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Unmanned Systems in Support of Future Medical Operations in Dense Urban Environments

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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

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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.

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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.

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