ideas and Science and Technology (S&T) developments can fill the void to fill in the picture. We need to avoid the urge to throw out what we have. As researchers have contemplated the next new idea, the aforementioned intelligence tools have stood the test of time and with a little modification, offer a solid approach to understanding and explaining the complexities of Megacities/Dense Urban Areas. Military intelligence doctrine provides a solid foundation on which to launch an expedition into identifying and explaining the complexity of the megacity that will increase situational awareness.

What is IPB and How is it Evolving in the Dense Urban Environment?

Intelligence Preparation of the Battlefield (IPB) is the systematic process of analyzing the four mission variables (enemy, terrain, weather and civil considerations) in an area of interest to determine their effect on operations (HQDA, 2014, ix). This is the foundation of all intelligence gathering exercises, to identify and explain these key variables that work to help the commander gain a clear situational awareness of the area of operations (AO).

One of the largest issues with this basic definition of IPB is that it often does not take into account how the variables explaining dense urban areas are increasingly interconnected. Change in urban areas is not a unidirectional process in which the individual agent influences change in the area of interest. As a result of interacting with the area of interest (AI), the agent is also influenced as a result of social and environmental change.

Anthony Giddens refers to this process as the *Duality of Structure* (Giddens, 1979: 5). This duality is important in understanding dense urban areas. Often we look very directly at the influence of the mission variables, take them as given variables, well defined and unchanging, and do not address the recursive nature of society in which the enemy, the terrain and civil considerations often change rapidly based on the actions of agents in the area. For example, the enemy can shift dimensions and move from the surface to subterranean, introduce barriers to the terrain and develop a disinformation campaign that will fundamentally shift the societal characteristics of the area of operations.

Along with the recursive nature of mission variables, the interaction of variables has become almost more important than the variables themselves. For example, we are no longer able to extract terrain from the societal milieu and analyze it separate of civil considerations. Kilcullen (2013: 54), emphasizes the interaction of mission variables in his analysis of the attacks on Mumbai in 2008. The terrorists used the interaction of terrain (littoral situation of Mumbai) and civil considerations (the unregulated nature of the fishing fleet) to explain how the terrorists were able to gain access to the region virtually undetected.

Neither the terrain, nor the civil considerations alone are adequate to explain the situation in Mumbai. The complex connection between the two gives one a clearer situational awareness of the battlefield.

What is the Operational Environment?

Joint Publication (JP) 3-0 (2011) identifies the area of operations as an area defined by the commander that is large enough to accomplish the mission and protect the force. There is a tendency to treat it as a discrete region that can be circled on a map and discussed in a vacuum. It also identifies the operational environment as a composite of the conditions, circumstances, and influences that affect the employment of capabilities and bear on the decisions of the commander. The problem in the modern dense urban environment is that the OE, including the area of operations, often extends much further than in the past. The impact of connections and linkages, facilitated by globalization, advances in communication technology, and media access challenge the traditional idea of a unique OE that can be isolated for analysis by an intelligence team. These connections must be addressed as part of the analysis. At an even more fundamental level, is the AO the appropriate scale of analysis in a dense urban area/megacity? Should intelligence analyses be conducted at the Area of Influence or Area of Interest level? How do we define these spheres? How do we isolate regions that cannot be isolated from outside influences? These are the challenging questions that face intelligence analysts as they conduct IPB and commanders trying to gain an awareness of an urban region.

One of the major challenges in defining a discrete Area of Operations, is the connectivity and complexity that defines the modern age of globalization. Wielhouwer (2005) addresses this complexity through the u *rban triad*. The triad includes: “complex manmade terrain superimposed on natural terrain, a large and densely distributed population, and physical and service infrastructures. These characteristics interact to make each urban area a complex and dynamic system of systems, with a unique physical, political, economic, social, and cultural identity.” (Weilhouwer, 2005: 2). Taken a step further, these systems are not static and, based on the recursive nature of societal change, always in flux as agents are influenced by the system and the system is influenced by the agents. The dynamic nature of the modern urban environment demands an expansion of traditional IPB thinking where terrain is fixed and generally unchanging. The *urban triad* helps portray a more complex terrain, both in terms of the amount of components that make up the terrain and also the continual nature of change on the terrain.

The IPB Manual, ATP 2-01.3 emphasizes the multidimensional nature of the operating environment, but offers little instruction on how to address the complex, multidimensional environment. Multidimensionality is defined by the IPB Manual (HQDA, 2014: 9-1) as “a blend of horizontal, vertical, interior, exterior, and subterranean forms superimposed on the natural relief, drainage, and vegetation.”

Blend is the key word here. Groups utilize various dimensions in an effort to increase mobility through the urban region. Historically, our thinking about battlespace has been two dimensional. While the IPB Manual does mention and define multidimensionality, it provides little in operational advice or examples. Technologically, this is a huge gap to fill. Technology developments, including, but not limited to, the ability to track people in three-dimensional space and systems to promote greater situational awareness, are needed to increase situational awareness in three dimensional space, from the subterranean through the vertical high rise tower. The need for greater situational awareness is magnified as individuals will not stay on one level for an extended period, but rather will change dimensions to avoid detection, gain a tactical advantage, increase security or facilitate movement.

The traditional concept of the AO and the AI are also challenged by the connectivity of the modern urban center. The city is connected globally by many different means, including: economics, culture and social media. While the IPB Manual does address cross border threats (HQDA, 2014: 7-9), the role of information is different than military or paramilitary forces coming across a boarder and influencing an AO. The Arab Spring and the Occupy movements have demonstrated that the ability to control information in the modern age is limited, at best and how virtual communities and shared ideology are created using social media and modern communication/information dissemination techniques. These movements also demonstrated that as governments attempted to control access to social media, that attempt to seize control acted as a unifying force to bring together various, disparate, social movements under a common goal. (Castells, 2015: 62).

The other major area of concern highlighted by the IPB manual is the discussion of approach and mobility corridors. Table 4-2 (HQDA, 2014: 4-6) identifies the minimum distance between terrain features required for avenues of approach. In urban settings, the two kilometer requirement for the battalion is not possible. This requires a rethinking of our mobility plans and how to control and maneuver through significantly narrower avenues of approach and to consider the possibility of nonstandard mobility corridors, those subsurface and overhead.
In addition, line of sight analysis will be substantially limited and visibility will be influenced by obstructions. For example, Begin Morning Nautical Twilight (HQDA, 2014: 4-18) will most likely not occur at 12 degrees below twilight as suggested by the IPB Field Manual. Buildings will obstruct view, shortening daylight hours in an urban environment as opposed to an open field. These small considerations could substantially impact operations in dense urban areas. Both mobility corridors and line of sight concerns show how the unique environment of dense urban areas challenge many standard conventions of intelligence

preparation and situational awareness.

How do the Analytical Tools of Intelligence Inform IPB in Urban Settings?

ASCOPE, PMESII-PT, and SWEAT-MSO are used extensively as the foundational analytical tools for intelligence operators to provide information to promote situational awareness. While the foundational concepts are very useful in urban environments, it is essential to view these as not discrete elements, but as interconnected elements that interact with each other, change the environment and are changed as a result of interactions with each other and the social environment. For example, how do medical conditions interact with political and capabilities? No longer are these elements in a vacuum. It is necessary to view the connectivity in a complex and changing matrix.

Dense Urban Areas and Insurgency Theory

Along with interconnectivity, another key question is what happens when civil capabilities decline, or were never developed in a region? Who steps in to fill the void? This is the foundation of the 2006 version of the Army's counterinsurgency doctrine (HQDA, 2006: 1-3). As mentioned in the Counterinsurgency Field Manual (HQDA, 2006: 1-2), irregular threats strongly influence insurgencies. Also, due to the rise of asymmetrical warfare and increasing number of insurgencies, the nature of combat effectiveness has changed in the modern era. External support is critical in modern AOs. Often this is requested/provided through social media interactions, video uploads, onsite media, elements that are difficult to control. The IPB Manual (HQDA, 2014: 5-15) emphasizes that the "effectiveness of unconventional warfare depended heavily on support and relationships." The question is how do we measure support and how do we determine the strength of relationships? Social media analysis provides a starting point to see how people form social media networks, social media clout scores provide examples of an individual's influence on a specific movement/idea.

What causes the decline in civil capabilities? That becomes another key question in understanding the uncontrollable nature of dense urban settings. Vulnerability, declining environmental security and declining (or non-existent) political capabilities are key drivers in the decline of civil control in regions. One example of the decline of civil capabilities and the rise of vulnerability is in Kampala, Uganda.
Kampala is Uganda's capital city with a population of 1.5 million in 2014. Uganda as a whole has one of the world's highest population growth rates and, like many African countries, half of its population under 15. During the last two decades, the city has expanded in all directions. Growth is primarily concentrated along main roads. Between 1989 and 2010 the total built-up area increased exponentially. Sprawling, unplanned urban growth often results in slum development. Slums are

the primary destination for migrants, and are generally informal settlements. Much of this migration is rural-urban, however there is also considerable movement between cities. Slums make up at least a quarter of the total city area in Kampala, housing roughly 40% of the total city population. The demand for municipal infrastructure is far out pacing supply. This creates countless human security challenges in the realms of sanitation, clean water availability, and environmental degradation.

Davis (2006: 87) also points to an example of loss of civil control in terms of land ownership. Often, public land is illegally controlled by various agents who extract significant rent from local poor who are forced to live on the periphery of the city. Often this land is marginal, vulnerable and is one of the breeding grounds for insurgent actions within the city. Thus making them areas of prime interest for potential military operations in dense urban environments. The major problem here from the perspective of situational awareness is to understand who controls/ "owns" the land?

How to Model Overlapping Threats?

Weilhouwer (2005: 6), using the Army's primary lessons learned document about the war in Iraq, *On Point*, identified two deficiencies from joint urban operations in Iraq. First, the primary training facilities for U.S. forces are small towns or villages, rather than major metropolitan areas. Second, legacy computer simulations are insufficiently realistic to prepare joint force commanders and warfighters for urban operations. The first deficiency endures—urban training facilities will always be limited in size, and military units are limited in what kinds of training can be conducted in real built up areas. The second deficiency may be easier to overcome than the first, but simulations that are able to replicate the complexity of dense urban areas have yet to be created, and will be very resource intensive. So what might be done to better understand and plan for the complexities of operations in dense urban areas? Scenario planning offers some solutions.

Scenario planning was developed by military strategists following World War II, and has been refined and adopted by others in the intelligence community, business, and academia. Most scenario planning exercises seek to satisfy one or more of the following objectives: to make sense of a confusing situation, to develop a strategy, to anticipate future events, or to facilitate organizational learning. Scenarios are especially appropriate for very complex problems that exhibit high uncertainty and involve numerous, uncontrollable variables (van der Heijden 2005). Unlike forecasts or models, which usually attempt to predict specific outcomes, scenarios seek to identify a limited number of *plausible* outcomes.

In the context of IPB and planning for operations in dense urban areas, scenario planning offers several constructive alternatives to more traditional methods. First, scenario planning can be done with limited resources. A scenario planning exercise can be conducted with a small group of people (as few as three or four, but scalable for much larger groups or staffs), and can last from a few hours to several days, depending on time available. Unlike modeling or forecasting, a simple scenario exercise requires minimal information-technology support. Second, scenario planning facilitates 'out of the box' thinking about complex problems. Instead of trying to understand and map the interaction of dozens or more variables, scenario planning constrains the number of variables considered, and forces participants to think about unique ways a few variables may interact over space and time. During the scenario planning process, groups develop plausible storylines that describe alternative futures. Often, during the development of such storylines, participants identify gaps in their understanding of the problem, or find new ways of thinking about a situation. Third, scenario planning can be done with groups who have no previous scenario planning experience—all that is required is a trained facilitator to explain the process, guide dialog, and capture the scenarios as they are developed. Finally, scenario planning exercises provide excellent forums for networking, team building, and learning among participants.

Scenario planning provides a method to come to terms with the complexity of dense urban areas. Scenario planning offers a tool to enhance IPB. Since scenarios are not predictive in nature, they allow for a number of plausible solutions and provide an opportunity to look at the process of working through the scenario to determine gaps in our knowledge. The basic concepts used by intelligence sections provide a point of departure as we begin to tackle the wicked complex problems of dense urban areas. The complexity does not lie in the basic concepts, but in the interconnectivity between discrete defining variables in the AO. Understanding the interconnectivity of ideas and spaces will be a major step forward in starting to grasp the complexity of dense urban environments.

Bibliography

Castells, Manuel. (2015). *Networks of Outrage and Hope: Social Movements in the Internet Age*. 2nd ed. Cambridge, UK: Polity.

Davis, Mike. (2006). *Planet of Slums*. London: Verso.

Giddens, Anthony. (1979). *Central Problems in Social Theory: Action, Structure and Contradiction in Social Analysis*. Berkley: University of California Press.

Headquarters, Department of the Army. (2006). FM 3-24: Counterinsurgency. Washington, DC: Department of the Army.

Headquarters, Department of the Army. (2014). ATP 2-01.3: *Intelligence Preparation of the Battlefield*. Washington, DC: Department of the Army.

Joint Chiefs of Staff. (2011). *JP 3-0: Joint Operations*. http://www.dtic.mil/doctrine/new_pubs/jp3_0.pdf. Last accessed: 10 February, 2016.

Kilcullen, David. (2013). Out of the Mountains: The Coming Age of the Urban Guerrilla. New York: Oxford University Press.

van der Heijden, Kees. (2005). Scenarios: The Art of Strategic Conversation, 2nd Ed. Hoboken, NJ: Wiley.

Wielhouwer, Peter W. (2005). "Preparing for Future Joint Urban Operations: The Role ofSimulations and the Urban Resolve Experiment." *Small Wars Journal* 2 (July 2005). www.*smallwarsjournal.com/documents/urbanresolve.pdf. Last accessed: 10 February, 2016.*

Megacities and Dense Urban Environments: Obstacle or Opportunity?

By ***Dawn A. Morrison and Colin D. Wood***

Originally published in Small Wars Journal on 23 February 2016

Available online at: http://smallwarsjournal.com/jrnl/art/megacities-and-dense-urban-environments-obstacle-or-opportunity

Introduction

The United Nations (UN) projects that by 2030 there will be more than 41 megacities, with the majority of them located in Africa and Asia. These 41 cities alone will house approximately 9% of the world's population, as rural life declines.[i] Approximately 54% of the world's people are now urban residents, with 66% expected to be urban by 2050.[ii] More alarming, the number of people worldwide living in urban slums has increased by 33% since 1990.[iii] As rural to urban migration continues to increase, experts expect more frequent requirements for the U.S. military to be involved in responding to conflicts and disasters in densely populated urban environments. As more of the world population resides in littoral cities, natural disasters such as hurricanes, floods, health epidemics, and resource scarcity could pose significant challenges for military intervention. "While the U.S. military continues to protect U.S. national security interests across the globe, it must focus on protecting those interests where they are in most jeopardy. The greatest potential threats to those interests lie in Asia and the Middle East, and the U.S. Army's role extends to both."[iv] Of the 41 projected megacities, 25 are located in the Asia-Pacific and Middle East regions. Doctrine further recognizes the potential for urban areas to become redoubts for enemy forces and acknowledges that "joint operations will require land forces capable of operating in congested and restricted urban terrain,"[v] thus indicating U.S. doctrinal intent to operate within megacities and dense urban environments. In short, megacities and dense urban environments are firmly on the horizon as likely and potential environments for future warfare and humanitarian engagements. Are we prepared?

Current military thinking tends to present the megacity and dense urban environment as challenging, intimidating, and as a source of anxiety for military commanders who contemplate its operational environment. While megacities and dense urban environments *are* challenging and complex, we argue that the unique characteristics of these environments offer many opportunities and leveraging points that future U.S. military forces can use to their advantage to conduct successful military operations. The first step toward this new paradigm requires a solid method for understanding the operational environment of megacities and dense urban areas. We believe this can be done by operationalizing the megacity framework proposed by the Chief of Staff of the Army's Strategic Studies Group.[vi] Not only does this framework allow megacities and dense urban environments to be understood as a system of systems akin to a living organism, it also categorizes the level of integration between the systems. Operationalizing this framework was accomplished in Morrison et.al. (2016)[vii]. Here we discuss how the resulting composite index (Table 1) that was generated may be helpful in understanding the operational environment of different megacities, including the challenges of operating in these environments. By examining these challenges, however, we discovered that the framework allowed us to re-conceptualize the megacity *not* solely as an impossible military challenge, but rather as a place of potential opportunity offering several leverage points advantageous to future forces if new technology, tactics, techniques, and procedures can be adopted. This paper presents a brief overview of the operationalized megacity framework and demonstrates how it may be used to better understand the future operational environment. We consider the challenges presented to the military by the megacity and dense urban environment under current military thinking. Lastly, we explore several ways in which the military might meet and overcome these challenges by leveraging the megacity environment to its advantage, and capitalizing on the opportunities afforded by the complex environment.

Defining the Area of Regard (Megacity and Dense Urban Environments)

The megacity concept has a common operating definition: an urban or metropolitan area with a population of 10 million people or more.[viii] Less well-defined is the concept of dense urban environments. There is currently no standardized, metric-based definition for what constitutes a dense urban environment or for determining the point at which an area switches from urban to dense urban. The U.S. Census Bureau defines the minimum threshold to be considered urban as an area with 50,000 or more people with a minimum threshold of 1000 people per square mile, but does not define anything beyond the dichotomy of urban/rural.[ix] The fields of urban planning and urban design often factor in floor area ratio (FAR) and dwelling units per area (DU/Area) along with population density, and then examine the persistence of these metrics over scale, ranging from block or developmental parcel upwards to neighborhood, then district to city or region.[x] Using these metrics, we can begin to understand dense urban environments as places where either all three metrics—FAR, DU/Area and Population—are high (e.g., high rise districts of Tokyo, London or New York), or where DU/Area and Population remain high while FAR decreases (e.g., favelas of Rio de Janeiro or the slums of Dhaka). Employing a combination of these metrics may help provide a more accurate determination of urban density as they normalize population by infrastructure capacity, thereby allowing us to better identify and measure dense urban environments for the purposes of planning and execution of military operations. These metrics enable planners to understand the spatial distribution of the density and whether it is stacked vertically (high FAR, DU/AREA and Population) or concentrated at ground level (low FAR, high DU/Area and Population).

SSG Megacity Framework

To better understand megacities and dense urban environments, we implemented the megacity framework presented by the SSG.[xi] The SSG megacity framework is based on five characteristics—Context, Scale, Density, Connectedness and Flow—which are used to determine the level of integrated systems—Highly Integrated, Moderately Integrated and Loosely Integrated—found in each megacity. Integration, in turn, is based on the level of formal versus informal systems, the quality of infrastructure, and how regulated is the flow capacity of goods, resources, people, and information. Morrison et. al. (2016) operationalized the SSG megacity framework by compiling a composite index for each of the U.N.'s projected 41 megacities (Table 1) based on an extensive data matrix assembled from open sources. Metrics collected in the data matrix were selected to cover the five characteristics above, and then cross-walked to address the integration areas of system types, infrastructure quality and regulated flow capacity. For example, data was collected on such topics as governance, rule of law, stability, quality of life, politics, airports, seaports, railroads, roads, economic growth and performance, communication, demographics and other associated human geography variables.[xii] Much of the data used to compile the index is drawn from regularly updated metrics so that the operationalized framework has the ability to remain current over time. We believe this index adequately represents the level of integrated systems for each megacity and allows opportunity to better understand both the positives and negatives of the megacity and dense urban environment in terms of military operations and how they will vary depending on the level of integration; for example, responding to a natural or man-made disaster in a highly versus loosely integrated megacity.

Morrison et al (2016) further connected the operationalized megacity framework to data compiled from the Global Conflict Risk Index (GCRI) and NASA's Socioeconomic Data and Applications Center (SEDAC) to assess the level of risk associated with conflict and environmental hazards for each projected megacity.[xiii] They found that according to the GCRI, more than 70% of the projected megacities are situated in countries with a high probability for conflict in the near future. Similarly, over half of the projected megacities are at risk for environmental hazards (e.g., drought, flood, cyclone, landslide, and earthquake), including both highly integrated cities such as Tokyo and Los Angeles, as well as moderately and loosely integrated cities such as Kolkata, Bogotá, Lahore and Manila. These findings support the June 2014 SSG report which posited that instability and environmental stressors are likely to be what leads to U.S. military intervention in a megacity. Since 1980, the U.S. military has responded to a wide variety of threats and operations impacting national security, but the majority of these operations have consisted of humanitarian assistance/disaster relief (HADR) operations, both CONUS and OCONUS, rather than major combat operations.[xiv] With climate change and sea-level rise, we should expect to see drastic change in many of the world's littoral areas in the coming decades, and a U.S. response to follow.

Given this, the U.S. military needs to consider and be prepared for how the type of megacity (i.e., loosely, moderately or highly integrated) presents varying orders of magnitude to the complexity of operations.

Conducting any type of operation in a highly integrated city such as Tokyo, London or Paris, even with host nation cooperation, will still be challenging, but those challenges may differ significantly from conducting similar operations in a loosely integrated megacity such as Dhaka, Lahore or Lagos. The operationalized megacity framework, by looking at and evaluating the level of interconnected systems within, throughout and between megacities, characterizes the dense urban environment in the narrative of a living organism. As with all living organisms, megacities and dense urban environments have strengths, weakness, and leverage points that can be identified by understanding the level of formal versus informal systems, the quality of infrastructure, and the regulation of the flow capacity of goods, resources, people and information.[xv] These circumstances, while perhaps challenging to conventional military wisdom, may actually present spaces of opportunity for military advantage from a different perspective.

Framework Applied: Regulated Flow Capacity

The operationalized framework is useful for understanding the military operational environment of megacities and dense urban environments; knowing whether a place is highly or loosely integrated will significantly impact how the U.S. approaches a mission, as well as the expected consequences of various military activities. If military action affects the flow of a city (e.g., cordoning off the city or parts thereof, blocking access points, etc.), the effects could be tremendous. Depending on the market importance of the city, world economies could quickly experience adverse effects. Looking at various global indices[xvi] that assess urban areas based on their business activity, economic status, culture, politics, information exchange, human capital, productivity, infrastructure, environment and quality of life metrics, we find that the highly integrated megacities (e.g., Tokyo, New York, Paris, London) tend to be ranked near the top of each list, as expected. However, we also see cities such as Istanbul, Turkey; Chengdu and Shanghai, China; Delhi, Mumbai and Kolkata, India; Jakarta, Indonesia; Buenos Aires, Argentina; and Sao Paolo, Brazil ranking relatively high on these lists due to their economic importance, even though their systems are moderately or loosely integrated.[xvii] These indices also reflect the level of difficulty that would be involved with attempting to isolate any of these cities, or subparts therein, and the potential cascading impact on the world's economy that could result. Indeed, even the most loosely integrated megacities (e.g., Lahore, Karachi, Dhaka, Ahmadabad, Dar es Salaam), play significant roles in the world economy such that isolating them will have ramifications in places far flung. For example, Dhaka has a $19 billion/year garment industry which makes up 77% of its total merchandise export economy, and is second only to China in the world ready-made garment economy; cordoning off any part of Dhaka, and disrupting the garment industry would have rippling effects far beyond Bangladesh's borders.[xviii]

Framework Applied: Infrastructure Quality

Quality of infrastructure within a megacity and dense urban environment is also critical to understanding the operational environment and the effects and consequences of military action therein. For example, mobility in a megacity and dense urban environment will be greatly affected by the integration level of the city. Troop movement is dependent upon both built and human environments—the densities of people and structures in a megacity can be such that movement is slowed, sometimes to a standstill, as roads become impassable. This, in turn, impacts security: soldiers attempting to reach their objective may be forced to dismount from vehicles to cordon and search an area while they wait for a clearing, or sit in their stationary vehicles which quickly become targets for small arms, rocket, and IED attacks. Intratheater airborne operations may also be hindered due to the lack of appropriate ground-based landing zones (LZs), with skyscrapers and shanty structures providing additional obstacles that further complicate maneuverability.[xix] Likewise, Medical evacuations (MEDVAC) may be significantly challenged in a megacity due to time and distance constraints imposed by quality and/or density of infrastructure and traffic congestion. There are certain time-frames within which casualties need to make it to a higher echelon of care (such as the "Golden Hour" and the "Platinum Ten")[xx] to have a greater chance of surviving their injuries. While not hard and fast rules, such time-frames are essential to improving mortality rates in battle. A more highly integrated megacity may have better infrastructure than a more loosely integrated city to accommodate mounted movement, but population density often causes extensive travel delays and choking traffic. According to the TomTom Worldwide Traffic Index,[xxi] Istanbul, Mexico City, Rio de Janeiro and Moscow are the top 4 cities with the worst traffic, and 11 of the top 20 most congested cities in the world are on our list of megacities.

Intertheater maneuverability—with its reliance on commercial and military air and seaports—may also be challenged by the megacity and dense urban environment. [xxii]. While all of the projected megacities have major commercial airports, accessing those airports will not always be straightforward, whether due to disrepair, or the inability to accommodate the weight and size of U.S. military aircraft. The placement of the airport within the urban environment and security issues related to landing within a dense urban environment immediately surrounded by potential enemy forces are cause for additional concern. For example, in September 2014, India's federal government asked Mumbai officials to clear the slums surrounding the Chhatrapati Shivaji International Airport due to increased concerns over terrorist attacks against airports in the region. The effort will involve removing 90,000 people—the population of a mid- sized American city—from roughly 309 acres of land.[xxiii] Even in highly integrated megacities, the use of airports may be restricted to U.S. military forces due to congestion by commercial and industrial ventures that, if disrupted, could have consequences far flung beyond the area of operations. Port access is even further restricted than airports: 10 of the countries containing the projected megacities have port facilities with infrastructure quality rated at average or above, and only 16 of the cities have a major port, the rest either being landlocked or without access to a major body of water to support port facilities.[xxiv]

Framework Applied: Systems

Human settlements, regardless of density or size, exist as a system of systems. How integrated and functional these systems are largely determines the success and livability of the settlement. As such, the operationalized megacity framework is useful in assessing the integrated system quality of each megacity and dense urban environment for purposes of projecting the effects of military operations in that environment. The need for positioning U.S. forces in such an environment is one clear example of the importance of understanding the impact of military operations on urban systems. Positioning U.S. forces often requires enough land to house personnel, materiel, and necessary facilities. General base camp land use planning factors for a Heavy Brigade Combat Team-sized element, for example, call for between 1,780 - 2,185 total acres in order to meet requirements.[xxv] In practice, contingency bases are often larger than this, such as Camp Diamondback in Mosul, Iraq, which was roughly 2,200 to 2,300 acres. [xxvi] Finding that amount of space in a megacity or dense urban environment may be difficult, though, with the availability of airports and other urban industrial areas, not impossible. Still, population displacement will always be an issue under current military convention. Dhaka provides an excellent example of the tradeoffs that will need to be made if following doctrine for positioning U.S. troops. Areas that provide the requisite space may come at a cost to security, access to adequate utilities or expose deployed soldiers to environmental hazards, and will likely require significant displacement of the local population, in some cases upwards of a quarter million people just to make room for a contingency base equivalent to the size of Camp Diamond Back in Iraq. It is important to note, however, that loosely integrated cities may have poorly designed and inadequate infrastructure to support contingency basing in these environments. Moreover, U.S. use of host nation space and infrastructure will tax already limited resources, potentially destabilizing both social and physical infrastructure beyond the scope of operations.

Megacity and Dense Urban Environments: Moving on Up!

Are megacity and dense urban environments challenging, complex operating spaces? Absolutely! As the above demonstrates, current military operating procedures and perspective may not be adequate to overcome these challenges. However, these environments also offer significant opportunity for military advantage and overmatch if we are willing to think outside of the box and look at the area of regard from a different angle. While the problems and obstacles associated with the megacity and dense urban environment are numerous and myriad, they create opportunities for the military to engage through adaptive technologies and methodologies. We believe the most fertile areas for creating military overmatch in these environments will be in exploiting the vertical space, leveraging the natural flows and patterns of life of the population and through technological advancement tailored to the specific challenges of a dense urban environment.

Rather than focus on the density of buildings, infrastructure, and people that may choke out traditional military tactics at the ground level, megacity and dense urban environments offer a manmade high ground—replete with over watch, standoff distance, free from urban canyon bandwidth affects and, with advancing technological support, potential for rapid ingress/egress with minimal local population engagement. We argue that the greatest advantage and opportunity afforded by these environments resides in exploiting the vertical space inherent in all urban centers. One of the larger issues of infrastructure often pointed to in a megacity is that of the vertical space. Tactically, the military has long known that taking and owning the high ground is advantageous. In an urban environment, however, “owning” the high ground—skyscrapers—is not only fraught with difficulty, but can bring about other issues from a structural/physical security standpoint. New technological approaches to securing the space, providing greater stand-off from explosives, and options for areal refit (creating add-on LZ’s for vertical lift capability) would greatly improve the outlook for a military operating in this environment. Current technological advances in net zero basing systems could also be developed to ensure a fully contained and controlled environment within the skyscraper for U.S. forces that is not reliant on the existing building systems. Further, distributed high ground basing throughout the megacity would also allow for greater command and control of the environment through extended visual over watch. Exploiting the vertical space would also entail greater use of unmanned systems in lieu of ground-based patrols.

The population of the megacity and dense urban environment—rather than being an obstacle to military operations—may be the next greatest leverage point of opportunity for future military operations if we are willing and able to change our perspective on how to conduct military operations. The local population is an organic landscape feature that unlike buildings, ebb and flow through the physical environment on dynamic temporal schedules that have daily, weekly, monthly, seasonally and yearly variance. In the megacity, and particularly in dense urban environments, we argue that the population creates incredible complexity and results in novel challenges for military operations. But, better understanding the spatial and temporal patterns of daily life will enable high-fidelity modeling and forecasting of population movement, behavior and reaction within the dense urban and megacity environment. Can we use this understanding to better blend in with the local context so as to also hide among the people? Likewise, if we can learn and adapt to the social and cultural systems and their associated patterns of life, could we train our soldiers to become adept at local "street smarts"? In the same way that Google Glasses now offer on the spot place-based information for way finding, could technology be developed that provided on-the- spot translation and interpretation of language, behavior, dress, and other social and cultural signs, symbols and cues? In this way, could we enable our future soldier to use the crowd as camouflage—ergo, get lost in the crowd, and not in translation? At the same time, new technological advances in analytical capabilities, such as those of IBM's i2 EIA, [xxvii] will enable the future force to quickly identify key players in the crowd, as well as to better understand the connectivity among actors and persons of interest.

Understanding the patterns of daily life of the local population would also facilitate the ability to go "with the flow" of the dense urban environment rather than against it when trying to move large equipment and/or troops? In a megacity, there will always be a "flow", it is just a matter of being able to identify the one most suited to the mission set. Moreover, understanding the recurring temporal patterns inherent to how the local population moves through and makes use of their urban environment would also provide the future force with a built-in barometer for identifying adverse activities, sentiment and change that taps into the local knowledge base. For example, in Iraq, the noticeable absence of women and children and/or deserted areas that are normally busy potentially signaled an impending IED attack, or other adversarial action.[xxviii] In the megacity and dense urban environment, particularly if we leverage vertical space which would allow the future force to more clearly see the ebb and flow of the local population, identifying aberrations in generally recurring patterns of life may provide a significant tactical edge.

Leveraging technology is another way that the U.S. can achieve overmatch in the megacity and dense urban environment. Future research and development, if tailored to the specific context of the megacity operating environment, could result in new technologies and techniques that take advantage of the opportunities presented by this unique environment. Are there technological solutions, perhaps in the field of robotics that can assist U.S. forces in bridging the gap between (current) required force strength ratios given the immense population size of the operating environment? Are there ways to leverage and use specific integrated systems or certain “flows” to cordon off and control sections of a city without disrupting global economic processes? Traditional fortification methods that create significant standoff distances between troop positions and the local population may be impractical in a megacity or dense urban environment, thus requiring technological solutions to compensate. Conversely, are there low-tech options ripe for advancement that would bypass the ever-growing reliance on energy and networks that may provide future forces with military overmatch in dense urban environments? What will be the future equivalent in matching the simplistic elegance of the Navajo Code Talkers?

Summary

It behooves the U.S. military to not only understand the megacity and dense urban environment in the context of a living organism wherein all elements are connected in an integrated system, but to be able to identify the strong and weak areas of the systems that can be used as leverage points to achieve success (ergo, where does the U.S. need to focus efforts to strengthen/buttress the system as well as where are the pressure points in the system that may trigger a desired end-state tipping point). Switching the emphasis from kinetic, human in the loop military tasks that focus on person-on-person interaction between our forces and the population of the megacity (inclusive of adversaries, neutrals and supporters), to strategically supporting, manipulating and/or undermining the flows, infrastructure and systems of the megacity and dense urban environment as a whole itself may transform what was previously viewed as intimidating complexity with too many moving parts (all those millions and millions of people!) into a sophisticated, integrated, and manageable system of systems. By focusing on the integrated system of systems inherent to the megacity and dense urban environment, by leveraging and taking control of the vertical space, by fully understanding the population and—most importantly, by bringing to bear our capability for technological overmatch that will enable all of the above, we believe future U.S. military forces will have the ability to successfully operate in megacity and dense urban environments as they do now in open terrain.

Tables

City (Urban Agglomeration)	Country	Typology Score
Tokyo	Japan	3.0
London	United Kingdom	3.0
New York-Newark	United States of America	3.0
Paris	France	2.9
Los Angeles-Long Beach-Santa Ana	United States of America	2.8
Kinki M.M.A. (Osaka)	Japan	2.7
Johannesburg	South Africa	2.2
Istanbul	Turkey	2.2
Buenos Aires	Argentina	2.0
Ciudad de México (Mexico City)	Mexico	2.0
Krung Thep (Bangkok)	Thailand	2.0
Shenzhen	China	1.9
Shanghai	China	1.9
Kolkata (Calcutta)	India	1.9
Mumbai (Bombay)	India	1.9
Lima	Peru	1.9
Beijing	China	1.9
Chennai (Madras)	India	1.9
Hyderabad	India	1.9
Delhi	India	1.9
Chengdu	China	1.9
Rio de Janeiro	Brazil	1.8
Ahmadabad	India	1.8
Moskva (Moscow)	Russian Federation	1.8
Jakarta	Indonesia	1.8
Chongqing	China	1.8
São Paulo	Brazil	1.8
Bangalore	India	1.8
Guangzhou, Guangdong	China	1.8
Al-Qahirah (Cairo)	Egypt	1.8
Tianjin	China	1.8
Manila	Philippines	1.7
Bogotá	Colombia	1.7
Thành Pho Ho Chí Minh (Ho Chi Minh City)	Viet Nam	1.6
Lahore	Pakistan	1.5
Karachi	Pakistan	1.5
Dar es Salaam	United Republic of Tanzania	1.4
Lagos	Nigeria	1.4
Dhaka	Bangladesh	1.3
Luanda	Angola	1.3
Kinshasa	Democratic Republic of the Congo	1.0

Table 1: Projected megacities typology scores (sorted by score); 3 represents highly integrated, 1 – loosely integrated

End Notes

[i] United Nations, Department of Economic and Social Affairs, Population Division (2014).
World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352).

[ii] ibid.

[iii] UN Habitat, *State of the World's Cities 2012/2013* (2013).

[iv] TRADOC Pam 525-3-0, 2-1c
[v] TRADOC Pam 525-3-1, 2-3.b(5)
[vi] Chief of Staff of the Army, Strategic Studies Group (April 21, 2013). "A Proposed Framework for Appreciating Megacities: A US Army Perspective," *Small Wars Journal*. See also, Chief of Staff of the Army, Strategic Studies Group (June 2014).

Megacities and the United States Army: Preparing for a Complex and Uncertain Future.

[vii] Dawn A. Morrison, Colin D. Wood, Timothy K. Perkins, Carey A. Baxter. 2016. “Extreme Environment Basing: Contingency Basing in Megacity and Dense Urban Environments,” Center for the Advancement of Sustainability Innovations (CASI), ERDC/CERL SR-15-DRAFT (Forthcoming March 2016).
[viii] United Nations, Department of Economic and Social Affairs, Population Division (2014).
World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352).

[ix] U.S. Census Bureau Online. Geography Reference Section. http://www.census.gov/geo/reference/urban-rural.html.
[x] For a good explanation of these metrics, see MIT’s Density Atlas project: http://www.densityatlas.org/
[xi] See Chief of Staff of the Army, Strategic Studies Group (April 21, 2013; June 2014).
[xii] Data is available upon request.
[xiii] GCRI. **http://conflictrisk.jrc.ec.europa.eu/**. Website hosted by the Joint Research Center of the European Commission; Center for Hazards and Risk Research - CHRR - Columbia University, Center for International Earth Science Information Network - CIESIN - Columbia University, and International Bank for Reconstruction and Development - The World Bank. 2005. Global Multihazard Frequency and Distribution. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). **http://dx.doi.org/10.7927/H45718Z5**. Website hosted by **CIESIN** at **Columbia University**.
[xiv] Sukman, Daniel. “The Past as a Prologue: The Future of the U.S. Military in One Graphic.” *The Strategy Bridge*. Dec. 18, 2015. Retrieved from **http://www.thestrategybridge.com/the-bridge/2015/12/20/the-past-as- a-prologue-the-future-of-the-us-military-in-one-graphic**, Feb. 02, 2016.

[xv] See Chief of Staff of the Army, Strategic Studies Group (April 21, 2013; June 2014).
[xvi] E.g., City Prosperity Index (CPI), 2012, United Nations Human Settlements Programme, Global Urban Indicators Database; Global Power Index (GCPI) 2009, **http://www.citymayors.com/economics/power-cities.html**

;http://www.citymayors.com/economics/power-cities.html Global Cities Index (GCI), 2014, by AT Kearney; Global Metromonitor, 2014, Brookings Institution, Metropolitan Policy Program; Mercer’s 2015 Quality of Living City Rankings, https://www.imercer.com/uploads/GM/qol2015/h5478qol2015/index.html.
[xvii] See Morrison et.al. (2016) for a detailed discussion and breakdown of how these, and other open source indices, were used to operationalize the megacity framework.
[xviii] "Textiles on the WTO Website" http://www.wto.org/english/tratop_e/texti_e/texti_e.htm. WTO Secretariat. See also, Hildegunn Kyvik Nordas (2004), “The Global Textile and Clothing Industry post the Agreement on Textiles and Clothing.” Geneva, Switzerland: World Trade

Organization.
[xix] TRADOC Pam 525-3-6, 3-4b
[xx] The “Golden Hour” is the first hour following a trauma injury, which is considered the most critical for successful emergency treatment. Likewise, the “Platinum Ten” refers to the period in which medical personnel arrive on and assess the scene, initiate treatment, and transport for injured personnel.[xx]
[xxi] TomTom Worldwide Traffic Index, 2015, http://www.tomtom.com/en_gb/trafficindex/#/list.
[xxii] TRADOC Pam 525-3-6, 3-4a

[xxiii] Anurag Kotoky (September 11, 2014). “Mumbai Airport Slum Removal Sought by India Over Terror,” *Bloomberg Business*.

[xxiv] See Morrison et.al. (2016).

[xxv] EP 1105-3-1, E-4

[xxvi] Area calculations for Camp Diamondback were determined using ESRI GIS ArcMap 10.1 and images from Google Earth.
[xxvii] Tucker, Patrick. “Refugee or Terrorist? IBM Thinks Its Software Has the Answer.” *Defense One*, January 27, 2016. Retrieved from: **http://www.defenseone.com/technology/2016/01/refugee-or-**

terrorist-ibm-thinks-its-software-has-answer/125484/?oref=d-channelriver**, Feb. 02, 2016.**

[xxviii] U.S. Marine Corps, “Improvised Explosive Devices (IED) B3L4118 Student Handout,” Pg8.

Megacities: The Good, the Bad, and the Ugly

By ***Russell W. Glenn***

Originally published in Small Wars Journal on 17 February 2016

Available online at: http://smallwarsjournal.com/jrnl/art/megacities-the-good-the-bad-and-the-ugly

Introduction

> "When [U.S. military] officers objected that Kahn was ill-equipped to speak on military affairs…he'd shoot back, 'How many thermonuclear wars have you fought recently?'… They admitted they had no actual experiences with these weapons. 'O.K., Kahn would grin, 'Then we start out even.'"*[i]*
>
> -- Ghamari-Tabrizi, *The Worlds of Herman Kahn*

Today's armed forces and those accompanying their security efforts worldwide have no more conducted major operations in a megacity – those urban areas in excess of ten million population – than have they participated in a nuclear war. Fortunately, however – and unlike the case with the officers above – recent experience and history's lessons from undertakings in cities short of the ten million mark have much to offer. Much, but those offerings will fall short of the comprehensive. The same is true for those in civilian clothes – government and otherwise. Megacities are sure to challenge every member of a coalition.**[ii]** How these urban areas might do so in the intelligence realm in the near future is the primary focus of this offering, one that can but provide but a brief taste of the sweet, savory, and bitter implications involved. **[iii]**

The facts are well known, some so often repeated as to be all but common knowledge. Among them:

- Over half the world now lives in urban areas; nearly a quarter resides in those with over one million population.**[iv]**
- Eighty percent of the world's population lives within one hundred miles (160 kilometers) of a shore, most in cities.**[v]**
- There were 132 cities of population one million or more in 1965. Such urban areas numbered 494 in 2015, thirty-four of which were megacities (urban areas with populations of ten million or more).**[vi]**

Though the waters are muddied by varied definitions of "city," "urban area," "metropolitan area," and others, it is inescapable that the world increasingly urbanizes and its largest cities/urban areas/metropolitan areas tend to swell at an even greater rate.[vii] Implications for coalitions are numerous and far-reaching. Non-state actors in particular have turned to urban terrain's density of hides, firing positions, and civilians providing sustainment willingly or otherwise to avoid confronting superior Western military technology and training, both of which tend to be designed for more open environments. Fortunate indeed will be the future military leader finding his enemy willing to evacuate a city as did the Iraqi Army Basra in 2003.[viii]

Were these not challenges enough, the varying definitions conceal social, political, and economic implications no less problematic. The *city* of Los Angeles proper – the political entity – is home to a population of but 3.8 million within the greater Los Angeles *urban area* of 15.1 million beings.[ix] (Thus Los Angeles qualifies as a megacity.) A coalition operating in such a region would find itself coordinating with hundreds of administrative jurisdictions: political, fire, law enforcement, transportation, and health to touch on a few, this regardless of whether the mission at hand involves armed force or not. Nor would opposing force's evacuation of an urban area guarantee relief. Removal of what might well have been coercive authorities too typical of the Third World removes the lid from a simmering pot; looting, surging criminality, and latent sectarianism could be only three of the newly arrived's rewards for assuming responsibility.

Yet all is not darkness. Though man has no more conducted major operations in a megacity than had those in Herman Kahn's audiences fought a thermonuclear war, we need to remind ourselves that similarities between undertakings in smaller urban areas have much to offer coalitions confronting others when a population exceeds ten million mark. The remainder of this essay will only sparingly touch on these commonalities. Analysis instead seeks to focus on issues particular to megacities. As the title suggests, operations and campaigns in these environments will provide the good (opportunities), the bad (challenges), and the ugly (especially difficult issues).

The Good

A recent chief of the US Army Capabilities Integration Center's Future Warfare Division stated, "Dense urban terrain favors the defender," a daunting prospect when one considers the expanses of tightly packed man-made structures characteristic of the world's largest urban conglomerations.[x] Reality fortunately confounds this common belief. Defense of cities, especially the vast expanses that are megacities, presents a situation akin to that described by Clausewitz in his contemplations of mountain complex defense:

> Defensive mountain warfare…. Is it meant to last only a certain time or to the end in definite victory? Mountains are eminently suited to defense of the first type…. For the second type, on the other hand, they are, except for a few special cases, generally not suited at all.… A small post can acquire extraordinary strength in mountainous terrain. [However,] in a decisive battle, mountainous terrain is of no help to the defender; on the contrary…it favors the attacker.[xi]

As in extensive mountainous terrain, the megacity defender will tend to lack the manpower, weaponry, and knowledge to prevent circumvention of its defensive positions. Further, unlike the Persians at Thermopylae, there will be no need for reliance on the good fortune of finding the singular individual knowledgeable in this regard. Residents familiar with their city and willing to guide a force to surface, subterranean, or super-terranean bypasses should not be hard to locate.

A first lesson is therefore to recognize that megacities' substantial populations, geographies, infrastructures, and other features offer benefits in addition to difficulties. Existing doctrine, past experience, and theory will all offer points from which to adapt. Factors more likely found only in these largest urban areas will enhance these opportunities. Larger built-up areas tend to offer a breadth and depth of information lacking in less populated environments. The navigation application Waze, for example, can be of limited value in infrequently traveled rural regions. Relying on user-submitted data, it is of notable value in densely populated areas, however. Waze tells users not only how to get from point A to point B but also provides real-time status regarding ongoing construction, accidents, roadway debris, and (yes) police speed trap and fixed camera locations amongst other information. The app employs this input to redirect users from their normal home-to-work and other routes to less congested alternatives.
Military units could conceivably adapt such applications, allowing for inclusion of secure inputs regarding threat locations, raw material stockpiles of potential operational value, and suspicious road conditions (e.g., possible spots where an improvised explosive device might have been emplaced), perhaps linking drivers' observations targeting assets. Integrating secure with Waze (or a similar application's) open- source information would at once increase routing efficiency and force protection while reducing opportunities for theft of supplies. (Armed robbers in Lagos, Nigeria, for example, routinely rob occupants of vehicles trapped in the city's notorious traffic jams.)[xii]

Urban areas are also hives of official and commercial demographic information. Robert Dixon's "Bringing Big Data to War in Mega-Cities" discussion regarding the types and value of urban databases applies equally to humanitarian response and other contingencies not involving combat.[xiii] Census information, marketing survey results, and property records are but a sampling of what military and broader coalition authorities would find beneficial for addressing tasks inherent in urban undertakings. Cell phone data has especially notable potential to assist a coalition during crises. Call data records providing the number, time, and cell tower location of use have already been used to track malaria outbreaks in Africa.[xiv] Captured in a timely fashion, they could similarly help trace the flow of commuters later found to have been contaminated in a biological agent attack. As with an interactive traffic application, larger urban populations enhance the potential value of analyzing cell phone record data; those in cities are more likely to possess cellphones than others in remote rural areas. The sophistication of databases and their potential value may surprise. Geo-profiling shows promise for finding terrorists via analysis of where incidents occur. Most attacks are within a short distance of perpetrators' residences or materials storage locations, reducing chances of confronting checkpoints when moving to targets. Further, extremists may avoid certain neighborhoods due to discomfort with activities there, e.g., those in which the sex trade is commonplace.[xv] Police records and accompanying analysis software in some US cities provide timely color coding regarding risk levels associated with individuals and addresses. Dispatched officers receive in-route evaluations after database searches regarding information such as whether a resident has a record of weapons possession or past violent crimes.[xvi] These capabilities could be used in conjunction with local knowledge as possessed by members of Terrorism Early Warning Groups (TEWG) such as that found in Los Angeles. TEWGs offer arriving coalition members valuable local and broader regional knowledge memberships that include representatives from police, fire, coast guard, federal law enforcement, and other organizations familiar with both the immediate urban area and more far-flung reaches. (Links between various city's TEWGs or similar organizations can likewise be invaluable when an event in one megacity threatens distant locations, e.g., when the aforementioned bio-contaminated individual departs for another destination.) Knowing how to access, organize, and make good use of these various troves of information will take practice. Training with megacity authorities such as those in TEWGs would provide insights regarding both the specific urban area represented and others more generally applicable to such megalopolises.

Nor should one assume capabilities of this type are restricted to the First World. When Liberian Patrick Sawyer collapsed on arrival in the Lagos, Nigeria airport, local authorities soon recognized he – and potentially passengers on his plane – posed a potential medical disaster. Sawyer had brought the Ebola virus to Africa's and one of the world's largest megacities, estimated population 30.6 million. Despite the city's doctors being on strike, refusal of the Nigerian Medical Association's chairman to terminate the strike in the face of the threat, and exposure of hundreds to those confirmed or possibly infected, actions by working medical personnel, aggressive and successful efforts to trace and get in touch with the 891 individuals possibly or actually exposed, and coordination of operations by a Gates Foundation-funded clinic converted into an emergency command center precluded wider infection.[xvii] The quick reaction included nongovernmental, inter-governmental, commercial, and governmental organizations in addition to mobilized volunteers and the United States Centers for Disease Control.[xviii] That Lagos was so large an urban area increased the likelihood that appropriate medical facilities were on hand. (Two laboratories in the megacity were able to test for the Ebola virus.) That Nigeria's capital was also an epicenter of the country's educated and the expert and veing a "wired city" was fundamental to the disease being interdicted with only twenty infected and a total of eight deaths. A doctor in the hospital to which Sawyer was taken not only recognized the symptoms; she prevented the uncooperative patient from forcibly leaving the medical facility and resisted pressures that included those from the Liberian embassy.[xix] World megacities are more likely to have similar in-place emergency response procedures and other resources key to effective crisis response. Even preparations for dislike events have potential to assist a coalition's urban operations. Provisions for action in the aftermath of a major earthquake, for example, will have value during responses to other disasters, e.g., a major terrorist attack.

Access to megacity information, authorities, and other key resources will assist not only during general planning and conduct of urban area operations. They will likewise be invaluable in determining what specific communities within a built-up area (or country or region more broadly) offer greatest promise for supporting (or impeding) coalition objectives. No force will be large enough to control an entire megalopolis. Knowing likely hotspots, identifying centers or gravity and decisive points, and locating acceptable base areas from which to conduct operations will do much toward making the apparently overwhelming a manageable undertaking.

The Bad

A megacity is the un-consumable elephant; the number of bites needed to address all of its requirements would far exceed any coalition's capabilities. Progress and ultimate success is further made difficult in that the armed forces likely to lead such ventures have doctrines that go little beyond generalities when it comes to dealing with the largest of urban agglomerations. A United States Marine Corps comment from over a decade ago holds true both for its specific topic and other functional areas during urban operations:

> Formal, written urban combat reconnaissance doctrine—the foundation (at least in theory) for the planning and execution of operations and training, the development of organizational structure, and the basis for equipment procurement—is essentially nonexistent.[xx]

The need for more urban (and megacity)-specific doctrine is evident to any who since 2002 found themselves in Baghdad, Kandahar, Fallujah, or any other of the many urban environments in which the men and women of the US and its closest partners have served. There will be "other-governed" communities, those ruled by less-than-official (but not necessarily less effective) authorities, often with criminal or other nefarious intentions, Sadr City in Baghdad being an exemplar. Misnomers, misunderstandings, and mistakes left unaddressed in recent guidance pose threats to urban operations success; they portend outright disaster when the numbers involved grow to double-digit millions. The assumption that provision of aid and quality of life improvements is fundamental to gaining and maintaining public support is one perhaps resting on dubious foundations. Eric Hoffer's classic *The True Believer* warns of a conundrum rarely recognized: the destitute are too worried about the source of their next meal to have interest in rebellion or resistance. Lifting them from this hand-to-mouth existence, however, threatens creating tinder ready to flare given expectations of yet further improvement, expectations that may be beyond the abilities or intentions of a coalition to meet, particularly one confronting the scope of issues inherent in megacity operations.[xxi]

Intelligence implications are clear. Far more than estimates of conventional enemy capabilities and intentions will be called for. Those of the many insurgent, criminal, militia, and other armed threats will be no less important. Identifying key formal and informal power brokers in neighborhoods and political jurisdictions and determining the most effective means of communicating with both these social nodes and the population at large will be fundamental to maintaining even minimal control. The larger the urban area, the greater the number of threat groups and the wider the regional dependencies linked to the city.

Collection of the information needed to feed what is sure to be a voracious intelligence beast will demand manpower and equipment resources in excess of any currently available to even the most ambitiously conceived deployed force. The sheer extent of megacity operations-related information from human, visual technology, acoustic and vibratory sensor, signals collection, and other sources will overwhelm today's analytic capabilities. Add to this quantity the vast expanses of line-of-sight terrain and additional influences such as having to separate relevant information from the mundane inherent in the habitual "noise," "hum," or vibration of megacity daily activities and the challenge is further exacerbated.

The Ugly

> *Munitions are now delivered reliably from distant launch systems and brought onto target by units that can remain hidden…. It means the demise of infantry battalions, tank regiments and armoured brigades as they are currently structured for major combat operations.[xxii]*
>
> *Christopher L. Elliott,*

Not so fast, general. Let us not fall victim to believing that past activities will accurately reflect the nature of those yet to come. The same marines decrying doctrine's lethargy in meeting 21st-century urban reconnaissance demands found "controlling fires is difficult for us" urban area's ubiquitous buildings, the smoke and smog degrading both vision and laser designation, and polished surfaces reflection of those beams. Hamas and other foes confronted by the Israel Defense Forces (IDF) during recent operations increasingly make use of urban subterranean hides, headquarters, and passageways to deny observation and targeting. Below ground facilities are already inherent physical features of today's cities, their number and dispersion increasing as does population growth and accompanying structural spread. Detecting entrances and exits to facilities can be extremely difficult; determining their underground route nearly impossible given the depth of some such infrastructure and clever concealment of air shafts.[xxiii] Even when detected, valuable targets may be left unhindered due to their being positioned under proscribed civilian infrastructure. A Hamas command center remained unscathed beneath Gaza's largest hospital during 2014 Operation Protective Edge despite IDF leaders knowing its location.[xxiv] Determination of favorable laser designation and launch system locations; analysis of rotary-wing flight routes minimizing exposure to likely enemy air defense weapons sites; development of algorithms to support such analyses in operationally relevant timeframes; and commitment of resources to detecting, tracing, and targeting subterranean facilities all pose worthy challenges for the intelligence community.

Nor is it only those in uniform who will find megacity challenges overwhelming. Demands for capabilities essential to aiding so large an urban area's recovery may exceed what international and coalition governments can bring to bear even for a short period. The problem will be more difficult yet should years of assistance be necessary, a problem magnified if that assistance be needed beyond the bounds of the megacity alone. Difficulties are made worse yet when inappropriately manned advance parties and early information collection efforts fail to identify and thereafter focus on priority challenges.

No less ugly are cases in which shortfalls during previous urban campaigns are repeated. The commander drawing militarily-typical unit boundaries along physical features such as roads, rivers, and the like will find those boundaries become self-inflicted wounds should they not be realigned once combat operations recede. Savvy leaders can instead minimize liaison, communications equipment, and other demands by realigning boundaries with existing administrative jurisdictions. It is a lesson unfortunately repeatedly learned and forgotten, two of the most recent instances being during the Los Angeles 1992 riots and in 2003 Baghdad. Intelligence personnel's recognizing the importance of identifying administrative delineations, then providing them to operational planners could preclude yet another recurrence.

Toward Solutions

To describe megacities as "information rich" environments is an understatement. No less than their towering buildings and teaming masses, the information oceans can seem an overwhelming flood. Some simple – and logical – first steps can provide a means of lending form to the seeming deluge. Regarding these environments in terms of underlying terrain, buildings, infrastructures (physical, social, and informational), and people creates "bins" to assist in managing collection and analysis…given that the bins do not become stovepipes hindering system-wide analysis. Likewise, recognizing that megacities' physical, human, and other characteristics can differ from smaller urban areas in terms of familiar concepts such as density assists in making the seemingly ungraspable graspable.**[xxv]**

Innovation will prove an indispensable commodity. Recognizing how lessons from previous operations in sub-megacities and during counterinsurgency operations can be molded in the service of new challenges would be a significant step forward. Modifying proven and well understood concepts will likewise provide payoff. Bringing maneuver into the 21st century would be one such re-forging. Previous operations – both urban and counterinsurgency – demonstrate the value of a comprehensive approach during which military, government civilian, and other relevant participants cooperate. All the more reason to embed the essence of maneuver's traditional definition:

> Employment of forces in the operational area through movement in combination with fires to achieve a position of advantage in respect to the enemy***[xxvi]***

in a more encompassing conceptualization:

> The employment of relevant resources to gain advantage with respect to select individuals or groups in the service of achieving specified objectives.*[xxvii]*

Similarly, the long-held understanding of a coalition as "an ad hoc arrangement between two or more nations for common action"[xxviii] would benefit from recognition that the scope of efforts requires synchronization of more than national assets alone. A better definition would account for nongovernmental, inter-governmental, private, and other organizations able to offer needed capabilities, making a coalition "an ad hoc arrangement between two or more organizations in the interest of common action."[xxix] Conceiving of "intelligence coalitions" along similar lines could significantly increase the number of information providers in support of megacity events. Much of the information needed to support intelligence requirements implied both explicitly and implicitly above is available in open sources. Pre-deployment and reach-back employment of interns and others to mine databases could dramatically increase the number of assets providing data. Much of the information would require revalidation, particularly in cases where physical destruction due to natural or man-made disasters is extensive or the numbers of displaced persons high, making large numbers of those capable of datamining an even greater asset. Manning would have to include sufficient personnel to confirm and reconfirm findings. Information sources inevitably conflict; some official sources are notoriously little more than fabrications designed to keep in-place authorities in power. It is obvious that training data miners should be undertaken before future operations the better to identify likely information requirements and minimize response times.

On the urban ground itself, the infantryman, pilot, NGO aid provider, truck driver, and every other participant becomes a potential source of information and recipient of resulting intelligence products (understanding all such participants are not equal when it comes to intelligence provision given differences in security clearances). Embedded personnel assisting with various government organizations should wear multiple hats. Those assisting in building governing capacity should at the same time be incorporated into information collection efforts, thereby enhancing understanding of megacity key relationships, fault lines, vulnerabilities, emerging requirements, and sources of opportunity in the service of coalition objectives. These same individuals will ideally be monitors confirming or alerting responsible parties when activities put short and longer-term objectives in tension as did one command in Iraq when members proposed providing small business startup grants at the same time other coalition authorities hoped to establish a program of bank micro-loans.

The far-reaching consequences of getting it right (or wrong) during operations in megacities demands not only innovative thinking, fresh doctrine, and multi-disciplinary assessments. Extreme war-gaming must become the norm. The Arizona Market outside Brcko, Bosnia-Herzegovina was a brilliant initiative, reestablishing as it did regional ties with that small city after years of violence had shattered previously longstanding economic links. Yet the immediate benefits gave way to the market's becoming a center of black marketing, fencing high-value products from Western Europe, and trafficking of women.[xxx] Rigorous and frequent war-gaming of possible alternative outcomes linked to intelligence collection regarding market activities should have been required the better to identify factors likely to promote slippage of the facility into illegitimacy. Such failing to actively monitor and analyze events during operations in a megacity could have adverse consequences extending well beyond the immediate region. The implications are once again complex. War games would require robust computer support given the rapid spiraling of second, third, and higher-order effects inherent in any action taken in megacities' innumerable and compacted interrelationships. Those interrelationships (and therefore those effects) will undoubtedly have regional, probably nationwide, and quite possibly worldwide effects. (Consider the global impact of the 9/11 attacks on New York City.) Change may be hard to detect given the constant and varied levels of activity in these megalopolises alluded to earlier. This need to war-game the status quo – what could happen from the situation as it is now – suggests the analysis will have to be nearly continuous. To assume otherwise is to overlook the very real possibility that today's brilliant successes are potentially seeds for tomorrow's disasters. The implications reach into pre-operation preparations: backward planning should begin at an end condition well beyond the re-assumption of governing responsibility by local authorities.

This monitoring and war-gaming assumes an understanding of a megacity's routines and patterns. Determining these patterns and variations therefrom will necessitate data compilation and analysis beyond anything available to coalition leaders today. Sophisticated use of the aforementioned big data, overhead monitoring by long on-station systems, and establishment of and reporting by contacts in local governments (e.g., police, fire personal, building inspectors, and tax collectors to mention only a few) and communities (taxi drivers, delivery personnel, neighborhood watch volunteers, and those manning hospitals) will have to be constant. Those in coalition militaries will be crucial components of this pattern definition. Logistics providers and foot patrols are among those from whom reporting should be frequent and for whom debriefings must be thorough, both of which will be enhanced by assigning these individuals "beats" similar to those of neighborhood policemen to the extent feasible. Those interviewing members of the population will have to be schooled in intelligence tradecraft. Anti-gang squads in Los Angeles, for example, canvas entire neighborhoods or city blocks in order to conceal the identify of the one individual from whom they know information is forthcoming. Robots, security cameras, and other means could provide additional monitoring. Shortages of interpreters can to an extent be overcome via reach-back sessions employing Skype- or Facetime-like connections with language speakers remote from the city itself. Simpler translation needs might be met one or more of the smartphone applications or other software currently available.

The challenges inherent in undertaking operations in a megacity will extend well beyond the sampling of intelligence-related concerns touched on above, instead permeating every military function and many civilian as well. New challenges will be commonplace, adapting lessons from those confronted before a routine necessity. New yes, but little will qualify as revolutionary. The urban-experienced soldier, sailor, marine, and airman will be a valuable asset, as will any who are well-read in the ways of urban operations, megacities, and fields with obviously applicable insights such as the previously mentioned counterinsurgency. Demanding as future megacity contingencies will be, however, innovations and initiative in drawing upon professional education and experiences are sure to provide far more of value than overzealous claims of having discovered a heretofore never seen form of conflict. The observations of both Eran Zohar and General James Mattis provide pertinent closing thoughts in this regard:

> *Wars became hybrid wars.… Being an old tactic practised by armies and guerrilla rebels, the "new" idea of an enemy that "disappears" from the battlefield and wages urban warfare is a fraud…. That rhetoric characterizes an organization that fails to conserve its memory and learn lessons from the past."*[xxxi]
>
> -- Eran Zohar

> *"Israeli military intelligence's understanding of the security environment in light of the Arab Awakening"*
>
> *For all the "4th Generation of War" intellectuals running around today saying that the nature of war has fundamentally changed, the tactics are wholly new, etc., I must respectfully say… "Not really": Alex the Great would not be in the least bit perplexed by the enemy that we face right now in [2013] Iraq, and our leaders going into this fight do their troops a disservice by not studying (studying, vice just reading) the men who have gone before us.*[xxxii]
>
> -- General James Mattis

End Notes

[i] Sharon Ghamari-Tabrizi, *The Worlds of Herman Kahn: The Intuitive Science of Thermonuclear War*, Cambridge, MA: Harvard University Press, 2005, 48-49.

[ii] 21st-century operations and campaigns – those in larger urban areas in particular – demand more than a "coalition" as currently defined in US joint doctrine: "an arrangement between two or more nations for common action." [Joint Chiefs of Staff, Department of Defense Dictionary of Military and Associated Terms, Joint Publication 1-02, Washington, D.C.: Joint Chiefs of Staff, November 8, 2010 as amended through January 15, 2016, 34, **http://www.dtic.mil/doctrine/new_pubs/jp1_02.pdf** (accessed February 3, 2016)] A broader conceptualization is called for: "an ad hoc cooperative arrangement between two or more organizations in the interest of supporting a common action." [Russell W. Glenn, *Band of Brothers or Dysfunctional Family: A Military Perspective on Coalition Challenges During Stability Operations*, Santa Monica, CA: RAND, 2011, 41, **http://www.rand.org/pubs/monographs/MG903.html** (accessed February 3, 2016).]

[iii] That many if not all observations made regarding megacities herein apply to the larger of world's cities with somewhat smaller populations is a given. Westerners' liking for multiples of five and ten should not cause us to limit insights to the serendipitous choice of the ten million mark.

[iv] *Demographia World Urban Areas*, 11th edition, 2015, 2, **http://www.demographia.com/db- worldua.pdf** (accessed January 28, 2016).

[v] Jonathan W. Greenert (Chief of Naval Operations, US Navy), "The World is Dependent Upon the Oceans…," presentation hosted by the Strategic and Defence Studies Centre, The Australian National University, Canberra, Australia, January 8, 2015.

[vi] Statistic for 1965 from Ronan Paddison, ed., *Handbook of Urban Studies*, Thousand Oaks, CA: Sage, 2001, 24. 2015 statistics from *Demographia World Urban Areas*, 11th edition, 2015, 2,

http://www.demographia.com/db-worldua.pdf (accessed January 28, 2016).

[vii] Statistics such as those just cited suffer from these sometimes considerable differences in definition. I will use the following descriptions for urban-related terms in this essay:

"An urban area is best thought of as the 'urban footprint' – the lighted area that can be observed from an airplane (or satellite) on a clear night. National census authorities in Australia, Canada, Denmark, Finland, France, the Netherlands, Norway, Sweden, the United Kingdom and the United States designate urban areas. Except in Australia, the authorities use a minimum urban density definition of 400

persons per square kilometer (or the nearly identical 1,000 per square mile in the United States)…. Urban Areas Contrasted with Metropolitan Areas: An urban area (built-up urban area or urban agglomeration) is fundamentally different from a metropolitan area…. A metropolitan area is a labor market and includes substantial rural (non-urban) territory or area of discontinuous urban development (beyond the developed urban fringe).” *Demographia World Urban Areas*, 11th edition, 2015, 3-4.
[viii] Christopher L. Elliott, *High Command: British Military Leadership in the Iraq and Afghanistan Wars*, Oxford: Oxford University Press, 2015, 151-152.

[ix] 2015 city of Los Angeles population estimate from ”Suburban Stats: Current Los Angeles, California Population, Demographics and stats in 2014 and 2015,” **https://suburbanstats.org/population/california/how-many-people-live-in-los-angeles** (accessed February 2, 2016); Los Angeles urban area population estimate from *Demographia World Urban Areas*, 11th edition, 2015, 35, **http://www.demographia.com/db-worldua.pdf** (accessed January 28, 2016).

[x] William Matthews, “Megacity Warfare: Taking Urban Combat to a Whole New Level,” *Army* (February 12, 2015) **http://www.armymagazine.org/2015/02/12/megacity-warfare-taking-urban-combat-to-a-whole-new-level** (accessed January 3, 2016).

[xi] Carl von Clausewitz, *On War*, ed. Michael Howard and Peter Paret, Princeton, NJ: Princeton University Press, 1976, 419, 420, and 423. (emphasis in original)
[xii] “Paralysed: Urban traffic,” *The Economist* (November 7, 2015), **http://www.economist.com/news/middle-east-and-africa/21677665-why-nigerias-largest-city-even- less-navigable-usual-paralysed** (accessed February 2, 2016).

[xiii] Robert Dixon, “Bringing Big Data to War in Mega-Cities,” *War on the Rocks*, January 19, 2016, **http://warontherocks.com/2016/01/bringing-big-data-to-operations-in-mega-cities/** (accessed January 19, 2016).

[xiv] “Call for help; Ebola and big data,” *The Economist* 413 (October 25, 2014), **http://www.economist.com/news/leaders/21627623-mobile-phone-records-are-invaluable-tool- combat-ebola-they-should-be-made-available** (accessed February 2, 2016).

[xv] “Shrinking the haystack: Counter-terrorism,” *The Economist* 418 (January 16, 2016): 78-79, **http://www.economist.com/news/science-and-technology/21688368-software-helping-search- guerrillas-and-terrorists-safe-houses-and** (accessed January 24, 2016).

[xvi] Justin Jouvenal, “The new way police are surveilling you: Calculating your threat ‘score’,”

The Washington Post (January 10, 2016), **https://www.washingtonpost.com/local/public-safety/the- new-way-police-are-surveilling-you-calculating-your-threat-score/2016/01/10/e42bccac-8e15-11e5-baf4-bdf37355da0c_story.html** (accessed January 14, 2016).

[xvii] Michael Bailey and John Via, "Military Medical Implications of Future Megacity Operations," *Small Wars Journal* (February 13, 2015), **http://www.smallwarsjournal.com/printpdf/21402** (accessed January 3, 2016); Geoffrey York, "Ebola: How Nigeria and Senegal stopped the disease 'dead in its tracks'," *The Globe and* Mail (October 19, 2014, updated October 20, 2014), **http://www.theglobeandmail.com/news/world/ebola-how-to-stop-the-disease-dead-in-its- tracks/article21159394/** (accessed February 2, 2016); and Akintunde Akinleye, "Nigeria isolated Lagos hospital where Ebola victim died," Reuters, July 25, 2014, **http://www.reuters.com/article/us-health- ebola-nigeria-idUSKBN0FX15420140728** (accessed February 2, 2016)..

[xviii] International Federation of the Red Cross and Red Crescent Societies, "Emergency Plan of Action Final Report-Nigeria: Ebola Virus Disease," August 31, 2014, **http://reliefweb.int/sites/reliefweb.int/files/resources/MDRNG017FR.pdf** (accessed February 2, 2016).

[xix] John Tozzi, "How to Avert an Ebola Nightmare: Lessons From Nigeria's Victory, *Business Week* (October 20, 2014), **http://www.bloomberg.com/bw/articles/2014-10-20/ebola-how-nigeria-averted-a- nightmare-in-densely-populated-lagos** (accessed February 2, 2016); and Will Ross, "Ebola crisis: How Nigeria's Dr Adadevoh fought the virus," BBC, (October 20, 2014), **http://www.bbc.com/news/world- africa-29696011** (accessed February 2, 2016).

[xx] Russell W. Glenn, et al., *Honing the Keys to the City: Refining the United States Marine Corps Reconnaissance Force for Urban Ground Combat Operations*, Santa Monica, CA: RAND, 2003, 11-12.

[xxi] Eric Hoffer, *The True Believer*, NY: Time, 1963, 29-30.

[xxii] Christopher L. Elliott, *High Command: British Military Leadership in the Iraq and Afghanistan Wars*, Oxford: Oxford University Press, 2015, 238-39.

[xxiii] During the 2014 Operation Protective Edge in Gaza, for example, IDF soldiers could not find tunnel exits in buildings despite being aware of the general location of the egress points and searching for them extensively, later suffering surprise attacks after Gazans emerged behind Israeli positions. Russell W. Glenn, *Short War in a Perpetual Conflict: Implications of Israel's 2014 Operation Protective Edge for the Australian Army* (draft), 2015, to be published in 2016, 123.

[xxiv] Russell W. Glenn, *Short War in a Perpetual Conflict: Implications of Israel's 2014 Operation Protective Edge for the Australian Army* (draft), 2015, to be published in 2016, 26.

[xxv] For a further discussion of urban densities and their influence on military operations, see Russell W. Glenn, *Heavy Matter: Urban Operations Density of Challenges*, Santa Monica, CA: RAND, 2000.

[xxvi] Joint Chiefs of Staff, *Department of Defense Dictionary of Military and Associated Terms*, Joint Publication 1-02, Washington, D.C.: Joint Chiefs of Staff, November 8, 2010 as amended through January 15, 2016, 145, **http://www.dtic.mil/doctrine/new_pubs/jp1_02.pdf** (accessed February 3, 2016).

[xxvii] Definition from Russell W. Glenn, *Rethinking Western Approaches to Counterinsurgency: Lessons from Post-colonial Conflict*, Abingdon, UK: Routledge, 2015, 270.

[xxviii] Joint Publication 1-02, *Department of Defense Dictionary of Military and Associated Terms*, Washington, D.C.: Joint Chiefs of Staff, November 8, 2010 as amended through January 15, 2016, 34.

[xxix] Russell W. Glenn, *Band of Brothers or Dysfunctional Family? A Military Perspective on Coalition Challenges During Stability Operations*, Santa Monica, CA: RAND, 2011, xiv.

[xxx] Dina Francesca Haynes, "Lessons from Bosnia's Arizona Market: Harm to Women in a Neoliberalized Postconflict Reconstruction Process," *University of Pennsylvania Law Review* 158: 1779, 1781 and 1794-98, **http://scholarship.law.upenn.edu/cgi/viewcontent.cgi?article=1163&context=penn_law_review** (accessed February 3, 2016).

[xxxi] Eran Zohar, "Israeli military intelligence's understanding of the security environment in light of the Arab Awakening," Defence Studies 15:3, 216-17 [complete article 203-234].

[xxxii] Geoffrey Ingersoll, "General James 'Mad Dog' Mattis Email About Being 'Too Busy To Read' Is A Must-Read," Business Insider (May 9, 2013), http://www.businessinsider.com.au/viral-james-mattis- email-reading-marines-2013-5 (accessed January 19, 2016).

Megacity Madness

*By **Gustav Otto & AJ Besik***

Originally published in Small Wars Journal on 8 June 2016

Available online at: http://smallwarsjournal.com/jrnl/art/megacity-madness

Are you in an urban area? Can you look around without seeing anyone? Try talking without being in earshot of someone who can easily overhear your conversation. Try walking side to side, front or back without having to watch out for someone or something. Now imagine the size and frequency of these events, so vast it takes hours to get to a place where you don't have these experiences at every turn. If these all exist you're probably in a megacity. So what is one? No one really knows, and that's a problem. Trying to define a megacity is hard enough, trying to win a decisive action, engage in governance and rule of law, or trying to provide relief? It could be maddening. So what is a megacity? US Supreme Court Justice Potter Stewart is famous for a remark in 1964 about pornography that he knows it if he sees it.1 That mental approach doesn't suffice when thinking of a megacity. More importantly we can't interact with it based on such a shallow understanding. The United Nations arbitrarily defines a megacity as something larger than 10 million people. John Wilmoth, Director of the UN's Department of Economic and Social Affairs (DESA) Population Division rightly states, "Managing urban areas has become one of the most important development challenges of the 21st century. Our success or failure in building sustainable cities will be a major factor in the success of the post-2015 UN development agenda."2 The problem is bigger even than a megacity. It is how to consider one. How does the international community analyze megacities? Reviewing over 400 documents, website and blogs suggests there's no single analytic, comprehensive tool for analyzing this new phenomenon.3 Arguably this is a classic interdisciplinary topic requiring a complex framework for analysis and evaluation, and ripe for innovation and creativity (design thinking).

The paper outlines a few ways to think about and analyze a megacity and make recommendations to prepare for operations in such an environment. The recommendations herein could not all encompassing, and likely never will be. It is an introduction by which a person or organization may consider the myriad of issues regarding a megacity, that when combined become vexing if not a wicked problem. But these problems are not insurmountable, nor impossible to operate in successfully.

Cities are often thought of as systems of systems. Utilizing this framework to conceptualize the issues in a megacity then allows the application of previous ideas that have been proven.

Problems may arise when the sheer scale of a megacity's issues come into play. This is where design thinking and generating multiple options rapidly allow for these issues of scale to be addressed, and thus be useful in the context of a megacity. We have lived and worked in some of these megacities, and watch with great interest the growing number of megacities around the world. There are a number of trends driving and driven by their growth. Among the two greatest are the draw of urbanization and the increase in globalization. They are complimentary, not exclusive. They are not the only reasons for their growth either. The growth of urbanization is recognized by authors as wide ranging as Thomas P. Barnett, author of The Pentagon's New Map, to the Christian Science Monitor or Forbes, to global consultants such Accenture, Deloitte and Frost & Sullivan and McKinsey & Company. Each of these has a different vantage point, and each is moving towards a more comprehensive consideration of this challenging discussion on megacities.

The term megacities itself is problematic. While an accepted benchmark, it fails to account for other factors including the sophistication of infrastructure or transient populations. Some cities are categorized as a megacity by outside organizations but not by their own municipal governments. Some are megacities, no matter what we call them, or if there's disagreement.

They present a rich, urban and dense location filled with endless challenges and opportunities for engagement, partnership, and profit. Therefore, accepting definitions of a city and a megacity differ is of little import. This paper seeks to look at a megacity as one might a computer – the combination of software, hardware and what the outcomes are. In the case of a megacity, the hardware may be the physical, the plants and facilities, the roads, electric and plumbing, the buildings, trains and tunnels. The software is what travels over, to and through the physical, and may include information or data, energy, even people. Finally the outcomes, the humanistic realities others will have to recognize, deal with, and live by.

The hardware/software/outcomes framework of analysis for these urban areas is intentionally oversimplified because it lends itself to a set of parallel measurements allowing for improved analysis and evaluation with every iteration. Over the last two decades it seems the international community, scholarly and otherwise, settled on the number of 10 million. There's little good argument for this number. Rather it appears arbitrary with little rationale tied to it. It is important to recognize 10 million offers no additional value other than a fictitious threshold.

Does a city with 9.5 million behave in much the way one with 14 million? Yes. Size matters, but so do issues like population density and scale.

A recent example might be the impact the Zika virus is playing in and around the megacity of Sao Paulo. As we saw the reeling of the community to the sharp incline of microcephaly there were questions about its origin, its spread, its containment and the human impacts around the region and the globe. Some indicators suggest it was visitors to Sao Paulo for the 2014 World Cup games who brought the virus to the region, and fears by the International Community it will not be contained in time for the 2016 Olympics. Treatment of the virus, treatment of the mosquito and its vectors, and treatment of its victims vary, and there remains no cure.

Quarantine of Sao Paulo is next to impossible. Full scale assault by the International Community, along with armies of aid and health workers wouldn't solve the problem. How can we think of dealing with calamities such as this in a megacity?

Any operations normally conducted in a city will obviously occur in a megacity. Indeed, many such cities already have effective, established measures to continue with the day to day actions that those governments conduct. The likelihood of US forces of any type operating in such an environment is very high, including cities inside our own borders. According to the National Intelligence Council (NIC), by 2030 individuals will see a substantial increase in autonomy and prosperity. There's a growing notion that megacities are becoming their own little sovereign nations. The growth of the global population, especially in urban areas, will lead to a majority of the world's population residing in cities where more economic and education opportunities exist. This urbanization will lead to a middle-class that is the "most important social and economic sector in the vast majority of countries around the world." With better access to education, affordable health care, and sources of information, the individual will be the driving force behind global change. This change may take on the form of renewed economic growth in historically poor regions of the world or allow super-empowered people to challenge the security apparatus and governmental legitimacy. These areas are then fraught with the potential for emergencies, man-made or natural. Situations such as this can be seen emerging in some areas of the world.

Situations that appear similar to those the US has previously operated in successfully. Urban Combat, Humanitarian Assistance, Stability Operations, all have been conducted by US Government agencies within the last decade. Scale however rudely interrupts the best-laid plans. These aren't necessarily new problems, just ones that planners may have believed solved previously. Need to bring water and food into a city that has suffered a naturally disaster? This has happened on countless occasions around the globe, both with US and international involvement. However what if the standard methods of bringing in supplies aren't feasible due to problems of sheer physics? If the normal seaport is closed and supplies must be trucked in but there are so many people to accommodate there is not enough physical space to park said trucks without clogging the supply routes. Issues that will compound when alternative remedies aren't available or don't meet the need in aggregate. So what kinds of analysis might prove useful in such an area? The list is long, and for the purposes of demonstration we offer only a few in the following paragraphs.

We're well served to think about communications and data and their growing importance to governance, awareness and human interaction. Consider well-developed megacities first. From London, to Seoul to Los Angeles, the physical infrastructure is governed by information. On the hardware front, information flows over copper wires, the airwaves and fiber-optics to keep things running smoothly. On the software front, data drives trains, planes and automobiles. On the outcomes front it cools towering high-rises so employees are more productive and computers don't break down, and warms delivery rooms for babies. The importance of the human in the loop is greater in developing megacities, but is ***the primary factor*** in all these systems. The presence of a functional technocracy keeps poor systems working. When these fragile systems are compromised the role of the technocrat becomes more apparent. Data isn't just important to the hard systems, they play a role in governance, especially during crises. How this data is developed, transmitted, consumed, etc, is more critical in a megacity than normal urban settings.

Another critical aspect to consider when analyzing any city is the population – as mentioned the primary human factor. This seems obvious, yet an in-depth understanding of populations is not always part of preparation. It is this fact that continues to vex US National Security Strategists in places like Iraq, Afghanistan, Syria and beyond. Cities exist to house, employ, and even contain human beings. The movement of people; their backgrounds, sociologies, education, ethnicity, gender and race; the culture(s) of the people living there; how these people choose to associate governance and politics; the work and social patterns of these people; the resultant rules and laws that are applied; how those rules and laws are upheld (or not); the services required for the people; and finally the tensions that exist, naturally, are all to be considered. Each of these could be layered in our conceptualization across four dimensions (three physical plus time = 4D = 3D + t). Unfortunately, there is little, perhaps no homogeneity or uniformity in these layers.

To suggest we could just label each like a sheet of paper, and lay them atop each other is naïve and misleading. It is important to stress the way these layers interact across and with each other, though not in a linear fashion. The alluded to human factor plays out on various stages, from the electromagnetic to the physical. In some cases those two above ideas of information and human landscape fuse as observed in the proliferation of social media. Decades ago, the Marine Corps had the foresight to describe the strategic corporal.4 While not a perfect analog, the idea is well founded, that individual actions can reverberate and cause problems far beyond the scope of the original intent. When thought of in the nineties the concept brought attention to the idea that the action of an individual operating at a low level can be perceived various ways when transmitted through modern media and lead to unintended strategic consequences. More simply, when attempting to engage one person the effects can be felt by millions. Often times this can be negative, as perceptions can be manipulated or capitalized on by various factions. This idea takes on a new significance when the millions of people that may have acquired a negative view of your operations are not found around the globe, but within ten miles of your operating space.

These kinds of effects were observed during the Arab Spring in 2011, when social media enabled mobilization on a scale that superseded the capabilities of the government to react.5 Conversely, this could prove to be positive if leveraged properly. Imagine that when responding to a crisis that the local population actually becomes some of the best publicity as images of first responders handing out food or the removal of a particularly unsavory local character goes viral. This was present in nascent form on September 11, 2001 when the first responders of New York's emergency services became instant celebrities and people from Europe to Asia bought NYPD or FDNY tee shirts. This reality must be taken into account as technology only makes the capability easier. As observed by several police departments, anytime an officer stops for any reason, a camera is present, or should be assumed to be.6 This must also be present in the preparation military or other groups' conduct prior to operating in such urban sprawls.

So what can the US Government, the US Intelligence Community, and the Department of Defense, among others do to enhance the understanding of megacities? It must seek to resolve situations before they become problems. To accomplish that goal, members of those organizations need to be able to assess situations through frameworks that have not been the historical norm for the defense or intelligence communities. As with most problems, training and education are critical; a different mindset about solution development and employment, and less emphasis on fighting wars and more on avoiding them.

Training must instill an understanding of the challenges that will be encountered. Soldiers, intelligence operatives, a new breed of first responders, all should have an understanding of the megacity characteristics that may affect their operations. All must become comfortable operating in an area where they are likely to interact with the local population in any number of ways. Participating in multiple iterations of training is the underlying principle. Three broad areas, combining emergent technology and principles, come to mind that will enhance proper understanding through training.

1. *Virtual Reality (VR).* The benefits of this technology are often improperly communicated. It is not a substitute for live training. It is a platform that can be leveraged to conduct iterative training. The US doesn't have a range or live-practice area where it can employ new concepts for engagement in a megacity. Therefore, well-crafted VR offers a way to work at an individual to group size level across the four dimensions of a megacity, with an appreciation of the hardware/software/outcome framework. Virtual Reality doesn't have to be cost prohibitive, it includes more than the idea of someone wearing goggles projecting images directly to their optical sensors. It can also involve systems younger operators are intimately familiar with, gaming platforms or computers. The base from which ideas for training are culled from must be expanded. Utilizing scenarios presented in media formats that would normally be viewed as skeptical (e.g. fiction) need to be considered. It is only through thinking in broad scope and considering possibilities however unpalatable that personnel will push their frameworks for understanding forward, even if the problems remain mundane in reality.

2. *Specialization*. New specialties that deal with the realities of urban infrastructure and populations are essential. Perhaps a pilot group of professionals from Special Operations Forces (SOF) could work with members of the State Department's Conflict and Stabilization Operations (CSO), and select member of the Intelligence Community to develop or cross-functional tactics, techniques and practices to deal with uncertain scenarios before they become problems. These aren't normally areas that operators are trained in, certainly not military forces. Using new frameworks will allow the military to work better across a whole-of-government construct, and in this likely absence be more effective at advancing non-escalating solutions in a megacity environment. Further, an education component should be developed where select members of the USG are trained specifically on these types of situations. These personnel would then be tracked while in government service and on stand- by to advise various organizations who are confronted or confounded by a particular megacity. The education would include living and working in a megacity, deep exploration and evaluation of the hardware/software/outcomes framework and the thinking therein. These are often called broadening assignments by the military and have not yet fully matured. Indeed it can be argued that despite the emphasis placed

on them by some senior leaders, they are still not considered advantageous for personnel to participate in. This needs to change if there is going to be an expectation that defense professionals understand the various systems that may be encountered in megacities. It could lead to urban planning education tracks as the solutions are tested and approved over the next several decades.

3. *Practice*. As with any endeavor, practice gives confidence to those that will conduct operations. Whether in small teams and coordinated live exercises in the future, in VR scenarios, or on tabletop exercises designed for failure, not success, practice is essential. The idea is to reinforce the necessity to conduct multiple iterations. This could be possible with physical training, either in Department of Defense owned bases that are nearly abandoned or in economically depressed cities. These costs may prove prohibitive, which is where Virtual Reality may prove a better avenue. However it is enabled, multiple iterations will force trainees to thinkof different ways to overcome situations. This can be said of most any endeavor. The key to training for megacity operations will be to emphasize how to think of the various systems present. Easy to understand, easy to access templates can be established, ***not***standards, for megacity challenges. Templates that convey understanding, not just lists, that explain why industrial or residential areas developed in a certain way in a geographic region. While no two cities have identical circumstances, there are well researched means of understanding the geographic layout based on history and resources. Why not more lists and standards? Standards are too static, and fail to allow for the flexibility required in a dynamic setting like a megacity. Part of the practice, building from the previous paragraph, would find a select group of US Government employees, and possibly service personnel "stationed" in megacities, working with the Nation State, the city governance councils, industry and the USG to learn more lessons, map out functions and add to the depth of understanding available on this complex topic.

Next steps? Do you buy these arguments? Along the way you were thinking, "I've never been to a megacity, and these guys are crazy". Maybe you grew up in Delhi, Tokyo or New York, and you think "these guys are mad". You're right. The thing is, megacities are hard, issues and problems compound over things that were solvable in other environments. They as difficult a challenge to plan for than anything the US Government has tackled previously. Of course, if you believe, as we do, that megacities may quickly resemble mini-countries, that you just need to change your thinking, you're also right. What we want to demonstrate is the importance of talking about them. The importance of understanding a megacity, and that they are more than a scale issue is critical. Our culture and our minds are designed to limit choices, and when we're overwhelmed with data we tend to freeze. The time for this analysis paralysis is over, the time for movement and flexibility is here. A hardware/software/outcome framework is part of the solution, but it is only a small part. A paper ten times this size will start to introduce the many factors each of these three criteria could consider. Even then, much work is left to do. As Andre Guide said "There are very few monsters who warrant the fear we have of them." We needn't fear megacities, we must start working hard to sort them though.

The views expressed in this article are of the authors, and do not necessarily reflect the view of the Department of Defense, the Defense Intelligence Agency, the U.S. Army, or any other agency of the Federal Government.

End Notes

1 Justice Potter Stewart's concurring opinion in *Jacobellis v. Ohio* 378 U.S. 184 (1964).
2 UN Economic and Social Affairs Press release July 10, 2014. Accessed February 8, 2016 at esa.un.org/unpd/wup/Publications/Files/WUP2014-PressRelease.pdf

3 Collating the research materials and sources of the US Army Chief of Staff Strategic Studies Group white papers "Megacities and the United States Army", June, 2014 and "Readiness in an Urban Era," May 2015.

4 General Charles C. Krulak, "The Strategic Corporal: Leadership in the Three Block War," *Marines Magazine*, January 1999.

5 Taylor Dewey, et al. "The Impact of Social Media on Social Unrest in the Arab Spring" (Paper presented at Stanford University, March 20, 2012) 17-91.

6 Author's Notes from "Readiness in an Urban Era," US Army School of Advanced Military Studies Lyceum White Paper, May 2015.

Operational Environment Implications of the Megacity to the US Army

By ***Darryl Ward***

Originally published in Small Wars Journal on 9 February 2016

Available online at: http://smallwarsjournal.com/jrnl/art/operational-environment-implications-of-the-megacity-to-the-us-army

Megacity Defined

The United Nations (UN) and the United States National Intelligence Council (NIC) define the megacity as a metropolitan area whose population exceeds 10 million people. While other definitions exist, this is the definition used as the basis for understanding future impacts of megacities to US Army operations. Depending on the statistical reference, there are between 23 and 30 megacities in the world. Statistical numbers vary primarily due to different interpretations of metropolitan limits and surrounding areas.

However, regardless of how megacities are quantified, trends within the global operational environment (herein referred as the “OE”) indicate that the number of urban areas will continue to rise. **[i]**

Global Drivers and Trends

In order to predict future impacts of megacities to the US Army, the global drivers and trends leading to megacity development must be identified. Drivers (as defined for this paper) are forces that always exist, such as demographics (people), natural resources (water, oil, land), and globalization (interconnectivity). Drivers constantly impact the OE.

Drivers are impacted by trends, which have life cycles with associated impacts on drivers. Trends are constantly analyzed in terms of their impacts to drivers. This article is not all inclusive but highlights some trend-driven impacts on drivers and resulting potential for involvement of the US Army across the range of military operations.

Demographics

Progressive ideologies; war; youth population bulges; unemployment; climate change; and scarcity of food, water, and medicine are among the reasons that human migration to urban areas is a trend expected to continue for several decades. The UN estimates that approximately 180,000 people move into urban areas every day and the Defense Intelligence Agency (DIA) estimates that 60 percent of the world’s population will live in cities by 2030.**[ii]** This constant influx of population is certain to stress megacity infrastructures, resulting in the potential for certain population groups to perceive disenfranchisement and leading to US Army military urban engagement in cooperation with host nation forces.

Demographic trends can greatly affect political decisions in countries striving to continue economic growth, maintain a military, generate tax revenue, and maintain alliances. Among demographic trends, the NIC estimates that by 2030 the world will have contracted from 80 to 50 countries whose populations will have a medium age of 25 years or less. Most countries maintaining a youth bulge are located in Sub-Saharan Africa, the Middle East, and in South and Central Asia.[iii] Those countries without a youth bulge in 2039 are located in Eastern Asia, North America, and Europe. In fact, the DIA estimates that by 2050 the most prevalent age group in Europe will be in the 55-69 year old category.[iv]

Natural Resources

Megacities are susceptible to natural and manmade disasters due to their physical proximity to large bodies of water. All of the top ten megacities fall into this category and eight of the ten are on a coast. Furthermore, the UN estimates that over 50 percent of the world's population lives within 120 miles of a coast.[v] Indeed, water near population centers has always been necessary for commerce, food, sanitation, etc. However, extreme water events caused by floods, hurricanes, typhoons, and tsunamis exacerbate life threatening situations in areas of increased urbanization. The US Army is likely to experience an increase in crisis response operations requiring foreign humanitarian assistance in large-scale urban environments.

Another complication megacities present is vertical growth. This is especially true in cities along coastlines, where expansion is naturally inhibited. Design and development of high-rise cities could lead to greatly compromised military operations in urban settings where the effectiveness of precision guided munitions; elevation of weapon systems; and intelligence, surveillance, and reconnaissance (ISR) collection platforms are limited.

Globalization

Globalization as a driver creates OE interconnectivity. As societies become more connected, events unfolding in one area of the world are communicated and affect other areas. Some examples of potential manifestations of globalization and demographic interaction include:

- An increasing influx of Middle Eastern and African youth into Europe. Many of these migrants arrive without a formal education and are unemployed.
- Countries such as China wanting to attract migrants from low income countries to supplement its declining youthful workforce in order to sustain its

economy.

The NIC forecasts that the need to support economic growth combined with the lack of opportunities in areas of the world that maintain a youth bulge will create even faster demographic shifts than those that occurred in the last quarter of the 20th century. [vi] A huge migrant influx into megacities and urban areas in general has the potential for increased xenophobic feelings and conversely, perceived inequities may lead to violence and acts of terrorism as the world has already witnessed in megacities such as London and Paris. A question to consider is, at what point do states begin to enculturate the character/culture of rapidly increasing ethnic minorities?

A PMESII-PT Megacity Analysis

The following is an analysis of some of the trends affecting drivers from the perspective of the US Army doctrinal taxonomy of PMESII-PT. It is intended to articulate how these trends might affect or involve the US Army, but is not a detailed PMESII-PT megacity analysis.

Political: Futurist Thomas Frey notes that democracy could be viewed as an inferior form of government by 2030.[vii] In fact, a number of megacities or large urban areas are located in democracies with a high risk of failure due to religious extremism or other trends. Even in states where democracy is not threatened, it is important to consider that disenfranchised populations often harbor feelings of deprived rights and may tend to incite violence as a means to force political change. For instance, megacity gangs taking this approach could stress already taxed law enforcement to the point where the US military would be requested to provide foreign security assistance.

Military: An ever-narrowing gap between military capabilities, organization, and influence (due in part to globalization) is increasingly blurring distinctions between regular and conventional forces, irregular forces, and insurgents. When criminal elements are considered, a “hybrid threat” as defined in Army Doctrinal Reference Publication 1-02 emerges. While the term “hybrid threat” is relatively new, the concept behind it is not. There are many examples in military history of groups with military capabilities that unite either formally or informally to achieve a mutually desired outcome.

Hybrid threats (threats) seek ways to counter perceived strengths of their adversary. US Army military strengths such as situational awareness through mission command systems and ISR platforms, precision guided munitions (PGM), and protection/lethality provided by armored fighting vehicles (AFVs) afford the advantage to see, know, and act decisively. Threats study these advantages and deduct their own lessons learned. For instance, drawing US forces into urban areas compromises our technological advantages. Megacity congestion limits movement and predictable movement corridors will make the US Army susceptible to improvised explosive devices (IED), explosive formed projectiles, and an array of dual-warhead antitank (AT) missiles and rocket propelled grenades (RPGs). A recent RAND Corporation study "Comparing US Army Systems with Foreign Counterparts" noted the increasing weight in AFVs to protect against IEDs and other urban combat threats. Added weight, due to reactive armor, urban survival kits, and other protective enhancements affects vehicle dimensions and power train transfer. In an urban setting, conditions such as bridge classifications or road widths may prohibit where AFVs can travel as well as reduce AFV performance (vehicle power requirements vs. weight). The US Army must balance protection requirements while maintaining mobility.

Weight issues also apply to urban conflicts involving light infantry. The RAND report also noted the increasing loads that infantrymen are required to carry. One hundred pounds or more was cited as common practice.[viii]

Threats are subject to some of the same challenges. However, the OE will affect the threat much differently than it does the US Army. It is highly possible that initial US Army entry into a megacity and/or urban area will be expeditionary in nature and opposed by the threat. Operations will be primarily offensive and lines of communication (LOCs) will be under development. In addition, LOCs will be under the same scrutiny of predictability by the threat and hence subject to interdiction. Therefore, US Soldiers will be required to carry additional supplies (ammo, batteries, night vision, water, etc.) that at least initially threats will not face the same burden. When superior US military forces enter, threats will adapt to defensive operations while maintaining limited offensive actions such as raids and ambushes. Therefore, while threats still have logistical requirements, they have advantages in that they can cache supplies, do not need to carry loads similar to US infantrymen, and enjoy (at least initially) more mature LOCs.

Economics: The lure to megacities and urban areas because of employment opportunities is a trend that is likely to continue through 2030, especially for economies that are developing or want to sustain growth.
The NIC cites not only current economic leaders (e.g., China, Europe, or Japan) but also developing economies such as Columbia, Indonesia, Nigeria, and others are becoming increasingly important to the global economy. As previously mentioned, a number of established economies are challenged because an aging workforce may look to migrants from low income countries to replace labor needs. This could lead to megaslums if local economies and infrastructures cannot react in concert with the rapid influx of migrants. Slums tend to exacerbate disenfranchisement and lead to

conflict. Strategist and counterinsurgency expert David Kilcullen writes in *Out of The Mountains: The Coming Age of the Urban Guerrilla* that it is time to take what we have learned from the war in Afghanistan and think how it applies to future conflicts consisting of "…urban, networked, guerrilla warfare occurring in megaslums and megacities." [ix]

Social: The UN estimates that 180,000 people migrate to urban areas daily. The cities and megacities of Brazil, China, Democratic Republic of Congo, India, Indonesia, Mexico, Nigeria, Pakistan, Philippines, and the US are forecasted to make up approximately 60 percent of the global urban growth through 2030. [x] Diaspora from youth bulging countries bring their cultures, ideologies, and most important, expectations. However, increasing migration to urban areas could at least, initially result in the expansion of slums and the materialization of acute poverty. A rapid increase in minorities could erode social fabric and lead to violent friction and the potential for overwhelming state security force capabilities. This could lead to generating domestic and international requests for the US Army to provide military engagement, security cooperation, and deterrence.

Infrastructure: In addition to employment opportunities, another major contributor to urban growth is the need for food, fresh water, housing, and energy. Megacities and large urban areas in general have infrastructures to provide these life supporting necessities. However, the NIC estimates that the demand for food, water, and energy will increase by 35, 40 and 50 percent respectively over the next 40 years and that housing demand will equal the entire volume of construction worldwide to date.[xi] These figures are staggering and will surely stress infrastructure capacities. The effort to meet demands could result in poor construction quality, gridlocked transportation networks, and utility service failures. In addition, the fact that most megacities are located along coasts restricts horizontal development. Vertical development is more vulnerable to natural (earthquakes, tsunamis, typhoons, etc.) and man-made disasters. US Army assistance for civil support and civil-military operations may be in greater demand than ever before.

Information: Urban areas tend to have the most mature radio, television, and cellular networks. Information can be passed by the adversary using a variety of means with almost instantaneous results. High rise buildings afford nearly unobstructed signals for jamming of US PGM and unmanned ISR platforms therefore reducing US military technological advantages.

Physical terrain: Urban settings are dominated by buildings and roads that develop predictable man- made mobility corridors. Buildings can both impede and improve observation. High rise buildings provide both commanding observation and concealment for individually operated anti-tank launchers. They also create elevation issues for AFV weapon systems targeting such threats while serving as obstacles to acquiring aerial ISR platforms. Urban settings also have mature sub-surface structures such as sewer, drainage, and subway transit systems. Underground mobility is an important aspect of urban warfare. The use of existing subterranean features and tunneling can create elaborate defensive networks. Hence, megacity physical terrains present three-dimensional threat challenges to the US Army in that threats may occur simultaneously above, at, and below surface levels.

Time: It is assumed that potential US adversaries have developed operational plans that involve adaptive operations within urban settings. The use of urban terrain by militarily inferior opponents against superior opponents has been exercised throughout military history. Chechen tactics against the Russian military [xii] and Hezbollah's defense[xiii] against the Israeli Defense Force are recent examples of how urban terrain is used to engage and prolong conflict while using information operations to generate world opinion. Potential adversaries understand that the US has transitioned to primarily an expeditionary force, which could at least initially favor the adversary. Future adversaries do not need to win; they just need to avoid losing to force a stalemate.

Replicating Future Complexities at US Army Training Centers

What emerging technologies and capabilities should the US Army consider replicating in live, constructive, and virtual (LVC) training environments in order to realistically represent OE complexities?

Physical destruction in urban areas will further degrade the infrastructure and alter perception of non- combatants once supportive of US forces. Therefore, we must place more emphasis on employment of non-lethal weapons for more affective riot control and against military targets. Various types of stun guns, mood-altering gasses, and other temporarily incapacitating capabilities are needed to train for military engagement, security cooperation, and deterrence.

In addition, constructive and virtual gaming simulations must accurately reflect munitions effects ranging from small arms to artillery on different types of buildings and also reflect physical properties of how these buildings are constructed. The current multi-integrated laser equipment system (MILES) is ill-suited for registering effects in urban terrain. We need MILES to reflect partial and catastrophic destruction inflicted on buildings by both US and threat weapon systems. We also need improved personnel and equipment MILES that factor material used for cover in the probability of hit/probability of kill codes.

We must be able to see-through urban environments. We need ultrasound and xray technology that permits squad level US Soldiers to penetrate walls and below the surface in order to acquire adversarial information.

Dual warhead AT missiles and RPGs also pose a real threat to US Army AFVs. AFVs need the ability to automatically acquire, track, and launch countermeasures to neutralize and/or defeat these weapons.

Urban settings (physical structures, subterranean, population, etc.), reduce US stand-off weapon and ISR superiority, requiring close in combat to identify friendly vs. foe. Robotic platforms that serve a multitude of functions such as the ability to acquire, assimilate, and transmit biometric data and serve as weapon platforms are needed to offset the challenges presented by urban environments.

Conclusion

History shows it is difficult to predict with clarity what future conflict will look like. However, drivers and their trends analyzed through the lens of PMESII-PT lend some form of credence as to what future challenges megacities pose to the US Army. As such, the US Army must continue to prepare its training centers for replicating urban settings by establishing LVC training conditions that include the aforementioned emerging technologies and capabilities.

Credits

Out of The Mountains: The Coming Age of the Urban Guerrilla, Dr. David Kilcullen. (Oxford University Press, 2013)

Dramatic Predictions, Mr. Thomas Frey: **http://www.wfs.org/blogs/thomas-frey/33-dramatic- predictions-for-2030**

DIA: Long Range Futures Brief, Mr. Jesse Fairall (Defense Intelligence Agency, 29 July 2015)

UN Atlas of the Oceans, Human Settlements on the Coast: **http://www.oceansatlas.org**

RAND Research Report: Comparing US Army Systems with Foreign Counterparts, John Gordon IV, John Matsumura, Anthony Atler, Scott Boston, Matthew Boyer, Natasha Lander, Todd Nichols (RAND Corporation, 2015)

Global Trends 2030: Alternative Worlds, (National Intelligence Council, December 2012)

Fangs of the Lone Wolf: Chechen Tactics in the Russian-Chechen Wars 1994-2009, Mr. Dodge Billingsley and Mr. Lester Grau. (Combat Films and Research, 2012)

CALL Newsletter 11-34 Preparing for Hybrid Threats: Improving Force Preparation for Irregular Warfare, Mr. William Fleser (Center for Army Lessons Learned, June 2011)

End Notes

[i] NIC

[ii] DIA

[iii] NIC

[iv] DIA

[v] UN Atlas

[vi] NIC

[vii]Frey

[viii]RAND
[ix] Kilcullen
[x] NIC

[xi] NIC

[xii] Billingsley, Grau

[xiii] Fleser

Qualitative Analysis Concept in Support of Force 2025 and Beyond (F2025B) Maneuvers

*By **John Hoven and Joel Lawton***

Originally published in Small Wars Journal on 14 July 2015

Available online at: http://smallwarsjournal.com/jrnl/art/qualitative-analysis-concept-in-support-of-force-2025-and-beyond-f2025b-maneuvers

The use of qualitative analysis within the Army intelligence community can help remedy certain capability gaps in obtaining locally nuanced information. Reliance on quantitative driven surveys and methods such as PMESII-PT (Political, Military, Economic, Social, Infrastructure, Information, Physical Environment, and Time) and ASCOPE (Area, Structures, Capabilities, Organizations, People, and Events) questionnaires for understanding tactical information works largely from a hypothesis-driven approach which can ignore pertinent information (e.g., unknown-unknowns). Army Learning Concepts and their associated Army Warfighting Challenges (AWfC), used to analyze future requirements, present an opportunity to test a new approach for developing localized “situational understanding” (an objective of the AWfC framework). This paper will explore how *qualitative analysis can be used within the AWfC concept framework to support situational understanding leading to actionable intelligence.*

Army Campaign of Learning

Each year the U.S. Army conducts a Campaign of Learning to help model Army concepts that may lead to capabilities or support acquisition efforts corresponding to a projected strategic environment (SE), operational environments (OE), and subordinate areas of responsibility (AOR). Learning Campaigns include “studies, science and technology, seminars, wargames, experiments, and live exercises.”[i]US Army Training and Doctrine Command (TRADOC) Pamphlet 525-8-2, the Army’s overarching guide to 2015’s campaign objectives states that its purpose is to describe "an Army learning model that meets the All-Volunteer Army’s need to develop adaptive, thinking Soldiers and leaders capable of meeting the challenges of operational adaptability in an era of persistent conflict.”[ii] Learning Concepts are largely derived from definitions of the SE by national or service specific documents that may include: The National Intelligence Council’s *Global Trends 2030: Alternative Worlds,* The US Army’s Operating Concept *Win in a Complex World,* and US Army Training and Doctrine Command’s (TRADOC) *Operational Environments to 2028: The Strategic Environment for Unified Land Operations.*

During successive learning campaigns, the Army identifies broad functional areas needed to maintain a decisive advantage in the future SE. These functional areas are supported and defined by AWfCs and are given a proponent Army Center of Excellence or directorate to advance the development of concepts or capabilities based on their respective mission or utility. AWfCs are identified gaps in current Army capabilities that must be addressed to improve chances of success in future conflict. The current AWfCs are modeled to support the generating and operational force of 2025 and beyond (or F2025B). The 2015-2016 AWfCs that the Army is using to develop concepts include some 20 "first-order problem" areas[iii]: Develop Situational Understanding; Shape the Security Environment; Provide Security Force Assistance; Adapt the Institutional Army; Counter WMD; Homeland Operations; Conduct Space and Cyber Electromagnetic Operations and Maintain Communications; Enhance Training; Improve Soldier, Leader, and Team Performance; Develop Agile and Adaptive Leaders; Conduct Air-Ground Reconnaissance; Conduct Entry Operations; Conduct Wide Area Security; Ensure Interoperability and Operate in a Joint, Interagency, Intergovernmental, and Multinational Environment; Conduct Combined Arms Maneuver; Set the Theater, Sustain Operations, and Maintain Freedom of Movement; Integrate Fires; Deliver Fires; Exercise Mission Command, and Develop Capable Formations.[iv]

The use of qualitative analysis within the Army intelligence community may fit several of the ascribed AWfCs. The first AWfC, *Develop Situational Understanding*, however seems best suited to benefit from the methods and implicit value of qualitative analysis. Qualitative methods certainly have application throughout all military command echelons, but the relevance of its uses is especially striking for gaining tactical (i.e., battalion and below operations) "situational understanding."

Tactical Qualitative Analysis support to AWfC #1

Warfighting Challenge #1 seeks to develop concepts to mitigate the operational gap of: "How to develop and sustain a high degree of situational understanding while operating in complex environments against determined, adaptive enemy organizations."[v] AWfC #1 is assigned to the Intelligence Center of Excellence (ICoE) as the "lead" proponent and Special Operations Center of Excellence (SOCoE) and the Army Capabilities Integration Center's (ARCIC) Human Dimension (HD) Task Force as "support" to develop learning demands (i.e., essentials used to define and develop the AWfC) or concepts that can mitigate the gap identified.[vi] The employment of qualitative analysis for use in the tactical environment can be nested within AWfC's requirement itself: "Develop and sustain a high degree of situational understanding." The unique advantage to qualitative methods is its ability to overcome shortfalls in understanding complex environments through *causal inference in one-of-a-kind situations (sample size of one)* and *discovering answers* *to questions we are too clueless to ask.*

The ability of the Soldier to garner sensitive, locally-nuanced, and actionable information will hinge on the ability to adapt to ever changing environmental and social variables. The use of rigid questionnaires, structured interviews, and the impractical employment of probability sampling in an austere environment largely does not provide accurate or actionable information.

Many factors that military leaders need to address can only be understood by seeking “more depth but on a narrower range of issues than people do in normal conversations.”[vii] Quantitative methods aided through the use of computer processing can analyze massive amounts of data, but key factors are often unmeasurable. Current frameworks used by the Joint community, such as PMESII-PT and ASCOPE variables, to define the operational environment have value, but largely work from a deductive approach. Inductive reasoning as well as abductive reasoning (i.e., causal inference leading to a hypothesis) allow the collector or analyst to “think about observations, methods, and theories that nurtures theory formation without locking it into predefined conceptual boxes.”[viii]

Qualitative methods can support current frameworks, like those mentioned above, but gleam new insights and a deeper understanding of factors that influence people or affect stability. In order to accomplish this, intelligence specialists and those immersed in a tactical environment must be able to engage populations through conversation and develop follow-up questions that probe at new and undiscovered topics. Instead of asking questions from a preformatted list, Soldiers will be encouraged to ask questions on the spot based on their personal experiences, knowledge of the area, non-verbal cues, and environmental and circumstantial evidence. Rather than having a hypothesis and testing it through deductive methods, Soldiers would be encouraged to discover issues and topics without adhering to formatted or standardized question sets. This is not to say that Soldiers will be expected to completely engage people impromptu, but will be expected to go beyond simply adhering to the narrative of their questions. Current information sources such as PMESII-PT can help the collector with starter questions, but the collector will have the flexibility and means to branch out from basic fact-finding questions to discover new information.

In contrast, Army Field Manual, *Soldier Surveillance and Reconnaissance: Fundamentals of Tactical Information Collection,* states, "Ask only basic questions as described in this section."[ix] This severely impairs Soldiers’ ability to examine and discover locally nuanced information, as the manual intends: "Interaction with the local populace enables Soldiers to obtain information of immediate value through conversation."[x] A more effective way would be for interviews, conducted by Soldiers, to use probing and follow-up questions, and then reassess. After an initial reassessment of information collected during the opening round of questioning, new themes may emerge leading to follow-on questions to make causal inferences between the interviewee and a topic of interest. Ergo, "This is what we've learned, this is what we need to learn next, talk to these kinds of people, here are some starter questions to steer the conversation in the right direction." These methods allow for the collection of richly detailed, context- specific information rather than database variables, and collection and analysis work hand in hand rather than as separate endeavors.

Qualitative analysis uniquely supports collection efforts where a problem set may be ill-defined or little is known about an AOR. Qualitative analysis starts with unknown-unknowns, where there is no hypothesis to test. In contrast, most intelligence collection starts with a full set of alternative competing hypotheses. Starting with a hypothesis can be exemplified with collection efforts related to priority information requirements (PIR). Commanders will establish PIRs as a way to "identify a specific fact, event, activity (or absence thereof) which can be collected."**[xi]** PIRs support understood problem sets and help to identify, articulate, or validate our perceptions or concepts of the OE. Alternatively, qualitative analysis, using abductive reasoning, expects the unexpected (unknown-unknowns). Thus, if a problem set is not understood or poorly defined, the goal of qualitative analysis is to describe the problem or present enough information that makes the problem set a known-unknown (where a hypothesis can be tested). Qualitative analysis does not usually articulate hypotheses at the start of a collection effort, when so little is known. As when our understanding is so frail, one interview is enough (*sample size of one*) to find what we are looking at (i.e., the initial problem set) may be wrong. Progressively elaborating on initial question sets, refining your topics, and asking casually related follow-on questions discovers answers to questions we are too clueless to ask.

Moreover, the initial use of qualitative analysis to discover new and locally nuanced information can be conducted rapidly. This is the case because qualitative analysis does not require tedious probability sampling techniques which aggregates into statistically significant findings. Also, the use of probability sampling techniques prove inadequate for conflict zones. For example an UNICEF report, "Rapid Assessment Sampling in Emergency Situations," notes:

> Uncertainty over population figures and demographic information constitutes one of the main barriers to conducting accurate assessments. Standard approaches to data collection particularly with regard to sampling are typically not well adapted to volatile settings, and data collection in a humanitarian response can often lack technical credibility and statistical robustness.**[xii]**

Given even permissive circumstances, quantitative assessments cannot be conducted expeditiously. Fast learning happens when the cycle time between evidence-gathering and analysis is very short – even zero, when we ask a follow-up question. Qualitative analysis is further codified as a rapid technique to information collection as it does not require probability-based sampling techniques.

The core strategy of qualitative analysis is rapid-fire experimentation before, during, and after taking action: collect information, formulate hypotheses, collect confirming and disconfirming evidence, formulate new hypotheses, and so on: Constantly Collect-Analyze-Act-Assess. Qualitative analysis is not simply analysis of qualitative data. The role of qualitative analysis for actionable intelligence is to collect and analyze richly contextual data in a specific, poorly understood context, to understand quickly how and why relevant actors, actions, and relationships generate cause and effect.

Implementing Qualitative Analysis as a Concept

Improving situational awareness for future forces will require a whole-of-Army approach. Concepts will have to be developed to approach both operational (e.g., combat ready) and generating forces (e.g., training and developing) throughout the Joint Phasing model. The employment of qualitative analysis at the tactical level will improve upon general understanding of the AOR and will help the first users to derive locally nuanced information that will be the foundation for planning where Army forces are deployed and have to interact with local or indigenous populations.

Current efforts to promulgate concepts to enhance situational awareness for improving lower command echelons' situational awareness are being discussed within Headquarter (HQ) TRADOC, Fort Eustis and within the capability and concept development communities. The ICoE, SOCoE, and HD Task Force collaborate continuously to develop AWfC #1 and often seek academic and private sector input. The action officers at each of these organizations are likely candidates to present this topic to AWfC working groups as a potential solution. However, given the scope of the HD Task Force's mission within ARCIC, and their location at HQ TRADOC, they are most optimal change agents. The HD Task Force serves to provide concepts and solutions to the Army that "assist in the synchronization and integration of personnel-related policies, with 'training and education, science and technology (S&T), medical and social science efforts' as mechanisms for providing the Army with a "dynamic competitive advantage' in current and future [volatile, uncertain, complex, and ambiguous] environments.[xiii] Using their mission and proximity to general officer staff at within HQ TRADOC, the HD Task Force may be able to publicize concepts and capabilities supported by qualitative analysis.

For more information on how qualitative methods and analysis can support tactical intelligence operations and inform situational awareness, please see capstone paper: *John Hoven and Joel Lawton. "Locally Nuanced Actionable Intelligence: Operational Qualitative Analysis for a Volatile World."* (Forthcoming,

American Intelligence Journal https://app.box.com/s/ sl6a56fsgr3ywhvzkopt)

The opinions expressed in this paper are those of the authors, and do not represent those of the U.S. Government, Department of Defense, U.S. Army, or TRADOC.

End Notes

[i] US Army. *TODAY'S FOCUS: 2013 Army Campaign of Learning.* September 21, 2012. http://www.army.mil/standto/archive/issue.php?issue=2012-09-21.

[ii] US Army. "The U.S. Army Learning Concept for 2015." TRADOC Pam 525-8-2. 2011, 5. [iii] US Army. *Army Warfighting Challenges.* Information Paper, ARCIC, TRADOC, 2015, 1. [iv] US Army. *Army Warfighting Challenges.* Information Paper, ARCIC, TRADOC, 2015, 5-6. [v] US Army. *Army Warfighting Challenges.* Information Paper, ARCIC, TRADOC, 2015, 5.

[vi] Ibid.

[vii] Rubin, Herbert J. and Irene S. Rubin. *Qualitative interviewing: The Art of Hearing Data*. 2012, 3e. http://books.google.com/books?id=T5RDmYuueJAC&printsec=frontcover#v=onepage&q&f=false

[viii] Tavory, Iddo. *Abductive Analysis: Theorizing Qualitative Research.* 2015. http://www.academia.edu/8745150/Abductive_Analysis_Theorizing_Qualitative_Research (accessed 02 22, 2015).

[ix] Army FM 2-91.6 Headquarters, Department of the Army. *Soldier Surveillance and Reconnaissance: Fundamentals of Tactical Information Collection.* 2007, 1-16. http://www.fas.org/irp/doddir/army/fm2-91- 6.pdf.

[x] Ibid.

[xi] Spinuzzi, MAJ Marc A. "CCIR for Complex and Uncertain Environments." 05 January 2007. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA470928.

[xii] United Nations. "Rapid Assessment Sampling in Emergency Situations." United Nations Children's Relief Fund, Asia-Pacific Shared Services Centre, 2010, 2. http://www.unicef.org/eapro/Rapid_assessment_sampling_booklet.pdf.

[xiii] Nabi, Farzana PhD. "Culture of Learning, Innovation & the Human Dimension." Information Paper, ARCIC Human Dimension Task Force, 2014, 2.

Using the Internet of Things to Gain and Maintain Situational Awareness in Dense Urban Environments and Mega Cities

By ***Alfred C. Crane and Richard Peeke***

Originally published in Small Wars Journal on 26 February 2016

Available online at: http://smallwarsjournal.com/jrnl/art/using-the-internet-of-things-to-gain-and-maintain-situational-awareness-in-dense-urban-envi

It may prove beneficial to leverage the internet of things (IOT) in order to provide our Soldiers, Sailors, Airmen and Marines the decisive advantage needed to fight and win future armed conflicts. It can be anticipated that connected devices such as game consoles, "baby monitors" (1) and "that smart meter (that) knows when you're home and what electronics you use when you're there" (2), for example, will be prolific in the future operating environment. With this in mind, the joint force will have opportunities to use these devices to gain and maintain situational awareness in a mega city or dense urban environment. Before Soldiers enter a building or deploy an unmanned system, they may have opportunities to access these existing "sensors" to build a picture of the building's interior. Also, being able to access personal electronic devices of the buildings occupants could, coupled with the deployment of unmanned systems, give the Warfighter a better picture of what awaits behind the next door, wall, room or floor. Not only knowing about the location and patterns of life of enemy combatants in the building and the ability to find out where non-combatants are would increase protection of the Warfighter, as well as, reduce the risk of civilian casualties. The data obtained from these connected devices, personal electronic devices and deployed unmanned systems would be rapidly stitched together to render a real-time 3D model of the building, as well as, show locations of the structure's occupants. An example of this can be seen in the films "Prometheus," (3) and "The Dark Knight" (4). This would give the Warfighter the needed edge to fight and win in complex urban terrain.

In addition to finding out how many occupants there are as well as their location, the Soldier will also need to gain and maintain situational awareness outside of buildings by being able to access traffic cameras, security cameras and so forth. Building a comprehensive, living model of a city or even a city block would enhance situational awareness and provide the necessary data for leaders to make rapid decisions and increase the protection of the combat element in an operational environment. This composited data could also be shared so that the operational commander would have a real-time view of the area of operations. Big Data Analytics and knowledge management / decision-making tools will be needed in order to filter and make sense of all of the data being obtained.

Of course these connected devices can be used for defensive as well as offensive operations. By knowing where allies and noncombatants are as well as movement of suspect personnel in an area of operations by target acquisition and tracking of personnel using biometric sensors and software will give the Warfighter the needed information to be lethal, informed, and protected.

A draw back to this is that without power, access to these connected devices may not be possible. Also, if we have the ability to access and use these connected devices then it can be anticipated that the enemy will have this ability, as well. Counter-measures and technologies to spoof, trick or deny enemy access to these devices will also need to be developed.

One of many the challenges in the operational environment is to distinguish between enemy combatants, non-combatants and friendly forces. In order to mitigate fratricide and collateral damage, transponders would need to be developed, that are either worn by the Warfighter or are subcutaneous, which can be picked up by friendly forces. These would need to be visible in different spectra and frequencies.

Vignette

In support of ongoing operations, United States forces have been assigned to rescue hostages held in a high rise building of a dense metropolitan area.

This is part of ongoing operations to remove hostile forces who are attempting to gain control of the capitol building and power grid.
Several hostages have been taken in order to pressure US forces to leave.

Multispectral, visual, as well as audio signals are used to locate the building where the hostages are being held.

As the US forces advance to the building they contact their Cyber Support Center (CSC) utilizing the cyber support officer (CSO) attached to their unit. As the CSC is contacted, unmanned aerial and ground systems that are organic to the unit are deployed.

A call for cyber effects is initiated in order to gain access to the city's security and traffic cameras. This coupled together with the sensors onboard the unmanned systems informs the small unit leader of the best avenue for advance.

Advanced recon to determine patterns of life and develop a target folder are initiated prior to advancement/execution of mission.

Simultaneously, an information campaign to provide a plausible cover story or shape public opinion against the hostage takers and delegitimize their insurgent movement is launched.

Once the safest route has been determined, the US element advances using visual and digital obscurants to cover their movement. A second cyber effect is requested to locate and gain access to connected devices and personal electronic devices in and around the building.

Swarming nano and small unmanned systems are deployed to map out the buildings floor plan and identify location of the occupants. After a few minutes, some cameras are accessed that are built in to game systems, security cameras, mobile phones, smart TV's and baby monitors. Access to these help develop a picture of where the building occupants are located. Two potential locations where the hostages are held are identified based on signals intelligence, cyber effects and the information gathered from the connected devices, mobile phones and unmanned systems.

The US forces enter the building and proceed with caution using the appropriate tactics, techniques and procedures to the two possible locations. After entering the building, US forces talk to a few civilians who have evaded capture and they are able to point out the target location.

A further cyber effect is requested and the location of the hostile forces within the room are identified through their mobile phones, a smart TV and a camera on an office computer. A diversion is created to distract the hostiles and using room clearing procedures, the US forces enter the room, eliminate the threat and rescue the hostages. Less than lethal/area-denial technologies to incapacitate the hostage takers and temporarily neutralize the threat to friendly forces are utilized.

Concluding Thoughts

Gaining and maintaining situational awareness in this age of technology can be challenging. If the Warfighter is left to fight and clear buildings in the same manner, same methods and same technology as seen in the battles of Stalingrad, Arnhem, Nuremburg or Fallujah we have failed.

In conclusion, investments in basic and applied research to develop the necessary technologies and software needed to gain and maintain access to personal as well as connected devices (to include denying access of these same devices to our adversaries) and utilizing elements such as Defense Innovation Unit X in Silicone

Valley will be needed to make these concepts a reality.

This paper addresses Army Warfighting Challenge number 1, Develop Situational Understanding (5).

The authors would like to extend a special thanks to COL Bryan Denny and Mr. Curtis Austin for taking the time to review and provide valuable comments and suggestions that enhanced this paper. I am truly grateful for their input.

End Notes

1- DiGangi, C. (2016, January 28) *6 Things in Your Home That Could Get You Hacked*. Retrieved from http://www.foxbusiness.com

2- Kobie, N. (2015, May 6) *What Is The Internet of Things.* Retrieved from http://www.theguardian.com

3- Costigan, M. (Executive Producer), & Scott, R. (Director). (2012). *Prometheus.* United States: Twentieth Century Fox.

4- De La Noy, K. (Executive Producer), & Nolan C. (Director). (2008). *The Dark Knight.* United States: Warner Brothers.

5- ARCIC Future Warfare Division. (2015, October 7) Army Warfighting Challenges Army Operating Concept

6- Burrus, D. (2014, November) The Internet of Things Is Far Bigger Than Anyone Realizes. Retrieved from http://www.wired.com

7- Meek, A. (2015, October 16) Body cams, smart guns and tracking darts: policing and the internet of things. Retrieved from http://www.theguardian.com

SECTION 4: Freedom of Movement and Protection

This section includes published articles from Small Wars Journal that we received from the call for papers. The section will explore issues, concepts, and capabilities as they relate to future land forces gaining freedom of movement or protection in megacities or dense urban areas in 2025 and beyond.

U.S. Army Mega City Operations: Enduring Principles and Innovative Technologies

By ***Frank Prautzsch***

Originally published in Small Wars Journal on 22 February 2016

Available online at: http://smallwarsjournal.com/jrnl/art/us-army-mega-city-operations-enduring-principles-and-innovative-technologies

> "…and the worst policy of all is to besiege walled cities. The rule is, not to besiege walled cities if it can possibly be avoided. The preparation of mantlets, movable shelters, and various implements of war, will take up three whole months; and the piling up of mounds over against the walls will take three months more.
>
> The general, unable to control his irritation, will launch his men to the assault like swarming
>
> ants, with the result that one-third of his men are slain, while the town still remains untaken. Such are the disastrous effects of a siege. Therefore the skillful leader subdues the enemy's troops without any fighting; he captures their cities without laying siege to them; he overthrows their kingdom without lengthy operations in the field."
>
> -- Sun Tsu – The Art of War, 500 B.C.

Introduction

By 2050, urbanization will arguably be the most consequential event in the history of mankind. Out of every 100 children born at that time, 57 will be Asian, and 22 will be African. The majority of those new babies will live in cities. Over the last two decades, developing nations have added 3 million new people per week. This is the equivalent of adding the city of Seattle to the planet *daily*. Starting in 2018 the world's global rural population will peak at 3.5 billion and then proceed to fall by almost a billion new migratory city citizens. [1]

In conjunction with a massive demographic shift to urbanization, there are also shifts in wealth and in aging. The developed world is losing its edge over developing nations in wealth, while Central and South America bear the brunt of a radically aging population.[1]

For the U.S. Army to conduct future missions, Sun Tsu's principles may be more fitting than ever. While U.S. Army may not always lay siege to a city, the preparation for any military urban operation is not a short term event, nor is the planning ad hoc. The spectrum of operations spanning non-combat and combat missions in the face of natural or adversarial threats, makes this preparation a multi-dimensional problem requiring significant attention and forethought. As we proceed to investigate and plan for Mega City operations there are a few key points that must be made:

1. Mission success is contingent upon the will of the population, as well as the coalitions, governments, religions and tribes in occupancy not purely the strategy, tactics and planning of the U.S. Army.

2. The U.S. Army cannot "fight its last war". Lessons learned from battles such as Fallujah, Aleppo, or throughout densely populated Palestine don't scale well, and are miniscule in size and scope compared to a Mega City battle.

3. Mega City warfare is a highly 3 dimensional event. Unlike rural warfare with focus upon capturing mountaintops, resources, and roads, urban key terrain belongs to the defender and suggests skyscrapers, bridges, tunnels, subway systems, energy and water distribution, telecommunications, airports and rail stations are the discriminators.

4. Mega Cities with a subterranean network, capable of threat transit (subway, water drainage, sewage) will offer a compounded advantage to a defender or asymmetric threat. Most subterranean geospatial data is a non-integrated stack of reference materials, maps, and overlays. Often these references don't exist or are completely unreferenced or surveyed resulting in C2 and situational awareness failures.

5. The U.S. Army must understand that technologies that would be used for missions in 2040 Mega Cities don't exist yet. However, those technologies that do exist, may point towards needed future technical capabilities in some form or function.

6. The U.S. Army must assume that if specific technologies exist for supporting future operations, that an adversary may also have access to a derivative of such technology.

7. The value of C4ISR, mobile networks and unmanned/autonomous systems are exponentially more significant than today. With this comes an implied task to have spectrum supremacy or the above capabilities are useless.

8. The resources of the U.S. Army may be called upon in more non-combat missions to protect or sustain life. (Power generation, water purification, water pumping, health care, engineer support, air drops, evacuations, psychological operations, sanitation, graves operations)

9. A determined adversary or a disgruntled population has time and mass on their side.

10. Logistics and energy rule. The "Achilles Heel" for a Mega City involves the lines of communication for power, water and food supplies.

Emerging, Enduring, and Endearing Technologies.

The U.S. Army should carefully evaluate, mature and mutate selected commercial technologies that aid Mega City operations. Each of these technologies exists or is emerging today and has some value in further research:

1. Broadband over power lines (BPL): Simply stated one key asset that most Mega Cities have is a reasonably well defined power grid. Today BPL technologies allow for networked and point-to-point transmission of 200-500 Mbps over simple modems and integrated network control capabilities. This is significant to spectrum supremacy, covert operations, remote sensing, and C2. Most wireless phone antennas are horizontally polarized and start to lose service at altitude above about 600 feet. Thus, communications in the highest floors of a skyscraper can be complicated by a lack of wireless quality of service which can be somewhat offset by BPL. Many BPL and Network Control capabilities can also interface on ad hoc with fiber, terrestrial and satcom systems at some designated nodes.

2. Tethered and untethered C4ISR Sensors: In a Mega City environment the need for persistent surveillance is paramount. While UAVs are vogue in 2016, the need for small positive buoyant gas envelops with sensors and visualization for hours-days is of necessity. Numerous systems exist today that are controlled or on tether. Additionally, controlled small airships afford the ability to conduct sustained observation of a target or area of interest, and also perform such functions as bottom side bridge inspection or bomb sniffing.

3. Manned, Unmanned and Autonomous Systems: Such capabilities are not limited to urban airspace, but also littoral and harbor areas with USVs, streets, tunnels and high risk areas with UGVs, and undersea operations along coastal and harbor areas with UUVs. New systems such as VTOL jetpacks, manned quad copters and air mules need to be considered for rapid equipment and team displacement, remote sensor placement, security and vantage of urban high ground, sniper and counter sniper operations, incident response, combat evacuation, and search and rescue.

4. Subterranean vehicles: More research is in order at developing capabilities that can allow the US Army to more effectively use rail and subway systems within a Mega City. This could include a rail gauge-scalable light armor assault and recovery vehicle that is both road and rail capable for supporting a squad infiltration or an evacuation/recovery of critical area when/if mass transit fails. (e.g. towing a metro rail train without power during a mass casualty evacuation)

5. Internet of Things: If there was ever a consideration that plays heavily into remote sensing, security, and situational awareness in a future Megacity, it will be the Internet of Things. Retail wireless companies already have the option of purchasing 15 thousand edge sensor devices smaller than a credit card, and an integrated router system that can aggregate all the devices, (one and 2-way), and wireless connectivity at up to 2.5 miles in unlicensed spectrum. Such COTS capabilities are both an enabler and a threat as they are not ITAR and can be implemented across a Mega City in hours.

6. Tunnel and Bridge Emergency Management: By far the biggest choke points and symbolic targets for a Mega City relates to bridges, tunnels and ferryboat operations. Inflatable plugs and barriers exist for sealing tunnels both to fire and to catastrophic breaches in their outer walls. While the Army has a

longstanding history and portfolio of expeditionary bridging capabilities, the expertise and experience for tunnel operations, advanced bridge security, and the security of ferryboat operations is perhaps an important future competency needed. In addition, most bridges and tunnels are conduits to Mega Cities for power, telecommunications, and in some cases, gas and water lines. Robotic and sensor integrity and inspection systems are essential. Failure to control and secure bridges and tunnels make any Mega City operation impossible.

7. Non-Lethal Weapons: Many missions in Mega Cities will likely have the potential of migrating from a peaceful and organized event, to a limited engagement and disorganized chaotic event. Intermediate capabilities to control crowds, and incapacitate via non-lethal means can retain the will of the people with the U.S. Army whereas casualties, however justified, could instigate disastrous consequences. While the Marine Corps continues to research future joint non-lethal weapons, much more must be done in non-lethal weapons research, breaching and riot systems, IT and PNT denial, micro-area cyber operations, localized Marx generation to incapacitate electronics, and non-lethal weapons for incapacitating insurgents or riotous masses.

8. Disease, WMD and CBRNE Detection: Mega Cities are both an incubator and a target for the worst of all scenarios. Greater sensor and detection systems and field response systems are now emerging in the scientific and consumer market. Such systems allow for field optical stereoscopy and spectroscopy for characterization of substances, DNA sequence analysis and Chemical-Biological Pathogen detection and field vitals and triage in handheld or small portable devices.

9. Augmented Reality, Night Vision and Situational Understanding: Electronics now exist that introduce affordable augmented reality in high resolution for the war fighter. These systems will mature dramatically in form factor, and content over the next two decades. It is safe to say that some form of augmented reality eyewear or headwear will be normal attire for the war fighter in Mega City operations. Current technologies in EO/IR have taken away the “ownership of the night” from the U.S. Army. Night vision modules that attach to intelligent phones cost less than most of the phones. Innovation in graphene points to phase shift single molecular layer carbons that will ultimately introduce a night contact lens. Of greater importance than the greatness of gadgetry, is the need for integrated understanding of intelligence and sensor feeds. It will not be adequate to have situational awareness, but understanding. The motives, patterns, behaviors, and predicted next steps of a threat will be the “new normal” for missions. In a Mega City, future commanders won’t decide courses of action without understanding the motives and intent of the adversary.

10. Illumination: Technology now exists to provide high lumen lighting in an area the size of a football field in a hand-carry device. LEDs give us a distinct advantage in crisis lighting for subterranean, catastrophic point-of-event, and emergency services operations. Such systems are now DC powered and operate with up to 400w/45000 lumens in hand carry form factor. Such a capability would also be practical for integration on selected autonomous or unmanned systems and selected urban terrain vantage points.

11. Through-obstacle detection and characterization: Current systems exist that

can detect life under up to 27 feet of rubble by measuring the displacement of the lungs and processing respiratory level and pulse rates. While such ultra wideband systems are a mercy tool for earthquakes, explosions, and bombings it can also be an important tool in determining threats behind closed doors or walls. Additionally, such a system can identify elevated heart and respiratory rates in a crowd, acting as a physiological marker to a potential threat. In 2016, mobile technology to monitor though-walls is smaller than a breadbox. For free space monitoring of heart and respiratory rates the entire module is the size of a small paperback book.

12. 3D/4D Geospatial Referencing: By 2050, most all image sciences will be 3D and also include a fourth dimension of time. Current systems in LIDAR, light field camera techniques, 2/3D ortho- recification against point clouds, and structure internal GIS mapping and referencing will be the norm for navigation and negotiation of Mega City movements and coordination. This will also include 3D synthetic geospatial night vision mosaics. 3 and 4D systems will not only aid the war fighter in understanding context, but also vertical, subterranean, and hidden threats. In addition, the geospatial data will be essential to autonomous systems operation.

13. Weather and Micro-weather: Weather is not limited to trafficability and complications to operations in rural areas. Mega City operations in adverse weather introduce unexpected threats, opportunities and consequences. Systems exist now to introduce micro-weather prediction by analyzing weather formations and road conditions from traffic cameras. One system today has an aggregate capacity of over 165K cameras that provide integrated hyper local weather and environmental intelligence.

14. Specialty Vehicles: Consideration should be given to vehicles that can operate in more than one domain. Platforms exist today that can cover transitions between land and water, air and sea, surface and subsurface and air and land. These systems are essential in Mega City operations for mission agility, selected concepts of operation, surprise, and range extension.

15. Communications: By 2050, the world will have embraced 5 and 6 G wireless services and ad-hoc networks between mobile platforms and users will involve transmission=s from 5 Gbps-1 Terabyte/second. 5G starts fielding in 2020 and should move to consumer acceptance by 2025. Laser high fidelity communications are currently under demonstration and testing. LI-FI will soon supplement or replace selected WI-FI applications in urban areas. Since LI-FI does not consume RF spectrum and operates at significantly higher data rates, it will gain acceptance for selected network applications. Basic 5G speeds will exceed 4G LTE service by a factor of 65000. 4D Virtual reality, instantaneous downloads, mission rehearsals, and multi-intelligence, multi-language machine learning systems will be commonplace. With communications and networks our ability to rationalize the future is most difficult and we have successfully written requirements for capabilities that have been surpassed by technology time and time again. Additionally, old technologies in acoustics and older spectrum such as HF may have a calling for mission specific support, operations during RF spectrum denial, or surprise.

16. Gunshot and Explosive Detection and Characterization: Force protection will

always be an issue with Mega Cities. While the need for new and protective forms of armor and TALOS-like exoskeletal capabilities are needed, the ability to deal with snipers and improvised explosives, and trigger systems can only expand exponentially in a gigantic population center. The ability to disguise and surprise with asymmetry, calls for improved acoustic geolocation, predictive crime models, and new sensors such as graphene trough sensors or piezo-electric cantilever sensors that can detect explosive particle residue at range.

17. Armor and Blast: While the metallurgical and ceramic armor communities continue to develop plating solutions, new inventions in flexible body armor from spider silk, tight woven hemp, advanced plastics, kevlar, and graphene are redefining ballistic protection that is flexible and agile, while still maintaining the performance of plating techniques. The use of syntactic foams with tailored density resins and tailored size micro-balloon glass particles introduces unique blast protection features as the foam distributes energy radially and radically from the highest point of an acoustic wave impact and distributes that blast energy in effective nullification. Such a capability offers progressive and aggressive force blast protection by introducing such capabilities in the platforms, building processes, and troop protection. Advanced electro spray techniques allow for the development of active armor that has different molecular composition at different levels in the armor. Such armor changes the Vickers Index properties of the materials from which it is made (e.g. aluminum armor) and allows for boutique armor capabilities against different threats using heat or shaped charges, higher grade explosives, or high velocity projectiles from the blast effect.

18. A New "MacGuyver^2" Squad: For each prevailing Mega City, a subject matter expert cadre should be passively maintained, that are versed in that Mega City, have lived in that Mega City, or have insight on capabilities involving its government and its infrastructure. Such a Squad must be able to facilitate host nation and Mega City support, telecommunications, emergency shelter, fuel, energy, water, and how to operate critical infrastructure, such as transportation, with or without city employees. This should include HUMINT and several insights on technical, religious, and political intelligence about that Mega City. This squad should be "doers" that can improvise anything, and not be totally contract/transactional support.

Conclusion

Mission support within Mega Cities, across the continuum, on an objective timeline 24 years away, requires vision, invention, innovation, technical ingenuity, commercial off-the-shelf solutions, host nation support, and legacy systems integration. The technology vectors professed in this paper are critical future Mega City missions. They will emerge with or without U.S. Army involvement, since in various forms, each of these technologies **already exists in 2016**. It is our charge to challenge the "Art of the Possible", not await or monitor it. The U.S. Army cannot simply study or analyze Mega City warfare. Failure to prepare for statistically inevitable Mega City peaceful or violent missions is beyond foolhardy. Unlike Sun Tsu's warnings about impatient generals that will not tolerate 6 months of preparation to besiege a city, the U.S. Army may not have such luxury of time.

End Notes

[1] Laurence C. Smith, New North: The World in 2050, (London: Dutton Publishing/Penguin Group, 2010

[2] Richard Dean Anderson, MacGuyver. TV Series, ABC TV, Hollywood, CA and Vancouver Canada, 1985-1992.

Unmanned Systems in Support of Future Medical Operations in Dense Urban Environments

By ***Nathan Fisher and Gary R. Gilbert***

Originally published in Small Wars Journal on 4 February 2016

Available online at: http://smallwarsjournal.com/jrnl/art/unmanned-systems-in-support-of-future-medical-operations-in-dense-urban-environments

Introduction

The growing planned use of unmanned systems (UMS) and robotics on the future battlefield affords both great opportunities and challenges to far future medical operations, especially in Dense Urban Areas. The future operational environment in decentralized urban environments is likely to cause severe restrictions on the mobility of vehicles used for medical missions including both air and ground platforms used for medical evacuation (MEDEVAC), casualty evacuation (CASEVAC), and medical logistics missions, due to area denial challenges. In situations where medical resources are already spread thin, e.g. during a mass casualty event or natural disaster scenario, mobility of medical resources becomes of paramount importance. Unmanned systems could serve as a force multiplier for medical operations in future environments as their capabilities continue to evolve and mature to include providing medical logistics support (e.g. medical resupply/delivery of blood products), aid in the delivery of telehealth/teleconsultation to the point of care, and provide opportunities for expedited casualty evacuation.

There is a clear emerging capability in future unmanned vehicle programs to provide multi-purpose utility by being reconfigurable to accommodate different mission-related payloads. A good example of an emerging Unmanned Aerial System (UAS) that is designed to be reconfigurable to support multiple missions is DARPA's Aerial Reconfigurable Embedded System, which specifically includes a conceptual detachable mission module for CASEVAC [1]. A more feasible approach than a dedicated CASEVAC module might be a multipurpose (cargo hauling, troop carrying, potentially ground mobile) module that could also support CASEVAC missions when quickly equipped with a lightweight, easily assembled trauma patient care module that could support attended, tele-operated or even closed loop autonomous enroute care. Having the ability for future UMS to be reconfigurable to support CASEVAC in critical operations could be an enabler for the maneuver Commander, who is ultimately responsible for the task of clearing wounded from the battle space. Providing future UMS with a key secondary utility as a vehicle of opportunity for CASEVAC should effectively increase the overall mobility of units in future operational environments. It's worth noting that CASEVAC using UMS (or perhaps more accurately, pilotless systems, whenever casualties or medical attendants are onboard) should only be utilized under careful consideration, and only when acting in the best interest of the wounded, which may necessitate a medic attendant providing care during autonomous flight.

The ability of UMS to provide these benefits to future health support of operations depends on the maturation of key enabling technologies in the areas of robotics and communications. Advancements in vehicle autonomy systems will likely bring about a future in which autonomous vehicle systems will leap ahead of conventionally piloted vehicles, at least in some key performance parameters. However, increases in the technical performance of robotics technology alone are not enough to fully realize the benefits of unmanned systems for future medical missions. Improvements in the speed and efficiency in which soldiers are able to interact with unmanned systems, the ease of collaboration between different robotic platforms, and the capability of rapid dissemination of information to multiple echelons is also required.

Unmanned Aerial Systems for Future Medical Missions

The U.S. Army Roadmap for UAS 2010-2035 [2] states that "Over the next 25 years, the Army aviation force mix shifts from being almost entirely manned to consisting of mostly unmanned and [optionally- piloted vehicles]." With rapidly increasing levels of autonomy, future unmanned systems will transition from filling niche roles to providing multi-functional utility, to include tasks such as casualty evacuation (CASEVAC), and emergency medical resupply, as outlined in the Department of Defenses' "Unmanned Systems Integrated Roadmap FY2013-2038" [3]. Already a proven capability for remote resupply mission, Vertical Takeoff and Landing (VTOL) UAS have the potential to be multi-purposed to provide emergency medical resupply and CASEVAC capabilities in situations in which traditional manned aircraft cannot be utilized. As outlined in the roadmap, the Department of Defense expects unmanned systems to play a key role in many of the Tier One Joint Capability Areas (JCAs), and specifically mentions the capabilities of unmanned systems to provide medical resupply and casualty extraction and evacuation as future systems are enabled through greater autonomy with respect to both navigation and manipulation [3].

The path for adoption of UAS capabilities for medical missions will likely start with medical resupply to provide support to medics in the field in situations in which manned-aircraft are not available or denied access. In the mid-term, UAS capabilities will likely mature to the level in which safe troop transport is possible. This will enable the possible use of UAS to evacuate casualties with an attending flight medic, or casualties that are sufficiently stable to be transported without an attending medic (i.e.

the "walking wounded"). In the long-term, with the development of advanced autonomous/closed-loop systems for patient monitoring and care, the capability envelope of UAS casualty transport could be expanded to include a larger patient population, which may become increasingly important as medical resources become strained in future combat theaters with large casualty evacuation distances are area denial challenges (i.e. Dense Urban Areas). In the future operational environment, UAS casualty evacuation is most likely to be employed in circumstances in which tradition MEDEVAC is not available or is too high risk, and only when it is in the best interest of the patient and the mission. Under these carefully defined circumstances, there is clearly a set of patients that rapid UAV evacuation could provide a survival benefit.

Novel Medical Uses of Small Unmanned Aerial Systems

Small Unmanned Aerial Systems (sUAS) broadly defined here as aircraft much smaller than traditionally piloted vertical takeoff and landing aircraft, have the potential to provide some unique capability in providing medical logistics compared to larger aircraft due to the increased mobility afforded to their smaller form factor. For example, sUAS are able to more easily navigate in congested urban environments and require much smaller landing zones (if they even need to land at all). Because of the additional mobility afforded by sUAS in dense urban areas, they are likely to be widely used for other purposes, e.g. intelligence, surveillance, and reconnaissance, cargo delivery, and communications relay. The operational medicine community should be prepared to utilize these multi-functional sUAS platforms to provide additionally support for medical operations.

The tradeoff for this increased mobility is a smaller payload capacity and shorter flight duration, but in certain circumstances, the payload capacity and range of a sUAS could be sufficient in providing life- saving emergency medical resupply in support of field medics that are unreachable through more traditional means. Prolonged field care situations in which casualties are unable to be evacuated due to area denial challenges would particularly benefit from a sUAS capability of medical resupply. In addition to the delivery of medical supplies (medical devices, drugs, blood products, etc.), the sUAS could potentially deliver a telemedicine system which could provide a solider/medic direct audio and video teleconsultation from a medical expert. In the operational battle space of the future, it is likely that the time required to evacuate casualties will increase not only due to the lack of mobility in dense urban environments, but also because of predicted increases in distance between the point of injury and the closest medical treatment facility. Therefore, improving the far forward casualty care capabilities of medics in the field will become increasingly important in future combat. The agile medical resupply capability afforded by sUAS could become a catalyst in improving the far-forward field medic's capabilities by ensuring that they have the required medical resources (consumables, specialty tools/devices, and teleconsultation) that they need to provide life-saving casualty care; essentially bringing the advanced treatment to the casualty in situations in which the casualty cannot be rapidly evacuated to the medical treatment facility. The military could potentially leverage the considerable investments currently being made by industry to advance research and development efforts in UAS delivery of commercial packages [4][5], which share many of the same performance requirements of a future UAS conducting an emergency medical supply mission.

Enabling Technologies

Autonomy and Performance

Unmanned Systems (UMS) currently in-use today have very limited autonomy. UMS vehicles of today are normally operated under the manual control and close supervision of a remote operator (teleoperation). In order to fully realize the potential benefits of unmanned systems for medical missions,
the UMS operator (potentially a field medic) needs to interact with the UMS at a task/goal level, providing the UMS with high level commands and mission parameters and providing only supervisory-level control. In this way, the UMS operator's cognitive burden can be dramatically reduced, allowing him/her to conduct other tasks or control more UMS assets. Advancements in vehicle autonomy systems will fully automate many of the vehicles functions, including route planning, navigation, obstacle avoidance, and landing zone evaluation. Vehicle autonomy systems will likely continue to evolve to the point that they will outperform traditional human pilots/operators in many areas, for example, operations in extreme weather conditions. Even human-piloted military vehicles in the future will be augmented by vehicle autonomy technology that will provide the pilot with increased situational awareness and safety systems, which is becoming increasingly true in today's consumer car industry.

Much of the capability that is required for a UAS to navigate autonomously in a dense urban environment has been demonstrated to some degree in current science and technology research programs, to include GPS-denied navigation and landing zone evaluation [6] Autonomous systems will continue to evolve to provide increasingly sophisticated perception and planning systems through improvements in both hardware (sensors and processing) and software. The size, weight, and power (SWaP) requirements of autonomous sensor systems is also likely to dramatically decrease, allowing even small UAS the ability to carry the sensor systems required for sophisticated Sense and Avoid capabilities.. For example, the LIDAR sensors, which are heavily relied upon in today's autonomous vehicles to observe distances to physical objects in its surroundings, are likely to become much smaller and inexpensive as solid-state LIDAR systems begin to replace current systems with mechanically-directed optics [7].

Teaming, Interoperability, and Human-Robot Interfaces

The US military will not be the only international actor which will have advanced UMS assets in the future operational environment. The opportunity for overmatch relies heavily on the ability of our manned systems and unmanned systems to effectively operate as a highly integrated team. This will require efficient and effective teaming not only between manned and unmanned systems, but also between different UMS platforms. Today's command and control systems for disparate UMS platforms have limited levels of interoperability, and almost no functionality for UMS to UMS direct communication. For future systems, the level of interoperability will need to be dramatically increased, and the capability for unmanned systems to effectively communicate and share information with each other will need to be developed, including cross-platform communications. This will allow for the type of rapid UMS-to-UMS communication required for advanced swarm maneuvers, which could provide a tactical advantage in future operational environments. DARPA's "Gremlins" program has a shared vision of using small unmanned air systems with coordinated and distributed capabilities that would offer U.S. forces improved operational flexibility over larger and expensive "all-in-one" platforms [8].

In the near-term, the military could increase UMS interoperability by developing a common controller capable of providing command and control to multiple UMS platforms. However, the future focus should be on the adoption of common reference architecture, like the maturing UAS Control Segment (UCS) [9], which will provide a common framework for human operators to interact with UMS and for UMS to rapidly communicate and disseminate information to other UMS. A common communications framework could enable the development of multiple compatible controllers which could take advantage of various form factors, with some form factors being more suitable for different mission types.

A key factor in the adoption of UMS technology for medical applications is the quality of the interface provided for interacting with the UMS asset. It is particularly important for a field medic to interact efficiently with future UAS due to the cognitive and physical demands of actively caring for a casualty. The medic is also responsible for the difficult task of documenting and transmitting tactical combat casualty care information for incorporation into the electronic health record. Given the magnitude of the demands on the medic's time and attention, the medic needs a highly effective interface for providing command and control to future UMS.

Conclusion

Unmanned Aerial Systems are likely to be used ubiquitously in future combat operations in dense urban environments due to the increased freedom of movement that they afford to a wide range of mission types. These unmanned systems will be multi-purpose in nature, and could be called upon in support of critical medical missions if certain medical-specific considerations are addressed as these future UMS platforms are being developed. Support from unmanned systems could become increasing important in other situations in which mobility is restricted, such as during a natural disaster or other mass casualty event. The medical application of unmanned systems and robotics in future environments has the potential to evolve health support of operations throughout the range of military operations, to include peacetime humanitarian support missions.

End Notes

[1] DARPA, "Aerial Reconfigurable Embedded System (ARES)", 2016. [Online]. Available: http://www.darpa.mil/program/aerial-reconfigurable-embedded-system. [Accessed: 02- Feb- 2016]. [2] "U.S. Army Roadmap for UAS 2010-2035", U.S Army
[3] "Unmanned Systems Integrated Roadmap FY2013-2038", Department of Defense
[4] Amazon.com, "Amazon Prime Air", 2016. [Online]. Available: http://www.amazon.com/b?node=8037720011. [Accessed: 02- Feb- 2016].
[5] A. Madrigal, "Inside Google's Secret Drone-Delivery Program", The Atlantic, 2014. [Online]. Available: http://www.theatlantic.com/technology/archive/2014/08/inside-googles-secret-drone-delivery- program/379306/. [Accessed: 02- Feb- 2016].
[6] Office of Naval Research ,"Autonomous Aerial Cargo Utility System", 2016. [Online]. Available: http://www.onr.navy.mil/en/Media-Center/Fact-Sheets/Autonomous-Aerial-Cargo-Utility-System.aspx. [Accessed: 02- Feb- 2016].
[7] E. Ackerman, "Quanergy Announces $250 Solid-State LIDAR for Cars, Robots, and More", *Spectrum.ieee.org*, 2015. [Online]. Available: http://spectrum.ieee.org/cars-that- think/transportation/sensors/quanergy-solid-state-lidar. [Accessed: 02- Feb- 2016].
[8] DARPA, "Friendly "Gremlins" Could Enable Cheaper, More Effective, Distributed Air Operations", 2016. [Online]. Available: http://www.darpa.mil/news-events/2015-08-28. [Accessed: 02- Feb- 2016].
[9] "Mission and Objectives, UCS Architecture", 2016. [Online]. Available: https://ucsarchitecture.org/pages/mission-and-objectives#objectives. [Accessed: 02- Feb- 2016].

SECTION 5: Expeditionary Operations

This section includes published articles from Small Wars Journal that we received from the call for papers. The section will explore issues, concepts, and capabilities as they relate to future land forces conducting expeditionary operations in megacities or dense urban areas in 2025 and beyond.

A Revolution in Military Affairs (RMA) versus "Evolution": When Machines are Smart Enough!

By ***Tom Keeley***

Originally published in Small Wars Journal on 8 January 2016

Available online at: http://smallwarsjournal.com/jrnl/art/a-revolution-in-military-affairs-versus-%E2%80%9Cevolution%E2%80%9D-when-machines-are-smart-enough

There is a general perception that the Operational Environment (OE) will "evolve" as technology evolves at an incremental rate: smaller, cheaper, faster… The "evolution" term is used throughout the Mad Scientist call to action. But there have been revolutions or significant paradigm shifts that have transformed the military in the past: The transition to bows and arrows from clubs allowed engagement away from the target. The transition to guns from bows allowed more accuracy and more power. The emergence of radar from visual sighting allows early detection. Mobile communication extended the reach of command. Airplanes allowed engagement from above. Ballistic missiles delivered more destructive power, allowed engagement from even further away and kept the missile user out of harm's way. Remotely piloted drones allow the delivery of ordnance into rapidly changing target areas, while still keeping warfighters out of harm's way. The Internet of Things (IoT) suggests the potential for more connected devices to be used to more rapidly share information. So one could hypothesize a war room where information was coming from everywhere; allowing battle space commanders to allocate resources to achieve their goals while sitting in the comfort of their bunkers (potentially far from the battle zone). A futurist of the past may have suggested pursuing better and better bows and arrows.

This paper suggests that this is an obsolete picture of the future. The previous scenario includes humans- in-the-loop. There is still a perception that humans need to be making all the critical decisions: When should force be applied? How much force should be applied? How much collateral damage is acceptable? … There is a perception that only humans can effectively handle this level of complexity.
The fog of war is perceived to be too complex for any machine to handle. A human has approximately 100 billion neurons (brain cells) and 1,000 trillion synaptic connections. We are far from packaging that level of computing into a chip. Right?

There are two ways to approach the future:

1. Look at where you are today, and consider how you want to invest your money to create a solution for tomorrow (evolution).
2. Pick a point in the future and identify the hurdles that have to be overcome to get there. Jump over those hurdles and jump past the evolutionary models.

So, the future capability that will be explained later in this document is that machines will have the ability to remove humans from the real-time decision-making loop. This will greatly speed up the decisions (offensive and defensive). And these decisions are not just the point decisions: how, what, when, where, and why. They are the adaptive command and control decisions: how much, how much over time, how much and where over time. This is an adaptive, analog distribution of force over space and time.

Before we get to the "new" approach, let's look at a picture of the battlespace as it could be delivered today.

Today's Commercial-Off-The-Shelf Technology

The hobbyist community has effectively commoditized the drone. While there will be enhancements made to the power system that allows for longer flight, remotely piloted vehicles can be purchased by anyone. With a small upgrade to the drone controller, anyone can use open-source Mission Planner[i] software to plan and execute missions for individual drones based on Google Earth / GPS data. These are not completely adaptive goal seeking systems, but if all goes well, they can perform their human defined mission by moving from point to point and performing selective actions. Another example: The self- driving car developers have learned how to package more real-time observation skills into their ground systems. Even as presently developed, they could be used as weapons.

Another view of Human Intelligence

There may be a perception that since the human brain is so complex, it must be used for a machine to accomplish the same tasks. There are researchers that are pursuing goals to create a machine with the ability to fully emulate a human; however this is not necessarily required for machines of war. A human is an example of a greatly adaptive machine that can be challenged with an almost infinite variety of goals. It can use almost any tool. It can conceive of, and build, new tools. But if we look at the creation of war "systems", they don't have to be that capable. And even if you looked at individual humans and assigned them only a selective set of tasks, then what they do is greatly simplified. And if you give up pro- creation responsibilities things get even simpler. In fact, one might suggest that during working hours, a human is really limited in what he/she can do with the tools and information that are available to them.

Humans are not responsible for all positions and all knowledge in order to make all tactical and strategic decisions. A pilot flying an aircraft has only a few controls at his/her disposal. The pilot has to decide where to go and what to do, but their options are really limited.

The Conventional Technology Options and Issues (or - Why isn't everything automated today?)

Now that we have explained why the problem is not so big, it is important to understand why everything has not already been automated by now. Perhaps it has been the technology that has been applied…?.

First there is conventional IF THEN ELSE logic. Whatever programming language you might choose, this stuff works. If you ask a programmer if he/she can write a program to solve a problem the likely answer is "yes", if you can explain the problem and the solution. It is simply a matter of time and money. And, even for simple systems we are asking the machines to interpret complex information sets in order to pursue goals on their own. That brings us to the mathematicians that use predicate calculus. Here is what predicate calculus provides: a formal way of defining functional relationships between information items. But the domain expert is probably not a mathematician, or a programmer. So now we have a cost and schedule issue. Neither schedules, nor pocketbooks are infinite. In addition, the domain expert is not likely to be able to explain the problem (and the desired solution) in a manner that can be understood "easily" by the software engineer or the mathematician. Usually every time a concept is transferred between one individual and the next, something is lost in the translation. Again, this results in long development and debug cycles. This is likely why complex problems have not been addressed with conventional programming.

Then there are the neural net designers. Using the human brain model they expose the neural net to patterns and teach it value systems. The resulting neural net system interpolates between what it was taught, and what it sees. Unfortunately, teaching neural net systems takes a lot of time. And if the systems are not appropriately taught, then just like humans, bad judgmental decisions can be made. In addition, if you want to add new sensors (information sources) to the system, the neural net system may have to be completely retaught. There are also researchers that want systems to learn on their own (just like humans). There are people who are concerned that weapon systems might learn on their own how to switch sides (because those systems decided on their own that it was the right thing to do at the time). Another issue with neural nets is that they cannot easily explain why they did what they did. Perhaps we are not quite ready to turn human evolution over to a self-learning machine.

Threats and Opportunities and a Value System

Now back to our problem space. If we expect to automate the battlespace at all levels, what would this system look like? Whether it is offense or defense based, one is dealing with competing capabilities and competing goals. For any kind of automation, we are dealing with measurable entities (measurable information items). These items can be treated as either threats or opportunities. Sometimes they can be both threats and opportunities when applied to different parts of the problem space. All items are measurable. Example: When humans perform tasks during scheduled working hours, the human is constantly balancing opportunities and allocating resources at his/her disposal in order to accomplish multiple simultaneous tasks. The human is inhaling / exhaling, eating, moving toward/away from obstacles, and performing tasks as appropriate. The human is operating alone, or with others (as appropriate). The human is collaborating as needed, and when asked. The human's value system (their needs) is used to prioritize tasks and allocate resources. The human's value system changes and adapts to its situation. The human's history, biases, knowledge, and risk tolerance applies a weight (a value) to the different factors. What we have just described is an analog system. Now, for our autonomous battlespace, we have goals and objectives (offensive and defensive). In the future machines may set their own goals and strategies, however, in the near term humans will likely retain control. So, in the interim it will be up to humans to create policies that control the behavior of machines.

The Paradigm Shift

The paradigm shift that we are describing in this paper is that a new information model will be needed to both define and execute information. This model will keep humans in control (humans-on-the-loop), while at the same time keeping them out-of-the-real-time-loop. Policies will be created by humans that understand the capabilities of their machines and how those capabilities should be deployed. A hierarchy of battlespace management will be deployed from individual units (devices) through a loosely coupled chain of command. Policies will be created that define how organizations of machines can come together and break apart to fulfill the broad objectives of the battlespace. Since the policies will be created by humans, the decisions and actions of units, teams, and battalions will be traceable to the policies, and then to the humans that created the policies. Organizations that control these systems (and systems of systems) will be able to monitor their competition and decide how to spend their money (offense and defense, small and large, short term and long term).

What if Accomplishing this is Easy?

If we stopped at this point, one could ask: "What is new? We have just continued our evolutionary work and automated more 'stuff'". However, the technology we are describing exists now, and it is simple to use. It is platform and architecture independent (so it is not tied to any specific hardware platform or software development environment). It occupies a very small memory footprint, which means it can be implemented in the small hobbyist drones available today.

When we say simple, we mean that you can be productive in a week and working on complex policies the next week. And, even if you are not a policy expert (defining who to shoot and when, or choosing between one tactic or another, or … it is easy to create the policy - and test as you go. You don't need a team to support the process. So anyone that wants to build and test a policy that describes how machines want to pursue goals can start the process and see results in a very short time. This may not be impressive if you are competing with a brick, because the brick will not change its tactics or strategies. But in a conflict domain, the tactic that may be working one day will have to change the next day to keep up. So the primary paradigm shift comes with ease-of-use. The secondary driver is that complex behaviors can be deployed in very low cost platforms.

Knowledge Enhanced Electronic Logic (KEEL) Technology[ii]

The technology that allows humans to package policies to control the behavior of our battlespace systems and devices is KEEL Technology. It was introduced to NATO in an offensive role in 2014[iii]. It was introduced to NATO in a defensive role in 2015[iv]. KEEL Technology allows domain experts / Subject Matter Experts (SMEs) to create and test policies and create (auto-generate) conventional code that can be handed off to the software engineers for insertion into the target system / device. No "calculus" (in the conventional definition) is required. Several years ago a 13 year old learned and used KEEL in only a few hours. More recently, a 15 year old created adaptive policies for an Arduino (hobbyist) drone. KEEL Technology is supported with the KEEL Dynamic Graphical Language which makes it easy to create and test policies and to "see the information fusion process" in action. You can "see the system *think*" through a process called language animation.

It's simple: If you know what a bar graph looks like, and if you understand that a taller bar is more important than a shorter bar, then you are on your way to being able to create an adaptive KEEL-based policy that can run in a device, in a computer, and distributed across the cloud.

Decisions and actions are of three types:

1. Go/No-go (do something, or refrain from doing something)
2. Select the best option
3. Allocate resources (do so much of some number of things)

More complex decisions are combinations of all of the above. These decisions can be distributed and shared across the hierarchy of systems and devices. The policies will define how and when to share information, and how to operate when information links are broken. (Just like policies for human organizations.)

Summary

Given that humans "in" the battlespace can be replaced by software applications and devices, how will the questions posed by the Megacities/Dense Urban Areas theme be addressed?

Situational understanding: Information will be collected and abstracted into measurable terms. Confidence will be determined and assigned by weighted factors in the system. The KEEL-based systems will be answering these questions throughout the hierarchy:

- What does it all mean?
- What should I {the element within the battlespace} do about it?

Human created policies will define how the entities should (and are allowed to) adapt. They will decide if they can operate on their own. They will decide if they can ask for help. They will switch objectives. All of this can be accomplished according to the human created policies. This doesn't mean humans are without responsibility. Opposing forces will be continually updated with new tactics and strategies (value systems). New sensors will be introduced to provide better and better information. With KEEL it is easy to add new information items into the policy, but it is still work for humans. Plus there will be after- mission reviews. Is the value system correct? Did the system (system of systems) perform as desired? Could it have performed better if the policy was adjusted? Was the system tricked? How can this be avoided in the future? How has the human population in the battlespace responded? Are the political, social, economic impacts appropriately considered in the system policies? Humans are still in control.

Freedom of movement and protection: Mathematically explicit policies will be created and executed. The future will be similar to a chess match because adversaries will adjust their tactics and strategies (and acquire devices with different capabilities) to probe the weaknesses of the opposition. There will be a transition from training humans (starting over with every warfighter) to continual refining of the operational policies.

Expeditionary operations: Policies of every type will be developed. They will be constantly upgraded and changed. It will be a war of information and disinformation.

Future training challenges: Training individuals in the use of KEEL will be easy. Much more emphasis will be on tactics and strategies and information warfare (trickery and deceit) where the effort will be to try and convince the opposition to shoot itself in the foot. Some of this will be social warfare to teach humans how to interact with the machines.

The platforms of conflict: By creating KEEL-based policies for autonomous systems

the systems/devices can operate independently, they can automatically decide when a group or team would be more/or less effective and self-organize, automatically create a command hierarchy, and pursue goals based on mathematically explicit policies. They can use a value system understood across the entire spectrum of devices that understand and can operate almost immediately to change anywhere in the battlespace. Unlike humans, these machines can have self-value determined by their owners. Unlike some present organizations where they have to recruit suicide bombers, devices can be used (by the "system") to probe defenses. Their destruction will be assumed and be an accepted part of the overall human controlled strategy. The result is that one ends up with platforms executing the "best" tactics and the "best" strategies as determined by the human chess players.

NOW (For Organizations That Can Accept New Ideas)

KEEL Technology is available now, not 20 years from now. It is possible to create these adaptive policies today. In the past, governments have had the luxury of fighting wars with individual humans. They trusted that those humans would behave in a desired manner. When some humans fail, failure is accepted, because they were human. When machines fight the wars, it will not be acceptable to mass produce bad behaviors. KEEL allows policies to be created and executed with mathematical precision, and those policies are 100% auditable. Organizations that understand the potential of KEEL Technology first will have an advantage compared to those "late to the table". This is just like an experienced chess player who competes against a novice. Granted, it will take time to automate the behaviors of the entire battlespace hierarchy. However, it will take a whole lot more time to do this using conventional approaches- if KEEL Technology isn't used.

The challenge to the US military is this: whether they want to be a leader or a follower using KEEL Technology in their autonomous systems. If a new technology is available that is so easy to use, and that technology can change how conflicts are fought, and determine who wins and who loses, then the balance of power can shift, almost over-night. New platforms can be created and deployed in months, rather than years. New platforms can cost hundreds of dollars, not billions. An organization with what appears to be superior capabilities one day can be following a small terrorist cell or individual anarchists the next day. Government "experts" who are paid for their knowledge may reject the idea that anything new can be invented that they don't know about, or that they haven't invented themselves (it's called "cognitive dissonance").

KEEL is not "artificial intelligence". It is an enabling technology that makes it easy to package human judgment and reasoning skills (expertise) into machines so the machines can behave as if the subject matter experts, operating with their rules of engagement, organizational structures, tactics and strategies were deployed in small inexpensive disposable devices.

Are you ready?

End Notes

[i] Mission Planner, http://planner.ardupilot.com/

[ii] Knowledge Enhanced Electronic Logic (KEEL) Technology;

http://compsim.com/Papers2014/About_KEEL.pdf ; http://compsim.com/military/index.html

[iii] NATO MCDC Workshop, http://www.compsim.com/Papers2014/News%20Release%20-%20MCDC2014.pdf

[iv] NATO Berlin 2015, http://www.compsim.com/Papers2014/News%20Release%20-%20KEEL%20Technology%20for%20Counter-UAS11162015.pdf

“TRAuma Care In a Rucksack” (TRACIR), a Disruptive Technology Concept

By ***Jan Berkow and Ron Poropatich***

Originally published in Small Wars Journal on 19 February 2016

Available online at : http://smallwarsjournal.com/jrnl/art/%E2%80%9Ctrauma-care-in-arucksack%E2%80%9D-tracir-a-disruptive-technology-concept

Introduction

Trauma care in future military environments will require medical technological innovations for an integrated force with the attributes and capabilities to mitigate risks and maximize clinical effectiveness in an Anti-Access, Area Denial (A2/AD) insurgency scenario. [1] According to the U.S. Army Roadmap for Unmanned Aerial Systems 2010-2035 [2], the aviation force mix will shift to mostly unmanned and optionally piloted vehicles. This necessitates accompanying autonomous and semi-autonomous Tactical Combat Casualty Care (TCCC) capabilities to support future UAS missions.

From the Medical Command Operational Order document, the Secretary of the Army and Chief of Staff Army (SECARMY)/(CSA) have initiated Force 2025 and Beyond (F2025B) - a holistic modernization strategy to develop and deliver Landpower concepts and capabilities to the Joint Force and integration into Doctrine, Organizations, Training, Materiel, Leadership, Personnel, Facilities, and Policy (DOTMLPF-P). [3] This strategy will field interim solutions to complete Army 2020, develop and field required capabilities for Force 2025, and set the conditions for forces in the far term horizon of 2040. The Chief of Staff of the Army envisions a future Army that is expeditionary, lethal, responsive, engaged and that is capable of shaping the operational environment. This vision will shape the future force requirements to include combat casualty care and medical evacuation, utilizing both autonomous and semi-autonomous systems. To address the autonomous requirement, it is posited that the practice of TCCC must undergo disruptive changes that enable the development of an “intelligent” TCCC platform. Applying concepts similar to those employed in robotics, an intelligent system is one that “has the ability to recognize objects and events and to represent knowledge in a world model”. [4] Further, “it is the integration of knowledge and feedback into a sensory-interactive, goal-directed control system that can make plans and generate effective, purposeful action directed towards achieving them”. [4]

It is further posited that the starting point to construct an intelligent TCCC platform demands the capture of quantifiable biomarkers that enable recognition of a trauma event and are supportive of trauma model development. This requires a paradigm shift in the practice of operational medicine from an “art” that employs subjective measures to assess and treat, to a “science” based on employing objective quantifiable measures. This will in turn, provide a fundamental change to the form of medical data that is captured, enable a more accurate depiction of poly-trauma model complexities, and an accounting of those tactical and operational practices to assess goal-directed effectiveness based on data derived actionable knowledge.

This change will also address several military operational needs identified during the period of 2001-2013 that include more accurate data collection from point of injury to a Role 3 facility as well as dissemination of patient status to enable improved telemedicine support and casualty care hand-over through the echelons of care. [5] This form of “operationalized “ medical data will also enable the trauma registry to serve as a tactical knowledge repository to which analytics can be more effectively applied, offering greater opportunity for continuous improvement of TCCC protocols.

Autonomous care also requires the pursuit of challenging critical care interventional system advances that can support closed-loop cardio-pulmonary resuscitation and robotic-driven imaging technologies to enable more precise patient assessments or guide critical care interventions during ground or air transport. The TCCC platform must also undergo a significant change in form factor (cube and weight) that is conducive to a transportable rapid deployment scenario such that it can fit into a Rucksack. This will require miniaturization of these advanced medical tools that can be quickly set up by one person near the point of injury. System portability also addresses the versatility requirement needed to support the use of any casualty for any “vehicle of opportunity” designated for casualty evacuation. These disruptive technology advances to the TCCC platform are paramount to address future theatre needs.

Disruptive Technologies

Significant improvement in pre-hospital far forward survival rates have been achieved from previous conflicts by continued analysis of injuries and mortalities that has resulted in the refinement of tactical combat care practices. The reduction of Golden Hour en route transport times, use of alternative resuscitation blood products, and changes in tourniquet practices are examples of evolutionary changes that have been implemented and have had a profound impact on survival rates. It is proposed that beginning with a new paradigm for those biomarkers used to recognize a disease condition, there are several disruptive technologies needed to develop an autonomous small form factor medical platform that is envisioned as providing “Trauma Care in a Rucksack”. Each technology proposed (Figure 1) serves as a building block to the next to fully address future theater requirements. The following is a list of proposed disruptive technologies needed to address future dense urban combat casualty theater requirements.

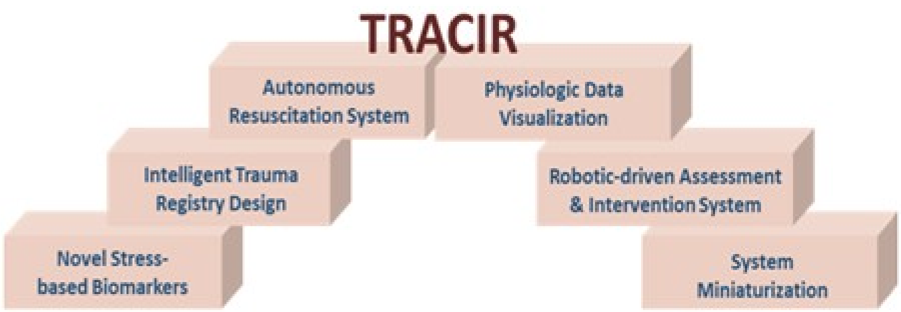


Figure 1: TRACIR's Disruptive Technology Building Blocks

Novel Stress-based Biomarkers

While many improvements to Tactical Combat Casualty Care (TCCC) have been made, advancements in the fundamental practice of battlefield medicine where the use of patient vital signs and symptomatic measures (signs and symptoms) to assess and treat the patient have languished. It is posited that this has been the primary impediment towards improving TCCC. Similar to civilian trauma care, the practice of TCCC relies primarily on training the medic or corpsman in the art of interpreting signs and symptoms that are then applied to a complex poly-trauma protocol to guide interventions. Practicing this “art of care” approach is extremely challenging even in a more controlled domestic emergent care facility without the logistical challenges of tactical field care or evacuation care or the threat of performing care under fire.

It is widely accepted that regardless of how miniaturized and portable, the use of vital sign sensors such as blood pressure and the capture of symptoms such as the pallor of skin or capillary refill, provides poor detection sensitivity offering limited advanced

warning to recognize an impending unstable condition.
This is because signs and symptoms occur during latter stages of a response to a trauma insult and are more indicative of the degree of compensatory exhaustion. Signs and symptoms also provide limited discriminatory accuracies to enable early recognition of the different causal poly-trauma states that serve as key decision points to determine an optimal intervention from the TCCC guidelines.

A more valuable biomarker reflects an autonomic nervous system (ANS) stress response. This is because the ANS response is a patient-specific measure of how the cardiovascular (CV) system is adapting to varying forms of stress (e.g. cognitive "fight or flight", physical exertion, environmental such as heat or cold, disease, trauma insults, etc.) in order to remain stable. Stability can be defined as the ability to constantly adapt circulatory flow to stress related changes in blood flow demand in order to maintain adequate oxygen delivery to the tissues and organs. The current use of signs and symptoms reflects latter stage measures for how well the CV system is adapting to the aggregate effects of stress placed upon it. An abnormal sign or symptom measure is evident when CV adaptation is failing. For example, a static blood pressure provides a general range for when the CV adaptive mechanisms to maintain stability from the stress of hemorrhagic shock have been exhausted offering little to no advanced warning for when to act nor any discriminatory value as to cause.

Alternatively, it is possible to capture non-invasive hemodynamic and metabolic biomarkers that correlate with the various CV adaptive mechanisms themselves that provide an early stage, patient-specific means to characterize a specific stress response. For example, a primary adaptive response to stress is small artery vascular constriction which causes the transfer of blood to flow to the central circuit. [6] [7] This constriction response is activated by a drop in aortic (baroreceptor detected) pressure that enables recognition of increased circulatory flow demand that may have been triggered by the circulatory stress from hemorrhage, exercise or other causes. Activation of small artery vasoconstriction occurs prior towhen changes in vital signs and symptoms become evident. Use of a measure of small artery vasoconstriction can serve as a broad event indicator to recognize an impending unstable CV condition and provide an adequate interventional time window to act prior to when the patient decompensates.

Further, if multiple CV adaptive mechanisms (or correlates) inclusive of both hemodynamic and metabolic measures are captured, a more precise characterization of the type of stress response can be captured. Use of machine learning methods can be applied to identify combinations of these novel temporal pattern-based biomarkers with the most predictive accuracy to recognize a specific form of poly- trauma stress response in the future. Further, these poly-stress responses can be translated into software rule-based events similar to how computers continually monitor data streams for software viruses. The use of a poly-trauma event (PT) provides a more precise characterization of the patient's physiologic states that can serve as the primary building block needed to build an intelligent TCCC platform.

Intelligent Trauma Registries

Registries are currently used for "strategic" medical purposes to enable determination of optimal practices that provide the best outcomes as opposed to having tactical utility. The Office of the Secretary of Defense/Health Affairs directed the services to implement the "Joint Theater Trauma Registry" (JTTR) in December 2004, and more recently evolved into the DoD Trauma Registry (DODTR). The DODTR has had a major impact in documenting the types of wounds and treatments rendered, resulting in clinical process improvements and standardization of provider practice for hospital care. However, still lacking is a comprehensive and integrated system for data collection and analysis to improve performance at the pre- hospital level of care. Capture of the TCCC based casualty cards, after action reports, and unit-based pre- hospital trauma registries, linked with novel sensor biomarkers need to be implemented globally and linked to the DoD Trauma Registry in a seamless manner that will optimize pre-hospital trauma care delivery. [8]

A future value of the data registry is to capture more granular medical data to determine the optimal protocol to perform for a specific poly-trauma event. This could be called an "Intelligent Registry" where the product is a catalog for event-driven, goal-directed care using "operationalized" medical data (captured from point of injury to Role 3 medical facilities) across the evacuation continuum and added to the JTTR. Such an "Intelligent Registry" would not only include the current critical care data elements (i.e. vital signs, treatments rendered) but also include novel biomarkers (i.e. arterial vasoconstriction measurements) in a robust data set leading over time with machine learning to predictive analytics and improved clinical outcomes.

The first data requirement is the need to capture "context" that includes data to describe the patient type. This includes demographics and current physiological state of the casualty to further classify the patient. This is another aspect of the "art of care" that many take for granted, where a clinician typically assimilates information such as ambient temperature and patient age for example, that may be a means to discriminate PT events from one another. This form of medical data can be acquired physiologically or from a medical record such as one stored on a barcode worn by the patient.

The next type of medical data required are those interventions that have been performed on the patient. In an OR setting, the anesthesiologist factors in the type of anesthetics used for example, to anticipate decreases in blood pressure due to known vasodilatory effects from the anesthetic used. Without determining whether the current PT event is resultant of a pharmacological intervention for example, it may be difficult to predict how a patient will respond to additional interventions. This suggests that some cataloged PT events are poly-trauma stress responses in combination with a pharmacologic, blood product or other physiology altering prophylactic. This also implies that there must be some kind of methodology to automate the documentation of interventions employed. In an automated scenario, this becomes much simpler as every intervention is performed by the TCCC device platform and can therefore be recorded. Ultimately a taxonomy of PT events can be developed.

Another important component of the "Intelligent Data Registry" is the knowledge-building aspect of the registry that focuses on building a predictive capability for the efficacy of an intervention performed on a specific patient type exhibiting a specific PT event. This requires performing an ongoing retrospective analysis to evaluate or "score" which interventional protocol has the optimal near-term response and longer-term outcome. Development and sharing of civilian trauma registries with DoD operational medical data registries will accelerate the critical mass of evidence-based medical data needed to more rapidly refine the discriminatory accuracy of PT events to achieve optimal interventional strategies.

Semi-autonomous and Autonomous Resuscitation

Once an intelligent trauma registry structure has been created to capture PT events, formalization of the pathophysiological progression of different types and combinations of trauma insults can be documented. This offers the potential to construct models beginning with animal trauma studies that allow for identification of quantifiable detection thresholds and intervention endpoints that can be further refined with ongoing human registry data collection.

This evidence-based intelligent trauma registry content can, in turn be used to construct an intelligent advisor to guide the corpsman or medic. Alternatively, an autonomous or closed-loop resuscitative capability can be developed. Interventions and key data inflection points can be translated into upper and lower control limits for a servo-driven infusion pump or respirator resuscitation system. Current closed- loop designs provide generalized algorithms with broad utility across many patient types and underlying trauma etiologies. Autonomous systems that have the benefit of ongoing learning from Intelligent Trauma Registry access will be able to continuously refine the evidence-based protocols employed that will ultimately result in improved outcomes and strategies to address outliers not currently possible.

Physiologic Data Visualization

Newer physiologic monitoring device interfaces have a dashboard-like appearance that allow the user to quickly determine whether the physiology parameters collected are within the acceptable ranges per the current standard of care. Current military training relies on visualization of the stop light analogy – i.e. green, yellow, and red indices - reflective of safe, indeterminate or danger zones, respectively. Future user interfaces will appear more like a multi-dimensional 3-D contour plot to reflect the operating ranges for each compensatory mechanism (Figure 2). A prominent bounded operating range will be constructed from evidence-based upper and lower operating control limits for each compensatory dimension contributing to patient stability. By providing a multi-dimensional process control-like visual, it will be intuitive when patient stability is beginning to head outside of optimal operating range and which compensatory contribution requires intervention - a minor or major adjustment. Data visualization tools constructed in this way will also provide more informative remote patient monitoring data to empower telemedicine resources or facilitate improved patient hand-over through the en route care continuum.

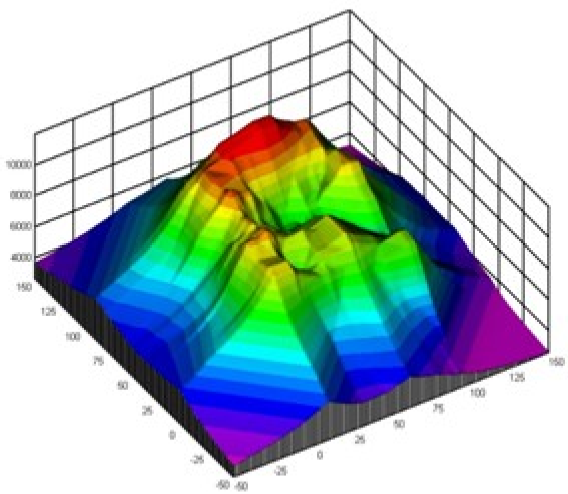


Figure 2: A Visual of a Multi-dimension Contour Plot

Robotic-Driven Assessment & Intervention

An autonomous system must be capable of performing a more comprehensive patient assessment and initiate cardio-pulmonary resuscitation related interventions to support prolonged field care for durations of up to two-hours [5]. Lightweight, highly accurate robotics such as in the form of a “soft” robotics body-wrap will be required to manipulate both the patient and embedded visual arrays with imaging devices to provide a more complete assessment of the patient. Likewise, image-guided robotic strategies can be employed to identify those physiologic landmarks to perform image-guided needle placement to facilitate ventilatory (cricothyrotomy or thoracostomy) or circulatory (endovascular aortic balloon placement for non-compressible hemorrhage) interventions. These capabilities are perhaps the most “DARPA-hard” of the disruptive technologies mentioned. More extensive discussions are required to accommodate all possible use cases and logistical challenges to fully assess the requirements for this type of capability.

System Miniaturization

Common to all technologies discussed, a primary consideration must be given to size and weight requirements that enable accommodating a "rucksack" form-factor. Given the advances made in integrated sensor design, mobile platform computational capabilities capable of rapid local signal processing, integrated communications, and nominal power requirements, miniaturization is perhaps more evolutionary rather than revolutionary and disruptive. However, the clinical utility afforded by a portable ICU quality TCCC platform that can be easily transported to the point-of-injury is indeed disruptive.

Conclusion

The "Trauma Care in a Rucksack" (TRACIR) concept addresses many of the combat casualty care operational deficiencies identified in past conflicts by proposing a novel approach to a fundamental technical challenge. This challenge is to overcome the pervasive use of subjective physiologic signs and symptoms used as the standard of care to triage or assess and treat patients that is also an obstacle towards providing a semi-autonomous and autonomous Tactical Combat Casualty Care (TCCC) solution. A set of disruptive technology building blocks is proposed to create a paradigm shift in how medical data is defined, stored, captured, visualized, and shared such that a more easily transportable semi-autonomous and autonomous TCCC solution can be developed. The proposed TRACIR platform satisfies key operational requirements for use by any vehicle of opportunity, during prolonged field care in denied environments, and for future Unmanned Aerial Systems' needs.

References

1. Thomas B, Amouzegar MA, Costello R, Guffey RA, Karode A, Lynch C, Lynch KF, Munson K, Ohlandt CJR, Romano DM, Sanchez R, Tripp RS, Vesely JV. Project AIR FORCE Modeling Capabilities for Support of Combat Operations in Denied Environments. **http://www.rand.org/content/dam/rand/pubs/research_reports/RR400/RR427/RAND_RR427.pdf** ; accessed 11 February 2016.
2. U.S. Army Roadmap for UAS 2010-2035.**http://www-rucker.army.mil/usaace/uas/us%20army%20uas%20roadmap%202010%202035.pdf**; accessed 11 February 2016.
3. Force 2025 and Beyond: Preparing to Win in a Complex World. **http://www.arcic.army.mil/Articles/f2025bd-Force-2025-and-Beyond-Preparing-To-Win-In-A- Complex-World.aspx**; accessed 11 February 2016.
4. Meystel AM, Albus JS; Intelligent Systems Architecture, Design, and Control; John

Wiley & Sons, Inc. 2002; page 3.

5. Combat Trauma Lessons Learned from Military Ops of 2001-2013.Defense Health Board, Office of Assistant Secretary of Defense; Health Affairs; March 2015.
6. Hall, John. *Textbook of Medical Physiology.* (12th ed.). Elsevier Science Publishers. p. 184. **ISBN** **9788480868198**.
7. Klaubunde, Richard. *Cardiovascular physiology concepts.* (2nd ed.). Lippincott Williams & Wilkins. p. 181. **ISBN 9781451113846**.
8. Kotwal RS, Butler FK, Montgomery HR, Brunstetter TJ, Diaz GY, Kirkpatrick JW, Summers NL, Shackelford SA, Holcomb JB, Bailey JA. **The Tactical Combat Casualty Care Casualty Card TCCC Guidelines - Proposed Change 1301.** J Spec Oper Med. 2013 Summer;13(2):82-7.

Assessing Physiological Response to Toxic Industrial Chemical Exposure in Megacities

*By **Danielle L. Ippolito***

Originally published in Small Wars Journal on 14 March 2016

Available online at: http://smallwarsjournal.com/jrnl/art/assessing-physiological-response-to-toxic-industrial-chemical-exposure-in-megacities-0

Introduction

Megacities—urban areas with populations of ten million or greater—and other dense urban environments are emerging and growing globally, posing new challenges for U.S. military operations. The United States (U.S.) military can be better positioned for potential future operations within megacities as part of a joint, interagency, intergovernmental, and multinational team by increasing its understanding of megacity environments (Harris et al., 2014). Chemical exposures pose risk to the health and readiness of Service Members operating in these environments. The Naval Research Laboratory (NRL) prioritized a list of the top 30 chemicals of concern for global military operations based on physical characteristics and available toxicology data (Sutto, 2015). Occupational exposure to these chemicals increases risk of developing adverse health effects during mission operations or post-deployment. Policy guidelines specifying the use of the appropriate personal protective gear constitute the first line of defense to protect personnel by limiting exposure in the field. After a confirmed or suspected exposure event, far-forward diagnostic tools are needed to quickly and effectively determine and manage the risk of adverse health effects post- exposure in order to make informed command decisions about return-to-duty and treatment options.

Identifying and quantifying biomolecular indicators in accessible biofluids such as blood, saliva, or urine is critically important for evaluating chemically-induced disease prognosis (Tawa et al., 2014; Ippolito et al., 2015). Biomarkers of end-organ toxicity can be integrated into a fieldable detection system to rapidly diagnose chemical exposure-induced adverse health effects in theater. Noninvasive or minimally invasive screening methods could enable early intervention, treatment, and informed decision making to optimize force readiness. Mapping biomolecular patterns of adverse health effects represents a promising solution to the complex problem of assessing health effects after exposure to mixtures of different chemicals and
/or pollutants and aggregated exposure effects over time (Silins & Högberg, 2011).

This systematic literature review identifies and assesses the level of evidence for candidate far forward diagnostic technologies and biomarkers that may be used to detect emerging health effects from exposure to militarily-relevant chemicals. The review emphasizes a subacute exposure window (i.e., days to weeks) best suited to the short-term exposure scenarios anticipated in military operations and mission scenarios. Biomarker development demands meeting rigorous regulatory and clinical standards before adoption in the field, but military investment in this research and development process has the potential for significant returns in military healthcare during the deployment life cycle. Biomarker-based screening technologies can benefit routine health care screening, return-to-duty decision-making, triage during mass casualty exposure events, and/or guiding the development of diagnostics to inform treatment options. Biomarker- based far-forward diagnostic strategies and technologies have the potential to transform military healthcare in the changing face of warfare in megacities and dense urban operating environments

Methods

The peer-reviewed literature was surveyed to evaluate the weight-of-evidence regarding biomarkers for emerging health effects resulting from exposure to militarily-relevant chemicals (Table 1). The target list of militarily relevant chemicals was based on 30 prioritized megacity chemical hazards outlined in the *NRL Industrial Chemical Assessment for Hazard, Probability, and Biomarker Prioritization* (Sutto, 2015). A biomarker was defined as a molecular, cellular, or biophysical event linked to an emerging health effect.

Table 1. High Priority Megacity Military relevant Toxic Industrial Chemical Hazards. Adapted from NRL Industrial Chemical Assessment for Hazard, Probability and Biomarker Prioritization (Sutto, 2015)

Global Rank	Toxic Industrial Chemical	Global Rank	Toxic Industrial Chemical
1	Chlorine	16	Phosphoryl trichloride
2	Ammonia	17	Chlorine dioxide
3	Hydrogen chloride	18	Bromine
4	Sulfuric acid	19	Nitrogen dioxide
5	Hydrogen fluoride	20	Phosphorus trichloride
6	Formaldehyde	21	Fluorotrichloromethane
7	Mercury	22	Hydrogen sulfide
8	Nitric acid	23	Molybdophosphoric acid
9	Sulfur dioxide	24	Toluene-2,4-diisocyanate
10	Phosgene	25	Fluorine
11	Hydrogen bromide	26	Malathion
12	Nitric Oxide	27	Parathion
13	Octamethyl pyrophosphoramine	28	Acetylene tetrabromide
14	Boron trifluoride	29	o-Anisidine
15	Methyl bromide	30	Phosphine

Databases searched included PubMed, Web of Knowledge, Google Scholar, ClinicalTrials.gov, publicly available Department of Defense (DoD) technical reports (e.g., Defense Technical Information Center), non-DoD sources, and the Center for

Disease Control Agency for Toxic Substance & Disease Registry and from the U.S. Library of Medicine Hazardous Substances Data Bank ("Agency for Toxic Substance & Disease Registry - Medical Management Guidelines Home Page," n.d., "U.S. National Library of Medicine - Hazardous Substances Data Bank," n.d.). Search terms were selected to identify studies that examined health effects associated with exposure to the high priority chemicals. The search was limited to articles published in English from January 2005 to May 2015.

Peer-reviewed articles were excluded if they (1) reported acute responses requiring immediate palliative care, (2) reviewed *in vitro* or computational toxicology sites that did not use publically available data sets, and (3) discussed mechanistic biomarkers without clear implications for candidate prognostic markers suitable for fieldable detection devices.

An objective two-step grading approach based on the U.S. Preventive Services Task Force Grade Definitions was used to assess the internal validity of individual studies published in peer-reviewed journal articles that met the inclusion criteria. The first step in evidence grading methodology identified and ranked the study design within a hierarchy of evidence, and the second step assessed the study quality (good, fair, poor). Study designs included the following categories: preclinical research (e.g., animal models), clinical research (e.g., clinical trials, diagnostic studies), epidemiological research (e.g., cohort studies, intervention studies), and secondary research (e.g., meta-analysis, systematic reviews). If a publication contained both a preclinical study and a clinical study, a separate grade was assigned for each study.

Results and Discussion

A review of 57 current papers in the diagnostic device literature identified five classes of biomarker detection devices (Figure 1). Most of the devices in development are lab-on-a-chip designs and paper- based lab-on-a-chip (LOC paper) protoypes. Frequently portable and disposable, these designs may be amenable to military field settings (Shafiee et al., 2015). Unique technological challenges limit the utility of many prototype diagnostics for use in a far-forward operational setting. Further research, clinical trials, and validation are needed to advance the devices beyond the prototype stage (Hoenigl et al., 2014). Ruggedization and miniaturization of laboratory prototypes are significant challenges in fielding these devices (Greenwood et al., 2007).

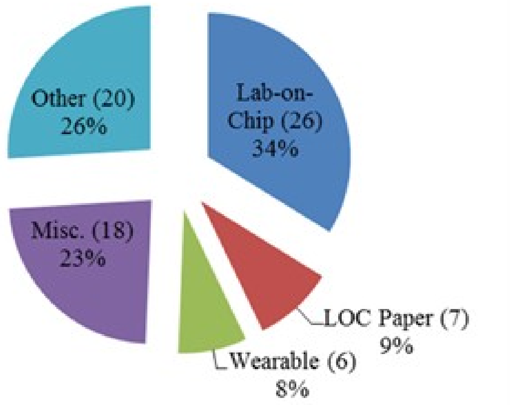


Figure 1. Biomarker detection devices under development identified by environmental literature scan. Modifications are necessary before many of these detection devices are available in far-forward diagnostic settings. (LOC, lab-on-a-chip)

Table 2 lists the target organs of adverse health effects following exposure to each of the chemicals. Table 3 reports the key acute, subacute, and chronic health effects for each target organ. Most of the data summarized in Tables 2 and 3 are derived from a scan of public toxicology data repositories (e.g., the Hazardous Substances Data Bank and related ToxNet resources). These repositories identify relevant studies outside the time frame of the systematic review (i.e., before 2005-2015).

Table 2. Top 30 prioritized militarily relevant toxic industrial chemicals by target organ adverse health effects.

High Priority Militarily Relevant Industrial Chemical	Target Organs								
	Lung	CNS/PNS*	Heart	Liver	Kidney	Gastrointestinal	Skin	Bone	Other
Chlorine	✓		✓			✓	✓		✓
Ammonia	✓	✓		✓		✓	✓		✓
Hydrogen chloride	✓					✓	✓		✓
Sulfuric acid	✓					✓	✓		✓
Hydrogen fluoride	✓		✓			✓	✓	✓	✓
Formaldehyde	✓					✓	✓		✓
Mercury	✓	✓	✓			✓	✓		✓
Nitric acid	✓					✓	✓		✓
Sulfur dioxide	✓						✓		✓
Phosgene	✓		✓				✓		✓
Hydrogen bromide	✓		✓			✓	✓		✓
Nitric oxide	✓	✓				✓	✓		✓
Octamethyl pyrophosphoramine	✓	✓				✓	✓		✓
Boron trifluoride	✓				✓		✓		✓
Methyl bromide	✓	✓				✓	✓		✓
Phosphoryl trichloride	✓					✓	✓		✓
Chlorine dioxide	✓					✓	✓		
Bromine	✓	✓				✓	✓		✓
Nitrogen dioxide	✓		✓						✓
Phosphorus trichloride	✓					✓	✓		✓
Fluorotrichloromethane	✓	✓	✓			✓			
Hydrogen sulfide	✓	✓	✓						
Molybdophosphoric acid	✓					✓	✓		✓
Toluene-2,4-diisocyanate	✓					✓	✓		✓
Fluorine	✓						✓		✓
Malathion	✓	✓	✓			✓	✓		✓
Parathion	✓	✓	✓			✓			
Acetylene tetrabromide	✓	✓		✓	✓	✓			✓
o-Anisidine	✓	✓	✓	✓	✓		✓		✓
Phosphine	✓	✓	✓	✓		✓			

* CNS/PNS = Central Nervous System/Peripheral Nervous System

Table 3. Key acute, subacute, chronic health effects by target organ associated with exposure to the top 30 prioritized megacity chemicals

TARGET ORGAN		HEALTH EFFECTS		
		Acute	Subacute	Chronic
Lung		• Inflammation/ulceration of respiratory tract, and airway damage (e.g., nasopharyngeal/tracheal burns, epistaxis) • Acute pulmonary edema • Severe pulmonary injury leading to pneumothorax and pneumomediastinum • Respiratory failure	• Delayed lung damage including pulmonary edema • Respiratory failure • Acute lung injury / acute respiratory distress syndrome (onset typically within 48–72 hr)	• Inflammation/ulceration of respiratory tract, and airway damage (e.g., nasopharyngeal/tracheal burns, epistaxis) • Acute pulmonary edema • Severe pulmonary injury leading to pneumothorax and pneumomediastinum • Respiratory failure
CNS/PNS		• CNS depression • Neurobehavioral effects (e.g., drowsiness, agitation, confusion) • Seizures • Unconsciousness • Loss of coordination	• Neuropsychiatric sequelae (e.g., ataxia, nystagmus, tremors, myoclonus, seizures, dementia, psychosis) • Speech difficulty	• Neurodegeneration • Neurobehavioral effects (e.g., anxiety, depression, suicide ideation) • Visual, speech, and memory disturbances • Neuromuscular effects (e.g., weakness, motor disturbances)
Heart		• Arrhythmia (e.g., bradycardia, tachycardia) • Dysregulation of blood pressure (depression, hypertension)	• Myocardial injury	• Heart failure
Liver		• Hepatosplenomegaly • Acute liver failure	• Liver damage	• Liver damage or failure • Cancer
Kidney		• Acute kidney injury (potentially with oliguria, anuria)	• Renal damage	• Renal damage; Chronic renal failure
Gastrointestinal (GI) Tract		• Inflammation, ulceration, and burning throughout the GI tract • Salivation • GI dysfunction (e.g., cramps, stomach pain, vomiting, diarrhea, fecal incontinence, blood in the feces)	• Gradual and lingering narrowing of the esophagus	• Persistent GI distress, including gastritis • Dental discoloration or erosion • Cancer
Other	Bladder	• Urinary incontinence		• Cancer
	Blood	• Hypoxic conditions (e.g., methemoglobinemia, increased sulfhemoglobin, cyanosis)		• Anemia • Reticulocytosis
	Bone			• Bone Loss
	Lymphatics/ Immune	• Hepatosplenomegaly		• Allergies
	Musculature	• Muscle twitching, weakness (due to neuromuscular damage); tissue damage (e.g., deep burns)		
	Pancreas	• Beta-cell injury	• Beta-cell injury; insulin resistance	• Beta-cell injury and insulin resistance; risk of diabetes
	Peripheral Nervous System	• Diminished reflexes	• Peripheral neuropathy	• Peripheral neuropathy
	Reproductive			• Menstrual disorders

Articles meeting the inclusion criteria for adverse health effects were organized into eight specificntarget organ categories: lung, central nervous system (CNS), peripheral nervous system (PNS), heart, liver, kidney, gastrointestinal, other, and multiple (Figure 2). A summary of the literature review by target organ for five key target organs (lung, CNS/PNS, heart, liver, and kidney) follows.

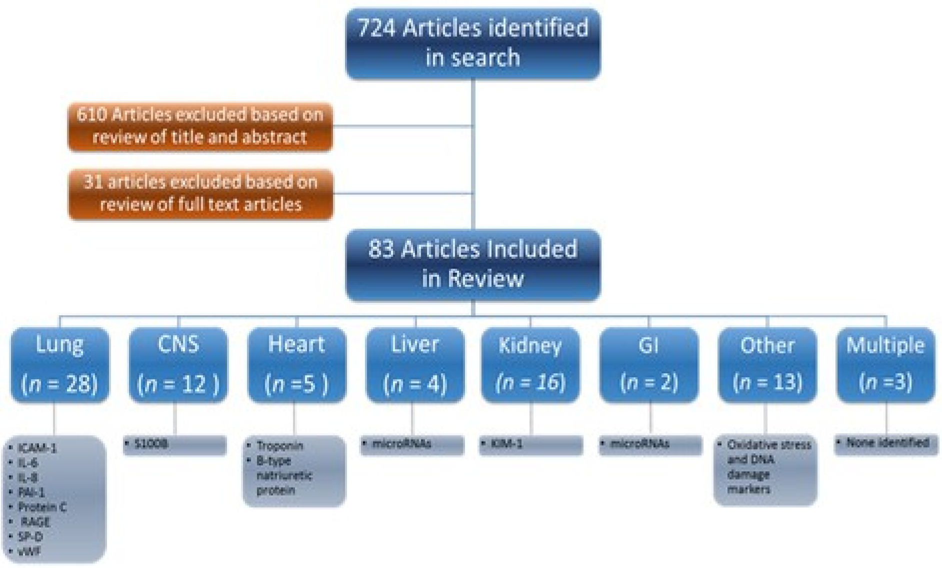


Figure 2. Systematic review scheme for selecting and grading articles identifying biomarkers of adverse health effects caused by exposure to 30 high priority megacity chemicals. Biomarkers associated with each target organ are listed.

Lung. Several of the 28 lung-related articles identified biomarkers correlating with acute lung injury/acute respiratory distress syndrome (ALI/ARDS): RAGE, ICAM-1, KL-6, SP-D, vWF, IL-6, IL-8, protein C, PAI-1, TNFR1 and 2, and thrombomodulin (Agrawal et al., 2012; Calfee et al., 2008; Calfee et al., 2009; Collard et al., 2010; McClintock et al., 2008; Parsons et al., 2005; Uchida et al., 2006). Many of these biomarkers were associated with clinical outcomes (e.g., ventilator-free days, organ-failure-free days, and mortality). Mean levels the proteins PBEF or MIF were significantly greater in serum of ALI patients than healthy controls although the specificity for ALI remains uncertain (Gao et al., 2007; Ye et al., 2005).

Combining predictive markers improved predictive power. Low levels of protein C and high levels of PAI- 1 were independent predictors of mortality, and the two markers had a synergistic interaction for the risk of death (Ware et al., 2007). Levels of RAGE, PCP III, BNP, ANG-2, IL-8, TNF-?, and IL-10 show potential as a diagnostic biomarker panel (Fremont et al., 2010). In two studies, combinations of clinical predictors and multiple plasma biomarkers measured in individuals with ALI/ARDS improved predictive power for mortality over either approach alone, with some evidence that trauma differentially affects odds of mortality (Calfee et al., 2011; Ware et al., 2010). Exposure to isocyanates (e.g., TDI and MDI) was linked to occupational asthma. Biomarkers associated with this clinical outcome included VDBP, MMP-9, VEGF, LSP-1, COR1A, HPX, and autoantibodies to tTG, CK18, and CK19 (Kim et al., 2011; Hur et al., 2008; Ye et al., 2006; Haenen et al., 2012). F_2-IsoP in plasma and lung tissue and SOD1 and COX2 in lung tissue may be associated with respiratory exposure to cadmium or silica nanoparticles (Coccini et al., 2012). Pulmonary fluid proteins and/or bronchial lavage proteins are biomarker candidates for lung injury, including ferritin, transferrin, CC16, ICAM-1, and PBEF (Hur et al, 2008; Kropski et al., 2009; Ye et al., 2005). Biomarkers in exhaled breath present an attractive alternative for accessibility in field settings (eNO and eCO_2 after exposure to chlorine and phosgene) or cytokines such as IL-4 after exposure to NO_2; Luo et al., 2014; Nath and Januszkiewicz, 2008).

Central and peripheral nervous system (CNS/PNS). The 18 articles associated with CNS/PNS injury included serum biomarkers associated with neurological sequelae, mostly associated with organophosphate pesticide (OP) exposure. These biomarkers of OP exposure and effect included a panel of autoantibodies (e.g., antibodies to NFP, TAU, MAP-2, MBP, GFAP, S100B), blood ChE/AChE, creatinine kinase, AST, LysoPC hydrolase in erythrocytes, SOD activity and/or LPO concentration after exposure to organophosphate pesticides (Abou-Donia et al., 2013; Rohlman et al., 2011; Bayrami et al., 2012; Vose et al., 2007; Colak et al., 2014; Aygun et al., 2007). Biomarkers to non-OP-related chemical exposures included GRIA 1 and glial S100B after exposure to mercury (Park et al., 2012) and serum S100B after acute CO poisoning (Abou-Donia, 2013).

Heart. A combination of biophysical and serum biomarkers were identified for the heart. Isoforms of troponin and cardiac natriuretic proteins released into the serum were associated with myocardial injury. Hydrogen sulfide poisoning resulted in cardiac proteins TNI and CPK-MB increased over time in conjunction with ECG data (Hirakawa et al., 2013). OP poisonings were associated with elevated TNI detecting acute early phase of cardiac injury (e.g., within the first 48 hours) (Cha, Cha et al., 2014). There is strong evidence for the emerging utility of cardiac troponins in stratifying toxicity risk (Dolci et al., 2008). Biophysical biomarkers included ECG measurements to determine risk of myocardial injury and arrhythmias (e.g., transmyocardial repolarization parameters to myocardial injury, left ventricle ejection fraction), especially after CO poisoning and OP exposure (Akilli et al., 2013). An emerging literature identifies micro-ribonucleic acids (miRNAs) in the prediction, detection, assessment, or treatment of myocardial damage and cardiac dysfunction (Sandhu & Maddock, 2014).

Liver. Four articles identified liver biomarkers in serum, including miRNAs (serum miR-125a-5p, miR- 192 and miRNA-122; Zheng et al., 2015; Zhang et al., 2010). Changes in miRNA levels assessed in liver tissue implicate miRNAs such as miR-34a as promising new candidates in serum or urine (Koufaris et al., 2012). Liver injury diagnosis is routinely made in conjunction with clinical chemistry data, including alanine amino transferase (ALT). A panel of plasma or serum biomarkers diagnosed liver fibrosis in animal models (fibrinogen precursor, ceruloplasmin isoform 1, insulin like growth factor binding protein, alpha-2-macroglobulin, and vitronectin) (Ippolito et al., 2015).

Kidney. The 17 kidney-related articles identified biomarkers in serum and urine. Acute kidney injury markers in serum included LG3, cathepsin L, NGAL, IL-6, soluble TNFR1 and 2, and PAI-1 as potential candidates (Haase et al, 2014; Liu et al., 2007). Clinical studies have identified promising urinary biomarkers of acute kidney injury and/or nephrotoxicity, including KIM-1 protein after TCE exposure (Vermeulen et al., 2012). Urinary panels include Alb, NAG and ?1-MG as indicators of fluoride and arsenic-induced glomerular and tubular injury (Zeng et al., 2014). KIM-1 predicted kidney injury earlier than the traditional biomarkers, such as creatinine, BUN, and/or NGAL (Rached et al., 2008; Vaidya et al., 2010; Wunnapuk, Gobe, et al., 2014; Zhou et al., 2008). Many of the preclinical studies examined urinary biomarkers of kidney injury other than KIM-1 (e.g., Cal, Clu, KIM?1, Lcn2, the three-branched chain amino acids [leucine, isoleucine, and valine], OPN, TTF3) and provide important foundational information (Boudonck et al., 2009; Fuchs et al., 2014; Hoffmann et al., 2010; Wunnapuk, Liu, et al., 2014; Yu et al., 2010).

***Other health effects*.** Other health effects with biomarker candidates included gastrointestinal, reproductive, cancer progression, blood, bone, and lymphatics (see Tables 2 and 3 and Figure 2).

Conclusions

As megacities and dense urban environments continue to grow in number and population size, there is an unmet need to understand the health threats of service members exposed to toxic chemicals and environmental hazards unique to the megacity operational environment. Properly validated biomarkers of exposure and effect can integrate with current biomonitoring systems throughout the soldier deployment life cycle to inform medical decisions during and after exposure events, especially in polluted megacity operational environments with increased risk of non-agent chemical exposure. Further research is needed to ensure the fieldability of ruggedized detection systems in the megacity environment.

Acknowledgements: This manuscript is based on a DTIC report submitted by Booz Allen Hamilton entitled "Biomarkers for Health Effects of Industrial Chemical Exposure Literature Review", submitted to USACEHR on behalf of USAMRMC-MOMRP on 26 June 2015. We gratefully acknowledge COL Thomas C. Timmes, USA, Commander of USACEHR, for programmatic support.

Acronyms and Abbreviations

AChE	Acetylcholinesterase
Alb	Albumin
ALI	Acute Lung Injury
ALP	Alkaline Phosphatase
ALT	Alanine Aminotransferase
ANG-2	Angiopoitetin-2
ARDS	Acute Respiratory Distress Syndrome
AST	Aspartate Aminotransferase
BNP	B-type Natriuretic Protein

BUN	Blood Urea Concentration
Cal	Calbindin-D28
CC16	Clara Cell 16
ChAT	Choline Acetyltransferase
ChE	Cholinesterase
CI	Confidence Interval
CK	Cytokeratin
Clu	Clusterin
CNS	Central Nervous System
CO	Carbon Monoxide
COR1A	Coronin 1A
COX2	Cyclooxygenase Type 2
CPK	Creatine Kinase
DNA	Deoxyribonucleic acid
ECG	Electrocardiogram
eCO_2	Exhaled Carbon Dioxide
eNO	Exhaled Nitric Oxide
F_2-IsoP	F_2-Isoprostanes
GFAP	Glial Fibrillary Acidic Protein
GRIA 1	Glutamate Receptor 1
HPX	Hemopexin
HSA	Human Serum Albumin
ICAM-1	Intercellular Adhesion Molecule-1
IL	Interleukin

KIM-1	Kidney Injury Molecule-1
Lcn2	Lipocalin 2
LG3	Prelecan C-terminal Fragment LG3
LPO	Lipid Peroxidation
LSP-1	Lymphocyte Specific Protein-1
LysoPC	Lysophosphatidylcholine
MBP	Myelin Basic Protein
MDI	Methylene Diphenyl Diisocyanate
MIF	Migration Inhibitory Factor
miRNA	micro-Ribonucleic Acid
MMP-9	Matrix Metalloproteinase-9
MPO	Myeloperoxidase
NAG	N-Acetyl-?-D Glucosaminidase
NFP	Neurofilament Triplet Proteins
NGAL	Neutrophil Gelatinase-associated Lipocalin
NMP22	Nuclear Matrix Protein-22
NO^2	Nitrogen Dioxide
OP	Organophosphate
PAI-1	Plasminogen Activator Inhibitor-1
PBEF	Pre-B-Cell Colony-Enhancing Factor
PCP III	Procollagen Peptide III
PNS	Peripheral Nervous System
RAGE	Receptor for Advanced Glycation Endproducts
S100B	S100 Calcium-Binding Protein B
SOD	Superoxide Dismutase
SP	Surfactant Protein

TCE	Trichloroethylene
TDI	Toulene-2,4-Diisocynate
TFF3	Trefoil Factor 3
TIC	Toxic industrial chemical
TIM	Toxic industrial material
TNFR	Tumor Necrosis Factor Receptor
TNI	Troponin I
Tp-e	Tpeak-Tend
U.S.	United States
USACEHR	United States Army Center for Environmental Health Research
VDBP	Vitamin-D-Binding Protein
VEGF	Vascular Endothelial Growth Factor
vWF	Willebrand Factor
?1-MG	?-1-microglobulin

References

1. Abou-Donia, M. B., Abou-Donia, M. M., ElMasry, E. M., Monro, J. A., & Mulder, M. F. A. (2013). Autoantibodies to Nervous System-Specific Proteins Are Elevated in Sera of Flight Crew Members: Biomarkers for Nervous System Injury. *Journal of Toxicology and Environmental Health, Part A*, *76* (6), 363–380. http://doi.org/10.1080/15287394.2013.765369
2. Agrawal, A., Zhuo, H., Brady, S., Levitt, J., Steingrub, J., Siegel, M. D., … Liu, K. D. (2012). Pathogenetic and predictive value of biomarkers in patients with ALI and lower severity of illness: results from two clinical trials. *American Journal of Physiology - Lung Cellular and Molecular Physiology*, *303*(8), L634–L639. http://doi.org/10.1152/ajplung.00195.2012
3. Akilli, N. B., Akinci, E., Akilli, H., Dundar, Z. D., Koylu, R., Polat, M., & Cander, B. (2013). A new marker for myocardial injury in carbon monoxide poisoning: T peak-T end. *The American Journal of Emergency Medicine*, *31*(12), 1651–1655. http://doi.org/10.1016/j.ajem.2013.08.049
4. Aygun, D., Erenler, A. K., Karatas, A. D., & Baydin, A. (2007). Intermediate Syndrome Following Acute Organophosphate Poisoning: Correlation with Initial Serum Levels of Muscle Enzymes*. *Basic & Clinical Pharmacology & Toxicology*, *100*(3), 201–204. http://doi.org/10.1111/j.1742-7843.2007.00042.x

5. Bayrami, M., Hashemi, T., Malekirad, A. A., Ashayeri, H., Faraji, F., & Abdollahi, M. (2012). Electroencephalogram, cognitive state, psychological disorders, clinical symptom, and oxidative stress in horticulture farmers exposed to organophosphate pesticides. *Toxicology and Industrial Health*, *28*(1), 90–96. http://doi.org/10.1177/0748233711407243
6. Boudonck, K. J., Rose, D. J., Karoly, E. D., Lee, D. P., Lawton, K. A., & Lapinskas, P. J. (2009). Metabolomics for early detection of drug-induced kidney injury: review of the current status. *Bioanalysis*, *1*(9), 1645–1663. http://doi.org/10.4155/bio.09.142
7. Calfee, C. S., Eisner, M. D., Ware, L. B., Thompson, B. T., Parsons, P. E., Wheeler, A. P., … Matthay, M. A. (2007). Trauma-associated lung injury differs clinically and biologically from acute lung injury due to other clinical disorders. *Critical Care Medicine*, *35*(10), 2243–2250.
8. Calfee, C. S., Ware, L. B., Eisner, M. D., Parsons, P. E., Thompson, B. T., Wickersham, N., … NHLBI ARDS Network. (2008). Plasma receptor for advanced glycation end products and clinical outcomes in acute lung injury. *Thorax*, *63*(12), 1083–1089. http://doi.org/10.1136/thx.2008.095588
9. Calfee, C. S., Ware, L. B., Glidden, D. V., Eisner, M. D., Parsons, P. E., Thompson, B. T., & Matthay, M. A. (2011). Use of risk reclassification with multiple biomarkers improves mortality prediction in acute lung injury. *Critical Care Medicine*, *39*(4), 711–717. http://doi.org/10.1097/CCM.0b013e318207ec3c
10. Cha, Y. S., Cha, K. C., Kim, O. H., Lee, K. H., Hwang, S. O., & Kim, H. (2014). Features and predictors of myocardial injury in carbon monoxide poisoned patients. *Emergency Medicine Journal: EMJ*, *31*(3), 210–215. http://doi.org/10.1136/emermed-2012-202152
11. Cha, Y. S., Kim, H., Go, J., Kim, T. H., Kim, O. H., Cha, K. C., … Hwang, S. O. (2014). Features of myocardial injury in severe organophosphate poisoning. *Clinical Toxicology (Philadelphia, Pa.)*, *52* (8), 873–879. http://doi.org/10.3109/15563650.2014.944976
12. Coccini, T., Roda, E., Manzo, L., Barni, S., & Signorini, C. (2012). Isoprostanes as Biomarkers for In Vivo Evaluation of Nanoparticle-induced Oxidative Stress: a Study with Silica Nanoparticles Doped with Cadmium. *International Journal of Theoretical and Applied Nanotechnology*. http://doi.org/10.11159/ijtan.2012.001
13. Çolak, ?., Erdogan, M. Ö., Baydin, A., Afacan, M. A., Kati, C., & Duran, L. (2014). Epidemiology of organophosphate intoxication and predictors of intermediate syndrome. Retrieved from http://dergipark.ulakbim.gov.tr/tbtkmedical/article/viewFile/5000022935/5000023173
14. Collard, H. R., Calfee, C. S., Wolters, P. J., Song, J. W., Hong, S.-B., Brady, S., … others. (2010). Plasma biomarker profiles in acute exacerbation of idiopathic pulmonary fibrosis. *American Journal of Physiology-Lung Cellular and Molecular Physiology*, *299*(1), L3–L7.
15. Dolci, A., Dominici, R., Cardinale, D., Sandri, M. T., & Panteghini, M. (2008). Biochemical markers for prediction of chemotherapy-induced cardiotoxicity: systematic review of the literature and recommendations for use. *American*

Journal of Clinical Pathology, *130*(5), 688–695. http://doi.org/10.1309/AJCPB66LRIIVMQDR

16. Fuchs, T. C., Mally, A., Wool, A., Beiman, M., & Hewitt, P. (2014). An Exploratory Evaluation of the Utility of Transcriptional and Urinary Kidney Injury Biomarkers for the Prediction of Aristolochic Acid–Induced Renal Injury in Male Rats. *Veterinary Pathology Online*, *51*(3), 680–694. http://doi.org/10.1177/0300985813498779
17. Gao, L., Flores, C., Fan-Ma, S., Miller, E. J., Moitra, J., Moreno, L., … Garcia, J. G. N. (2007). Macrophage migration inhibitory factor in acute lung injury: expression, biomarker, and associations. *Translational Research*, *150*(1), 18–29. http://doi.org/10.1016/j.trsl.2007.02.007
18. Greenwood, D. Q. (2007). *Reconstructing operational theory: A framework for emerging threats in a complex environment.* Marine Corps University, School of Advanced Warfighting. Quantico, VA.
19. Haase, M., Bellomo, R., Albert, C., Vanpoucke, G., Thomas, G., Laroy, W., … Haase-Fielitz, A. (2014). The identification of three novel biomarkers of major adverse kidney events. *Biomarkers in Medicine*, *8*(10), 1207–1217. http://doi.org/10.2217/bmm.14.90
20. Haenen, S., Clynen, E., De Vooght, V., Schoofs, L., Nemery, B., Hoet, P. H. M., & Vanoirbeek, J.
A. J. (2012). Proteome changes in auricular lymph nodes and serum after dermal sensitization to toluene diisocyanate in mice. *Proteomics*, *12*(23-24), 3548–3558. http://doi.org/10.1002/pmic.201200264
21. Harris, M., Dixon, R., Melin, N., Hendrex, D., Russo, R., & Bailey, M. (2014). *Megacities and the United States Army: Preparing for a Complex and Uncertain Future*.
22. Hirakawa, A., Takeyama, N., Iwatsuki, S., Iwata, T., & Kano, H. (2013). Delayed myocardial injury following acute hydrogen sulfide intoxication. *Ch?doku Kenky?: Ch?doku Kenky?kai Jun Kikanshi = The Japanese Journal of Toxicology*, *26*(1), 44–48.
23. Hoenigl, M., Prattes, J., Spiess, B., Wagner, J., Prueller, F., Raggam, R. B., … Buchheidt, D. (2014). Performance of galactomannan, Beta-d-Glucan, aspergillus lateral-flow device, conventional culture, and PCR tests with bronchoalveolar lavage fluid for diagnosis of invasive pulmonary aspergillosis. *Journal of Clinical Microbiology*, *52*(6), 2039–2045. http://doi.org/**10.1128/JCM.00467-14**
24. Hoffmann, D., Adler, M., Vaidya, V., Rached, E., Mulrane, L., Gallagher, W. M., … Mally, A. (2010). Performance of novel kidney biomarkers in preclinical toxicity studies. *Toxicological Sciences*, kfq029. http://doi.org/10.1093/toxsci/kfq029
25. Hur, G.-Y., Choi, G.-S., Sheen, S.-S., Lee, H.-Y., Park, H.-J., Choi, S.-J., … Park, H.-S. (2008). Serum ferritin and transferrin levels as serologic markers of methylene diphenyl diisocyanate–induced occupational asthma. *Journal of Allergy and Clinical Immunology*, *122*(4), 774–780.
26. Ippolito DL, AbdulHameed MDM, Tawa GJ, Baer CE, Boyle MH, Hobbs CA, Streicker MA, Snowden BS, Lewis JA, Wallqvist A, Stallings JD. Gene

expression patterns associated with histopathology in toxic liver injury. *Toxicological Sciences*. 2016 149(1):67-88. doi: 10.1093/toxsci/kfv214.

27. Kim, J.-H., Kim, J.-E., Choi, G.-S., Kim, H.-Y., Ye, Y.-M., & Park, H.-S. (2011). Serum cytokines markers in toluene diisocyanate-induced asthma. *Respiratory Medicine*, *105*(7), 1091–1094. http://doi.org/10.1016/j.rmed.2011.03.005
28. Koufaris, C., Wright, J., Currie, R. A., & Gooderham, N. J. (2012). Hepatic microRNA profiles offer predictive and mechanistic insights after exposure to genotoxic and epigenetic hepatocarcinogens. *Toxicological Sciences*, kfs170. http://doi.org/10.1093/toxsci/kfs170
29. Kropski, J. A., Fremont, R. D., Calfee, C. S., & Ware, L. B. (2009). Clara cell protein (cc16), a marker of lung epithelial injury, is decreased in plasma and pulmonary edema fluid from patients with acute lung injury. *Chest*, *135*(6), 1440–1447. http://doi.org/10.1378/chest.08-2465
30. Liu, K. D., Glidden, D. V., Eisner, M. D., Parsons, P. E., Ware, L. B., Wheeler, A., … Matthay, M. A. (2007). Predictive and pathogenetic value of plasma biomarkers for acute kidney injury in patients with acute lung injury. *Critical Care Medicine*, *35*(12), 2755–2761.
31. Luo, S., Trübel, H., Wang, C., & Pauluhn, J. (2014). Phosgene- and chlorine-induced acute lung injury in rats: comparison of cardiopulmonary function and biomarkers in exhaled breath. *Toxicology*, *326*, 109–118. http://doi.org/10.1016/j.tox.2014.10.010
32. McClintock, D., Zhuo, H., Wickersham, N., Matthay, M. A., & Ware, L. B. (2008). Biomarkers of inflammation, coagulation and fibrinolysis predict mortality in acute lung injury. *Critical Care*, *12* (2), R41. http://doi.org/10.1186/cc6846
33. Nath, J., & Januszkiewicz, A. (2008). *Early Systemic Biomarkers of Acute Lung Injury: Application of Multiplex Proteomic Array Technology*. Walter Reed Army Institute of Research Silver Spring MD. Retrieved from http://www.dtic.mil/docs/citations/ADA505713
34. Park, E., Ahn, J., Min, Y.-G., Jung, Y.-S., Kim, K., Lee, J., & Choi, S.-C. (2012). The usefulness of the serum s100b protein for predicting delayed neurological sequelae in acute carbon monoxide poisoning. *Clinical Toxicology*, *50*(3), 183–188. http://doi.org/10.3109/15563650.2012.658918
35. Parsons, P. E., Matthay, M. A., Ware, L. B., Eisner, M. D., & National Heart, Lung, Blood Institute Acute Respiratory Distress Syndrome Clinical Trials Network. (2005). Elevated plasma levels of soluble TNF receptors are associated with morbidity and mortality in patients with acute lung injury. *American Journal of Physiology. Lung Cellular and Molecular Physiology*, *288*(3), L426–431. http://doi.org/10.1152/ajplung.00302.2004
36. Rached, E., Hoffmann, D., Blumbach, K., Weber, K., Dekant, W., & Mally, A. (2008). Evaluation of Putative Biomarkers of Nephrotoxicity after Exposure to Ochratoxin A In Vivo and In Vitro. *Toxicological Sciences*, *103*(2), 371–381. http://doi.org/10.1093/toxsci/kfn040
37. Rohlman, D. S., Anger, W. K., & Lein, P. J. (2011). Correlating neurobehavioral performance with biomarkers of organophosphorous pesticide exposure. *Neurotoxicology*, *32*(2), 268–276. http://doi.org/10.1016/j.neuro.2010.12.008

38. Sandhu, H., & Maddock, H. (2014). Molecular basis of cancer-therapy-induced cardiotoxicity: introducing microRNA biomarkers for early assessment of subclinical myocardial injury. *Clinical Science (London, England: 1979)*, *126*(6), 377–400. http://doi.org/10.1042/CS20120620
39. Shafiee, H., Asghar, W., Inci, F., Yuksekkaya, M., Jahangir, M., Zhang, M. H., … Demirci, U. (2015). Paper and flexible substrates as materials for biosensing platforms to detect multiple biotargets. *Scientific Reports*, *5*. http://doi.org/**10.1038/srep08719**
40. Silins, I., & Högberg, J. (2011). Combined Toxic Exposures and Human Health: Biomarkers of Exposure and Effect. *International Journal of Environmental Research and Public Health*, *8*(3), 629–647. http://doi.org/10.3390/ijerph8030629
41. Singh, S., Kumar, V., Thakur, S., Banerjee, B. D., Chandna, S., Rautela, R. S., … Rai, A. (2011). DNA damage and cholinesterase activity in occupational workers exposed to pesticides. *Environmental Toxicology and Pharmacology*, *31*(2), 278–285. http://doi.org/10.1016/j.etap.2010.11.005
42. Sutto, T. (2015). *NRL Industrial Chemical Assessment for Hazard, Probability and Biomarker Prioritization* (No. NRL FR 6364-14-14, XXX) (pp. 1–35). Washington, DC: Naval Research Laboratory.
43. Tawa, G. J., AbdulHameed, M. D. M., Yu, X., Kumar, K., Ippolito, D. L., Lewis, J. A., … Wallqvist, A. (2014). Characterization of Chemically Induced Liver Injuries Using Gene Co-Expression Modules. *PLoS ONE*, *9*(9), e107230. http://doi.org/10.1371/journal.pone.0107230
44. Uchida, T., Shirasawa, M., Ware, L. B., Kojima, K., Hata, Y., Makita, K., … Matthay, M. A. (2006). Receptor for Advanced Glycation End-Products Is a Marker of Type I Cell Injury in Acute Lung Injury. *American Journal of Respiratory and Critical Care Medicine*, *173*(9), 1008–1015. http://doi.org/10.1164/rccm.200509-1477OC
45. U.S. National Library of Medicine - Hazardous Substances Data Bank. (n.d.). Retrieved June 9, 2015, from http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB
46. Vaidya, V. S., Ozer, J. S., Dieterle, F., Collings, F. B., Ramirez, V., Troth, S., … Bonventre, J. V. (2010). Kidney injury molecule-1 outperforms traditional biomarkers of kidney injury in preclinical biomarker qualification studies. *Nature Biotechnology*, *28*(5), 478–485. http://doi.org/10.1038/nbt.1623
47. Vermeulen, R., Zhang, L., Spierenburg, A., Tang, X., Bonventre, J. V., Reiss, B., … Lan, Q. (2012). Kidney toxicity in Chinese factory workers exposed to Trichloroethylene. *Carcinogenesis*, bgs191. http://doi.org/10.1093/carcin/bgs191
48. Vose, S. C., Holland, N. T., Eskenazi, B., & Casida, J. E. (2007). Lysophosphatidylcholine hydrolases of human erythrocytes, lymphocytes, and brain: Sensitive targets of conserved specificity for organophosphorus delayed neurotoxicants. *Toxicology and Applied Pharmacology*, *224*(1), 98–104. http://doi.org/10.1016/j.taap.2007.06.008
49. Ware, L. B., Koyama, T., Billheimer, D. D., Wu, W., Bernard, G. R., Thompson,

B. T., … Matthay,
M. A. (2010). Prognostic and pathogenetic value of combining clinical and biochemical indices in patients with acute lung injury. *Chest*, *137*(2), 288–296. http://doi.org/10.1378/chest.09-1484

50. Ware, L. B., Matthay, M. A., Parsons, P. E., Thompson, B. T., Januzzi, J. L., Eisner, M. D., & National Heart, Lung, and Blood Institute Acute Respiratory Distress Syndrome Clinical Trials Network. (2007). Pathogenetic and prognostic significance of altered coagulation and fibrinolysis in acute lung injury/acute respiratory distress syndrome. *Critical Care Medicine*, *35*(8), 1821–1828. http://doi.org/10.1097/01.CCM.0000221922.08878.49
51. Wunnapuk, K., Gobe, G., Endre, Z., Peake, P., Grice, J. E., Roberts, M. S., … Liu, X. (2014). Use of a glyphosate-based herbicide-induced nephrotoxicity model to investigate a panel of kidney injury biomarkers. *Toxicology Letters*, *225*, 192–200.
52. Wunnapuk, K., Liu, X., Gobe, G. C., Endre, Z. H., Peake, P. W., Grice, J. E., … Buckley, N. A.
(2014). Kidney biomarkers in MCPA-induced acute kidney injury in rats: Reduced clearance enhances early biomarker performance. *Toxicology Letters*, *225*, 467–478.
53. Ye, S. Q., Simon, B. A., Maloney, J. P., Zambelli-Weiner, A., Gao, L., Grant, A., … Garcia, J. G. N. (2005). Pre–B-Cell Colony-enhancing Factor as a Potential Novel Biomarker in Acute Lung Injury. *American Journal of Respiratory and Critical Care Medicine*, *171*(4), 361–370. http://doi.org/10.1164/rccm.200404-563OC
54. Ye, Y.-M., Nahm, D.-H., Kim, C.-W., Kim, H.-R., Hong, C.-S., Park, C.-S., … Park, H.-S. (2006).
Cytokeratin autoantibodies: useful serologic markers for toluene diisocyanate-induced asthma.
Yonsei Medical Journal, *47*(6), 773–781.
55. Yu, Y., Jin, H., Holder, D., Ozer, J. S., Villarreal, S., Shughrue, P., … Gerhold, D. L. (2010). Urinary biomarkers trefoil factor 3 and albumin enable early detection of kidney tubular injury. *Nature Biotechnology*, *28*(5), 470–477. http://doi.org/10.1038/nbt.1624
56. Zeng, Q., Xu, Y., Yu, X., Yang, J., Hong, F., & Zhang, A. (2014). The combined effects of fluorine and arsenic on renal function in a Chinese population. *Toxicology Research*, *3*(5), 359–366. http://doi.org/10.1039/C4TX00038B
57. Zhang, Y., Liu, X., McHale, C., Li, R., Zhang, L., Wu, Y., … Ding, S. (2013). Bone marrow injury induced via oxidative stress in mice by inhalation exposure to formaldehyde. *PloS One*, *8*(9), e74974. http://doi.org/10.1371/journal.pone.0074974
58. Zheng, J., Zhou, Z., Xu, Z., Li, G., Dong, P., Chen, Z., … Yu, F. (2015). Serum microRNA-125a-5p, a useful biomarker in liver diseases, correlates with disease progression. *Molecular Medicine Reports*
. http://doi.org/10.3892/mmr.2015.3546
59. Zhou, Y., Vaidya, V. S., Brown, R. P., Zhang, J., Rosenzweig, B. A.,

Thompson, K. L., … Goering, P. L. (2008). Comparison of Kidney Injury Molecule-1 and Other Nephrotoxicity Biomarkers in Urine and Kidney Following Acute Exposure to Gentamicin, Mercury, and Chromium. *Toxicological Sciences*, *101*(1), 159–170. http://doi.org/10.1093/toxsci/kfm260

How to Hold or Take a Big City -- Seven Lines of Effort

By ***Geoff Demarest***

Originally published in Small Wars Journal on 18 February 2016

Available online at: http://smallwarsjournal.com/jrnl/art/how-to-hold-or-take-a-big-city-sevenlines-of-effort-0

This essay proposes adoption of a specific planning framework for urban operations.[1] An American armed force smaller than, say, that used in Sadr City, Baghdad might well achieve victory in a future urban environment.[2] The imagined geographical context for the presentation of this planning framework is that of a large city, and the situation one that features active opposition by at least one well- armed organization of significant organizational and communications capacity. How large a city and how powerful an opposing force are of course consequential questions. Cities considerably smaller than what are generally taken as megacities still present significant, unique military challenges.[3] The armed opposition imagined here does not include the committed military of a large country that might assign significant national resources to either taking or holding the city with regular formations. The imagined opposing force might nevertheless be able to move several thousand armed fighters and employ a range of sophisticated weapons and surveillance systems to include those mounted on aerial drones. Regardless of the size and sophistication of the opposing force, the lines of effort for success in taking or holding a city can be placed in basically the same seven proposed categories. The reader is invited to assume that opposition entities (there likely being more than one) will not share with us the same scruples or social and political delimitations regarding how they will apply coercive violence. That is to say, as to any dissimilarity in the mixes of resources available to the contenders, moral asymmetry may be the most pronounced and consequential.

We can measure victory (our own or that of any of the competing entities) cartographically. The physical geographic space within which a contender can effectively punish its opponents, plus the geographic space in which a contender can remain impune from that punishment (sanctuary) will constitute the definitive map.[4] If throughout the city one of the parties to the contest were able to apply concepts and processes of justice as it sees fit, and can simultaneously protect individuals it chooses to protect from punishment by others, that party is *eo ipso* the complete victor. Perhaps total control of the whole urban place never becomes a practicable goal for any contender. Nevertheless, if the cartographic extent (within which whole or partial impunity is achieved) exceeds an entity's goals, one can fairly argue that it succeeds exactly to that extent. As to an American force overseas, at least a partial victory reasonably could be claimed if the US force could be withdrawn without the balances of impunity changing unfavorably, that is, without there being a change in the boundaries of sanctuaries.

Not contemplated here as part of the definition of victory is the attainment of any particular conditions of material life such as electoral suffrage, infant mortality, showers taken, calories consumed or political legitimacy. While perhaps rightfully interested in the improvement of material wellbeing, or justified in pursuit of such progress for its own sake, material improvement may have insignificant if any measurable, timely influence on the outcome of an armed competition as to who dominates whom.[5] In some areas and to some degree, the conditions of human suffering and injustice (or, perhaps, how a populace sees how the parties addresses such conditions) can have a recognizable effect on relative competitive prospects. Sociocultural conditions are not to be ignored, but they are best understood as potential influences on, and not conflated with measures of military success. Impunity can be gained or lost almost irrespective of socioeconomic conditions.

We can assume that a conflict may end in some sort of settlement, the result perhaps of a formal negotiation. Such a settlement would be the price of real or perceived relative weakness, however. In other words, ignorant of the situational details, we cannot claim that any contending party would necessarily have enough strength to dominate totally. It probably will not. The degree to which party A might have to settle is a fair measure of the extent to which it did not win, since negotiated settlement would mean that its opponents enjoy some degree of impunity from A’s coercion, or perhaps that they retain some capacity to impose punishment on A. Experiences indicate that some areas of a city may be hotly contested while other areas are fully controlled by one party or another, and these variously controlled locales may or may not be contiguous. Contestants may have to either take or hold according to a patchwork of urban sectors. There are likely to be more than two major contestant organizations, not simply a government versus an anti-government resistance or defiance. In addition, urban areas are intertwined with surrounding geographies we might prefer to categorize as suburban or rural or sea or hinterland.[6] With all the caveats in mind, however, seven lines of effort provide a reasonable starting template for planning.

They are as follows:

1. Maintain and improve advantage in anonymity

2. Maintain and improve advantage in competitive distances

3. Control the disruption of service flows

4. Control convocation spaces

5. Progressively reduce enemy sanctuary space

6. Pursue the *mens rea*

7. Punish the enemy

Measure the physical geography of all of the above

Ultimate goal: Dominate the granting of impunity

1. **Maintain and improve advantage in anonymity**.[7] Implement specific actions and programs whose immediate goal is to tip the balance of anonymity, that is, encourage and enable the reporting of information, especially regarding the whereabouts of elements of the enemy's armed members and leadership. These actions can include construction of reporting websites and phone numbers, or designing offices wherein a citizen can report without being seen doing so by an agent of an opposing force. The side currently able to openly occupy space can more easily flood public places with closed circuit cameras, for instance, but some use of cameras will be available to the other side as well. Include here also a number of considerations for the preservation of secrets, such as polygraphing, background investigations, oaths and the like. Those implementing siege of urban territory or the take-over of buildings have less opportunity for actual, physical presence by which to instill a 'rule of silence.' For them, the creation of psychological presence is made more difficult, but hardly impossible.

2. **Maintain and improve advantage in competitive distances**.[8] One of the most significant lines of effort is the building of walls, doors and bridges.[9] This is best done in an overall urban plan that considers travel distances among police stations, public convocation sites, likely sites of opponent perpetrations and government enforcement initiatives. Conversely, for the siege, approach distances to service nodes, convocation areas, and other valuable terrain need to be prepared.[10] Especially this initiative needs to anticipate withdrawals or escapes. Tunnels are a classic siege preparation, but way- stations made from the offices of front organizations, or the coopting of transportation networks are now typical. In Bogota, the FARC had briefly converted the immense garbage disposal network into a back

alley taxi service.

3. **Control the disruption of service flows**.[11] As cities grow they tend to change in step fashion. That is, urban phenomena may appear fairly rapidly to bring the city to a new stage or status that has direct bearing on prospects in armed competition. For instance, a small city might overnight be home to a radio controlled taxi network while a megalopolis might finally gain a third major airport, bringing a closer coordination of airspace control and all but sealing out some classes of aircraft. Also among the effects of scale may be a tendency toward single contract or single network consolidation of some services, for instance, sewage removal. As a service provision becomes monopolized or centrally regulated, it also acquires a vulnerability in that the geography of the reins of control may become centralized or present very specific nodes or constrictions. These need to be physically protected, as do the executives or key technicians who wield control. Because large cities often find economic advantage in consolidated service systems, the nodes and constrictions in these systems present geographically specific targets, targets that can not only be physically occupied, but the occupation of which can be defended for sufficient time to make power concessions appear economically and politically attractive.

4. **Control convocation spaces**.[12] Convocation (causing crowds to form) is hardly a new tactic, but social media has augmented their practicability. Rules of operational art still apply, however, to actions based on the massing of people, including protests, demonstrations, or marches. Regardless of the speed of instruction, coordination, and movement of such aggrupation, the characteristics of the spaces to which people can go to accumulate count for a great deal when it comes to how consequential or dangerous a crowd might be to the survival of an established governmental or economic structure. Some cities, because of ancient land use planning, have open areas that straddle important lines of communication or threaten significant economic nodes. If, on the other hand, a formation of large crowds can be diverted to open spaces that present little threat to principle transportation links or other pieces of economic terrain, the ability of resistance leadership to extort concessions from government is greatly reduced. For the government planner, in other words, it is smart to orchestrate the architectural, spatial relationship of constrictions and access points to open spaces such that, whatever the speed of social media, there is a lessoned potential for economic threat resulting from the fact of a crowd itself.

5. **Progressively reduce enemy sanctuary space**.[13] A sanctuary is that space within which a contestant cannot be punished by their opponent. Sanctuary may be attained through anonymity, legalities, moral and electoral risk, and physical distance. Sanctuary is in any case a physical material place. One either enjoys a place wherein they are safe from the punishments that their foes can be impose upon them, or they are not. As such, the sanctuary space can be mapped, and while the cartographic delineations of sanctuary space will be hypothetical, it is that hypothesis exactly that

can guide the application of competitive resources in order to shrink the sanctuary space of one's competitors and to increase one's own. In addition, every attempt should be made to map the likely routes to and from sanctuary spaces.

6. **Physically pursue of the *mens rea*.**[14] The challenge posed here is more than just a 'small fries' versus 'big fish' distinction. The locus of dangerous intent is the human mind, and while it may profit us to work intellectually against those ideas and messages that we find in some way dangerous, sending our opponents a stark physical message can be ultimately influential. To the extent it is apparent to our opponents that we can and will bring dire physical consequences upon those who lead others to act in ways we cannot abide, our goal of holding or taking the city will be more economically achieved. A competitor is most likely to be effective who can mount constant, physical pursuit of the human initiative of what aggravates him. It is leaders' corporeal impunity from punishments (and in turn the impunity they can grant to others) that must be challenged and dismantled. If there exists a single imperative for any durable victory, it is that we definitively disprove any suggestion that our opponent can bestow physical impunity to his followers. If the good guys are not capable of physically pursuing the bad guys within whom resides the *mens rea*, it is unlikely that the good guys are making progress in the direction of durable victory.

7. **Punish the enemy**.[15] This to an extent is a repetition of line of effort 6 above. Pursuit of the *mens rea* is valuable in itself in that a vigorous pursuit keeps the opponent off balance, makes it difficult for him to take initiative, and whittles at his moral. However, the act of pursuit is not a goal. Punishment alone is proof of the absence of impunity. The punishments might include no more than the stripping of wealth or of public authority, but to be absolutely effective the punishment of the *mens rea* probably has to be corporeal, that is, confinement or death. The operant psychology is one of visibly extending punishments to the enemies' *mens rea*. This may mean capturing or sniping leaders. To the extent it becomes clear that 'we' have a monopoly of punishment over 'them', that is, we can punish them, but they cannot punish us, we win and can negotiate from strength in view to the future. If on the other hand, they can close our sanctuary space, that is, they can occupy and use the mayor's office, the court building or the police station, etc., or they can kidnap our daughters at the school or theatre, then we are well along the way toward losing. Ultimately, for winning (that is, controlling territory, that is, effective/efficient/sufficient influence, that is, controlling impunity, that is, 'we dominate them'), we must be capable of punishing them and they not capable of punishing us.

How to Organize the Study of a Big City to Support the Seven Lines of Effort

This section proffers a separate list, suitable for research or intelligence, of phenomena on which to focus in order to make an explanatory description of a large urban area. I propose twelve research categories. All are relevant to resourcing and implementing the seven lines of effort, although some of the twelve more clearly allude to a specific line of effort.

1.Constriction points in the lines of supply into the city (water, power, food, and telecommunications)

a. Practical distance to and from ('practical' meaning cost or friction distances from a party's start points or bases, i.e., time, fuel, money etc.)

b.What organizations control

-- Headquarters locations

-- Practical distance to and from

2.Constriction points in the lines of waste in and going out of the city (garbage, sewage, hazmat, death and medical)

a. Practical distances to and from

b.What organizations control

-- Headquarters locations

-- Practical distance to and from

3.Key control points for city services within city (vulnerable nodes) (transportation, convocation, comfort)

a. Practical distances to and from

b.What organizations control

-- Headquarters locations

-- Practical distance to and from

4.Most commercially valuable terrain (banks, by the way, are valuable. That's where the money is)

a. Practical distances to and from

b. What organizations control

-- Headquarters locations

-- Practical distance to and from

5. Key events times, locations, movement and normal participations (both recurring and special events)

a. Practical distances to and from

b. What organizations control

-- Headquarters locations

-- Practical distance to and from

6. Key recreation (especially sinful recreation) locations, times, normal participations (for a party's own members as well as for opponents', but especially for opponent parties' leadership)

a. Practical distances to and from

b. What organizations control

-- Headquarters locations

-- Practical distance to and from

7. Collective identities of note (political, ethnic, gang affiliation, etc.)

a. Physical locus, scale and range

b. Representation (agents, especially exclusive agents)

-- Physical locus, extent, density and movements

-- Means of wielding influence

-- Capacities for physical coercion

8.Exclusive agents (those who set themselves up as representatives of others and are jealous of that representation – like lawyers, politicians, union bosses, priests, etc.)[16]

a. Physical locus and movements

-- Practical distance to and from

b.Means of influence

c.Instruments of physical coercion

d.Available resources

e. Known vulnerabilities and locations in time

-- What they love

-- Practical distance to and from

f. Level of will (ruthlessness, courage, etc.)

e. What nodes, constrictions, and key locations they control or occupy; which they do not control but are attempting to control, and which should they logically want to control.

9.Grievances of note

a. Associations of grievances with namable collective identities

b.Representation, especially exclusive representation of the grievance

Resolution possibilities and physical locus and range of resolution mechanism (i.e. jurisdictions)

10. Symbols of note (flags, songs, historical and literary figures, etc.)

a. Physical locations where found, density or duration of occurrence

b. Depth and extension of awareness and affectation regarding symbols

c. Psychological, affective and political correlations

11. Known relevant attitudes (regarding us, allies, enemies, etc.)

a. Location, density, intensity, range, durability

b. Reflections in symbols, events, communications

All of the categories are inter-related and if for some reason facts asserted within a category do not reconcile with those of others, then something is amiss which requires a disclaimer, reconsideration of the assertions and probably more field research. A competitive objective, for instance, would be to control nodes physically - - the other factors (like knowing who exactly controls those nodes, the sources of their power to do so, and especially their physical vulnerabilities, feeds into possibilities of physically changing control the node, or alternatively, to protect the status quo.

Once nodes, etc. are identified along with their respective 'ownership', we can begin to measure how much strength it would take for other competitors to hold or to take, and to remain. If we correctly identify the nodes, constrictions and most valuable terrain, then the next step would be to understand the cost and risk distances in getting to those places and staying there. How far is each in practical terms, what resistance could be generated against getting to and staying in each place, as well as the likely useable routes of escape and withdrawal from attempts to take or hold the key locations -- all this is subject to geographic study.

What may seem as an emphasis on physical locations and their control is not a dismissal of the psychological or sociological elements (perhaps the 'subjective' dimensions and options), but it is intended to seek relative efficiency and appropriateness in the short-term use of coercive force.**[17]**

The views expressed in this article are those of the author and do not necessarily represent the official policy or position of the Department of the Army, Department of Defense, or the U.S. government.

End Notes

[1] Meaning the range of armed coercive force available to a city's government along with the forces in play from any of the higher administrative levels to which a city might belong (department, nation, region, coalition, etc.). Units might include police military paramilitary militia, intelligence etc.
[2] See, regarding urban operations in Iraq see, Chris Bowers, "Future Megacity Operations—Lessons from Sadr City." *Military Review*, May-June, 2015.
[3] See, on this point, Michael Evans, "The Case against Megacities: The Megacity Myth," *The United States Army War College Quarterly, Parameters*, Vol 45 No 1 Spring 2015, pp. 33-43.

[4] The idea of the use of the control of impunity as a proxy for victory is adapted from Geoffrey Demarest. *Winning Irregular War: Conflict Geography*. Ft. Leavenworth, Kansas: Foreign Military Studies Office (FMSO), 2015, **http://fmso.leavenworth.army.mil/documents/Winning-Insurgent-War/WIrW_2015.pdf**.

[5] For expansion on this point see, "Section 39, Socioeconomic Causation," ibid. 155-158.
[6] To expand on this theme see, "Section 34, Urban or Rural," ibid. pp. 133-136.
[7] To expand on this theme see, "Section 2, Anonymity," ibid. pp. 4-5.
[8] To expand on this theme see, "Section 64, Measuring Distance and Comparing Power," ibid. pp. 262- 66; "Section 32, Land-use Planning," ibid. pp. 126-129.
[9] See, on this point, "Section 32, Heavy Machines," ibid. pp. 119-120.
[10] To expand on this theme see, "Section 33, Engineers and the Built Environment," ibid. pp. 130-132.
[11] To expand on this theme see, "Section 91, Forts and Walls," ibid. pp. 366-370; "Section 94, Poop," pp. 379-380; "Section 63, Roadblocks and Checkpoints," pp. 258-261.
[12] To expand on this theme see, "Section 27, 'Nonviolent' Action," ibid. pp. 110-115.
[13] To expand on this theme see, "Section 7, Sanctuary," ibid. pp. 22-27; "Section 23, Mens Rea," pp. 96- 98.
[14] To expand on this theme see, "Section 23, Mens Rea," ibid. pp. 96-98; "Section 10, Decisive Battle," ibid. pp. 36-39.

[15] For more on this theme see, “Section 1, Impunity,” ibid. pp. 1-3.
[16] For more on the theme of exclusive agency see the index entry of that term in *Winning Irregular War*, ibid.
[17] Pardon a bit of atmospherics, but the terms ‘long-term effect’ and ‘short-term effect’ are themselves relative, and it might be vanity to claim long-term goals are fundamentally better than short-term goals, or that ‘long-term’ is, without specific context, a more strategic notion than ‘short term’.

Integrated Global Health Surveillance and Response through Multi-Source Technologies

By ***Paul O. Kwon***

Originally published in Small Wars Journal on 7 March 2016

Available online at: http://smallwarsjournal.com/jrnl/art/integrated-global-health-surveillance-and-response-through-multi-source-technologies

Introduction

Since 1980, one to three new human infections have been identified annually. These Emerging Infectious Diseases (EIDs) impact social, political, economic and environmental arenas. In response, the *International Health Regulations* (2005) provide a legally binding framework to guide international member states of the World Health Organization (WHO) to “detect, assess, and report” potential outbreaks and other public health emergencies. More importantly, infectious disease is the one of the leading cause of morbidity and mortality around the world impacting socioeconomic stability. Globally, the Avian flu pandemic ($3.78 trillion) and Ebola outbreak ($32.6 billion) revealed critical shortcomings in mobilizing and leveraging public and private sectors that threaten global public health and security. More recently, vector borne diseases such as Chikungunya and Zika virus have threatened migration towards the southern borders of North America. Thus, forecasting outbreaks is crucial in planning for an effective response strategy.

Similarly, the U.S. has also developed key policy milestones for greater interagency support for national and global EID efforts (1997 Presidential Directive; 2014 Global Health Security Agenda). Interestingly, a common virus such as the seasonal flu has a significant annual impact within the U.S. population (up to 5- 20%) and healthcare (over 200,000 hospitalizations and 3,000-49,000 deaths with over $87 billion in reduced economic output). Understanding the dynamics of disease forecasting is therefore essential for prevention and mitigation strategies; however, there must be a mobilization towards a multidisciplinary and holistic approach in these proactive measures. In the face of budget constraints and limited resourcing, truly there is a need for an Integrated Global Health Surveillance and Response Program through a complex web of surveillance, education, and interactive coordination (“network of networks”).

Background

In the past decade, there has been a significant technologic advancement in disease surveillance capabilities. Several bioinformatics science and technology enterprises have developed a number of tools that leverage data science and existing open source data. With the ubiquitous desire to seek technologic advantages (internet, social media, smart phone and apps), the social network provides a wealth of information that can enhance the Warfighters' force health protection and offer solutions towards predictable models in reference to EIDs and environmental threats to major populations.

Worldwide, six billion persons have mobile phones according to a recent U.N. report and there has been a rapid global proliferation of cellular phones in the last three decades. According to the PEW Research, more than 90% of all U.S. adults own a cell phone and 50% download apps. Trends also include a rise in smart phone purchasing (up to 1.45 billion in 2015). Consumers are spending more time on their apps than ever before, the abundance of mobile devices has transformed the information age, and the Neilson Company reports no signs of slowing. By the Pew research, more than half of smart phone users get health information (62%) and navigating through apps with worldwide trends up to 4.4 billion by 2017. Fortunately, this complex web of information (social media, app development, short messaging system (SMS) or text messaging, and GPS locators) can assist in continuous surveillance, information sharing, education and training, risk communication, and modeling to help predict critical nodes for quick response to potential emerging threats.

In fact, smart phones assisted disaster relief in the 2010 Haiti Earthquake by SIM cards to track population movements during cholera outbreaks. Smart phones were also used for emergency reporting systems on mosquito-borne Dengue virus to help predict epidemics and model predictors as an "early warning" device. Smart phone apps also helped educate and train first responders and clinicians. Social media activity predicted and tracked outbreaks of syndromic flu. This same network can be used to receive population surveys as well as risk communication to alleviate fear-inspired flight of misinformation. In short, leveraging this technology can enable enhanced communication, surveillance, intelligence and population management to protect health and national security.

Further, there have been recent advances in genetic sequencing, sequence analysis, and mathematical epidemiology with the convergence of several exponential trends that are cost effective and user friendly improving disease surveillance and response. This meaningful use of the bioinformatics analyses can also be performed now on web based or local systems. Additionally, DNA sequencers can diagnose disease and monitor new outbreaks. The readily available use of data collection, analyses and communication have spurred real-time access via internet, cell phone, and social media arenas. While capabilities are continually maturing, coordinated efforts to readily deploy and train these existing technologies are still in need. Specifically, Los Alamos National Laboratory (LANL) has developed tools and applications in each of these areas (genomics, disease outbreak analysis and forecasting, and the integration of genomic data into epidemiological analyses).

Empowering the Development of Genomics Expertise (EDGE) is a highly adaptable bioinformatics platform that allows laboratories to quickly analyze and interpret genomic sequence data (Figure 1). The bioinformatics platform allows users to address a wide range of use cases including assay validation and the characterization of novel biological threats within clinical and complex environmental samples. It is designed to allow users with minimal expertise in bioinformatics to be able to conduct a number of sophisticated analyses. It also aligns to real world use cases, makes use of open source (free) software tools, and runs analyses on relatively inexpensive hardware. It addresses the distinct need for advanced, yet user-friendly bioinformatics solutions, and can be provided to foreign country partners' labs to facilitate successful adoption and use of High-Throughput Sequencing technologies. This is critical because overseas deployment of sequencers allows biological analysis closer to the acquisition point of samples increasing efficiency and effectiveness. Particularly, EDGE provides support for bio threat rapid identification, detection, and surveillance. Additionally, it can validate currently fielded polymerase chain reaction (PCR) assays as well as enable rapid design of new assays. This capability is a force health multiplier especially in Outside the Continental United States (OCONUS) and forward deployed environments where human resources, space, bandwidth, and time are limited.

Figure 1: EDGE Overview

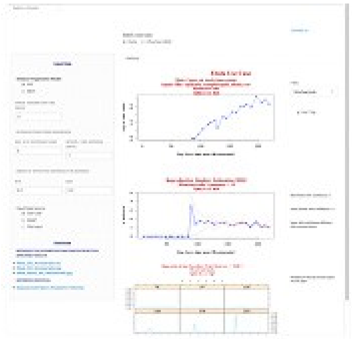


Figure 2: EpiEarly User Interface

Currently, LANL has two concurrent projects running that are developing tools for epidemiologic analysis. A forward looking internally funded project is working to integrate data from the Los Alamos genomics group into epidemiologic models that address the extensive co-morbidities in malaria holoendemic areas of Western Kenya (Siaya). A Defense Threat Reduction Agency (DTRA) project is geared towards making the necessary *diversity* of epidemiologic tools available to the Analysis, Planning, Operations and Response communities through DTRA's Biosurveillence Ecosystem. This project also addresses the uncertainty quantification that is necessary to provide decision support. Five modeling and analysis tools and one uncertainty quantification tool are being provided. The first three (EpiEarly, EpiRapid, EpiZoo) are available in a useable form currently. Two (EpiCast and EpiRapid) are in development. Because there is no "one-size fits all model" in mathematical epidemiology, these tools span the range of granularity from aggregated case-count data (EpiEarly) to event-driven agent-based models (EpiAgent). These tools are designed to look at these issues at different levels and to address a range of population sizes, mitigation detail, demographic fidelity, and computation effort as well as designed to be available to the individual analyst for force protection, operational status planning, and bio-event management and mitigation.

EpiEarly is a Bayesian estimator of reproductive number and only requires the user to input a time series of cases and the diseases' serial generation time in order to return an estimated reproductive number with certainty (Figure 2). EpiRapid and EpiZoo are geographically compartmentalized SIR-type model (*susceptible, infected, recovered*) with mitigations adapted to human and animals, respectively, and allow "what-if planning and analysis scenarios" to be examined (Figures 3 & 4).

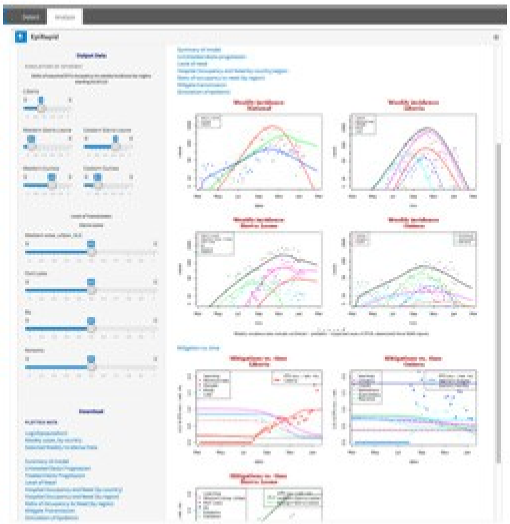


Figure 3: EpiRapid User Interface

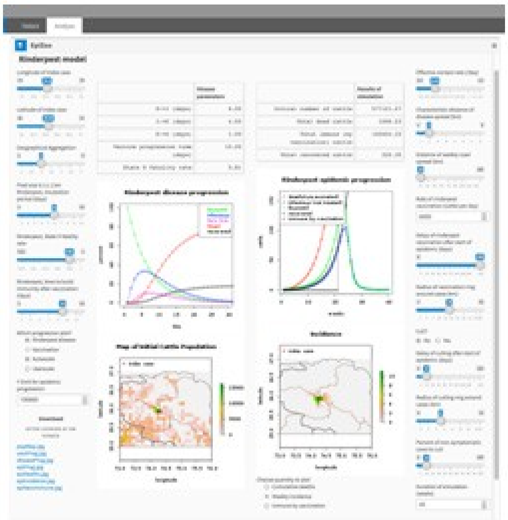


Figure 4: EpiZoo User Interface

EpiCast is an agent-based day-night model with stratified mixing groups (SIR-type), explicit agent motion, and a concept of places (home, work school, neighborhood, census tract, etc.). All motion and infection are modeled at day-night granularity. It has detailed model of disease progression to allow fine- grained simulation of interventions (e.g. vaccination, school closure, etc.). EpiAgent is fine-grained in time, space and allows behavioral simulation (mask use, social distancing), agents with definite locations (latitude/longitude type data), and infection in short-time intervals (5 min) based on the agent being in a "place." These parameters are adaptable to specific locations. EpiUpdate (in development) addresses the uncertainty within and between models providing confidence bounds that will allow analysts to appropriately qualify their work product for consideration by decision makers. This allows the data to be interpreted by the user with levels of predictability.

All these tools have interfaces that are designed to be easily understood by a user and provide sufficient flexibility that many situations of interest can be analyzed using analogy that are parallels, but without requiring that every analytic task be a research project. Data sharing and expert analysis of incoming information are key factors to enhancing situational awareness of an unfolding event. LANL has developed an integrated suite of tools to enhance situational awareness for global disease surveillance that provide actionable information and knowledge for enhanced situational awareness during an unfolding event: Biosurveillance Resource Directory (BRD), Biosurveillance Analytics Resource Directory (BARD), Surveillance Window App (SWAP), and Epidemiologic Information Collection tool (EPIC).

The BRD is a searchable database to facilitate obtaining disease surveillance information. It contains information on disease surveillance resources worldwide. All resources are described using a comprehensive framework that describes the fundamental elements of infectious disease surveillance and contain information on how to access the data.

The BARD is a searchable database that catalogs and classifies epidemiologic model specific information to allow selection of appropriate models for use in disease prediction, monitoring or forecasting. A systematic model characterization framework has been developed to allow consistent epidemiologic model description and facilitate "apples to apples" comparison for multiple models available for the same disease.

EPIC is a data collection and visualization tool for notifiable disease data from around the world. The tool uses various scrapers to collect information from national health websites and digests it into a database that allows the data to be easily visualized, compared and exported (Figure 5).

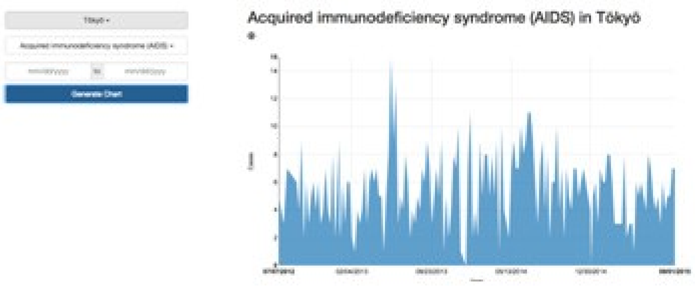


Figure 5: Epic User Interface

The SWAP is an app developed to provide context and a frame of reference for disease surveillance information about an unfolding event through matching of user input to a library of global historical disease outbreaks (Figure 6). Each historical outbreak is a “case study” and contains information on case counts, location, data sources used (from the BRD), disease models used (from the BARD), risk factors, mitigation efforts, and other epidemiologic relevant information. The SWAP is intended to provide a frame of reference for incoming data for a particular location and time during a disease outbreak so that the user is able to understand and qualify the situation to facilitate actions to prevent, stop or mitigate the event. It can also make a short term forecast for the unfolding disease situation based upon user input data.

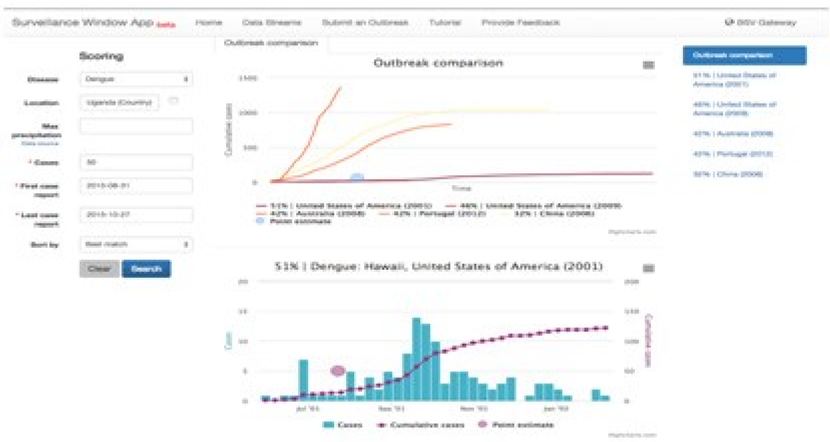


Figure 6: SWAP User Interface

All these tools described are either online, or shall be quickly available online and would require minimal modification to be able to deploy them into the hands of analysts and health officials (Table 1).

	Tool	Online	Modification required	URL
Genomics	EPIC	Yes	No	https://github.com/LANL-Bioinformatics/EDGE
	EpiEarly	Yes	No	Need Permission to Access
	EpiRapid	Yes	Yes	Need Permission to Access
	EpiZoo	Yes	Yes	Need Permission to Access
	EpiCast	No	Yes	Need Permission to Access
Forecasting	EpiAgent	No	Yes	Need Permission to Access
	BRD	Yes	Minimal	http://brd.lanl.gov/oppie/service
	BARD	Yes	Minimal	http://brd.bsvgateway.org/brd/
Decision	SWAP	Yes	Minimal	http://swap.bsvgateway.org/
Support	EPIC	Yes	Minimal	http://epic.bsvgateway.org/

Table 1: Summary of Tools

Conclusion

In the face of budget constraints and limited resourcing, there is a need for an Integrated Global Health Surveillance and Response Program through a complex web (data sharing among veterinarians, entomologists, climatologists, microbiologists, clinicians, and public health officials) of surveillance, education, and interactive communications, otherwise known as “network of networks.” This is particularly important for expeditionary operations and Army Health Support of Operations in order to enhance Department of Defense (DoD) capabilities and to minimize population disease outbreaks that create geopolitical and socioeconomic instability. However, this concept can also affect large populations in times of war (WWI, WWII, Vietnam, Iraq, Afghanistan, and Syria) and peace (natural disasters and public health emergencies) based on strategic goals of governmental states around the world. Technologies and existing data science platforms such as those expressed by LANL provide up to date resources towards a more multi-source approach on population health.

Material has been reviewed by the Walter Reed Army Institute of Research. There is no objection to its presentation and/or publication. The opinions or assertions contained herein are the private views of the author, and are not to be construed as official, or as reflecting true views of the Department of the Army or the Department of Defense. Research was conducted in an AAALACi accredited facility in compliance with the Animal Welfare Act and other federal statutes and regulations relating to animals and experiments involving animals and adheres to principles stated in the Guide for the Care and Use of Laboratory *Animals, NRC Publication, 2011 edition.*

Pain Management: Maintaining the Force

By ***Marcie Fowler and Laura L. McGhee***

Originally published in Small Wars Journal on 8 March 2016

Available online at: http://smallwarsjournal.com/jrnl/art/pain-management-maintaining-the-force

Introduction

Combat injuries can result in severe acute pain, and options for pain control on the battlefield are currently limited. There is a need for improved pain control on the battlefield, as well as in higher echelons of casualty care. Initial pain control can increase patient comfort and aid in evacuation from the point of injury [1-3]. The development of novel analgesic agents may identify medications that produce decreased side effects as compared to morphine, which can result in respiratory depression, immunosuppression, hemodynamic effects, and cognitive deficits [4, 5]. The ultimate goal of Force Health Protection (FHP) is to preserve the fighting force [6-8], and pain is the ultimate performance degrader for Service Members.
The implementation of more effective pain control on the battlefield will affect not only individual Service Members but also overall mission accomplishment. Additionally, effective initial pain control can decrease the incidence of chronic pain development, which could affect return to duty rates, and can also reduce patient care and rehabilitation expenses.

Current State of Pain Management from the Battlefield to the Hospital

The foremost barrier to effective pain management on the battlefield is the fact that pain management immediately following combat trauma is often deprioritized in favor of resuscitation and stabilization for rapid transport [9]. The situation can be further complicated by the potential detrimental effects of pain therapeutics on respiration and blood pressure. Logistic concerns and supply quantity requirements must also be considered when planning for medical care for both combatants and noncombatants, particularly in densely populated urban areas in asymmetrical warfare [8].

When a Service Member is injured on the battlefield, the first medical attention received, known as level I care, consists of self-aid, buddy-aid, or care administered by the combat medic. Once removed from the fight, the Service Member may be resuscitated and stabilized for transport to a level II care facility, which is staffed by a Forward Surgical Team, or a level III Combat Support Hospital [9]. If deemed unlikely to immediately return to duty, the injured service member is then air evacuated to a definitive care facility [3]. The care available at each of these levels is discussed below.

Level I-II: First-Responder Pain Management on the Battlefield

An individual Service Member may carry a combat pill pack, which includes NSAIDs, that are generally effective for mild pain and allow the Service Member to remain in the fight. A combat medic has access to additional analgesics, potentially including both opioid and non-opioid analgesics, to be given if the service member can no longer remain in combat. In the past, if intravenous (IV) or intraosseous (IO) access is not obtainable or is not required, the medic could administer intramuscular (IM) morphine via an autoinjector mechanism. Other analgesic possibilities include fentanyl or ketamine [10].

However, opioid-induced respiratory depression and decreased cardiovascular function limit opioid usage in wounded Service Members who are bleeding. Due to the nature of combat injuries sustained in asymmetrical warfare, this includes a significant percentage of casualties, creating a major challenge for pain management on the battlefield. In addition, the analgesic efficacy of morphine and other drugs given IM is also significantly reduced during hypovolemic shock, as blood is shunted away from the limbs to maintain organ function, preventing IM administered drugs from entering circulation efficiently. The lack of pain relief may then lead the medic to administer additional doses of a medication, resulting in the simultaneous central nervous system availability of a large amount of analgesic following resuscitation. This may lead to additional side effects and requiring the use of additional medications to counteract these effects.

Finally, the nature of the battlefield poses unique concerns with the use of narcotics for pain management. Specifically, the cognitive and motor function effects, which are manageable in a traditional hospital setting, can be especially detrimental on the battlefield. If the injured Service Member experiences these effects, they may require assistance and monitoring from additional Service Members, thus further reducing combat numbers and further risking mission accomplishment. These effects can also make the evacuation of the casualty to a higher level of care more difficult because they are unable to participate actively in their own evacuation.

A recent study reported that only 39% of combat casualties in Afghanistan received analgesics at POI, whereas 92% received analgesics during tactical evacuation (TACEVAC) [10]. It is unclear why most casualties did not receive analgesia at POI; it could be due to lack of availability, prioritization of other life-saving interventions, or lack of self-reported pain. However, it is clear that better pain control is needed on the battlefield. In order to treat pain immediately on the battlefield, during evacuation, and in other austere environments, unique considerations must be taken into account. Pain therapeutics must be easy for a combat medic to carry among many other items, have minimal abuse potential to discourage illegal use, be easy to quickly administer in an austere and dangerous environment, and have limited effects on Service

Member cognition and motor function to allow for evacuation. For severely injured trauma patients, pain therapeutics cannot interfere with life-saving measures and resuscitation; therefore, a pain therapeutic with limited side effects, including lack of respiratory depression and hypotension, should be selected. Current Tactical Combat Casualty (TCCC) guidelines recommend that, for severe pain when IV/IO access is not required for other purposes, OTFC or IM ketamine be administered. If IV/IO access is obtained, the recommendations are IV morphine or IV/IO ketamine. Opioids are not recommended if the casualty exhibits decreased consciousness, respiratory distress, or shock [11].

Level III-IV: Theater and Stateside Hospital Pain Management

Combat casualties evacuated from theater are treated and stabilized at tertiary hospitals associated with the US Department of Defense, with a full complement of medical and surgical services, comparable to any civilian tertiary hospital. Pain management at these facilities encompasses all varieties and etiologies of pain. Still, systemic opioids and NSAIDs are the most frequently administered drugs due to their ease of dosing and relative efficacy. In hospital patients at Landstuhl Regional Army Medical Center or the Walter Reed Army Medical Center, 56% of casualties injured in Operation Iraqi Freedom (OIF) received NSAIDs, 49% were prescribed opioids and 41% received an anticonvulsant or antidepressant [12]. While advanced pain management options, including interventions such as nerve blocks, are available at this level of care, the nature of injuries sustained in asymmetrical warfare are often severe and offer significant challenges to successful pain management. For example, a Soldier injured by an improvised explosive device (IED) while on foot patrol would likely present with polytrauma, potentially including multiple amputations, fractures, shrapnel wounds, burns, and/or traumatic brain injury (TBI). The pain resulting from such widespread physical injuries may be exacerbated by psychological sequelae, such as post- traumatic stress disorder (PTSD), resulting from combat experiences. Taken together, such patients require the implementation of multimodal pain management strategies because their injuries and the resulting pain are too complex to effectively treat with a single medication or intervention.

Level V: Pain Management During Stateside Hospitalization and Rehabilitation

Pain management for these polytrauma patients during hospitalization and the transition to rehabilitative care remains complex. These patients have often developed opioid tolerance, and it important to ensure that appropriate pain management is achieved using a combination of medications, interventions, and treatments. These combinations may include not only short and long-acting opioids, but also NSAIDs, anticonvulsants, antidepressants, or other medications Additionally, interventions, including nerve blocks and surgeries, as well as device implants can be performed in a pain clinic as necessary. Finally, interdisciplinary care, including cognitive behavioral therapy (CBT), acupuncture, medical message, movement therapy, physical therapy, and occupational therapy may also be employed in the pain management plan for patients during rehabilitation and return to duty/function.

Challenges Specific to Densely Populated Urban Operations Environments and Asymmetrical Warfare

Multiple unique considerations must be taken into account when planning for and implementing pain management strategies in densely populated urban operations environments [8]. For example, when conducting Intelligence Preparation for the Battlefield (IPB) is such environments, it is important to take into consideration the medical needs of both combatants and civilians. This concept becomes increasingly important when considering operations, whether war-related, humanitarian, or other, in densely populated urban areas or megacities. Pain itself will affect each civilian as well as each Service Member at some point; however, enough medications would likely not be available in the event of the use of a weapon of mass destruction, such as a thermonuclear device, in a megacity. Thus further research into novel, potent pain medications, as well as triage techniques and prioritization guidelines, is warranted. Additionally, because pain is a disease of perception that is mediated centrally, it is uniquely linked to psychosocial factors that can affect response to treatments as well as outcomes. Awareness of these issues is required for the preparation of an effective plan for pain management on a large scale during asymmetrical warfare.

Future Directions for Pain Management on the Battlefield

Current research efforts are geared towards developing fast acting, novel analgesics with limited side effects for use in forward operating environments. The ideal drugs will have decreased side effects, particularly in regard to hemodynamic, respiratory, and cognitive effects. These drugs will need to be easy to administer and exhibit limited monitoring requirements. Additionally, they should lack addictive or diversion potential. The candidate analgesics should also have a quick onset of action as well as a lengthy duration of action, to limit redosing requirements. A pharmacological solution for pain management fitting this profile will allow for the effective management of pain in densely populated urban areas and megacities during operations, as well as improve pain management strategies and patient outcomes in all environments.

Acknowledgements

This work was supported by the United States Army Medical Research and Materiel Command Combat Casualty Care Research and the Clinical and Rehabilitative Medicine Research programs.

The authors report no conflicts of interest. The opinions or assertions contained herein are the private views of the author and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

End Notes

1. Buckenmaier, C.C., et al., *Pain following battlefield injury and evacuation: A survey of 110 casualties from the wars in Iraq and Afghanistan.* Pain Medicine, 2009. **10**(8): p. 1487-1496.

2. Clark, M.E., et al., *Assessment and treatment of pain associated with combat-related polytrauma.* Pain Med, 2009. **10**(3): p. 456-69.

3. Clifford, J.L., et al., *State of the science review: Advances in pain management in wounded service members over a decade at war.* J Trauma Acute Care Surg, 2014. **77**(3 Suppl 2): p. S228- 36.

4. Passik, S. and K. Kirsh, *The need to identify predictors of aberrant drug-related behavior and addiction in patients being treated with opioids for pain.* Pain Medicine, 2003: p. 186-189.

5. Pergolizzi, J., et al., *Opioids and the management of chronic severe pain in the elderly: consensus statement of an International Expert Panel with focus on the six clinically most often used World Health Organization Step III opioids (buprenorphine, fentanyl, hydromorphone, methadone, morphine, oxycodone).* Pain Pract, 2008. **8**(4): p. 287-313.

6. Chapman, P.L., et al., *Training, deployment preparation, and combat experiences of deployed health care personnel: key findings from deployed U.S. Army combat medics assigned to line units.* Military Medicine, 2012. **177**(3): p. 270-277.

7. Patel, T.H., et al., *A U.S. Army Forward Surgical Team's experience in Operation Iraqi Freedom.* J Trauma, 2004. **57**(2): p. 201-7.

8. Command, A.T.a.D., *Urban Operations*, in *FM 3-06*, D.o. Army, Editor. 2006: https://rdl.train.marmy.mil/catalog.

9. Lenhart, M.K., Savitsky, E. and Eastridge, B. Eds., *Combat Casualty Care: Lessons Learned from OEF and OIF*. 2012, Fort Detrick, MD: Office of the Surgeon General. 719.

10. Shackelford, S.A., et al., *Prehospital pain medication use by U.S. Forces in Afghanistan.* Mil Med, 2015. **180**(3): p. 304-9.

11. Butler, F.K., Jr., et al., *A triple-option analgesia plan for tactical combat casualty care: tccc guidelines change 13-04.* Journal of Special Operations Medicine, 2014. 14(1): p. 13-25.

12. Cohen, S.P., et al., *Presentation, diagnoses, mechanisms of injury, and treatment of soldiers injured in Operation Iraqi Freedom: an epidemiological study conducted at two military pain management centers.* Anesth Analg, 2005. **101**(4): p. 1098-103, table of contents.

SECTION 6: Future of Training

This section includes published articles from Small Wars Journal that we received from the call for papers. The section will explore issues, concepts, and capabilities as they relate to future land forces training for or in megacities or dense urban areas in 2025 and beyond.

Man, Computer, and Special Warfare

By **Patrick Duggan**

Originally published in Small Wars Journal on 4 January 2016

Available online at: http://smallwarsjournal.com/jrnl/art/man-computer-and-special-warfare

> *"The confounded telegraph has ruined everything."*[1]
>
> *1855 Crimea--General Sir James Simpson*

Man-machine teaming is inexorable and Special Warfare[2] needs a blueprint to transform along with it. With every passing day, our hyper-connected landscape spawns a new class of threats more technologically evolved than the last. These 'hybrid-threats' confound establishment-thinking seemingly more preoccupied with conflict typology, than the innovation of new organizational concepts to counter them. Success in warfare is not derived by labeling its assembled parts, it is achieved by correctly assembling emerging technology and new capabilities into trusted fields of practice. U.S. military culture must increasingly confront technology's permutation of conflict, as great powers have contended since the 'dawn of machines' during the Crimean War. *This paper serves as one step in a larger man-machine journey, and advances a conceptual framework to align technology, tools, and tactics for a new contemporary cyber-enabled Special Warfare practice*. If successfully developed, this framework provides a mission-specific blueprint for the convergence of computers and man, and amplifies Special Warfare's capabilities to counter future hybrid-threats and deny them growing technological advantage.

Hybrid-Hype

Hybrid-warfare has been complicated with umbrella labels ranging everything under the sun. It has been defined as a "combination of conventional, irregular, and asymmetric means, including the persistent manipulation of political and ideological conflict, and can include the combination of special operations and conventional military forces; intelligence agents; political provocateurs; media representatives; economic intimidation; cyber-attacks; and proxies and surrogates, para-militaries, terrorist, and criminal elements."[3] The examination of hybrid-warfare has fueled spirited debate and spurred numerous papers over its characteristics, purpose, and parts; and no doubt, will continue for some time.

However, the truth is, hybrid-warfare is nothing new. It has, and always will be, a hodgepodge of previously labeled conflicts fused together by technology in unexpected ways. Hybrid-warfare is an asymmetric grab-bag of tricks that converges old and new technology and tactics to open new 'attack surfaces' against an adversary. Simply put, "the evolving character of conflict that we currently face is best characterized by convergence."[4] Hybrid-warfare's phenomena has only seemed to surge as a result of the tightening interaction between humans, the physical world, and cyberspace, whose connections produce a new class of threats increasingly adept in merging man and machine in a 'cybered' world. Powered by the steady proliferation, sophistication, and affordability of technology, hybrid-warfare is a useful means to inflict disproportionate harm against an opponent, relative to the size, resources, or geography of an adversary. Today, every country, non-state actor, or super-empowered individual can increasingly harness hybrid-warfare as a means to pursue their goals.

The most daunting challenge to hybrid-warfare is keeping pace for how fast adaptive adversaries are using the explosion of technology, information proliferation, and network connectivity for warfare. Their blistering speed in merging man and machine threaten US military advantages, and in some cases, outstrip our own innovation.[5] With an almost organic property to it, hybrid-warfare is in a state of perpetual change; and so long as technology continues to constrict the space between humans, the world, and cyber, its velocity will increasingly outpace a man's ability to process, respond, and counter on his own.

Unfortunately, technology does not lift the fog and friction of war, technology clutters it. Technology does not lead to more antiseptic conflicts, but instead, to messier, more complex, and ambiguous ones. Technology provides adversaries more lethality and precision, and empowers them with new innovative ways to obfuscate, circumvent, and obviate previous limitations for doing it. Simply put, "technology does not make war more clinical; it makes it more deadly."[6] Furthermore, US cutting-edge technology is used by adaptive adversaries to open new 'attack surfaces' against US vulnerabilities and push the limits of warfare norms and accepted conventions. Ironically, America may find itself a double victim of its own advanced technology; first, by failing to innovate sufficient new concepts for technology in conflict, and second, by failing to deny adaptive adversaries new technological advantages.

Human-Machine Teaming

The Department of Defense (DoD) is urgently exploring the future of human-machine teaming to spur new thinking and research on the changing character of warfare and the “types of new systems, organizations, and operational concepts needed to conduct it.”[7] The over-arching goal of DoD’s efforts is to create new paradigms, where machines and humans are “joined at the hip in a symbiotic relationship where each brings what it does best.” [8] Activities range from the experimentation of new technology, to rethinking organizational and operational force structures and tactical application. The “Third Offset Strategy is designed to create new advantages” over evolving-threats and explores promising technology like; advanced computers, big-data, robotics, artificial intelligence, semi/autonomous systems, and other cutting-edge technologies.[9] Ultimately, the Third Offset strategy is all about staying ahead of ‘hybrid- threats’ bent on the frustrating exchange of technology, tools, and tactics.

Each military service is exploring their own options for human-machine teaming and are questioning their own combat methods for fusing human-based strategic-thought with computer based tactical-acuity.[10] Ideally, the services must combine the precision and reliability of computers with the creativity and flexibility of humans.[11] Computer assisted human operations require the development of a common language which ties humans and technology to service specific lexicon, and must be accomplished in a simple way, using clear terms bound to missions and activities that resonate with commanders. Merging man with computers is not a technology thing, but rather cultural and organizational issues, which are vastly more challenging than just implementing things.[12] Excelling in the challenge requires each service to individually tailor organizational concepts that are true to their culture and amplify their specific missions.

Fortunately for the US, although adaptive threats may reverse engineer American technology, they can’t easily copy its greatest strength, its people and creativity. As recently expressed by Deputy Secretary of Defense Robert Work, “The human element is the secret sauce—the element that foreign powers can’t copy as easily as they can our software.”[13] When it comes to the race to merge man and machine, the competition depends upon harnessing the US’s two key advantages, its people and ingenuity, to assemble “the pieces of future military power better and faster than our rivals.”[14] Unfortunately for the US, there is an overall lack of man-machine concepts to merge technology in conflict, and this is a significant barrier for remaining competitive against adaptive adversaries.[15] More mission-specific concepts are needed across DoD, to include specialized missions like, Special Warfare, Irregular warfare, Counterterrorism, and Counterinsurgency, which “must also be updated to account for adversaries armed with advanced weaponry.”[16]

So the question for Special Warfare is, how do we assemble “the pieces of future military power”[17] into a framework that provides a culturally compatible mission-specific blueprint for computers and man? And then, how does Special Warfare use a growing-array of cyber-technologies like; wearable electronics, the Internet, social media, cyber-tools, and digital devices, to create new vulnerabilities and advantages against an adaptive enemy?

Crimean War--Dawn of Machines

Considered the first 'Modern or Industrial War,' the Crimean War (1854-1856) was allegedly fought by Britain and France to check Russian expansion into the Ottoman Empire. Less historically debatable, but perhaps more meaningful, the Crimean War also served as the backdrop for numerous wartime 'firsts' for machines invented during the Industrial Revolution era. The Industrial Revolution had produced more machines with wartime application than armies of the day "knew what to do with"[18] and included; steam powered trains and iron clad ships, breech loading and rifled canons, 'minie' bullets for rifled muskets, cameras, the telegraph, and many more. The new technology, coupled with industrial scale mass- production, impacted great and small Armies alike. Simply put, post-Napoleonic era militaries found themselves awash during the dawn of machines with a deficit of new wartime concepts, not unlike today.

An ancestor to modern-day computers, the telegraph's first use in combat was during the Crimean War; [19] and today, is remembered more for its war-journalism impacts than any tactical benefit. Bemused by the novelty, commanders had not anticipated or adequately prepared for the telegraph's military potential. Labor intensive and problematic, the British telegraph's "gutta-percha insulated lines" had to be laid by plow when ground and weather permitted, and were frequently and easily broken.[20] Lacking telegraphy concepts or specialized military forces prior to the war, the British Army relied on private sector expertise for battlefield training.[21] By the end of the war, the British had still not fully embraced the telegraph's potential for revolutionizing tactical communications, as they organizationally grew from zero to only one Telegraph Detachment and eight Field Stations,[22]and culturally, Commanders still preferred couriers for a primary means of communication. Even the 300 miles of cable which ran from Varna Bulgaria to Balaclava Crimea to connect the war to European circuits wasn't submerged until April 1855, only after private industry convinced British and French government and military officials to submerge the telegraph cables.[23] It wouldn't be until 1863, until the British Army standardized its telegraph equipment and tactics.[24]

Much to military commanders' dismay, the telegraph's most auspicious use was to connect the front to European audiences,[25] where bureaucrats and politicians micromanaged their field Armies with incessant questions, suggestions, and orders from afar.[26] "This was a substantial change in military strategy, and many tacticians lamented how the battlefield had become prone to interference by armchair warriors back at home."[27] Frustrated by the lack of perceived constructive use, other than "constant pestering from London," the British Commander-in-Chief General Sir James

Simpson famously quipped “the confounded telegraph has ruined everything.”[28]

Fueling commanders’ frustrations, newspaper war-correspondents used the Victorian Internet[29] to turn the Crimean War into “the first war in history to be the subject of daily reports from the fighting front.” [30] The telegraph’s rapid affront to military culture was a result of its natural tendency to centralize the conduct of the war, and resulted in a rift between military commanders on one hand and the “politicians, the war correspondent, and public opinion” on the other.[31] This growing divide led to another British Officer, Sir William Simpson, famous for painting the Charge of the Light Brigade, to deride wartime journalists as “the curse of modern armies.”[32] In short, the telegraph was more of a nuisance to the Armies of the day than a benefit.

“The Industrial Revolution was itself an information revolution,” and during the Crimean War, military organizations struggled to conform, adapt, and manipulate this new warfare environment, “just as militaries are striving to do today.”[33] A key lesson as history moves forward, is that “those militaries that took best advantage of the new technologies of the industrial age were not those that acquired the machines or weapons first, but those that recognized the broader informational implications and strove to organize themselves accordingly.”[34] Meaning, the dawn of machines in Crimea still symbolizes the cultural and organizational difficulties nations experience when new technologies are introduced in battle, but also urge the US to vigorously adapt, if it’s to succeed in today’s man-machine competition.

The Cyber-Enabled Special Warfare Pyramid

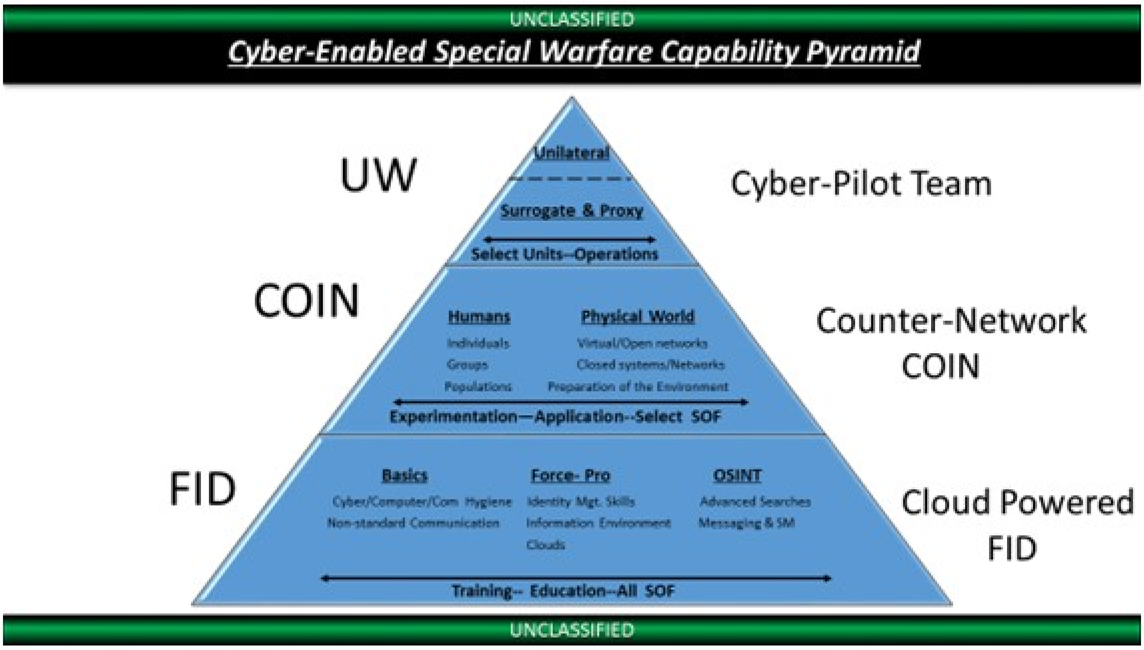


Figure 1. Cyber-Enabled Special Warfare Pyramid

What is it?

The cyber-enabled Special Warfare (CE-SW) pyramid is a conceptual construct that organizes reinforcing blocks of capability into three levels that are aligned to the three core missions of Special Warfare; Unconventional Warfare[35], Counterinsurgency[36], and Foreign Internal Defense.[37] The pyramid integrates technology, tools, and tactics into increasingly more advanced capabilities that support the three concepts of cloud-powered FID, Counter-network COIN, and UW Cyber-Pilot Teams.[38] The CE-SW pyramid aids "in identifying the new core tactical competencies, operational and organizational constructs and combat systems needed to survive and thrive in a cyber-environment"[39]and organizes capabilities in a manner to exploit closed and wireless computer networks with cyber electro-magnetic activities.[40]

Analogous to computer programming or 'chunking,' the CE-SW pyramid breaks down information (or training) into chunks, then arranges the chunks into blocks of capabilities which enable a specific function (or mission). The CE-SE pyramid begins at the base with cyber-technology skills, education, and training, which are the foundation for building higher levels.

Theory

The fundamental theory underpinning all cyber-enabled Special Operations is about leveraging cyber- technology's asymmetry to amplify the elemental aspects of what makes a special operation, special. Meaning, if correctly applied, cyber-technology amplifies a Direct Action mission's lethality, precision, and discreet nature; while in Unconventional Warfare's case, cyber-technology would amplify its ambiguity, deception, and resiliency. The "human element" is the glue that holds the pyramid's capabilities together and is the guiding principle for any man-machine arrangements. To be successful, the pyramid must be applied in manner that exemplifies the first SOF truth, "Humans are more important than hardware."[41]

Form

There are three levels to the pyramid which correspond to the three major missions of CE-SW; cyber- enabled Unconventional Warfare (CE-UW), cyber-enabled Counterinsurgency (CE-COIN), and cyber- enabled Foreign Internal Defense (CE-FID).

The CE-FID level primarily focuses on education and training for all practitioners and serves as the foundation for all CE-SW missions. This level's capabilities are divided into three major categories; the Basics, Force-Protection, and Open Source Intelligence. Each major category is further subdivided into sub-categories. The Basics has two sub-categories; Cyber, Computer, and Communication Hygiene, and Non-Standard Communications. In the middle, Force Protection is divided into three sub-categories; Identity Management Skills, the Information Environment, and Clouds. On the right, Open Source Intelligence is divided into two sub-categories; Advanced Searches, and Messaging/Social Media Fundamentals. Within each subcategory, there are numerous tools, technology, and skills which are sequenced to build reinforcing blocks of capability to support all other missions.

As an example, CE-FID would train practitioners on cheap, low-visibility, and indigenous devices which could be employed across the globe to help monitor "weak signals of social change" and "provide early indicators of danger or unrest."[42] CE-FID would educate practitioners on using simple commercial devices, like a Rasberry-Pi, to run a wide-array of communication, command and control, mapping, and meshed devices to network partners 'off the grid,' where there's little or no electricity, services, or power, as well as, the employment of non-standard devices to build mutual trust and interoperability through habitual 'telepresence' activities. Finally, CE-FID would train practitioners on methods for reacting to those "early indications of danger or unrest" so that they could enable foreign partners via remote virtual access kits in activities or locations where US involvement is problematic.

CE-COIN is more heavily focused on experimentation and conflict application for select SW practitioners. This level is divided into two major categories; Humans, and the Physical World. On the left, the Humans category is further divided into three sub-categories; Individuals, Groups, and Populations. On the right, the Physical World category is divided into three sub-categories: Virtual Systems and Open Networks, Closed Systems and Networks, and Preparation of the Environment Activities. Within each subcategory, there are tools, technology, and experimentation efforts deliberately sequenced to build reinforcing blocks of capability that support CE-COIN and CE-UW missions.

As an example, CE-COIN would train practitioners on how to employ UAVs to monitor, engage, and disperse crowds as part of cyber-enhanced population control measures. It would also educate practitioners on how to build and leverage crowdsourced, geo-tagged, and non-standard databases for micro-security operations.

Finally, CE-UW is more heavily focused on select units and clandestine operations. This level is the highest level of cyber-enabled capability and is divided into two major categories; Surrogate and Proxy operations, and Unilateral operations. Within each category there are several subcategories which bring together all earlier tools, technology, and training into the penultimate of strategic SW capability.

As an example, CE-UW would train SW practitioners on how to leverage 3-D technology and additive manufacturing to support resistance movements for a whole host of activities. The CE-UW level would educate practitioners on how to utilize 3-D prints like; computers, weapons, munitions, engines, UAVs, and IEDs, as well as, other possibilities being unlocked every day.

New Practice

The CE-SW pyramid borrows under-utilized tactics, capabilities, and tools from previously labeled conflicts, and unexpectedly fuses them together to open new 'attack surfaces' against an adversary. The new opportunities target humans, networks, and narratives in decentralized and disaggregated operations and uses a mix of both virtual and physical practice. Some examples follow:

Humans: CE-SW can target the life-blood of an adversary and erode human means for survival by disrupting financial sectors, private enterprises, government-backed corporations, and illicit economies. CE-SW can be used to slowly degrade the adversary's quality of life through long-term, low-grade, and persistent "financial-insurgency" tactics "rather than quick, high-profile battles with decisive results."**[43]** CE-SW can manipulate critical good prices, employ preclusive purchasing, **[44]** and combine other economic warfare tactics to disrupt an adversary's every-day life.

Narratives: CE-SW can use information and psychological means as a coercive tactic to change, modify, and punish an adversary's behavior. Whether coordinating sit-ins, directing "swarm stream attacks,"**[45]** or spreading social media whisper campaigns, CE-SW can use “cyber-smash mouth tactics”[46] to amplify its physical and virtual activities. CE-SW can vet and leverage sympathetic ‘privateers’, vigilante, crowd-sourced, as well as, employ false flag efforts to “create believable deceptions in cyber-space over a protracted period of time.”[47]

Networks: CE-SW can employ human, informational, physical, and intelligence networks to compromise the confidentiality, integrity, and availability of an adversary’s networks. CE-SW can access open network systems with suites of cyber-tools and penetrate closed network systems, like precision guided military weapons platforms. CE-SW can actively monitor private sector advancements to improve cyber-technology UW concepts, and deny adaptive adversaries technological advantage through counter-UW constructs.

Conclusion

This is a hyper-connected world producing increasingly adaptive and technologically-savvy ‘hybrid- threats.’ To remain competitive, the US must vigorously pursue new concepts which correctly assemble emerging technology and new capabilities into trusted fields of practice. As the telegraph’s use during Crimea signals, the integration of technology into conflict requires forethought about culturally compatible military concepts to organize around. The CE-SW pyramid serves as one step in that larger man-machine journey, and advances a conceptual framework to align technology, tools, and tactics for a new contemporary cyber-enabled Special Warfare practice. If successfully developed, this framework provides a mission-specific blueprint for the convergence of computers and man, and amplifies Special Warfare’s capabilities to counter future hybrid-threats and deny them growing technological advantage.

End Notes

[1] National Army Museum, “Field telegraph wire used during the Crimean War, 1855 (c).” **http://www.nam.ac.uk/online-collection/detail.php?acc=1965-10-202-4** (accessed December 25, 2015)

[2] Special Warfare is a broad term that doctrinally covers a range and combination of Unconventional Warfare, Foreign Internal Defense and Counterinsurgency operations. Special Warfare activities involve both lethal and nonlethal actions executed by a specially selected force steeped in regional understanding that is trained to fight alongside indigenous elements in permissive, uncertain, or hostile environments. U.S. Department of the Army, Special Operations, Army Desk Publication 3-05 (Washington, DC: U.S. Department of the Army, August, 2012), 9

[3] Robert A. Newsome, “Why the US Needs a Strategy to Counter Hybrid Warfare,” *DefenseOne.com*, October 23, 2014,

http://www.defenseone.com/ideas/2014/10/why-us-needs-strategy-counter-hybrid-

warfare/97259/ (accessed December 25, 2015)

[4] Frank G. Hoffman, “Hybrid Warfare and Challenges,” *Joint Forces Quarterly* 52, (1st Quarter 2009):

34. **http://ndupress.ndu.edu/portals/68/Documents/jfq/jfq-52.pdf** (accessed December 25, 2015)

[5] Robert O. Work and Shawn Brimley, *20YY Preparing for War in the Robotic Age* (Center for a New American Security: CNAS Publications, January, 2014), 20. **http://www.cnas.org/sites/default/files/publications-pdf/CNAS_20YY_WorkBrimley.pdf** (accessed December 25, 2015)

[6] Ibid., 9.

[7] Ibid., 9.

[8] Sydney J. Freedberg Jr., “Centaur Army: Bob Work, Robotics, & the Third Offset Strategy,” *Breaking Defense*, November 9, 2015, **http://breakingdefense.com/2015/11/centaur-army-bob-work-robotics-**

the-third-offset-strategy/ (accessed December 25, 2015)

[9] Sydney J. Freedberg Jr., “Will US Pursue ‘Enhanced Human Ops?’ DepSecDef Wonders,” *Breaking Defense*, December 14, 2015, **http://breakingdefense.com/2015/12/will-us-pursue-enhanced-human-**

ops-depsecdef-wonders/ (accessed December 25, 2015)

[10] Cheryl Pellerin, “Work: Human-Machine Teaming Represents Defense Technology Future,” *DOD News*, October 8, 2015, **http://www.defense.gov/News-Article-View/Article/628154/work-human-**

machine-teaming-represents-defense-technology-future (accessed December 25, 2015)

[11] “Centaur Army: Bob Work, Robotics, & the Third Offset Strategy,” 1.
[12] Mark Pomerleau, “For the military, the Internet of Things isn’t about things,” *Defense Systems,*November 12, 2015, https://defensesystems.com/articles/2015/11/12/internet-of-things-dod-cartwight-

csis.aspx?m=1 (accessed December 25, 2015)

[13] “Centaur Army: Bob Work, Robotics, & the Third Offset Strategy,” 1.
[14] Ibid., 1.

[15] Bryan Clark and Mark Gunzinger, *Winning the Airwaves, Regaining America's Dominance in the Electromagnetic Spectrum,* (Center for Strategic and Budgetary Assessments: CSBA Publications, 2015),

39. **http://csbaonline.org/publications/2015/12/winning-the-airwaves-sustaining-americas-advantage- in-the-electronic-spectrum/** (accessed December 25, 2015)

[16] *20YY Preparing for War in the Robotic Age, 21.*

[17] "Centaur Army: Bob Work, Robotics, & the Third Offset Strategy," 1.
[18] Patrick Murphy, "The Effect of Industrialization and Technology on Warfare: 1854-1878," *MilitaryHistoryOnline.com,1.* **http://www.militaryhistoryonline.com/general/articles/effectofindustrialization.aspx** (accessed December 25, 2015)

[19]Christopher Sterling, *Military Communications, From Ancient Times to the 21st Century* (Santa Barbara, CA: ABC-CLIO, 2008), 441.

[20] Steven Roberts, "Telegraph at War 1854-1868," *Distant Writing, A History of the Telegraph Companies in Britain between 1838-1868*, 2012, **http://distantwriting.co.uk/telegraphwar.html** (accessed December 25, 2015)

[21] Ibid., 1.

[22] Ibid., 1.

[23] Walter Peterson, "The Queen's Messenger: An Underwater Telegraph to Balaclava," *History of the Atlantic Cable & Undersea Communications*, July 14, 2015, 1. **http://atlantic- cable.com/Cables/1855Crimea/** (accessed December 25, 2015)

[24] Ibid., 1.

[25] "Telegraph at War 1854-1868," 1.
[26] *Military Communications, From Ancient Times to the 21st Century*, 441.

[27] Dwayne R. Winseck and Robert M. Pike, *Communication and Empire, Media, Markets, and Globilazation 1860-1930,* (Raleigh, NC: Duke University Press, 2007) 26.

[28] Emily O. Goldman, *Information and Revolutions in Military Affairs*, (New York, NY: Routledge, 2005), 61.

[29] Tom Standage, *The Victorian Internet,* (New York, NY: Bloomsbury, 2009), 1.

[30] George F. Botjer, *Samuel F.B. Morse and the Dawn of the Age of Electricity,* (Lanham, MD: Lexington Books, 2015), 52.

[31] *Communication and Empire, Media, Markets, and Globilazation 1860-1930,* 26.

[32] Mitchel P. Roth, *Historical Dictionary of War Journalism*, (Westport, CT: Greenwood Publishing, 1997), 72.

[33] *Information and Revolutions in Military Affairs*, 72.

[34] Ibid., 73.

[35] Army doctrine defines UW as "activities conducted to enable a resistance movement or insurgency to coerce, disrupt, or overthrow a government or occupying power by operating through or with an underground, auxiliary, and guerrilla force in a denied area." U.S. Department of the Army, Special Operations, Army Desk Publication 3-05 (Washington, DC: U.S. Department of the Army, August, 2012), 9.

[36] Joint doctrine defines COIN as "comprehensive civilian and military efforts taken to defeat an insurgency and to address any core grievances." U.S. Joint Chiefs of Staff, Counterinsurgency, Joint Publication 3-24 (Washington, DC: U.S. Joint Chiefs of Staff, November 22, 2013), I-2.

[37] Joint doctrine defines FID as "participation by civilian and military agencies of a government in any of the action programs taken by another government or other designated organization to free and protect its society from subversion, lawlessness, insurgency, terrorism, and other threats to its security." U.S. Joint Chiefs of Staff, The Department of Defense Dictionary of Military and Associated Terms, Joint Publication 1-02 (Washington, DC: U.S. Joint Chiefs of Staff, June 15, 2014), 103.

[38] Patrick Duggan, "Strategic Development of Special Warfare in Cyperspace," *Joint Forces Quarterly 79,* (4th Quarter 2015): 49-52. **http://ndupress.ndu.edu/Media/News/NewsArticleView/tabid/7849/Article/621123/jfq-79-strategic- development-of-special-warfare-in-cyberspace.aspx** (accessed December 25, 2015)

[39] *20YY Preparing for War in the Robotic Age,* 20.

[40] *Winning the Airwaves, Regaining America's Dominance in the Electromagnetic Spectrum,* 3.

[41] United States Army Special Operations Command, **http://www.soc.mil/USASOCHQ/SOFTruths.html** (accessed December 25, 2015)

[42] Patrick Tucker, "These are the Decisions the Pentagon wants to Leave to Robots,"*DefenseOne.com*, December 14, 2015, **http://www.defenseone.com/technology/2015/12/these-are-decisions-pentagon-wants-leave-robots/124480/** (accessed December 25, 2015)

[43] Hudson Institute, *Cyber-Enabled Economic Warfare: An Evolving Challenge* (Washington, DC: Hudson Institute, 2015), 98.

https://s3.amazonaws.com/media.hudson.org/files/publications/2015.08CyberEnabledEconomicWarfareAnEvolvingC

(accessed, December 25, 2015)

[44] Ibid., 52-53.

[45] Patrick Duggan, “Harnessing Cyber-technology’s Human Potential,” *Special Warfare 28*, no.4 (October-December 2015), 15. **http://www.soc.mil/swcs/SWmag/archive/SW2804/October%202015%20Special%20Warfare.pdf** (accessed December 25, 2015)

[46] Ibid., 15.

[47] Robert Schultz, “Countering Extremist Groups in Cyberspace,” *Joint Forces Quarterly 79,* (4th Quarter 2015): 55. **http://ndupress.ndu.edu/Media/News/NewsArticleView/tabid/7849/Article/621124/jfq-79-countering- extremist-groups-in-cyberspace.aspx** (accessed December 25, 2015)

Research and Vision for Intelligent Systems for 2025 and Beyond

By ***Brett Piekarski, Brian Sadler, Stuart Young, William Nothwang and Raghuveer Rao***

Originally published in Small Wars Journal on 7 April 2016

Available online at: http://smallwarsjournal.com/jrnl/art/research-and-vision-for-intelligent-systems-for-2025-and-beyond

The current Army Operating Concept document, "Win in a Complex World," lays out a future vision for Intelligent Systems out to 2040 as a force multiplier for improving the effectiveness and reach of Soldiers and units in complex worlds [1]. It indicates that these systems could be autonomous, semi-autonomous, have the ability to learn, reduce the cognitive burden of the Soldier, and assist in making rapid decisions [1]. Also, through their increased intelligence and autonomy they could perform tasks such as teaming of unmanned ground vehicles (UGV) and unmanned aerial systems (UAS) to conduct adaptive and persistent intelligence, surveillance, and reconnaissance (ISR) in areas inaccessible by human operators, operate dispersed over wide areas while possessing the mobility to concentrate rapidly, and develop situational understanding through action [1]. All of these concepts will play a significant role and impact the strategy and operational concepts for 2025 and Beyond in complex environments such as Megacities and Dense Urban Environments. But if we put on our Mad Scientist hats, this vision probably stops short of how far we could really push technology and a vision for 2025 and beyond. This paper examines the research challenges and ways we can augment that vision to enable even more capable systems and a larger impact on future operations through collective heterogeneous systems that exhibit distributed awareness, intelligence, adaptable and resilient controls and behaviors, and operational complexity.

Current roadmaps for UAS and UGV focus primarily on individual systems and multi-robot coordination is a future goal [2,3]. For the individual system they state that autonomous mission performance may demand the ability to integrate sensing, perceiving, analyzing, communicating, planning, decision making, and executing to achieve mission goals and adapt to changes as well as predict what will happen next by integrating cognitive behaviors [2]. But, most current unmanned robotic systems still rely heavily on teleoperation or have limited autonomy using GPS waypoint navigation. There is basic research ongoing within the DoD laboratories and academia to increase the levels of autonomy for both air and ground systems, increase the level of interactions with humans to create robotic teammates, and also demonstrate large numbers of collaborative systems. Commercial advancements are happening fast in driverless cars, large scale cooperation for logistics robots, small drones are becoming ubiquitous around the world, and advancements in Artificial Intelligence are happening for applications like IBM Watson. The vision put forth here builds off many of these advancements to integrate large numbers of heterogeneous systems to include; Soldiers integrated into the control architecture and as sensor nodes, large and small UAS and UGV, data from distributed unattended sensors, and information from knowledge bases into one large distributed and collaborative intelligent system. This vision is not so much about a singular system or technology but how to integrate varying levels of autonomy and intelligence across spatially and temporally distributed singular systems, small teams, and even swarm behavior under one robust and adaptable command and control architecture while augmenting the capability of the collective beyond that of any one component within it.

Many commercial networked technologies, such as computers and smart phones, and large commercial robotic system implementations, have moved towards homogeneity in design rather than heterogeneity. This is highly desirable from a modular design, manufacturing, and potentially cost viewpoint. However, it remains an open question for future Army systems as to the degree and mix of homo- and heterogeneity to balance cost, logistics tails, and broad applicability and adaptability of the overall system. It is not at all obvious what is the right mix of heterogeneity in sensing, computation, platforms, levels of autonomy, and human/robot teams; or what is the best or even a good ontology. Robotic ontology's exist, but are missing coupling with reasoning, cognition, and task allocation. What is clear is that, for future Army systems, there will be some, potentially high, level of heterogeneity. It is important to note, that as part of this heterogeneous system, there needs to be an effort in creating individual systems that have low price points, especially for small attritable systems. This vision for highly distributed and collaborative intelligent systems will drive new advances and system attributes such as Distributed Awareness, Distributed Intelligence, Adaptable and Resilient Controls, and Operational and Experimental Complexity, all of which are only starting to be realizable.

Distributed Awareness infers that the systems perceives the environment and gathers information from many different sources to provide situational awareness for the individual platform as well as the collective system. One aspect of this is distributed mapping and perception. As the Soldiers and intelligent agents disperse themselves through the environment, information will be collected across the collective and shared to augment missing, incomplete, or stale information to provide for example; multiple views and improved object recognition, 3-D scene generation, images and maps of areas not accessible by other systems, and understanding of population dynamics. How and what information to share given potential bandwidth limitations and how to represent this common model of the world across heterogeneous systems with varying levels of processing power, memory, or ability to act on the information is not a solved problem. While research is underway to extend this to much larger teams, distributed autonomous mapping and exploration has only been accomplished with a few air and ground platforms [4]. Research is also underway to fuse information from intelligent agents and humans [5,6]. Sharing maps, threat, and other information across a collective of soldiers and robots will greatly enhance the Soldier's, and robots, situational awareness in complex environments.

Access and utilization of the cloud, big data, social media, real world complex simulation models running on high performance computing platforms (e.g., weather, natural disaster evolution), and other knowledge bases should be included and leveraged to support functions such as intelligent/semantic routing of valuable information, or answering critical real-time questions as they arise. Future knowledge bases will be highly distributed and evolving. While knowledge bases provide rapid answers to queries, they are associative and rely on similarity, and typically provide many possible answers, some of which may be dramatically incorrect. Thus, mechanisms are needed for interactive querying and information push and pull. Even more fundamentally, a science and analytical framework is needed to bridge control and signal processing on the one hand, and associative knowledge bases on the other.

If we can incorporate deep learning methods and leverage distributed computing, the adaptability of the systems would be enriched. As an example, the deep learning methods employed by Google, Microsoft, Facebook, IBM and others [7,8] could be brought to bear on the perception challenges currently encountered by military robots. While our data sources are not as voluminous, and our opportunities for crowd-sourcing are restricted, the approaches should be brought into the current robot architectures.

Further, as events unfold in a region and are discussed on social media and from other data sources, this information could be utilized by the Soldiers and the robots to do a better job of reasoning about the activities they may encounter. This is especially important if we want the robots to adapt to their environments. Without this connectivity, the robot architecture will have no means to reason on data that may explain their environment. If this connectivity to distributed computing and intelligence sources is not tapped, the behaviors of the robots will be construed as brittle and not adaptable.

Distributed Intelligence infers that the individual and collective system can reason about the constantly changing local and collective situational awareness and the local and overall mission objectives to make predictions about future and perform real-time adaptations and decisions to optimize operations based on that future. A key element of future military intelligent systems is that they must make decisions on their own, likely at speeds beyond human operational tempo. However, this should not be misunderstood to infer that the robots will act unsupervised, or exhibit free will. Future robots must make decisions on their own to accomplish their mission, and this will have to be done at rates beyond which a human can control them. As an example, it is conceivable for a human operator to deploy and control a few UAS to engage with an enemy threat; however, this does not scale and what if he needs to deploy hundreds of systems.

The human will need to interact at a much higher level, for example with a high-level tasking using natural language, such as, "Deploy UAS robots to engage all incoming threats." A distributed collective of agents should make group decisions that are acceptable based on the cost/benefit preferences of the mission commander, yet we are far from a satisfactory means to achieve this reliably today. Foundations and methods need to be devised to provide distributed control and decision making that is responsive to human intent, interactive to changes in that intent, and function in complex environments with high degrees of a priori uncertainty.

When communication between agents is limited or even completely disrupted, the only way to counter such an adversary situation is to perform reasoning and prediction to predict the situation and future movements and decisions of allies and adversaries. Collective and distributed reasoning and prediction are critical when missions and objectives are not clear or change rapidly in dynamic and complex environments. Agents must preserve mission intent at operational tempo, and may be required to predict human courses of action. In addition, the intelligent system may face adversarial disruptions, requiring reasoning and prediction to enable appropriate real-time response at a pace that is far beyond what can be achieved with human interaction. Reasoning and prediction may also enable the determination and dissemination of critical and timely information. There are numerous challenges to achieving this level of collective intelligence, including knowledge representation, and real-time simulations and models and methods for understanding intent and its prediction. Research is underway to enable the teaming of autonomous air and ground robots with Soldiers. The current approaches include onboard computation, perception, and are beginning to incorporate reasoning to extract soldier intent from natural language commands and other cues for the robots to then execute [9,10]. However, if we extend this concept to incorporate distributed intelligence and awareness from broader sources of information, the progress we can make will be far greater.

Another important consideration of Distributed Intelligence is the opportunity of the robots to learn from one another. Over the last decade, we have been exposed to expensive robots, and because of their costs, we have not pursued some behaviors that might be pursued with less costly platforms. For example, instead of deploying 1-$100,000 robot, what if we deploy 100-$1000 robots, or even 1000-$100 robots. This scaling opens up many opportunities to distribute intelligence across many platforms and enable sharing of learning by all robots. By having many robots, behaviors that may result in failure of some platforms may actually benefit the collective whole. This is how humans learn. We learn from our own mistakes, and from the mistakes of others. If our robots are never allowed to fail, then we are significantly constraining their opportunity to learn, and thus improve their performance. Multi-agent learning is a potentially attractive alternative to directly coding teams or swarms of agents or robots. It is very challenging problem to provide the micro-level behaviors necessary to achieve a given macro-level phenomenon and more research is needed to find approaches to teach large numbers of heterogeneous agents how to do nontrivial collective tasks in real-time and in the physical world.

We posit that there are two fundamental shifts that have occurred in the past decade that will substantially alter how Soldiers will interact with autonomy moving forward. First, we have moved into a far more personal relationship with our autonomous systems, and secondly, and perhaps more importantly we have shifted from a mode where a task is no longer done by an autonomous agent OR a human but increasingly to a mode where it is done by an autonomous agent AND a human. Some examples of this include direct integration where we have begun to cede control to intelligent agents, and humans are no longer the sole arbiter of decision making. Intelligent agents within our automobiles that act as driver assistance tools, applying anti-lock brakes automatically when an obstacle is observed, parking for us, and maintaining lane position would be a few examples, but even these examples are just humans ceding control of sub- tasks, and the human still has the possibility to over-ride these intelligent agents. There has been a trend within DoD to invest in human “within the control loop” tasks, where humans AND intelligent agents are performing largely the same tasks, and the individual output of each agent, human and intelligent system, is fused together into a joint decision [5,6]. There have been a number of fundamental scientific studies examining how to enable this and how to properly assess, instrument, and monitor the agents [5,6]. What these studies have shown, though, is that when decisions are performed in this manner, substantial improvements in performance and accuracy are observed and errors minimized [5,6]. To accomplish this, means that humans have had to cede control of decision making to these intelligent agents, when those intelligent agents are performing better. To date, most of the tasks that have been examined have been fairly benign (e.g., image classification), but increasingly we, as a research community, are investigating how consequence, trust, confidence and accountability impact these decision paradigms. Technology has shown that these capabilities are real, if still nascent. To fully realize these capabilities, there are several investments in fundamental research that need to be addressed. An intelligent agent that has been imbued with a commander's desired outcome should be able to independently, or as part of a larger group, move through an environment, navigate unforeseen obstacles and accomplish the intent of the human. This implies many technologies that do not yet exist: the ability to quantify, codify human intent; adaptive group behaviors; the ability to fuse disparate inputs from distributed agents to develop a comprehensive understanding of the world. Research to enable augmented human capabilities has a key role to play to enable this transformation.

Adaptable and Resilient Controls that enable adaptable and assured individual and collective mission plans based on changing situational awareness are clearly desirable system traits. Finding optimal, or even good enough, plans for autonomous agents is computationally difficult, especially for systems in complex environments. For most military operations real-time operational tempo is needed, and plans must be dynamically adapted during execution. This problem grows combinatorially with large heterogeneous multi-agent systems, where planning must be coordinated across many heterogeneous sub- systems with varying mission objectives, where individual agents may or may not have the same goals, where some agents may not be able to complete their tasks due to failures, and there exist non-cooperative players or adversaries. Research is needed in sub-optimal planning and exploration of the tradeoffs in speed of planning versus the accuracy and optimality of the plan.

Resilience, the ability to recover after something bad happens, is critical for intelligent systems, yet very difficult to model, analyze, and put into practice. Resiliency of large multi-agent Army systems needs to be considered based on realistic networking, and uncertainties in localization, mapping, sensing, and the state of other agents. Wireless networking instabilities, time variation, bandwidth, and security have not been sufficiently accounted for in distributed control. Information representation must be optimized in the context of the system tasks, and random information loss must be accounted for. Coupling control with autonomous networking may provide new control paradigms that simultaneously support the setup and healing of networks, dynamic network reconfiguration, the ability to withstand and overcome severe electronic warfare threats, all while supporting the War Fighter objectives such as autonomous exploration or seeking and sensing threats. Morphing, reconfigurable, and adaptable platforms and systems performance are ways to offer increased resiliency. For these to be effective, behavior synthesis should be rapid and scalable (via "online behavior synthesis"). Learning methods could be applied to reduce needed synthesis, but both of these are complicated by the potential use of many small platforms with low capability.

What is the best organizational structure to offer a balance between resiliency and operational efficiency and how can we reconfigure teams in the middle of a mission using a distributed architecture? Complex missions may require multiple teams to simultaneously carry out multiple tasks. Agents may need to play multiple roles that may span across teams. As contingency situations arise, rapid reconfigurations in teams, both locally and globally, will be needed across the distributed architecture. Dealing with intelligent adversaries will force the team into unforeseen situations. The ability to generate new behaviors on-line are likely critical to deal with contingencies and for the system to exhibit resilient behavior. On- line behavior synthesis is a challenging problem even when using a central architecture. Performing on- line synthesis of behaviors in a distributed fast paced mission is beyond the state of the art. There is no general framework or design for large numbers of distributed heterogeneous agents. Flocking is reasonably well understood with respect to coordinated group movement, but this is a small piece of the distributed intelligence problem. More research is needed in new sophisticated hybrid control architectures for large heterogeneous teams that may include both global and localized control of single agents, spatially and temporally distributed small and large teams, and localized swarm behavior. A key issue is the abstraction of localized behaviors and local controls to enable global control. The control architecture must incorporate autonomous networking, with its many limitations and tradeoffs. For large heterogeneous teaming, it can be assumed that not all communications will be bi-directional and must be understood in the context of abstraction, roles, and heterogeneity.

Networking is obviously critical for distributed system operation, while simultaneously autonomous agents can dynamically adapt to create, support, and heal networks to match the environment and the desired state of the collective. To achieve this, an entirely new theoretical foundation is needed as the number of agents and their ability to network and operate autonomously grows. Wireless networking instabilities, time variation, bandwidth, and security have not been sufficiently accounted for in distributed control. Information representation must be optimized in the context of the system task(s), and random information loss must be accounted for. Coupling control with autonomous networking may provide new control paradigms that simultaneously support the setup and healing of networks, dynamic network reconfiguration, the ability to withstand and overcome severe electronic warfare threats, all while supporting the warfighter objectives such as autonomous exploration or seeking and sensing threats. Efforts in autonomous networking must proceed in a tightly coupled research spiral with intelligent system design. This must include pervasive consideration of security and electronic warfare threats from adversarial intelligent systems. The emerging paradigms of cognitive radio and dynamic spectrum access may be critical to achieving the desired networking capabilities. Critical to this is the creation and exploitation of massive diversity, through the use of multiple wavelengths in both radio and optical domains. Mobility control will be utilized to dynamically maintain and heal the network as desired. Low frequency operation, for example in the lower VHF, can be harnessed to provide persistent links in complex terrain such as mega-cities, due to the physics of penetration at longer wavelengths. Miniature antennas and cooperative arrays may be utilized to achieve robustness to interference, and multi-user technology, including full duplex operation and coding, will provide dramatic increases in the spectrum utilization.

Operational and experiment-driven research is critical to explore and discover the brittle connections and interdependencies between perception systems, interactions with external data sources, efficient data sharing and processing methods, intelligence and decision making algorithms, multi-agent navigation and collaborative behaviors, and the collective performing spatially and temporally relevant missions. There have been recent examples of operating singular fully autonomous systems in complex environments, small heterogeneous teams with moderate complexity and interactions, and large numbers of homogeneous agents/swarms in simple environments and with limited autonomy. In order to make these demonstrations tractable and fit within today's technology, researchers typically reduce the complexity along several axes: 1) number of agents; 2) degree of heterogeneity among the agents; 3) agent behavior complexity, autonomy, and adaptability; 4) the degree of interactions and communication among the agents; 5) speed of operation; and 6) the complexity of the environment and available infrastructure (e.g., GPS). Large scale experiments rely on readily available technology and so are limited in their ability to simultaneously push along these axes. Research in ways to simultaneously push the complexity along each of these axes is needed. A lack of design methods and models for such systems is a remaining critical issue, and foundations in this area may lead to new component technology that enables leap-ahead experimentation, as well as reduce the time cycle for technology development and costs related to iterative field testing of large complex systems. As the degree of heterogeneity increases, so does the design and task allocation complexity. Metrics and roles for heterogeneous elements must be understood.

Summary

There are many challenges to meeting the technical objectives laid out in this paper but it is envisioned that research in these areas will have a significant impact in shaping the future of Army intelligent systems and operational concepts in complex environments. These concepts for highly distributed and collaborative systems will change how intelligent systems interact with each other and the soldiers they are interacting with, the physical environment around them, and the cyber world to include access to knowledge bases and other sources of information. They will use this distributed and collaborative approach to develop a much greater understanding and awareness of the environment and the threats within than is capable with any one or even a few systems. Based on this continuing evolution and awareness, the collective will be able to exhibit complex autonomous behavior at the individual, team and swarm level to reason, predict, and adapt and respond to local stimuli while maintaining resiliency in the overall mission objectives. This will result in significantly increased capabilities for extended ISR reach in complex Megacity, dense urban environments, or areas with restricted or denied access. This approach will also enable flexibility on the battlefield and provide a capability to respond to changing social and population dynamics with varying levels of autonomy, intelligence, and even swarm behaviors for increased awareness or delivery of payloads; could provide real time resupply to dismounts and small squads in dynamic threat environments; enable robots to be used as a diversions or support fires and targeting; to be used as additional protection and to mask dismounted movements; and to collectively perform missions that otherwise would be unachievable, such as persistent surveillance of a particular region that exceeds the endurance of a single platform to ensure future tactical advantage.

Acknowledgements

The authors would like to acknowledge all the participants at the FY16 Army Science Planning Meeting: "Distributed and Collaborative Intelligent Systems," their discussions contributed significantly to the ideas captured in this paper.

References

1. TRADOC Pamphlet 525-3-1 "Win in a Complex World"
2. DOD Unmanned Systems Integrated Roadmap FY2013-2038
3. Unmanned Ground Systems Roadmap, Robotic Systems Joint Project Office, 2011
4. Nieto-Granda, C., Rogers, J. G., Christensen, H. I., "Coordination Strategies for Multi-Robot Exploration and Mapping," The International Journal of Robotics Research, 2014.
5. Amar R Marathe, Brent J Lance, Kaleb McDowell, William D Nothwang, Jason S Metcalfe, "Confidence metrics improve human-autonomy integration." Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction, 240-241, 2014/3/3.
6. Ryan M Robinson, Hyungtae Lee, Michael J McCourt, Amar R Marathe, Heesung Kwon, Chau Ton, William D Nothwang, "Human-autonomy sensor fusion for rapid object detection." Intelligent Robots and Systems (IROS), 2015 IEEE/RSJ International Conference on, 305-312, 2015/9/28.
7. **Yann LeCun**, **Yoshua Bengio** & **Geoffrey Hinton**, "Deep Learning," *Nature,* Volume: 521, Pages: 436–444, 28 May 2015.
8. Nicola Jones, "The Learning Machines: Using massive amounts of data to recognize photos and speech, deep-learning computers are taking a big step towards true artificial intelligence," NATURE, VOL 505, Pages: 146–148, 2014
9. D Summers-Stay, T Cassidy, CR Voss, "Joint Navigation in Commander/Robot Teams: Dialog & Task Performance When Vision is Bandwidth-Limited," V&L Net

2014.

10. CR Voss, T Cassidy, D Summers-Stay, “Collaborative Exploration in Human-Robot Teams: What’s in Their Corpora of Dialog, Video, & LIDAR Messages?” Proceedings of the Workshop on Dialogue in Motion (DM), 14th Conference of the European Chapter of the Association for Computational Linguistics, 2014

Technical Challenges for Simulation and Training in Megacities

By ***Jon Watkins and Chuck Campbell***

Originally published in Small Wars Journal on 12 February 2016

Available online at: http://smallwarsjournal.com/jrnl/art/technical-challenges-for-simulation-and-training-in-megacities

Introduction

Megacities, urban areas with populations over 10 million people, are of growing importance to the military, and thus are of growing importance to training. Training needs vary widely based upon maneuver or fighting in open desert, urban environments on the streets, and building interiors (room clearing). Training applications span aggregate commander and staff constructive trainers to individual combatant virtual simulation. It is critical for Modeling and Simulation (M&S) applications to represent those environments and situations which are inherently unusual or difficult to train live. An example of this is urban areas, which are difficult to recreate realistically for training. It is impractical to impossible to fully recreate megacities (like we do with MOUT sites) or to get access to real-world cities for live training. As a result, simulation becomes critical for both training and analysis use cases (i.e. analysis to assess if a particular weapons system or offensive plan might work better than another).

Figure 1: (L) Metro entrance in Canada, showing an example of the layers of features and activity at a single location; (R) Underground Mall in Taipei, showing the importance of advanced underground modeling.

As the threats to the U.S. change, megacities become increasingly relevant and important for preparing for the future. Violent extremist groups regularly innovate in their approaches to terrorism, creating new threats to U.S. troops. They operate out of a wide variety of locales around the world, to include large urban areas and megacities. In addition, a conventional war with a major power like China, North Korea, or Russia would inevitably involve urban environments. Modeling and simulation must be able to represent these megacities so that U.S. forces can more efficiently prepare to combat threats arising within the megacities of our world. Accurately representing megacities and dense urban environments provide particular challenges to the simulation and training community. This paper discusses those challenges from a Synthetic Natural Environment (SNE) standpoint.

Within modeling and simulation systems, higher level models operate on, around, and within the synthetic natural environment. The SNE is the foundation of M&S capabilities, and must be designed and developed to meet new and far-reaching requirements. If the SNE representation lacks a critical data element required for a model to function, then training may be impeded. For example, if the material characteristics of walls are critical for calculating damage, building collapse, mouseholes, or weapon penetration, then the SNE must contain that data or a reasonable approximation of it. Current SNE capabilities can be applied to the challenges with representing megacities in limited ways, but must advance exponentially to meet 2025+ challenges.

The two major challenge focus areas presented here are data representation and the environment model. While data collection and processing is a major concern for simulation of megacities, we do not focus on these issues here, since collection and processing is also an issue for operational situations as well, and thus is not unique to simulation and training. We do, however, reference collection and processing where we see M&S-specific issues.

Background

The authors have practical, real-world experience with SNE as it is designed, produced, and used in M&S today, and we are familiar with both strengths and weaknesses of the current state of the art. We have a long standing history of pushing SNE technology towards the future, having contributed to the design and development of the SNEs on many of the Army's simulation and training systems over the past 20 years, including WARSIM, CCTT, OneSAF, SE Core, and others. The authors are currently leading research efforts for the M&S community looking at complex urban environments, including megacities in general and underground representations in particular. This work is being conducted primarily for the U.S. Army Research, Development and Engineering Command (RDECOM) Army Research Lab (ARL) Human Research and Engineering Directorate (HRED) Advanced Training & Simulation Division (ATSD).

While the overarching scope of our work is to investigate the future direction of SNE for simulation in general, we are looking at megacities as a key area requiring improvement. This paper summarizes the high level concerns with megacity representation as we see it (relative to today's state of the art in fielded M&S systems).

Challenges

Inevitably, SNE requirements for the future must be driven by functional needs, since ultimately any SNE implementation exists to provide the context and surrounding environment for a larger system. For example, one training use case may consider it critical to represent power outages if power lines are damaged while others may consider this irrelevant. However, we can still extract several larger themes of concern with accurate portrayal of megacities, given the inevitable desire for increased fidelity and realism.

Data Representation

A new approach is needed for data representation. Current data representation approaches do not scale to the extent needed for the ultra-dense urban environment, as is seen with a megacity. Megacities will naturally require a wider breadth and higher density of data than is currently used in M&S applications.
In addition, to keep up with the increasing availability of new data and notifications of changes to existing data, mechanisms are needed to quickly update and modify data. Technology advancements enable rapid, continuous bursts of new information from the field, which should be integrated into the data to improve the representation of the environment within simulation. Several challenges arise when considering megacities.

Increased density. In terms of the environment, this means an increase in non-specific environment features such as clutter; items like benches, trash, signs, etc. Buildings will be large, close together, and will often require both interior and sub-subterranean representation. Transportation networks will be increasingly complex, requiring representation of roadways, railways, water ways, and subways, many of these transitioning frequently from above ground to below ground.

Figure 2: (L) A simple roadway interchange; basic traffic laws are obeyed by simulated vehicles;

(R) A complex highway interchange in Boston, MA; will require advanced representation and models (Google Maps).

Increased flexibility. Megacities have many characteristics in common, but training in one city is not directly applicable to training in another city. Simulations must be able to represent the key characteristics of various megacities so that training can occur in geo-specific locations around the globe. This diversity requires increased flexibility in how SNE data is represented. Every mission brings new and unfamiliar challenges. Just as the military must adapt quickly to overcome adversity, training simulation must respond accordingly to remain effective. Megacity representation requires a fluid SNE specification able to rapidly change to provide training for future, often unpredictable threats.

Vast relational challenge. Increases in urban density compound the complexity of relationships between infrastructure components. Critical infrastructure such as transportation networks become progressively complex as the interactions between environment features (roads, tunnels, railways, traffic signals, etc.) and moving actors (vehicles, pedestrians, etc.) become more frequent, with a greater number of variables and possible outcomes. Other infrastructure representations are in their infancy, such as computer and cellular networks, and challenges must be overcome to accurately represent these as well.

Streaming information at appropriate levels. Given the ubiquity of sensors and sensing platforms, live, up to the minute data is often available, and should be leveraged to maintain the environment representation accurately. This challenge has not yet been tackled in the modeling and simulation community to a level that is applicable for megacities. Data filtering becomes increasingly important with the rise of augmented reality systems.

Multiresolution representation. Megacity training objectives will be wide and varied. Some applications will need very detailed information while others will only need an abstract representation. For example, one trainer may need to simulate disabled power to a section of the city, whereas another may need to disable the power to a particular building. The effects of urban modeling should correlate at every level. In the power disruption example, the power grid is represented by power being distributed from power plants, across lines, through substations, transformers and other equipment. While this example focuses on electricity, the concepts apply to many SNE representational areas, including transportation/supply lines (including shipping and air), potable water, structural materials, communication, medical facilities, shelters, weather, and more. The SNE must be equipped to be able to manage the timely provision of high-resolution data in specific areas when it is required.

Environment Model

Megacities are inherently intricate in terms of how people interact with them, including complex effects on entities, secondary effects (such as damage to power lines causing lights to go off), implied or expected behaviors (such as traffic lanes or areas where civilians are likely to congregate), and multi-dimensional context (such as airport versus hospital/school versus police station). At least some of these complex effects must be captured in simulation in order for training to be effective and realistic.

Improved fidelity. In order to accurately portray the increasing complexity discussed above in relation to infrastructure, flexibility, and increasingly available data, environment models need to be more advanced, more capable, and of a higher fidelity. For example, models must take into account the difference between types of clutter. Clutter may create obstacles and change line of sight, but higher fidelity models should distinguish between a movable, non-blocking obstacle (trash bag) and a stationary, blocking obstacle (dumpster). As another example, advanced vehicle models will be able to use road lane and traffic signal data, and obey basic traffic laws of the city in which they are operating.
Cascading effects. Many environment models in M&S today effectively simulate the single function for which they are designed. As interactions between various models within the simulation increase, so do possible outcomes, issues, effects, etc. Infrastructure failure such as a water main break is one example of a cascading effect in an urban environment. Often what follows are flooded streets and subways, localized loss of electricity, increased vehicle traffic, etc. In addition, political, economic, and social models will need to be incorporated in order to support training for combating terrorist activities.

Weather realism. While weather is not specific to megacities, Army simulations currently have minimal representation and modeling of weather. Weather affects real world operations, and similarly should affect training, but it has not yet been a focus of Army simulations. Two critical components are required to achieve weather realism in modeling and simulation: accurate and complete weather models, and usage of the resulting weather data by other models in the simulation. Accurate weather models and weather data are available, although not often leveraged in M&S, and other models rarely consider weather conditions. Weather affects much of what happens in the real world (fog, haze, smog, precipitation, etc. all effect movement, visibility, etc.), and weather realism in simulation is a complex challenge. Localized weather effects can induce the need for immediate deployment of first responders to help those in need and quarantine unsafe areas. Considerations for weather in megacities are often unique, and may require additional data and models (e.g. the uncharacteristically high amount of snow in Boston, MA in 2015 presented new challenges with snow removal - there was nowhere to dispose of the excess snow from plowed roadways).

Figure 3: Rain is accumulating in the dug hole, and changing the composition of the soil. Dignitas added weather modeling and effects to a Construction Equipment Virtual Trainer (CEVT).

Current State of the Art

While the simulation and training community has made great strides in some areas related to dense urban environments, the community lacks the current capability to represent megacities at a sufficient level.

Current SNE capabilities exist in some key areas, which can be applied and leveraged to represent dense urban environments. For instance, high fidelity representation of building interiors has been achieved and applied in simulation training for tasks such as room clearing or attacks within a building. In addition, advances have been seen in visualization technologies, where visualizing urban and high density environments is no longer a struggle, and specialized, expensive hardware is no longer a necessity.

Computers have gotten faster, smaller, and more capable over the years, while visualization algorithms have improved, making it possible to visualize complex 3D scenes on inexpensive hardware. Representation of high density features has been achieved in support of computer generated forces as well. Simulation systems such as OneSAF, Close Combat Tactical Trainer (CCTT), and JCATS offer support for limited urban areas and building interiors. Although some strides have been made, many key elements of urban environments are notably missing from modern simulation systems.

The authors see the modeling and simulation community as largely unprepared to accurately represent the physical environment in a simulation context. Innovation to

address this challenge must come through targeted research to provide a foundation on which programs of record can base future requirements.
Visual systems required for virtual simulation are generally in a better position to represent complex urban environments, although much work remains in the detailed geometry, topology, and physical modeling of the environment required to provide supporting services.

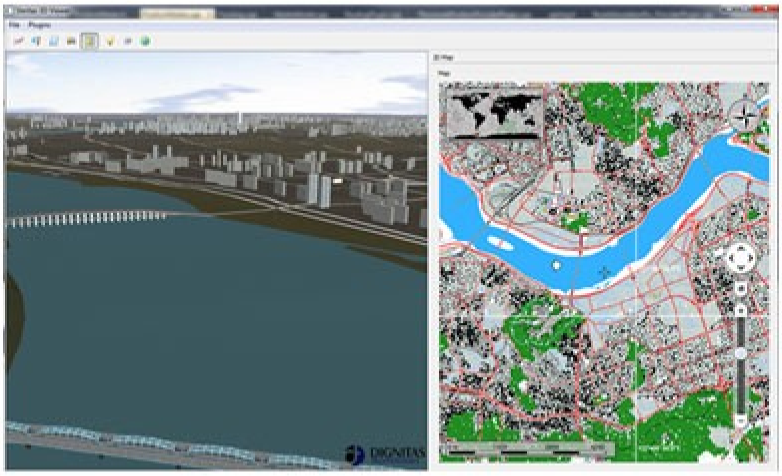


Figure 4: The Dignitas Veritas 2D/3D Viewer is used by LVC-IA and SE Core and runs on inexpensive laptops or desktop computers, with no specialized hardware requirements.

Below we discuss a selection of the issues that exist with the current state of the art.

Specialized Attribution Requirements. The modern battlefield is characterized by unparalleled access to data from a wide range of sensors. Open environments, such as those seen from air or space or easily observed from the ground, can be visualized and sensed in real-time. However, obtaining realistic and geospecific data for megacities is more complicated. Techniques that scan environments can be hindered by physical blockages (such as visibility into buildings or underground), as well as lack the ability to capture the intricacies of the man-made environment (such as such as material characteristics, access points, mobility information, etc.). Accurate simulation of a megacity synthetic environment will require access to these types of information or the ability to realistically infer or derive such data. These content requirements, of course, will be driven by training and functional requirements. If a training use case requires accurate representation of underground fire or smoke propagation, then issues like airflow, venting, etc., become important. If structural collapse or simulation of mouseholes is important, then structural attribution becomes more important.

Leveraging Commercial Data and Technology. In times of limited budgets, it is critical that the Army adapt to development of systems and technology that can more readily leverage commercial solutions. Current Army M&S solutions are stove-piped, built through specialized development with only limited reuse of open and commercial solutions. While specialized development may remain necessary in many areas, reuse can be increased.

Traffic and Crowd Modeling. The density and variety of human activity is a critical component in urban operations. Even in wartime situations, there may be civilians hiding out in cities, fleeing the hot zones, or congregating in the city's outskirts. When there is little warning of impending conflict, civilians may be *the* critical factor in operations. Military operations may need to be carried out with regular civilian activities occurring, as in Baghdad. Simulation of civilians requires specialized data in SNE, including things like traffic information (lanes, stop lights), designation of areas of heavy traffic (e.g. transportation hubs or malls would have more civilian traffic than a warehouse), etc. Public gathering locations such as stadiums, parks, hospitals, and churches can serve as terrorist targets or opportunities for civil unrest.

Underground and Interiors. While the Army has extensive recent experience in urban environments and building clearing, regional differences can make a tremendous difference. Clearing a high rise building requires different approaches than clearing a small building in a walled compound. Similarly, underground environments represent special risks due to factors such as collapse, access, and even air flow (for fires or smoke propagation).

Civilian Infrastructure. Megacities will have complex and widely varying types of civilian infrastructure including power networks, lights, water lines, specialized buildings (hospital, power plant), etc. This infrastructure can matter in physical ways (damage to gas pipes could be physically dangerous, knocking out power will disable lights) as well as in conceptual ways (approaches will vary for a hospital versus school versus police station). Large, open areas such as stadiums, playgrounds, and parking lots can have military significance in providing locations for displaced civilians, holding areas for detainees, or logistics support.

Physics Effects and Interactions. Complex physical interactions will be critical in representing urban environments, including structural collapse, weapon penetration of walls, cratering of roads, collapse of tunnels, etc. In more open, rural environments, these effects could often be minimized or avoided except at key chokepoints. Megacities are large aggregations of critical chokepoints.

Urban Clutter. In most Army simulations, the training environment is largely sterile and lacks dense clutter like dumpsters, parked cars, street side market stalls, utility poles, etc. Urban clutter is especially important for high-fidelity training where objects can reduce visibility, provide cover and concealment, and hamper movement.

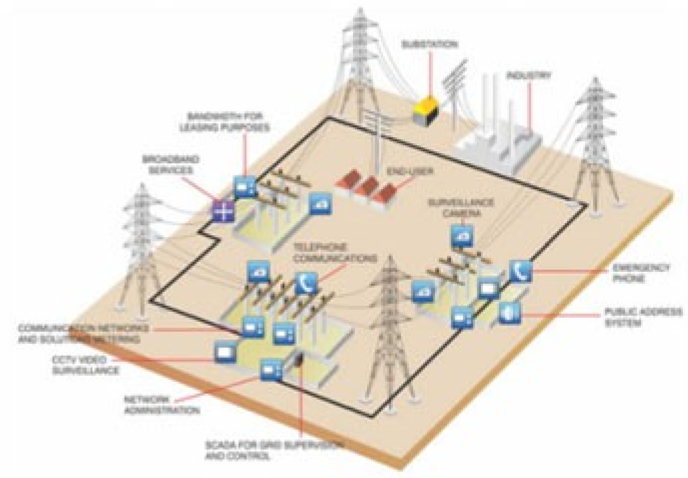


Figure 5: Complex civilian infrastructure must be modeled and considered in megacity operations. Emerging Technology

Keeping an eye on emerging technologies across the industry ensures re-use candidates can be identified and used as appropriate.

There is an emerging trend of crowd-sourced data and increased timeliness of geospatial and infrastructure data available from multiple sources. For example, navigational data on smart phones and GPS systems is updated frequently with up to date traffic data to indicate whether traffic is flowing smoothly or is backed up. Some navigational apps also include crowd sourced data, allowing users to input accidents, road hazards, and detours. However, such data sources must be carefully considered since they could easily provide a pathway for misinformation to enter into military systems. Critical areas and categories of data will remain difficult to obtain trust-worthy sources for, especially in foreign countries or network denied areas.

Figure 6: Google maps and GPS systems show live traffic status via colored lines (red for heavy traffic, green for clear) and icons for construction zones and accidents.

Game engines continue to evolve, but their focus is often in areas that are not important in military applications. Game engines often excel at providing highly realistic visual environments and compelling physical interactions, but the focus is generally on visual effect and gameplay rather than realism.

Realistic effects are of utmost importance to military simulations to avoid negative training. Similarly, realistic-looking effects in game engines are often achieved through extensive manual effort from artists and scenario developers. This approach is cost-prohibitive if representing large areas or when rapid turnaround is needed from source to training.

Figure 7: Realistic video game visuals require extensive manual designs and illustrations.

Cloud-based, thin-client solutions are a growing trend that could help facilitate training at point of need. As a download repository, cloud technology has no impact on SNE representation. But the notion of streaming SNE database information adds an additional layer of complexity to the solutions needed for megacity representation. To help combat delays caused by network latency, a number of techniques are available, including optimized data structures, compression, composition (configure what data is needed per application), predictive caching, and procedural generation of SNE features. Investigation and experimentation is needed to determine which technique or combination of techniques deliver best “bang for the buck” results.

Future Focus of Science and Technology Investments

We believe concentrated investment in government development is needed to meet military needs. Crowd- source and commercial technology is widely available, but doesn’t fully meet military needs and is susceptible to injection of misinformation. We also need pathways to connect simulation and training applications over to classified data or networks, and operational data to enhance training and realism. The authors' current research efforts are investigating methods to represent geometry and topology in separate ways, yet providing some assurance of correlation between them. Megacities will require complex geometries which will make it extremely difficult to automatically derive key behavioral aspects needed for automated opponents, such as logical firing and over watch positions. Current Army simulation systems have structured yet comparatively simplistic SNE data to reason on, often making broad assumptions (such as not worrying about overhead clearances). In megacities, these assumptions will not hold up. Our research will also consider how to use a mixture of automation, machine learning, and very targeted human in the loop attribution (for heavily used training areas) to support behavioral aspects.

Defining what types of data are needed for megacity simulation is critical for success. This will include not just obvious information…such as locations of buildings, bridges, and roads…but potentially far more complex data such as material characteristics, support structures (load bearing walls for collapse), topological information (turn lanes, stop lights, paths where civilians often travel on foot), and more.

Since elements of this data will be difficult to collect from standard sources (e.g. interiors and below ground geometry), it will be important for such information to be derivable in geotypical, realistic ways. Our research will focus on what is needed for runtime functional needs rather than considering methods for collection.

Megacity simulation will require different data and services for various training use cases. For example, an immersive simulation for individual soldiers will require a different type of detail and information than a strategic bombing simulation. However, to ensure communications and interoperability between simulations, these varying representations would ideally be derived from and relate back to a common overarching representation which can handle multiple resolutions or levels of detail. Our research will investigate techniques for how to represent varying levels of detail in a correlated and realistic fashion, while also supporting highly selective data use wherein a given simulation system only loads data that is relevant and useful to its use case.

The authors believe it important that future simulations support just in time data delivery and flexible paradigms for computing platforms and environments. A simulation run one day in the cloud, might be run on network denied devices the next. In addition, we expect frequent updates to geospatial, topological, and human behavioral data from a wide range of sources in the future. This concept requires the ability to distribute the latest data rapidly, consistently, and selectively so as to get maximum benefit out of limited bandwidth for edge devices. Just in time data processing and delivery will enable different data use cases, such as cloud-based simulation using data centers or highly select data sets for resource- and bandwidth-limited devices.

As data sources, content, and updates increase in complexity, the mechanisms and processes for verifying consistency, relationships, and interdependencies must grow. Seemingly simple changes in basic geometry for feature data can have complex secondary effects on other data. For example, if data becomes available for changing the function of a building (from office building to embassy, for example), it can impact secondary data, including crowd modeling flows, behavioral cues, and more. As we build up content requirements and update mechanisms in early years, the later years of our research will look at ways to reconcile all of this data and maintain consistency where it matters.

Work is needed even in areas where the Army simulation community has extensive previous experience, such as calculation of cover, conceal, or hide locations, basic movement planning, and line of sight. These algorithms will require a different level of complexity with different tradeoffs when working in complex megacity environments.

Conclusion

As the U.S. military adapts to operating in megacities, it will be critical to enable realistic training through simulation so that warfighters are able to refine and practice their procedures. This is necessary not just for training and experience, but also to assess effectiveness of new weapons systems and platforms. The simulation and training community faces a wide range of challenges to enabling this training, especially with regards to realistic representation of dense urban environments. The authors believe focused investment is needed to ensure the simulation and training community can meet the technical challenges required to enable analysis and training in megacities. We welcome feedback from and collaboration with other Army agencies and contractors working in this domain.

SECTION 7: About the Authors
This section includes the biographies or bylines of contributing authors for all content within the compendium.

- Berkow, Jan
- Besik, AJ
- Brown, Eddie
- Crane, Alfred C.
- Crites, Michael
- Demarest, Geoffrey
- Fisher, Nathan
- Fowler, Marcie
- Gilbert, Gary R.
- Glenn, Russell W.
- Hedges, William
- Herche, Wes
- Hoven, John
- Ippolito, Danielle L.
- Keeley, Tom
- King, Erin
- Knapp, David
- Krakowka Richmond, Amy
- Kwon, Paul O.
- Lawton, Joel
- McGhee, Laura L.
- Morris, Victor R.
- Morrison, Dawn A.
- Otto, Gustav A.
- Peeke, Richard
- Pike, Tom
- Poropatich, Ron
- Prautzsch, Frank
- Randall, Robb
- Read, Mark
- Santaspirt, Matthew
- Shields, Lori
- Shutters, Shade T.
- Staley, Jim
- Tansey, Colin
- Ward, Darryl
- Wolfel, Richard
- Wood, Colin D.

Jan Berkow

Jan Berkow is a medical device industry consultant and serves as a contractor to the Center for Military Medicine Research at the University of Pittsburgh as the TRACIR Program Manager. He has extensive domain expertise in the field of non- invasive cardiovascular hemodynamic monitoring and related sensor technologies. He was previously the Chief Technology Officer, co-founder, and inventor of Intelomed's CVInsight, a non-invasive cardiovascular patient monitoring platform that has been commercialized in the hemodialysis market to aid in providing treatment optimization. Prior to his current healthcare "treat-to-order" healthcare focus, he was an industrial process consultant focusing on "make-to-order" industry solutions where he focused on improving asset utilization, throughput, and production efficiencies. While performing in this role, he served as the principle investigator and prime contractor for a DoE sponsored R&D project that 'smelter- centric" intelligent process control for a large domestic aluminum producer.

AJ Besik

Mr. AJ Besik is an Armor officer in the U.S. Army Reserves and assigned as the secretary of the General Staff for the 100th Division. He is a veteran of deployments to Iraq and Afghanistan and a graduate of the U.S. Army Command & General Staff College's School of Advanced Military Studies. He is currently attending the University of Louisville's Brandeis Law School.

Eddie Brown

MAJ Eddie Brown is a Military Intelligence officer in the US Army. He is a SAMS graduate and has served as an intelligence planner for multiple tactical and operational military units.

Alfred C. Crane

Alfred C. Crane III currently works at the Army Capabilities Integration Center, Concepts and Learning Directorate, Science & Technology, Research and Accelerated Capabilities Development Division as a Spiral Developments Analyst. Mr. Crane has worked for the Army as a civilian since April of 1997. He has served as an Instructional Systems Specialist for the US Army Military Police School, Military Analyst for the Army Training Support Center and Army Futures Center, and Spiral Developments Analyst for the Army Capabilities Integration Center. Mr. Crane also served in the United States Marine Corps Reserve from 1990 – 1996. He holds a Master's Degree in Education (Teaching History) from Jacksonville State University and a Bachelor's Degree in History from Christopher Newport University. His hobbies include wargaming, painting miniatures, historical re- enacting, collecting toys and militaria, as well as historical and science - fiction books and movies. He also created and manages two Facebook forums (The Video Alternative and The Video Alternative Part 2) devoted to movies, books, music and gaming.

Michael Crites

Michael Crites works as a senior military analyst in TRADOC G-2. Crites retired after 30 years in the Marine Corps with tours in 2009 as a lessons learned analyst in Iraq recording the largest retrograde of equipment and Marines in the Corps' history; as the component commander's representative and senior Marine in Africa; and Commanding Officer, Headquarters Battalion, Marine Forces Pacific, 2003-2005, with oversight of counter-terrorism operations in the Philippines and the tsunami relief effort in Japan.

Geoffrey Demarest

Geoffrey Demarest is a researcher in the US Army's Foreign Military Studies Office at Ft. Leavenworth, Kansas. He holds a JD and a PhD in International Studies from the University of Denver, and a PhD in Geography from the University of Kansas. He is a graduate of the US Army War College at Carlisle Barracks, Pennsylvania, and of the School of the Americas at Ft. Benning, Georgia. Demarest's latest book is titled Winning Insurgent War.

Nathan Fisher

Nathan Fisher is a Project Manager, Mechanical Engineer, and Roboticist working for The Geneva Foundation as a support contractor for the US Army Medical Research and Materiel Command's (USAMRMC) Telemedicine and Advanced

Technology Research Center (TATRC) since 2014. Prior to this role, Nathan worked for eight years as a Mechanical Engineer supporting the design and manufacturing of various vehicle systems, including military combat vehicles and commercial aircraft systems. Nathan's current professional focus is in the adaptation of emerging robotics technologies to provide future capabilities for combat medics in far-forward operational environments. Nathan holds a M.S. degree in Mechanical Engineering from Johns Hopkins University and a B.S. degree in Mechanical Engineering from the University of Maryland.

Marcie Fowler

Marcie Fowler, Ph.D., is a research physiologist at the United States Army Institute of Surgical Research (USAISR). Since 2009, Dr. Fowler has conducted both clinical and preclinical research for the Battlefield Pain Management and the Burn Injuries Task Areas at USAISR. Her research focus has included the characterization of analgesic administration both in the hospital and in theater, as well as the development of novel animal models of pain and the analyses of efficacy and mechanisms of novel analgesics. Dr. Fowler holds a Ph.D. in Biochemistry and Molecular Biology from Louisiana State University Health Sciences Center-Shreveport and a B.S. degree in Biology from Louisiana Tech University

Gary R. Gilbert

After receiving advanced degrees in Agriculture, Dairy Science, and Management of Information Technology, from Cornell, Penn State and American University, Dr. Gilbert served in the U.S. Army as a Medical Service Corps Commander and Staff officer, which included service as a Special Forces Operational "A" Detachment Commander and Medical Plans, Operations, and Training Officer. Also while in the Army, he received a Ph.D. in Business with specialization in Artificial Intelligence and Medical Informatics from the University of Pittsburgh. He has served as Director of Information Systems (CIO) at Walter Reed and Tripler Army Medical Centers in Washington, DC, and Honolulu, HI; CIO of the Army Medical Research and Materiel Command (MRMC) and Director of the Army's Telemedicine and Advanced Technology Research Center (TATRC) at Fort Detrick, MD. He was instrumental in developing and implementing numerous Department of Defense medical information systems, initiating a variety of military medical informatics projects, and creating the Army's telemedicine program. After retirement from the Army, he became Associate Director of Advanced Technology and International Health at Rush-Presbyterian-St. Luke's Medical Center in Chicago before receiving appointments as a Research Associate Professor at the University of Pittsburgh and as an Intergovernmental Personnel Act (IPA) research manager at the Army Telemedicine and Advanced Technologies Research Center (TATRC), Fort Detrick, MD.

Russell W. Glenn

Dr. Russell W. Glenn is an associate professor with the Strategic and Defence Studies Centre, The Australian National University. He is a graduate of the United States Military Academy, thereafter completing a military career that included a combat tour during Operations Desert Shield and Desert Storm in Iraq. Dr. Glenn was a senior analyst with RAND (1997-2009) and A-T Solutions (2009-2013).

Past research includes published studies on counterinsurgency, urban operations, military and police training, and intelligence operations. He has a Bachelor of Science degree from the United States Military Academy and Masters degrees from the University of Southern California (MS, Systems Management), Stanford University (MS, Civil Engineering and MS, Operations Research), and the School of Advanced Military Studies (Master of Military Art and Science). He earned his PhD in American history from the University of Kansas with secondary fields of military history and political science. Military education includes airborne, Ranger, and pathfinder qualifications. Dr. Glenn is the author of over fifty books or book length reports in addition to many articles. His most recent book, Rethinking Western Approaches to Counterinsurgency: Lessons from Post-colonial Conflict, was published in April 2015. He is author/editor of Trust and Leadership: The Australian Army Approach to Mission Command, forthcoming as part of the Association of the United States Army book program.

William Hedges

William (Bill) Hedges, Command Sergeant Major (Ret), USA, is a liaison officer for the Intelligence & Information Warfare Directorate and the US Army's Intelligence Center of Excellence (ICoE), and additionally serves as a Science & Technology analyst for ICoE's Requirements Determination Directorate. A career intelligence analyst, Mr. Hedges has been posted to multiple senior intelligence analyst positions to include stints with: Field Station Berlin; the Central American Joint Intelligence Team (CAJIT-DIA); the Multi-national Force and Observers (Sinai); the Defense Intelligence Agency/CJCS-J-2; Task Force 134, Camp Cropper (Iraq); and the 501st Military Intelligence Brigade, INSCOM (South Korea). In his final assignment, he served as the Command Sergeant Major and Commandant of the Army's Intelligence Center's Noncommissioned Officer Academy. Prior to his present position, Mr.

Hedges served as the program manager, course manager, and master instructor for ICoE's Analytic Tradecraft program. His primary research areas are human domain-human dimension convergence, as a primary nexus towards producing future generations of master intelligence analysts. Mr. Hedges holds a B.S. degree in Political Science and is also a graduate of the Defense Intelligence Agency's National Intelligence University.

Wes Herche

Wes Herche is a research scientist with the Global Security Initiative at Arizona State University, with an additional appointment of senior sustainability scientist in the Global Institute of Sustainability. He holds a bachelor’s in geography from Southern Illinois University, an MBA from Thunderbird School of Global Management, and is currently completing a doctorate in sustainability science. His research focuses on energy security and policy. Wes was previously an intelligence analyst with the U.S. National Geospatial Intelligence Agency.

John Hoven

John Hoven <jhoven@gmail.com> (www.linkedin.com/in/johnhoven) is an innovation broker between those who do qualitative analysis and those who need its capabilities for operations and assessment. He recently completed a 40-year stint analyzing complex, dynamic relationships in merger investigations, as a qualitative microeconomist in the U.S. Justice Department's Antitrust Division. Dr. Hoven earned a Ph.D. in economics from the University of Wisconsin at Madison, an M.S. in physics from the University of California at Berkeley, and a B.A. in mathematics and physics from the University of Montana at Missoula.

Danielle L. Ippolito

Danielle L. Ippolito, Ph.D., is a Research Physiologist and Task Area Manager for the US Army Center for Environmental Health Research (USACEHR). She is a biomedical researcher with nearly 10 years of Army experience in clinical and laboratory research environments at Fort Detrick and Madigan Army Medical Center (Joint-Base Lewis McChord). She uses an integrative systems biology approach to develop medical diagnostics and decision aids that protect Warfighters from chemical threats in hostile operational environments.

Tom Keeley

Tom Keeley has over thirty years of experience in corporate life with General Electric and Rockwell Automation after graduating from Bradley University with an engineering degree During those years he held various development engineering, engineering management, technology transfer management, and corporate staff positions related to the development of US Navy Polaris / Poseidon program-inertial guidance and fire control systems, mini-computer design, computer aided dispatching systems for police and fire, cellular radio / cellular telephone, industrial robotics, intelligent sensors, RFID, vision systems, industrial automation communications systems, and industrial automation system architectures. He started Compsim in 1999 to provide a knowledge capture product. That product evolved to include a decision-making model that would "make soft decisions" faced by today's corporations and autonomous devices (and make the decisions explainable, auditable, and re-useable). With the ability for a computer to make "soft" decisions, Compsim transformed itself from a software product company to a "technology provider". KEEL ("Knowledge Enhanced Electronic Logic" Technology was created and patented.

Erin King

Erin King is a staff member of the Global Security Initiative at Arizona State University where she is completing a bachelor's in sociology and a certification in homeland security. Her research interests include a broad spectrum of security issues. Erin previously served as a counterterrorism intelligence intern in Israel with TAM-C Solutions.

David Knapp

Mr. David Knapp is the Associate Division Chief for Science and Technology in the Battlefield Environment Division at Army Research Laboratory (ARL). He supports the laboratory's new Atmospheric Science Center by leading efforts to develop new and strengthen current research collaborations in the areas of atmospheric sensing, characterization, and modeling for the Army's future battlefield needs. He recently completed a 10-year stint as chief of the Division's Atmospheric Modeling Branch, providing technical leadership to scientists and engineers focused on developing, validating, and fielding innovative atmospheric prediction capabilities tailored for all Army battlefield operational scales. Mr. Knapp has been with ARL for over 20 years in different research capacities related to battlefield weather forecasting. He retired from the Air Force Reserves in 2003 after serving a combined 22 years of active and reserve duty as a weather officer in a variety of operational forecasting, research, and leadership positions. He has extensive experience focused on applied research addressing specific Army weather capability gaps, with additional expertise in aviation weather research topics. Mr. Knapp received his B.S. in Meteorology from the University of Utah in 1981 and his M.S. in Meteorology in 1988 from North Carolina State University.

Amy Krakowka Richmond

Amy Krakowka Richmond is an associate professor of Geography in the Department of Geography and Environmental Engineering at the United States Military Academy at West Point NY. She applies her skills to understanding the interactions between environmental resources and human populations. Her current research on Sub-

Saharan Africa develops an interdisciplinary framework to investigate the relationship between environmental processes and human wellbeing that can be adapted to any geographic location.

Paul O. Kwon

LTC Paul Kwon is currently the Branch Director of Preventive Medicine at the Walter Reed Army Institute of Research located at Silver Spring, Maryland. His leadership roles include Chief of Pediatrics and Interim Chief of Behavioral Health at Fort Irwin, CA; Chief Medical Officer during Operation Iraqi Freedom; and Chief of Preventive and Occupational Medicine at Fort Wainwright, AK. Current research efforts in development, design and diplomacy of leveraging existing technologies to enhance Force Health Protection; Medical Accession Standards; training and development of future Public Health leaders; and threat reduction through training and education are currently underway within Preventive Medicine.

Joel Lawton

Joel Lawton <joel.b.lawton@gmail.com> (www.linkedin.com/in/joellawton0125) is a former member of the U.S. Army's Human Terrain System (HTS). His work with HTS included working in the U.S. and two tours to Afghanistan, where he conducted socio-cultural research management, collection, and support; as well as open-source intelligence analysis and qualitative data collection and analysis. Joel served in the USMC, deploying to southern Helmand Province in 2009 in support of combat operations. Further, Joel is an advocate of qualitative analysis and its use in military intelligence collection efforts. He currently works as an intelligence analyst for the Army, Training and Doctrine Command (TRADOC).

Laura L. McGhee

MAJ Laura L. McGhee, Ph.D., is currently the Executive Officer at the United States Army Research Institute of Environmental Medicine (USARIEM). Prior to this assignment, MAJ McGhee served as the Scientific Director of the Defense and Veterans' Center for Integrative Pain Management (DVCIPM), where she directed research on pain, analgesia, anesthesia, and patient/provider education. She is also the former task area manager for the Battlefield Pain Management Task Area at USAISR. In this assignment, she conducted preclinical pain outcomes research and also initiated the preclinical pain research program at USAISR. MAJ McGhee holds a Ph.D. in Biochemistry and Molecular Biology from Louisiana State University Health Sciences Center-Shreveport and a B.S. degree in Biology from the University of Tennessee-Knoxville.

Victor R. Morris

Victor R. Morris is a civilian instructor at the U.S. Army Europe's Joint Multinational Readiness Center (JMRC) in Germany. The views expressed in this article are those of the author and do not reflect the official policy or position of any mentioned intergovernmental organizations, JMRC, Booz Allen Hamilton, United States Government or NATO. Follow on Twitter @vicrasta3030

Dawn A. Morrison

Dawn Morrison is a researcher working for the U.S. Army Corps of Engineer (USACE), Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) in Champaign, Illinois. Her research focuses on analyzing and modeling how human populations interact with the built environment. She earned both a M.A. and Ph.D. in Human Geography from the University of Illinois, Urbana-Champaign, and a B.A. in History and Geography from the University of Chicago, The College.

Gustav A. Otto

Mr. Gustav A. Otto is the Distinguished Chair of Defense Intelligence, and DIA Representative to the Army Combined Arms Center & Army University. A career human and counterintelligence officer and veteran of eight deployments in and out of uniform. A graduate of National War College, Gus instructs and advises faculty, and students on issues spanning intelligence, national security and leadership, across government, academic and industry.

Richard Peeke

LTC Richard "Scot" Peeke serves as the Chief, Innovation Branch at HQ TRADOC, US Army Capabilities Integration Center, Science & Technology, Research and Accelerated Capabilities Division. His recent assignments include Graduate Research Student as part of the US Army Advanced Civil Schooling Program at The College of William & Mary Materials Science & Engineering - Nanomaterials & Imaging Lab; Special Operations Liaison Officer / Embedded Planner with the NSOCC / Special Operations Joint Task Force deployed to Afghanistan; Chief, Incident Analysis Branch, US Army, Joint Task Force-Civil Support Chemical, Biological, Radiological and Nuclear Response Operations; and Deputy Commander North Carolina Army National Guard, 42nd Civil Support Team North Carolina Area Weapons of Mass Destruction Response Operations. LTC Peeke holds a Master of Science, Applied Science - Materials Science and Engineering from the College of William and Mary and a Bachelor of Science in Biology/Biological Sciences, General from the US Air Force Academy.

Tom Pike

MAJ Tom Pike is a Strategic Intelligence officer in the US Army. He has studied Complex Adaptive System applications to analysis for the past 8 years, initiated and contributed to Inter-Agency Agent Based Modelling efforts, and served as a representative to the Defense Intelligence Socio-Cultural Capabilities Council.

Ron Poropatich

COL (Ret.) Ron Poropatich, MD retired from the US Army in 2012 after serving more than 30 years as a Pulmonary/Critical Care Medicine physician. His last assignment was at the US Army Medical Research and Materiel Command at Fort Detrick, MD serving as the Deputy Director of the Telemedicine and Advanced Technology Research Center where he managed large medical research programs and coordinated telemedicine deployment for the US Army for both US based and overseas locations. He currently serves as the Executive Director for the Center for Military Medicine Research, Health Sciences at the University of Pittsburgh. He is a Professor of Medicine in the Division of Pulmonary, Allergy, and Critical Care Medicine at the University of Pittsburgh and is also a Senior Advisor for

Telemedicine for the University of Pittsburgh Medical Center. Dr. Poropatich is an Adjunct Professor of Medicine at the Uniformed Services University of the Health Sciences in Bethesda, MD, and serves as an Associate Editor for the "Telemedicine and e-Health Journal". He is the former Chair of the NATO Telemedicine Expert Team (2000-2012), former President (2002-2003) and Board Member (1996-2004) of the American Telemedicine Association and a former practicing Pulmonary/Critical Care Medicine physician at the Walter Reed National Military Medical Center, Bethesda, MD.

Frank Prautzsch

In his current role as President of Velocity Technology Partners LLC, Mr. Prautzsch (LTC, Ret. Signal Corps) is recognized as a technology and business leader known for exposing or crafting innovative technology solutions for the DoD, SOF, DHS and Intelligence community. His focus is upon innovation and not invention. His waking moments are spent in the process of identifying and contriving use cases for global commercial technologies that the government is unaware of, or at best has yet to assume a use case for that could support their needs. Prior to his own consulting program, Mr. Prautzsch served as the Sr. VP for Government Programs for ORBCOMM, the Director of the Raytheon Rapid Initiatives Group (RIG), and Director of Army Requirements for Hughes Space and Communications Company.

While on active duty in the US Army, Mr. Prautzsch held a variety of Command, Staff, and Engineering positions. He served on numerous Joint Task Force, Army, and contingency missions across all operational environments and was instrumental in defining many of the Army's MILSATCOM concepts of operations and doctrine used today. He was the Secretary of the Army's selection to Lead the DoD MILSATCOM Architecture under the DoD Space Architect. During this process, he was instrumental in formulating a $42B investment plan for wideband, protected and narrowband communications for the Nation.

Mr. Prautzsch holds a Bachelor of Science in Engineering from the United States Military Academy at West Point, is a distinguished graduate of the Marine Corps Signal Advanced Course, Army Airborne School, Ranger School, and Command and

General Staff College. He attended Raytheon's University of Chicago Business Development School, and is Six Sigma qualified. He also holds a Master of Science Degree from Naval Postgraduate School in Monterey, California with a degree in Systems Technology (C3) and Space.

Robb Randall

Dr. Robb Randall leads the Army Research Laboratory's (ARL) Atmospheric Science Center, the Battlefield Environment Division's entity managing and coordinating ARL's open campus initiative, bringing together government, industry, and academia for the mission of advancing atmospheric science and its application to critical defense technologies through a collaborative, innovative research ecosystem. He is also Chief (A) of the Atmospheric Dynamics Branch. Dr. Randall recently retired from the Air Force after 28+ years. During his career he serve in Special Operations, Operational Weather Squadron, as a FOA Military Deputy Director and Division Chief, Advisor to the Iraqi Air Force, and Air Force Institute of Technology Professor. Before his retirement he served as the Commander, 16th Weather Squadron. The 16th Weather Squadron functions as the Air Force's center of excellence for atmospheric model development, implementation, and visualization.

As Commander, he executed a worldwide weather support mission that delivered advanced terrestrial and space environmental intelligence tools to Joint warfighters, national agencies, and allied nations for planning and execution of full-spectrum military operations in addition to providing meteorological support to DoD research and development, acquisition, testing and sustainment. Dr. Randall received a B.S. in Meteorology from the University of Oklahoma in 1995, M.S in Meteorology from the Air Force Institute of Technology in 2002 and PhD from the University of Arizona in 2007.

Mark Read

Mark Read is a Colonel in the U.S. Army, and serves as the Deputy Head of the Department of Geography and Environmental Engineering at the U.S. Military

Academy, West Point. A career infantry officer, Mark has served in a wide variety of assignments in the U.S, Europe, and the Middle East. He holds a BS in Environmental Engineering from West Point, and a MS and PhD in Geography from The Pennsylvania State University.

Matthew Santaspirt

Matthew Santaspirt is an intelligence representative from the US Army Armament Research, Development, and Engineering Center (ARDEC) at Picatinny Arsenal, NJ. He is currently assigned to the TRADOC G-2 office with a specific focus on Strategic Foresight. Before his work with TRADOC, he was an Army Materiel Command (AMC) Fellow and worked in the ARDEC Intelligence and Technology Protection Office.

Lori J. Shields

Ms. Lori Shields currently serves as the Strategic Communications Director and as a Financial Management Analyst for the Naval Expeditionary Warfare Division, OPNAV N95. Ms. Shields left Active Duty in 2010 and continues to serve in the Army Reserve as an Engineer and holds the rank of Major.

Shade T. Shutters

Shade T. Shutters is a research scientist with the Global Security Initiative at Arizona State University, with additional faculty appointments in the Center of Social Dynamics and Complexity, Center on the Future of War, and the Center for Policy Informatics. He holds a bachelor's in finance from Indiana University, a doctorate in theoretical ecology from Arizona State University, and completed a post-doc in applied economics at the University of Vigo, Spain. His research is focused on the dynamics of urban systems and the networks both within and between cities.

Jim Staley

Mr. Jim Staley leads the Army Weather Proponent Office (AWPO) at the U.S. Army Intelligence Center of Excellence, Ft Huachuca AZ. Since inception in 2008, the AWPO is responsible for investigating and processing Army-unique weather support requirements utilizing the DoD's Joint Capabilities Integration and Development System (JCIDS). The AWPO also identifies and disseminates Army weather support doctrine. Additionally, the AWPO interfaces with the Army-wide weather Research and Development community to incorporate Army weather requirements into collective R&D efforts. Mr. Staley has extensive experience focused on tactical Army and Special Operations weather support to world-wide DoD missions. During his career he led weather support to Joint Special Operations forces, conventional Army units at multiple levels, and to the Air Force Special Operations Command. In 2007 Mr. Staley retired from the U.S. Air Force after 23 years of service. Mr. Staley received his B.S. in Geophysics from Boise State University in 1984, and his M.S. in Atmospheric Science from Colorado State University in 1990.

Colin Tansey

Colin Tansey is a Major in the U.S. Army, and serves as the assistant course director for Physical Geography (EV203) in the Department of Geography and Environmental Engineering at the U.S. Military Academy, West Point. A career military intelligence officer, Colin has served in a wide variety of assignments in the U.S, Europe, and the Middle East. He holds a BA in Anthropology from California State University, San Bernardino, and a MA in Security Studies (Europe and Eurasia) from the Naval Postgraduate School.

Darryl Ward

Darryl Ward has 30 combined years of experience in Military Intelligence with the U.S. Army, civil service, and as a government contractor. He is retired from the U.S. Army and currently serving as an MCR contractor within the TRADOC G27 OPFOR Program Management Directorate supporting the U.S. Army Quality Assurance Program. He holds a BS in Education from the University of Arkansas and an MA in Health Business Administration from Webster University.

Richard Wolfel

Richard Wolfel is an associate professor of Geography and the Chair of Cross Cultural Competence in the Center for Languages, Cultures and Regional Studies at the US Military Academy, West Point. Rick is a social and political geography with strong research interests in urban geography, nationalism, social movements and migration with a regional interest in Post-Soviet Landscapes. He holds a BSED in American History and Geography from West Chester University, a MA in Urban Geography from the University of Cincinnati and a PhD in Geography from Indiana University.

Colin D. Wood

Colin Wood has 6 years of military service as a U.S. Army Combat Medic with an infantry battalion, and served in Iraq. He is currently a Federal Pathways Intern conducting research for the U.S. Army Corps of Engineers (USACE), Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), and an Atlantic Council, Veterans Take Point Initiative Fellow. His research interests center around insurgency, terrorism, and military intervention. He holds a B.A. in International Studies from the University of North Texas, is a former National Science Foundation Research Experience for Undergraduates (NSF-REU) Fellow, and a Department of Homeland Security, Homeland Security Science, Technology, Engineering, and Mathematics (DHS, HS-STEM) Intern.