U.S. ARMY TANK AUTOMOTIVE RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Operationalizing Big Data

What We Can Learn from Videogames and Professional Sports

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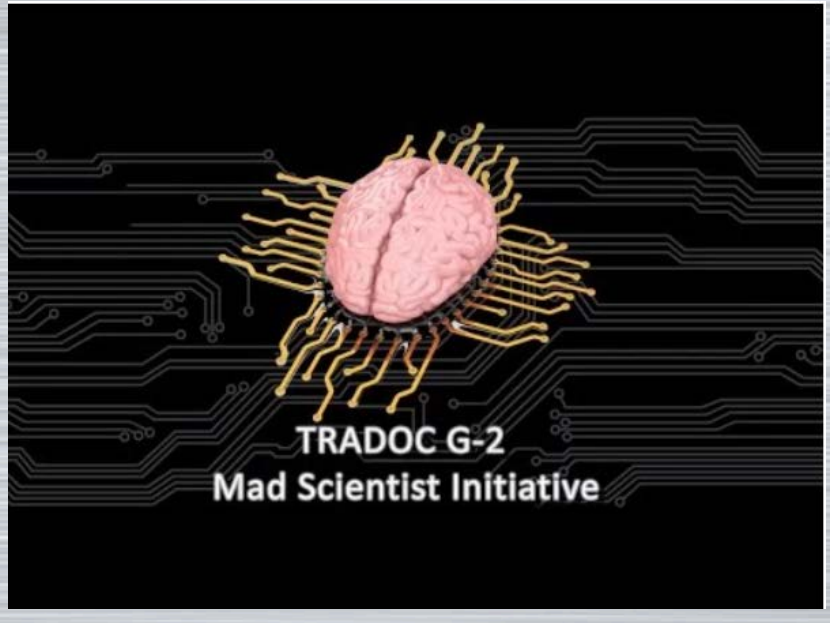

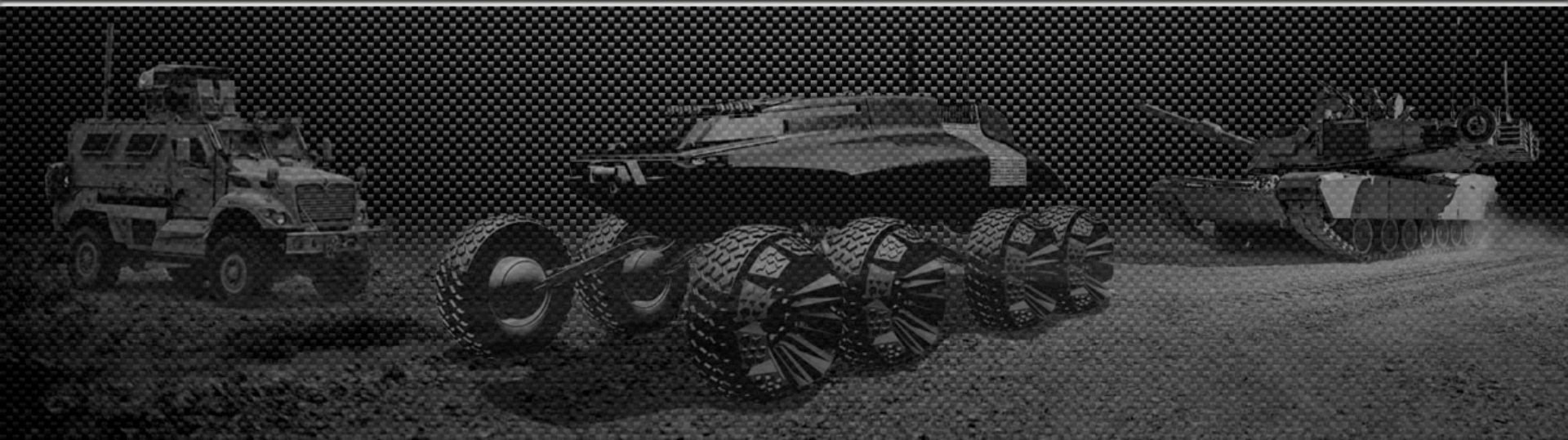

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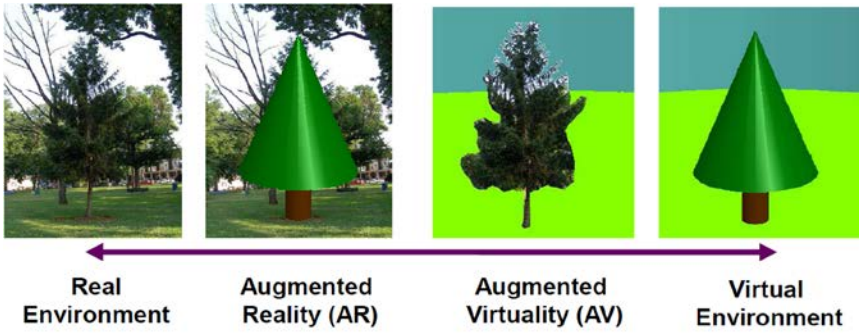
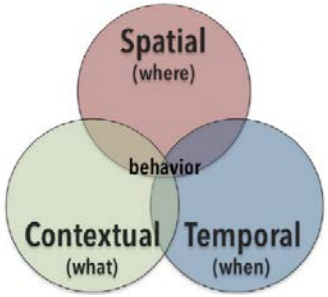
Topics

Professional sports and video games technologies related to:

- Augmented reality (AR)/ virtual reality (VR)



- Spatio-temporal (behavior) data mining



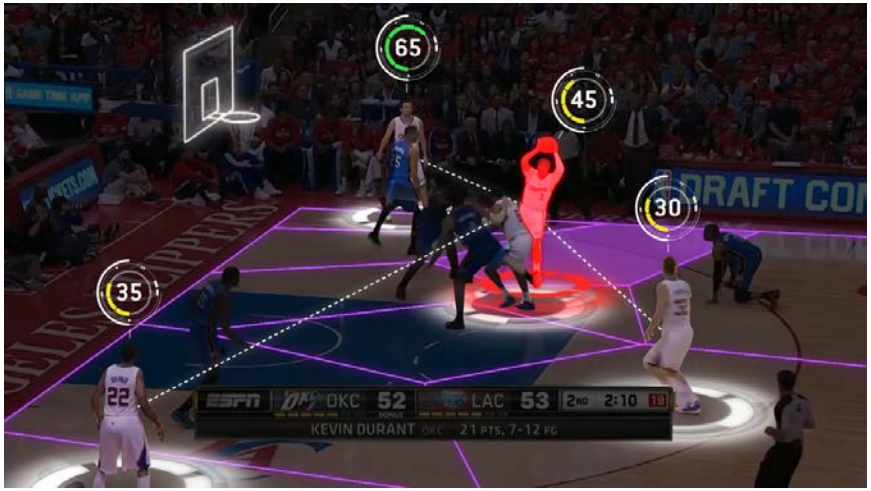
<u>What I'm not going to talk about</u>

- Intelligence data mining, predictive analytics, etc.
- Minimal discussion on training/ education

What Might We Learn from Gaming and Sports?

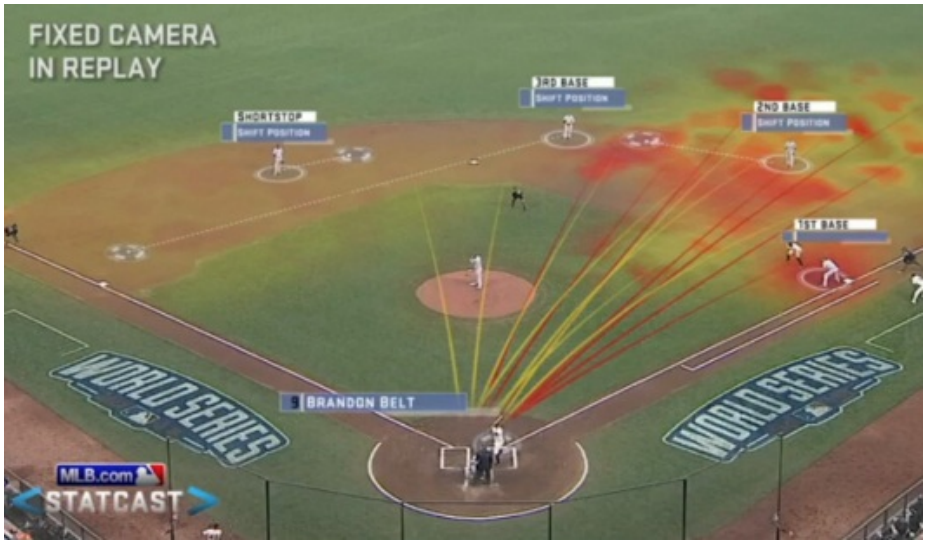
- “Serious sport is war minus the shooting” – George Orwell
- Ability of a coach/players to understand behaviors wins and loses games
- Multiple cameras now allow us to create data sets of player/ball telemetry
- Brain isn’t designed to aggregate hundreds or thousands of traces, but computers can discover complex or very subtle patterns
- Data could be presented to players on the field using augmented reality
- MIT Sloan has dedicated sports/ esports conference (way beyond moneyball) www.sloansportsconference.com february 23 - 24, 2018 | Boston

https://www.ted.com/talks/chris_kluwe_how_augmented_reality_will_change_sports_and_build_empathy

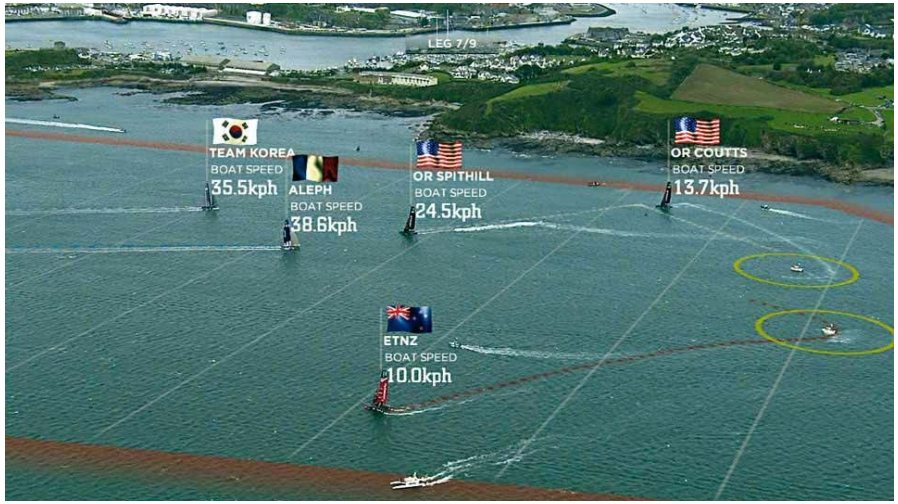


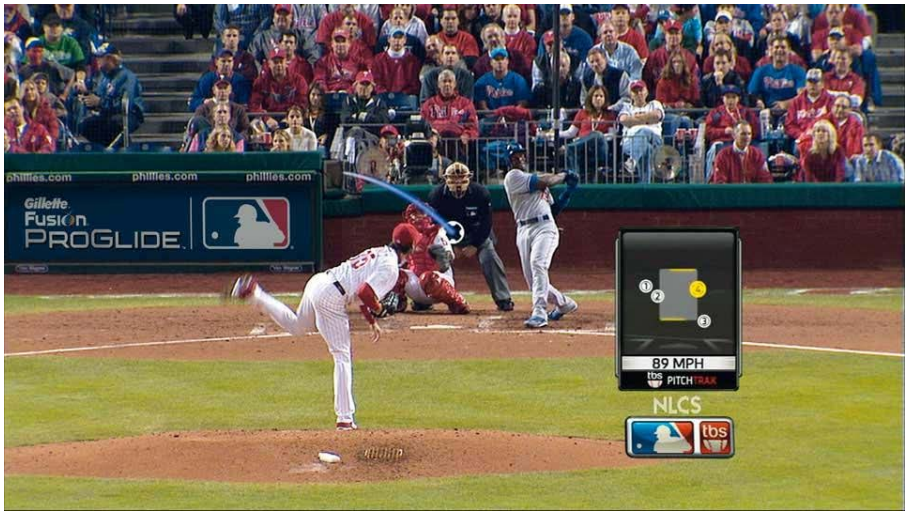
http://tedxtalks.ted.com/video/The-new-positions-of-basketball

Realtime Data Display (Imagine Used With AR)



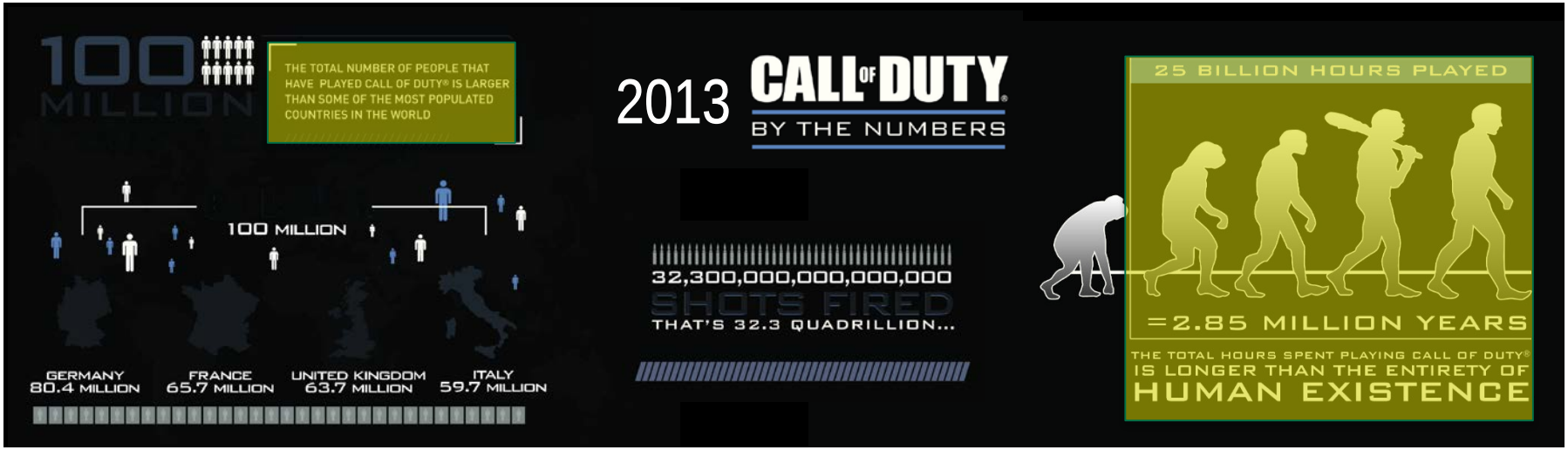
Statcast http://m.mlb.com/news/article/79566520/statcast-sheds-light-on-amazing-catches-by-yasiel-puig-and-andrew-mccutchen

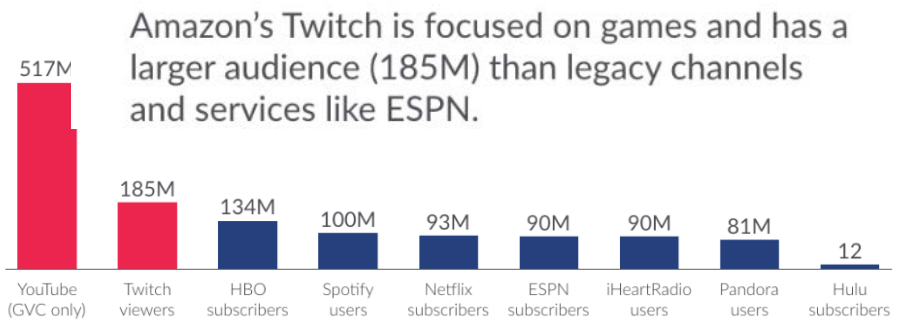




http://www.domusweb.it/en/design/2012/06/25/in-screen-sports-graphics.html

Stunning Commercial Gaming / eSports Numbers





Audience Size 2016

SUPERDATA

"Free to Play" Documentary: follows three professional gamers from around the world as they compete for DOTA 2 prize.

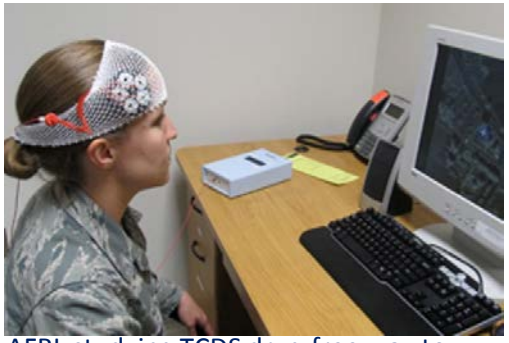
Commercial Game Metrics and Biometrics

- Video game analytics
  - goal maximize engagement/ profit
  - looking for playability, cheats, etc
  - methods:
    - Direct observation (watch people play game)
    - Surveys (subjective)
    - In game metrics based on telemetry and event data
    - Biometrics (eye tracking, skin conductance, facial expressions, EEG, etc)

https://www.slideshare.net/acagamic/game-metrics-and-biometrics-the-future-of-player-experience-research

- Bleeding edge is neurogaming
  - Read brain state from EEG
  - Adjust game engagement or provide stimulation effect
  - Possible to actively provide stimulation through scalp

Experiential Technology “XTech" conference combines digital technology with advances in neuroscience



AFRL studying TCDS drug-free way to double the speed of learning

Shown: Neuroelectrics Starstim

Importance of Data to National Defense

Per SCO Director, William Roper: https://www.youtube.com/watch?v=GLh_ApVVBU4

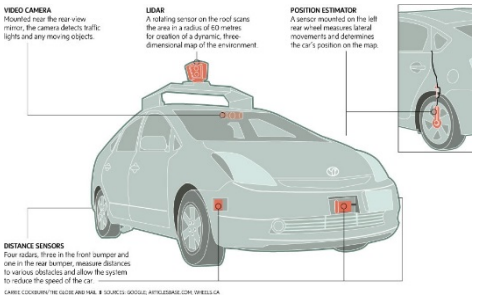
- Google, or Apple, or Amazon think people who have the most data is going to be able to train the most intelligent machine
- “Pentagon should be stockpiling all of its data from every flight, every mission, and every exercise in a way that is machine discoverable.”
- “Try to take a pentagon that is device centric—device being like fighter, bomber, submarine, or tank – and shift it to be data centric. To merely think of their systems as being data producers and the data being more important than the systems themselves.”

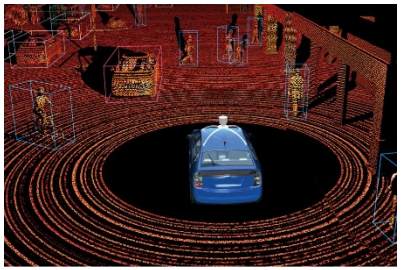
Per Vladimir Putin: https://www.theverge.com/2017/9/4/16251226/russia-ai-putin-rule-the-world

- Nation that leads in AI ‘will be the ruler of the world’
- Predicts that future wars will be fought by countries using drones. “When one party's drones are destroyed by drones of another, it will have no other choice but to surrender”

Data Science Is Driving Driverless Car Behaviors

- Waymo(Google) car ~1GB of sensor data / second
- 2 Petabytes of data per year (2 million GB) per car
- Data processed offline as anomalies identified
- It can learn when a pedestrian is ready to cross the street by observing behavior over and over again
- If it sees a cigarette butt, it knows a person might be creeping out from between cars. If it sees a rolling ball it knows a child might run out from a driveway.

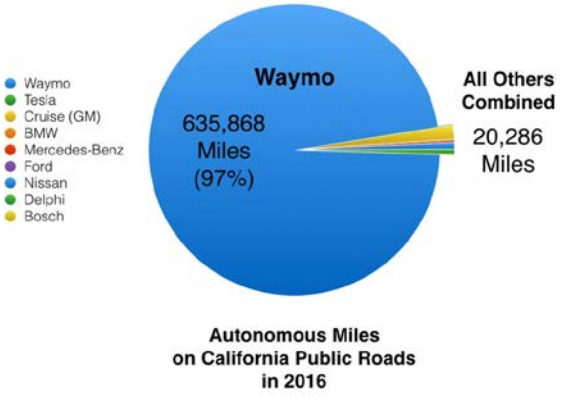




Tesla 1.3 billion miles of data from Autopilot-equipped vehicles operating (2016) with human driving.

Google developed have covered 2 million real-world miles—with employees on board—since 2009 (to 2016)

https://www.bloomberg.com/news/articles/2016-12-20/the-tesla-advantage-1-3-billion-miles-of-data



https://www.forbes.com/sites/chunkamui/2017/02/08/waymo-is-crushing-it/

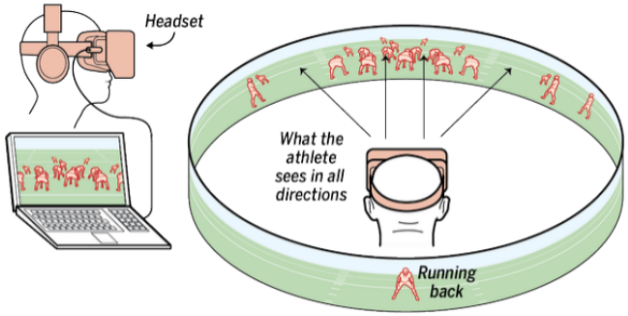
AIs without Data Useful Too

- Trained on DOTA2 solely by playing itself
- The AI win stunned the gaming community, because bots are generally considered inferior to expert human players.
- Probably best combination in future is by combining human heuristics and AI self-learning.
- The trick with most AI (neural networks) is we don't know what the network is learning.

http://money.cnn.com/2017/08/12/technology/future/elon-musk-ai-dota-2/index.html

https://www.youtube.com/watch?v=l92J1UvHf6M

Virtual Reality and the NFL



6 GoPros
$1499

GoPro
Fusion $699

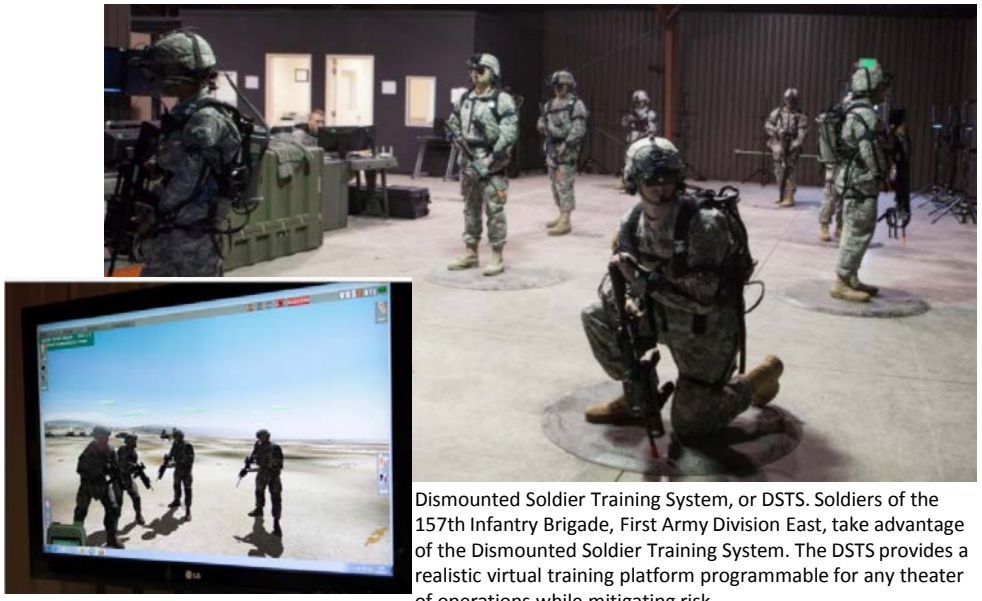
- Six NFL teams -- the Cardinals, Dallas Cowboys, Minnesota Vikings, Tampa Bay Buccaneers, San Francisco 49ers and New England Patriots -- are using virtual reality (2015).
- “On the field, everything is chaos. We have little sense of what is going on. AR and VR will help us see why the player didn’t make the play as if we were in his shoes”
- Can accrue experience without injury at a much faster rate of speed
- Toying with broadcast experience of game in 1st person view (similar to “angel” concept elsewhere presented to Mad Scientist)

http://www.cnn.com/2015/09/09/us/nfl-virtual-reality-training/

Exploiting Virtual Reality and the AOC

- Soldiers must accrue [SOF-like] experience at a much faster rate over a wide range of operations so they can adapt and innovate.
- Per Head Strong: How Psychology is Revolutionizing War:

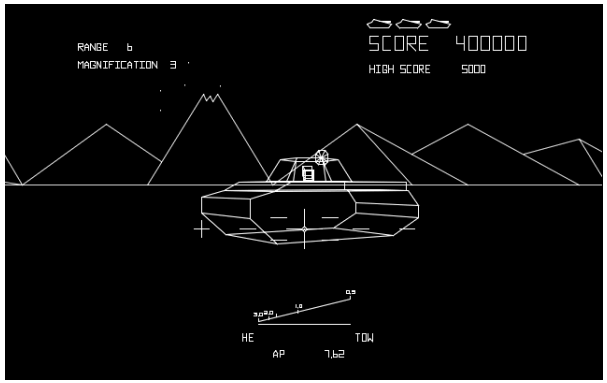
  Broad learning exposures allow experts to build huge pattern recognition ability and can modify/ act quickly.
- In complex world there won't be a "right way" for most situations (unpredictability is also an advantage)
- **Army will learn from students in Complex World**



Dismounted Soldier Training System, or DSTS. Soldiers of the 157th Infantry Brigade, First Army Division East, take advantage of the Dismounted Soldier Training System. The DSTS provides a realistic virtual training platform programmable for any theater of operations while mitigating risk.

TARDEC Ride Motion Simulator

Gaming Isn't New: 1980 Atari Bradley Trainer

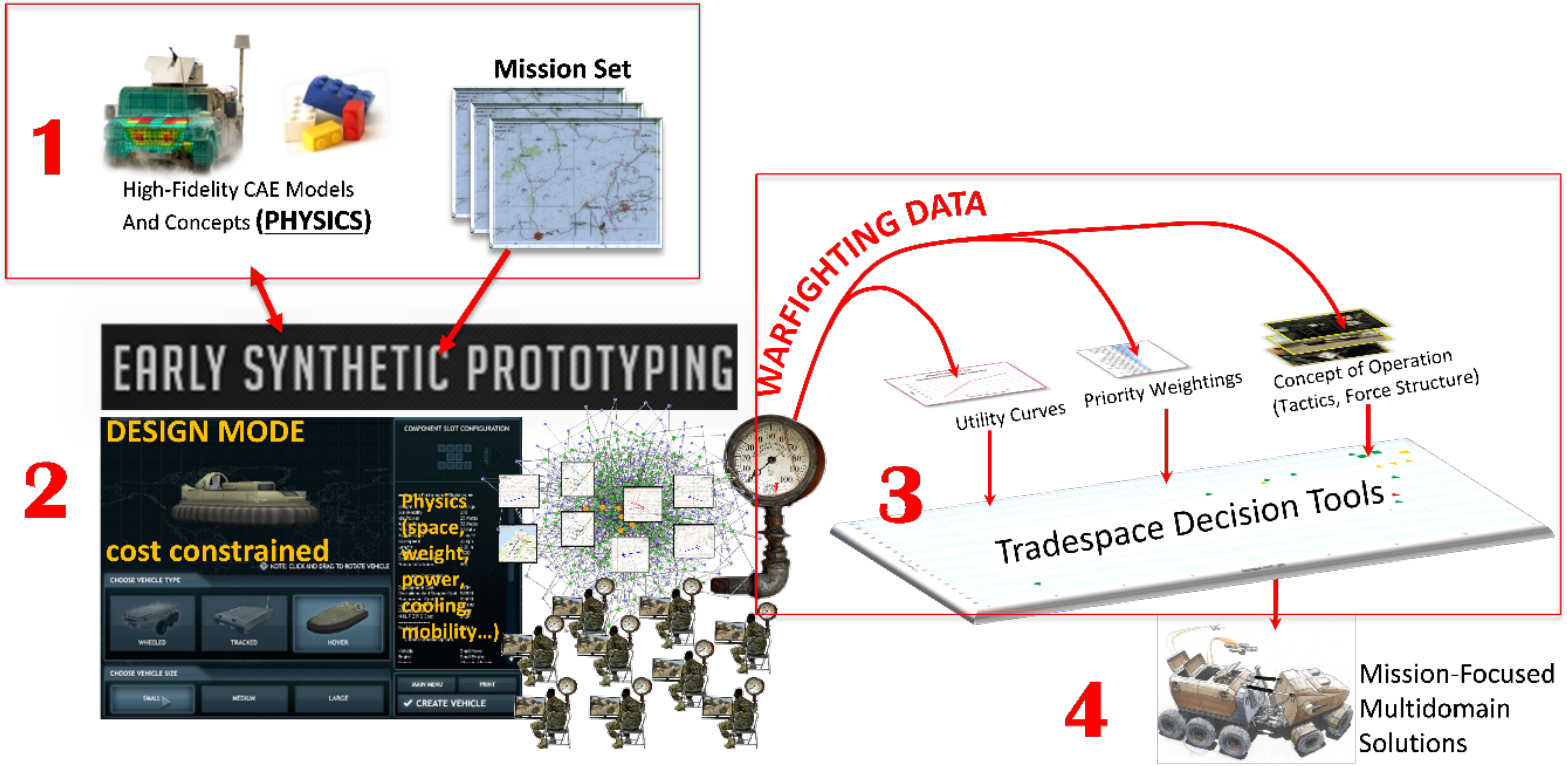


"I see a lot of people in those arcades learning something, and they're all volunteers, and they're paying a quarter to learn whatever it is they learn from these machines. I don't know what they learn, but I'm convinced they learn something, and that the Army needs to exploit it"

Army has mainly using video games for training. Early Synthetic Prototyping creates an ongoing experiment and tapping into the collective intelligence of 1000s of Soldiers.

Early Synthetic Prototyping (Operation Overmatch)

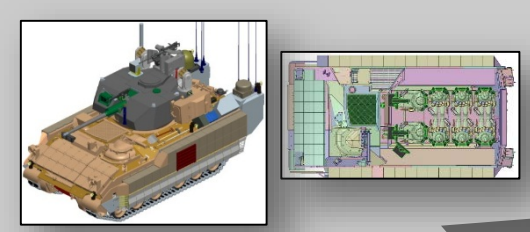
- TRADOC/RDECOM using gaming for acquisitions – not training
- Physics-based and crowdsourced
- First alpha out now Operation Overmatch, first person shooter
- Technical challenge in data mining 12 million hours of play / year



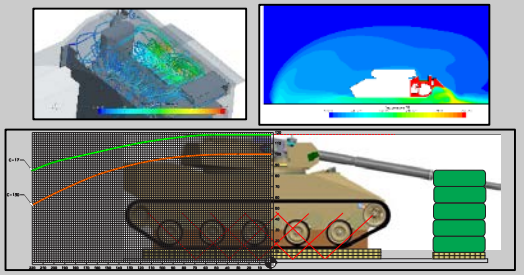
TARDEC is Exploiting Existing Non-Crowdsourced Game for Acquisitions Programs

Soldier Innovation Workshop

Engineering Concepts

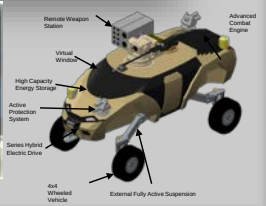


CAE Performance Analysis



Digital Prototyping and Experimentation

OBJECTIVE DATA
-and-
SUBJECTIVE SURVEYS



Soldier-Driven Program Requirements (ICD, CDD, …)

Why This Matters

- Future technical parity
- Goal: Ingest technology faster
  - figure out how to use it
  - produce it quickly
  - Soldiers understand how to employ it on the battlefield
- Harness creativity of Soldiers and engineers

"Where we have the advantage is the way that our technology interfaces with the Soldiers, the **Soldier-technology interface**, the way that, again, they can innovate with that, adapt and innovate. How quickly can they adapt to the conditions that they're operating in, and how rapidly can we increase that rate of innovation?" **GEN Perkins**

Perhaps We Can Identify The Future TRADOC CG

1980s Last Starfighter Movie

Current Acquisitions Situation (2008 Data)

- 108 SE's surveyed (18 DOD Orgs. and Major Contractors)
  - 36% never worked a program with a Concept of Operation (CONOP)
  - 73% did not complete CONOP by program start
  - 50% did not update CONOP
  - 30% did not even involve a user

SOURCE: Roberts, N., & Edson, R. (2008). *System Concept of Operations: Standards, Practices and Reality.* NDIA Systems Engineering Conference, San Diego CA.

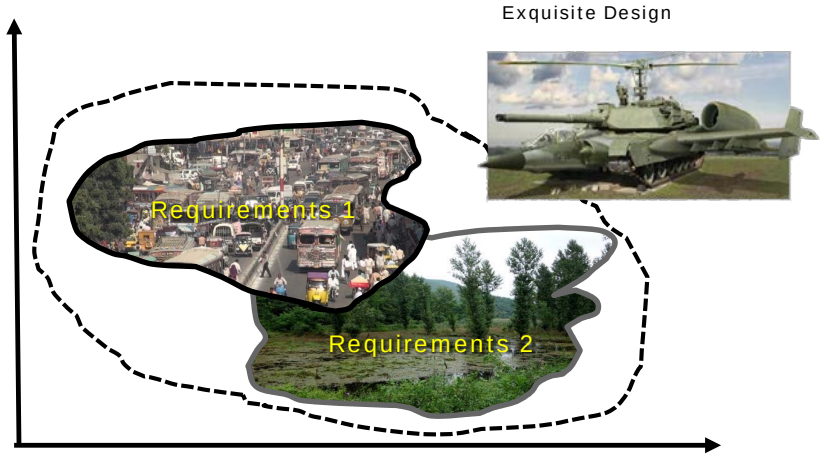
60 CONOP examined:

- took 3-30 months to complete
- 25% did not state mission needs
- 80% did not discuss system risks
- 50% did not include operational scenarios

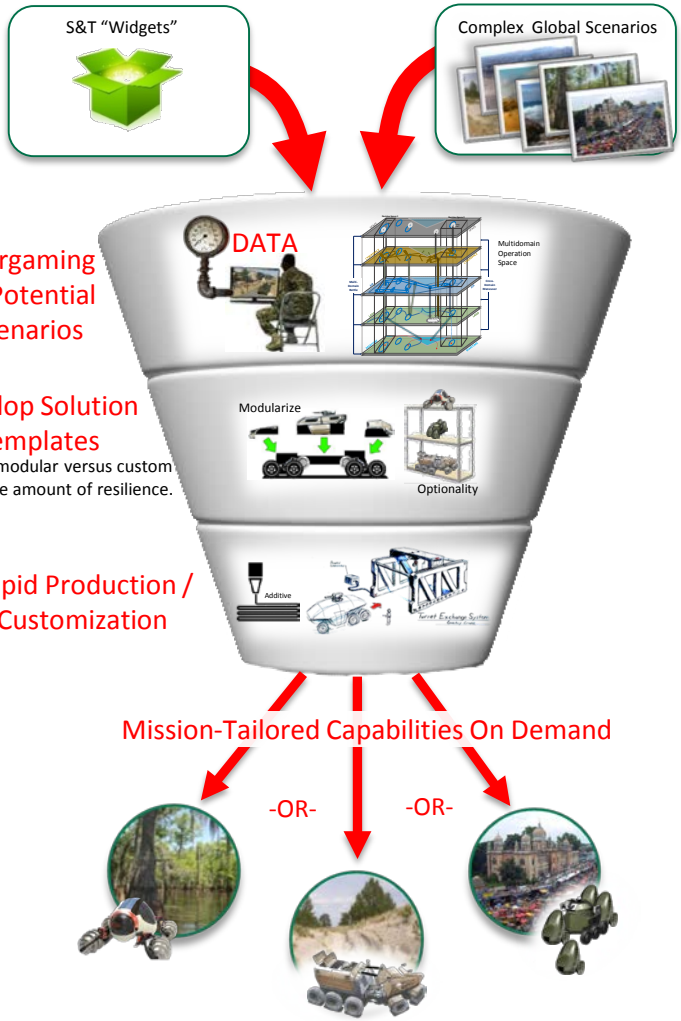
"With a few exceptions, **what we have is essentially a linear process** - going from an idea, writing up a big requirements document and then vetting it through multiple steps - it takes years, and it's just not going to be effective going into the future," **Gen. Mark Milley**, the Army's chief of staff

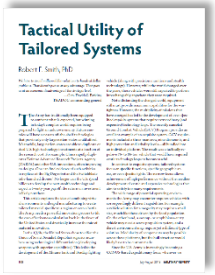
Operationalizing Technology at a Faster Clockspeed

Prototype Warfare *represents the paradigm shift from large fleets of common-one-size-fits-all exquisite systems to small quantities of rapidly-fielded tailored systems. Mission-tailored systems focus on specific functions, specific geographic areas, or even specific fights and are inexpensively produced and possibly disposable.*

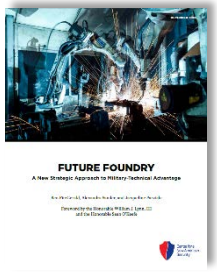


Single "do-all" designs that have too much mission scope will underperform and require expensive / possibly exotic technologies.





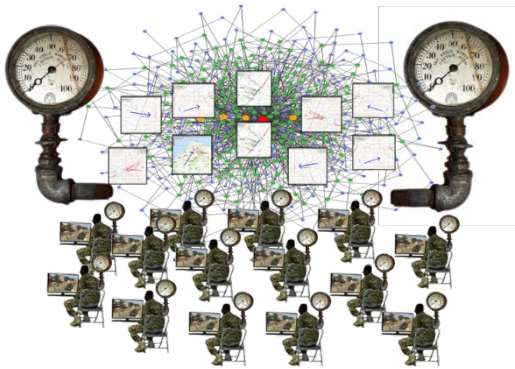
http://www.armyupress.army.mil/Portals/7/military-review/Archives/English/MilitaryReview_20160831_art019.pdf



https://www.cnas.org/publications/reports/future-foundry

Deeper Understanding Requires Game Analytics

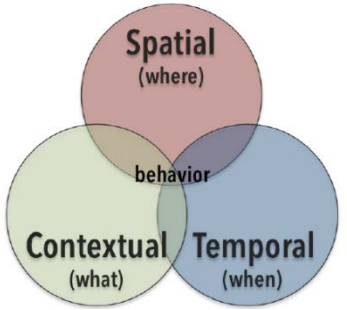
Virtual Physics-Based Gaming Environment



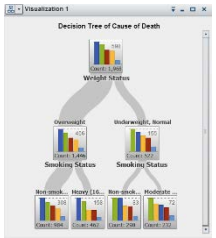
~12 million hours of Soldier gameplay per year

Data Mining

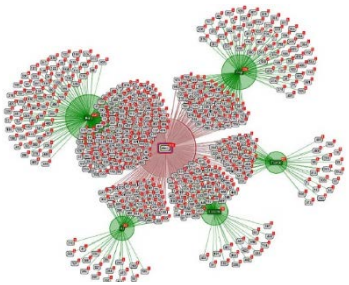
- What are they doing?
- Where are they doing it?
- Why they are doing it?
- How effective is this?
- Terrain versus movement choices
- What are they talking about/ when/ how often
- Optimal Force structure



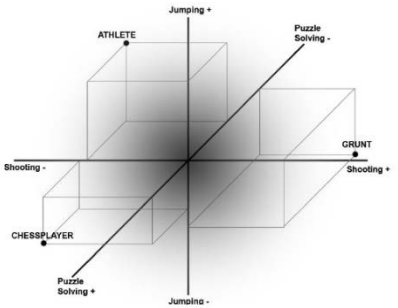
Visualization



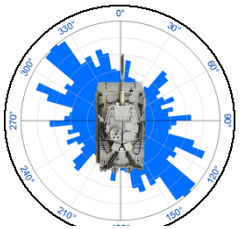
Decision Trees



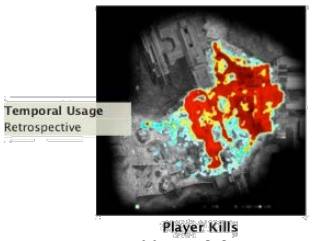
Clustering Cause of Death



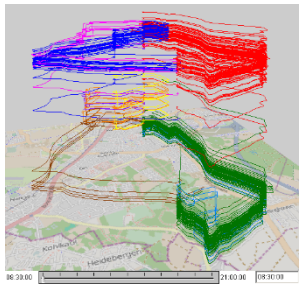
Player Personas



Engagement Sector Cardioid



Heat Maps



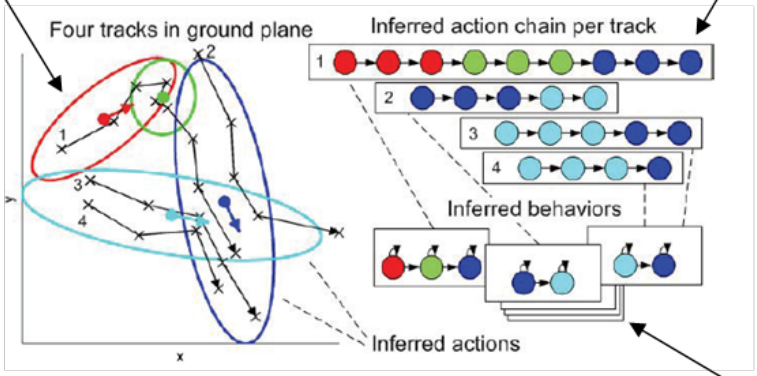
Multi-Run Movement Plots

Game Image Source: Game Metrics and Biometrics: The Future of Player Experience Research. http://www.slideshare.net/acagamic/game-metrics-and-biometrics-the-future-of-player-experience-research

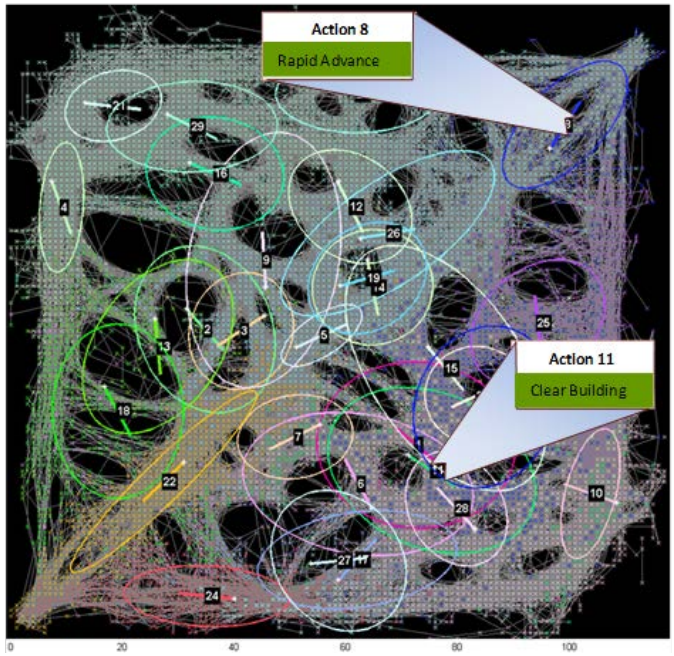
SBIR Research into Game Analytics
(Credit: Decisive Analytics Corporation)

Actions are inferred from trajectory/state data
- Standing
- Walking
- Walking with weapon drawn
- ...

Tracks are sequences of Actions

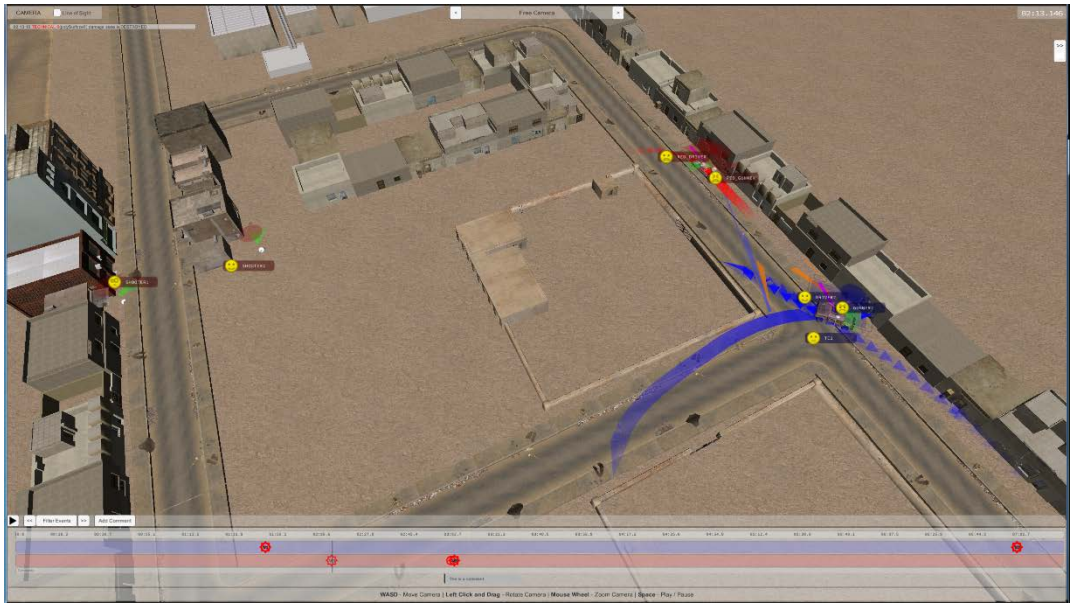


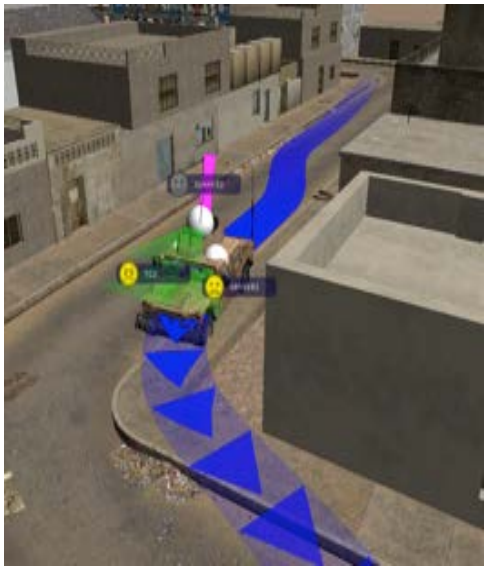
Behaviors are clusters of similar Action chains

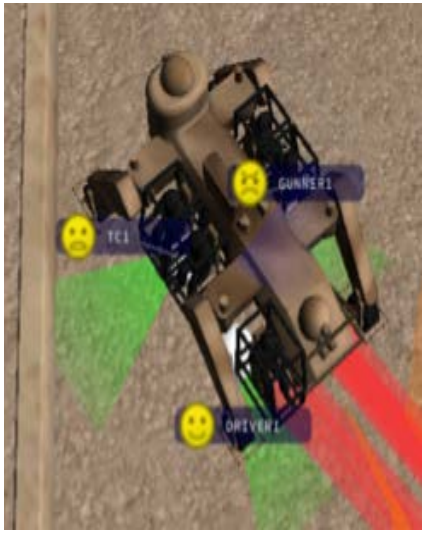


SOURCE: Decisive Analytics Corporation Phase I SBIR. Contract W56HZV-15-C-0190. http://www.dac.us/

ICT Demo ESP Environment – Emotion Tracking





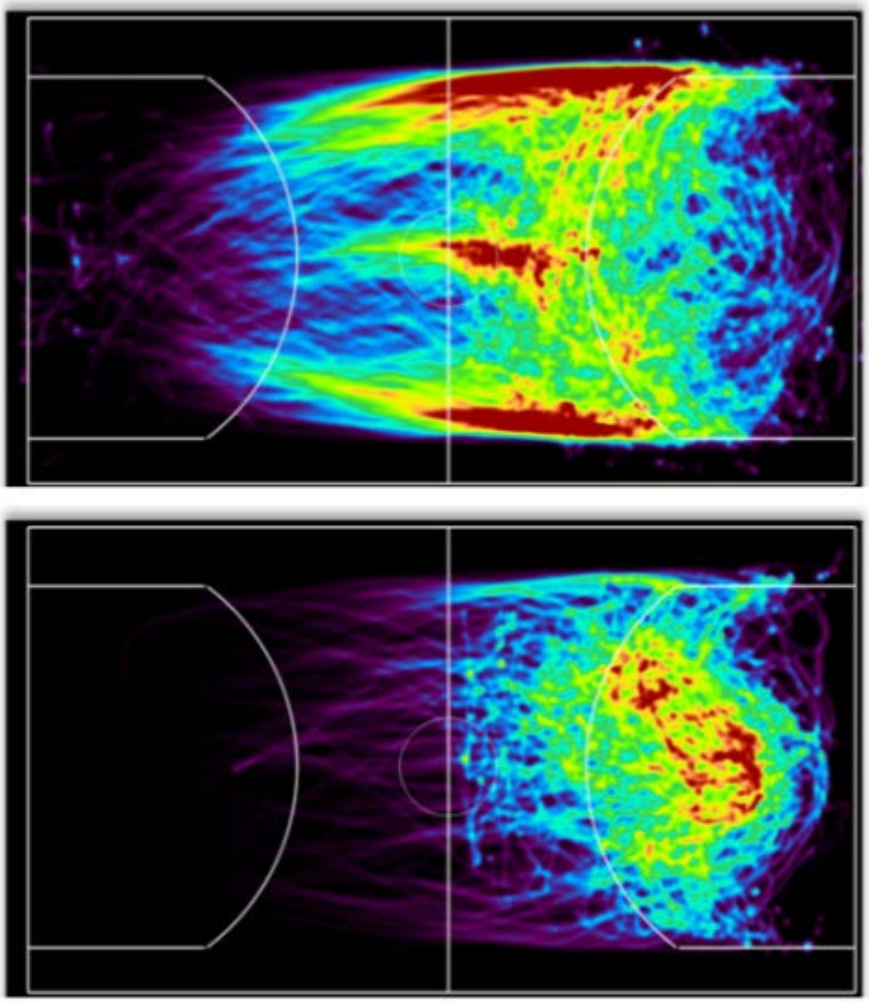


- Players on laptops w/ webcam
- Intel's Perceptual Computing SDK captures data about the user's emotional state
- Seven emotions (anger, contempt, disgust, fear, joy, sadness, and surprise) and three sentiments (positive, neutral, and negative).
- Also record voice annotation of events

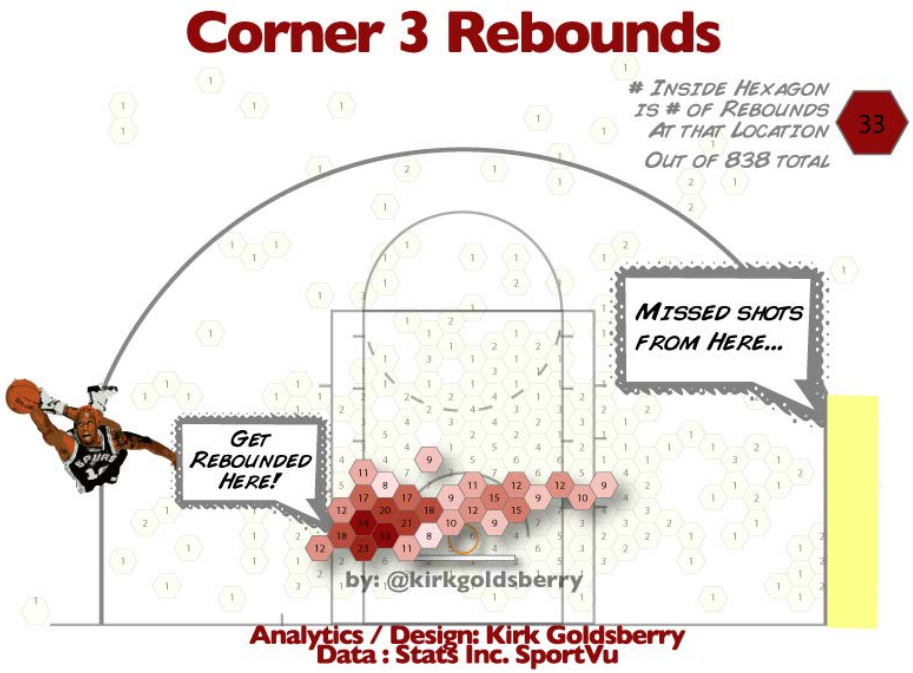
More info: http://ict.usc.edu/prototypes/early-synthetic-prototyping-esp/

USC Institute for Creative Technologies

Some Examples from Professional Sports

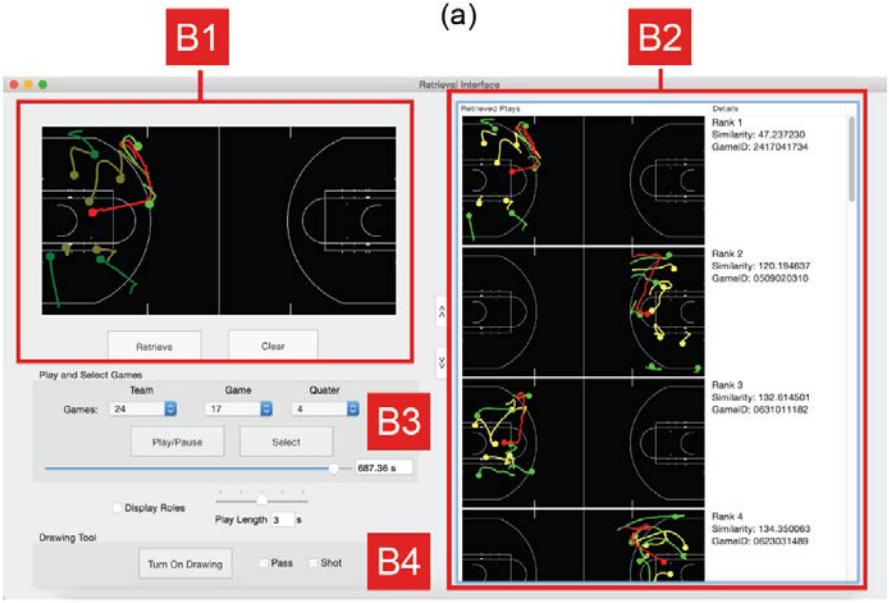


Basketball Shooting vs. Passing for a Particular Player. This player primarily passes after moving across the perimeter. (Kowshik, Chang, & Maheswara, 2012)



http://courtvisionanalytics.com/where-do-rebounds-go/

Disney Research Example: Chalkboarding: A New Spatiotemporal Query Paradigm for Sports Play Retrieval



http://www.yisongyue.com/publications/iui2016_chalkboarding.pdf

Labeling Data: Retrospective Interviewing

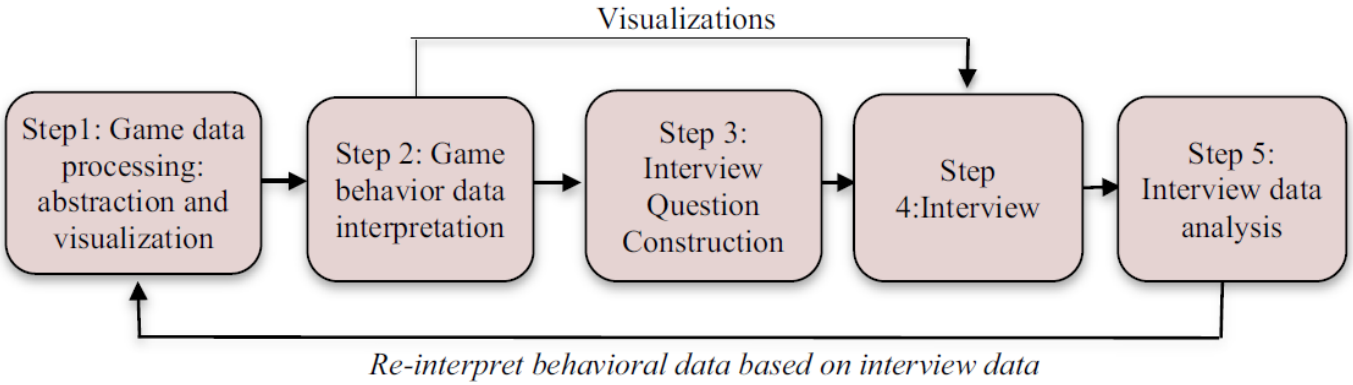
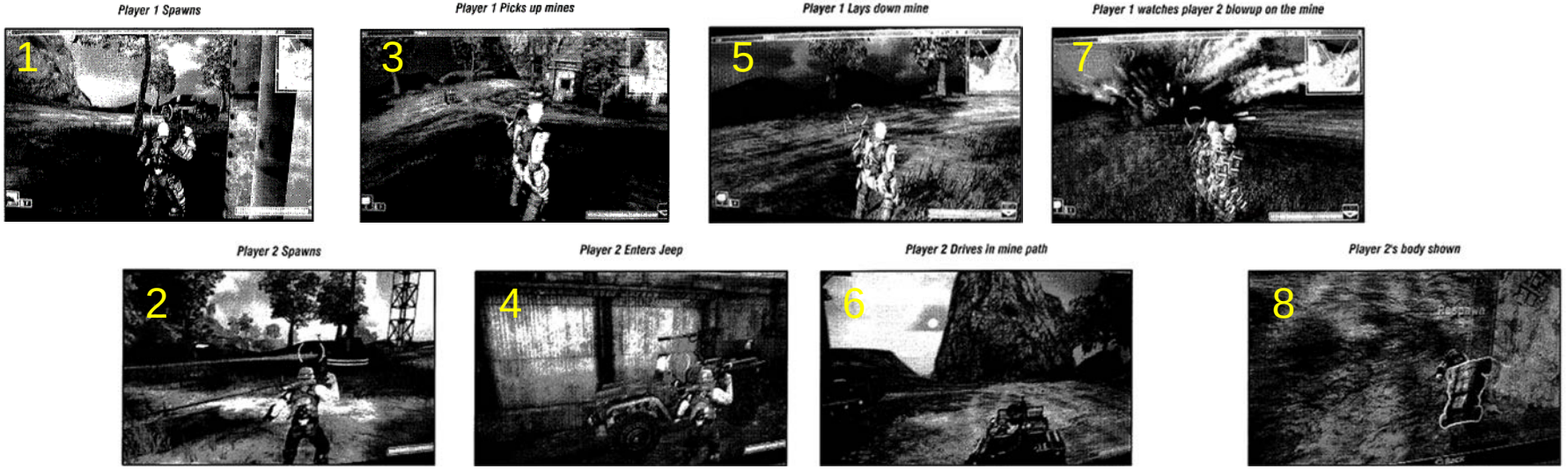


Fig. 1. Data-driven retrospective interviewing method overview.

How I See this Working w TVEC (Autonomous Highlight Reel):



Sources: System and method for automated creation of video game highlights. Sony Entertainment. D Cottrell - US Patent 8,515,253, 2013.

Seif El-Nasr, M., Durga, S., Shiyko, M., and Sceppa, C. (2015). Data-Driven Retrospective Interviewing (DDRI): A Proposed Methodology for Formative Evaluation of Pervasive Games. Elsevier Entertainment Computing Journal. Impact Factor 1.65

IBM / Fox Used Watson to Autonomously Generate Movie Trailer (Movie is Morgan)

- Trained AI on 100 horror movies and trailers
  - Visual analysis of scene objects/ background tagged with one of 24 emotions
  - Audio analysis of the ambient sounds, voice tones tagged
  - Scene's composition (such the location of the shot, the image framing and the lighting) Then run on Morgan
- Result is here: https://www.youtube.com/watch?v=gJEzuYynaiw&t=97s

https://www.ibm.com/blogs/think/2016/08/cognitive-movie-trailer/

DARPA OFFSET (BAA Open Now)

DARPA OFFSET: Confluence of Emerging Technologies

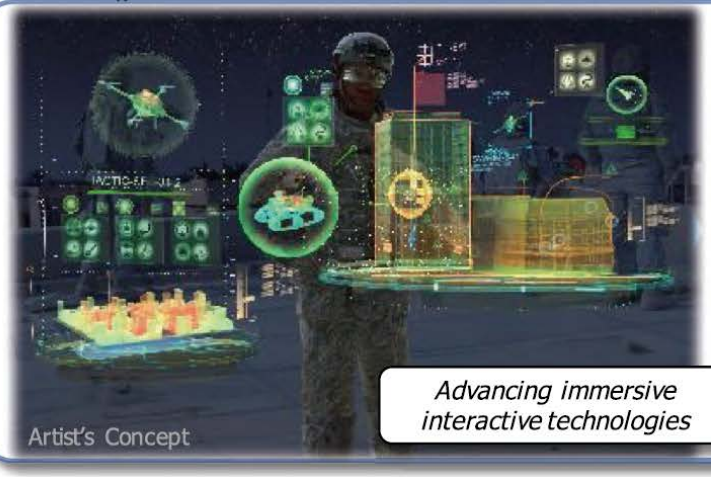
Designing games to create a "Swarm Tactics Exchange"

Create a **networked game environment** for rapid generation and capture of swarm tactics with a live-virtual-gaming architecture

Generate *swarm tactics*

Integrate *swarm tactics*

Design **intuitive swarm interfaces** with emerging multi-modal, mixed reality, interactive technologies



Advancing immersive interactive technologies

https://www.fbo.gov/spg/ODA/DARPA/CMO/HR001117S0011/listing.html

https://www.darpa.mil/attachments/OFFSET_ProposersDay.pdf

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- Tactical Utility of Tailored Systems (Another Mad Scientist Paper): http://www.armyupress.army.mil/Portals/7/military-review/Archives/English/MilitaryReview_20160831_art019.pdf
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Interesting TED Talks

- The new positions of basketball. http://tedxtalks.ted.com/video/The-new-positions-of-basketball
- How augmented reality will change sports ... and build empathy https://www.ted.com/talks/chris_kluwe_how_augmented_reality_will_change_sports_and_build_empathy

Great Industry Resources

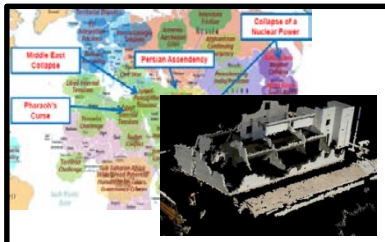
- Game Metrics and Biometrics: The Future of Player Experience Research. http://www.slideshare.net/acagamic/game-metrics-and-biometrics-the-future-of-player-experience-research
- MIT Sloan Sports Analytics Conference. www.sloansportsconference.com/
- Disney Research Modeling and Recognising Team Strategies, Tactics and Tendencies in Sports https://www.disneyresearch.com/project/modeling-sports-tendencies/

A 1st Armored Division "Old Ironsides" Soldier familiarizes himself with the M249 Squad Automatic Weapon user interface for Virtual Battle Space 3 during an Early Synthetic Prototyping pilot test held on Fort Bliss, Texas. (Photo by Sgt. Brooks Fletcher, 16th Mobile Public Affairs Detachment/Released)


QUESTIONS

How We'll Design and Manufacture Systems in 2025

Innovation / Training / Inception



3D Virtual World
Acquired on Demand

Persistent Synthetic
Gaming Environments
(Soldier Crowd Sourcing)

Pre-Engineered Plug and
Play Vehicle Templates

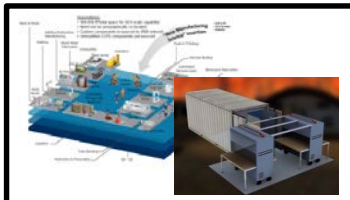
Detailed Engineering

Collaborative 3-d
Immersive Design
Environment

Semi-Autonomous
Virtual Prototype
Engineering
(proactive M&S that does
design and optimization)

Physical M&S and
Prototypes (Full Physics)

Manufacture/ Deployment



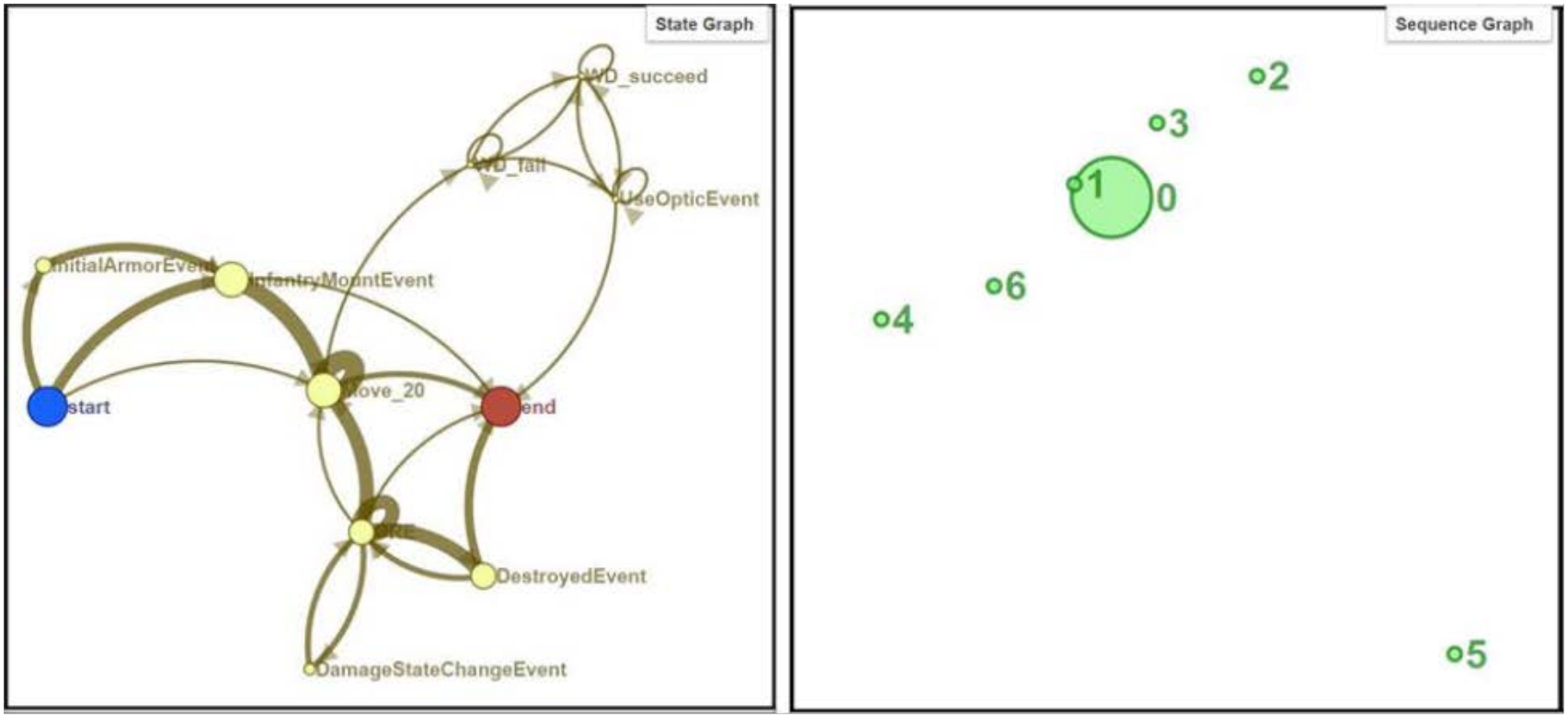
Layered Manufacturing, Repair,
and Logistics
(FOB Instant, Regional Rapid)

Customized Mission-Optimal
Ground System

Smith, Robert E., and Brian D. Vogt. *A Proposed 2025 Ground Systems, Systems Engineering Process*. DEFENSE ACQUISITION UNIV FT BELVOIR VA, 2014. http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA608885

SBIR Research into Game Analytics
(Credit: Soar Technologies and Northeastern Univ.)

State transition graph + Cluster of Sequences Graph



Glyph: Visual Analytics

State graph – shows transition between states in the game

Cluster of Sequences – shows how patterns cluster in space where distance is how similar they are (the more similar the closer)

SOARTECH
Modeling human reasoning.
Enhancing human performance.

Source: SoarTech/ ICT/ Northeastern University Phase I SBIR. Soldier Sourcing Insights Early with a Game Environment (SSIEGE). W56HZV-15-C-0188

Surrogate Dataset: DOTA-2 Commercial Game

- DOTA-2
  - Objective
    - 2 teams (Dire and Radiant)
    - 5 players each
    - Each team defends an “Ancient” building
    - 3 main “Lanes” between strongholds
  - Game player description
    - Players are called Heroes
    - 111 different Heroes available
    - Each Hero has different
      - Items (~equipment)
      - Spells (~skills & capabilities)
      - Gold
    - Players typically assigned a specific role within the team
      - Similar to the different roles soldiers have within a unit

Autonomous Generation of Mission Graphics

- Closely related, it would be useful to communicate the battle overview via military graphics discovered by data mining (combined with retrospective interviewing).

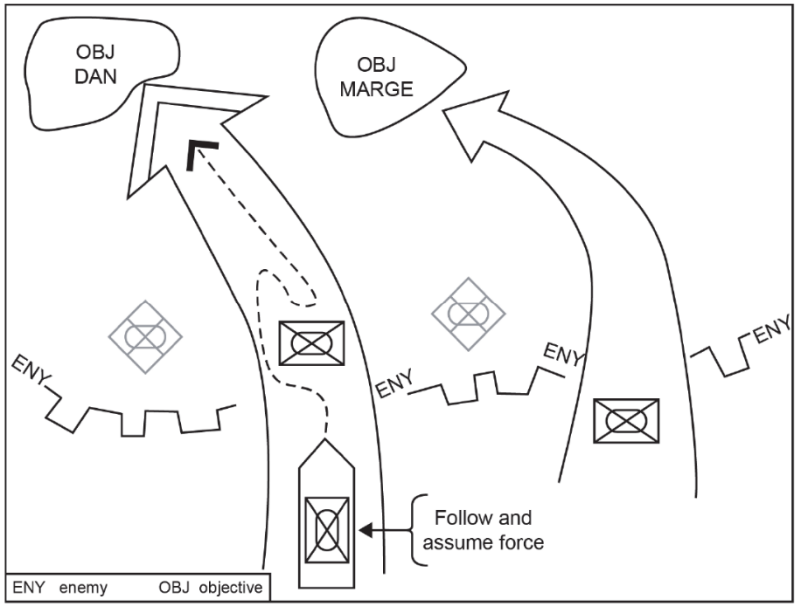


Figure B-6. Follow and assume tactical mission graphic

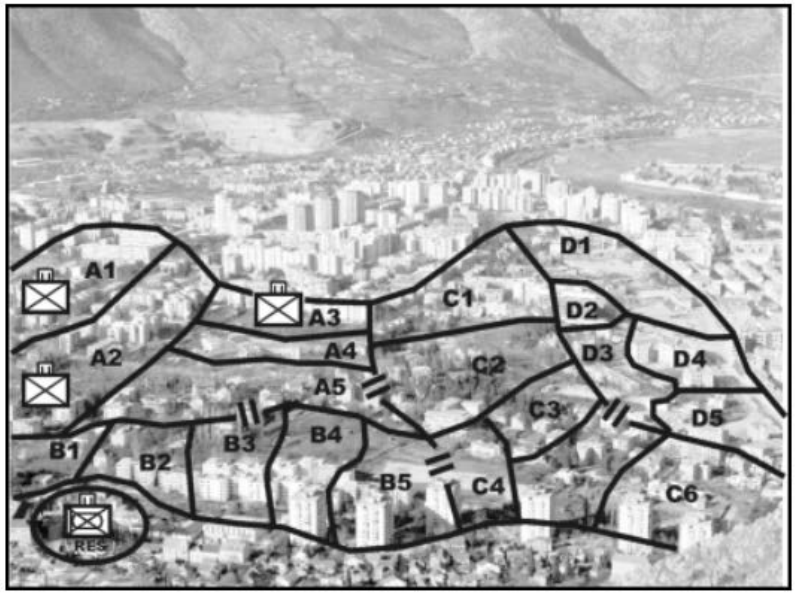
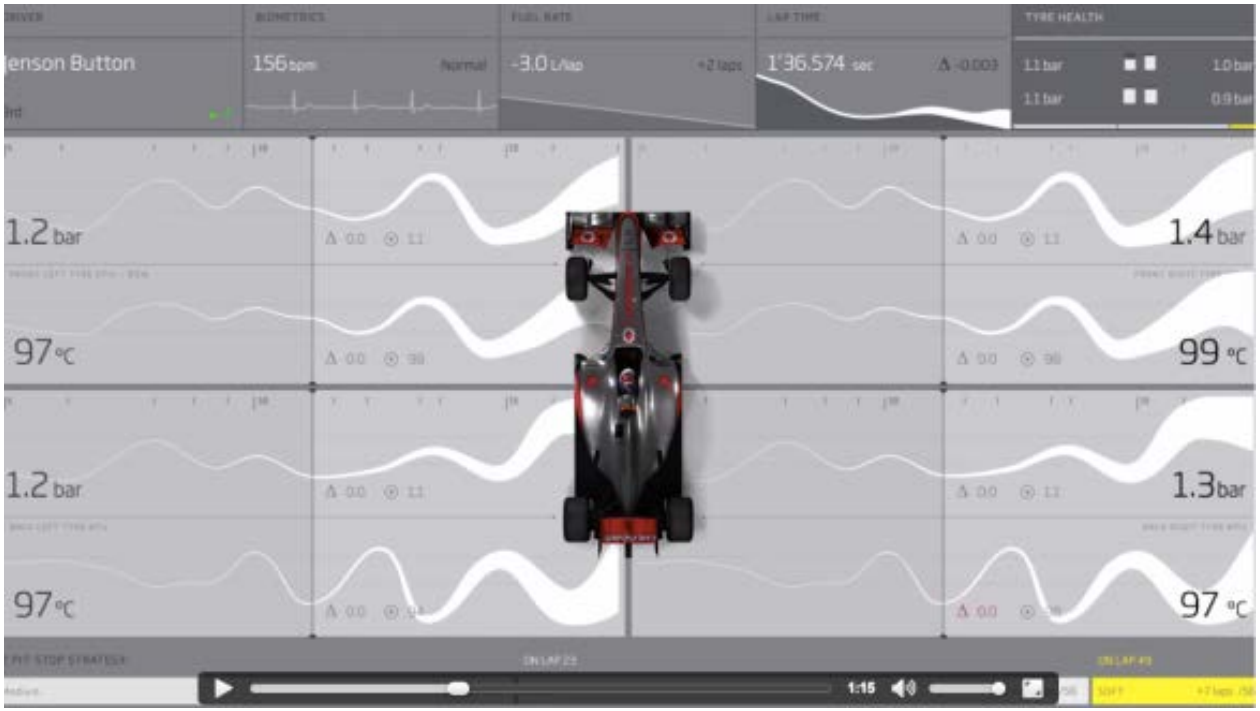


Figure 4-10. Search and attack technique.

How Formula 1 Racing is Using Big Data Analytics



- McLaren Race Team deploys over 160 telemetry sensors in each car which feed in excess of 1GB each race
- Example 2012 Brazilian Championship
  - car sustained damage on the first lap of the race
  - Immediately analyzing telemetry, engineers determined extent of damage
  - determined the car could continue racing, required replacement parts were identified and quickly made available to the Pit Crew

http://jeremystierwalt.com/2014/01/29/formula-1-and-hana-how-f1-racing-is-pioneering-big-data-analytics/

ESP = Using Physics-Based Gaming for Acquisitions

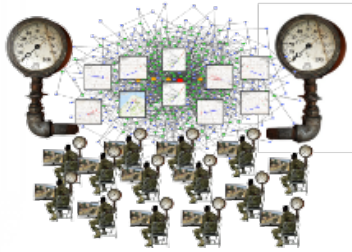
TODAY (TARDEC)

Soldier Experimental Gaming & Analysis

Future

FUTURE (RDECOM+TRADOC)

[ESP] EARLY SYNTHETIC PROTOTYPING

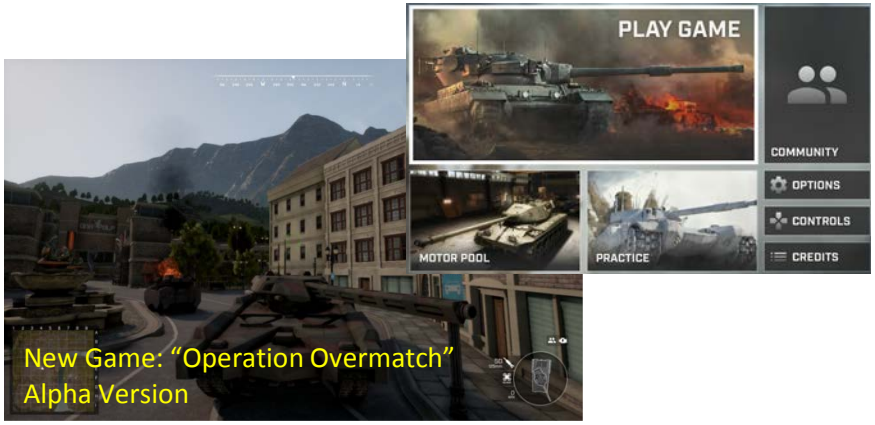


Estimated 120 million hours per year

- Uses Exisiting Commercial Game
- Run in a Lab w/ Dedicated Unit
- <75 Soldier Experiments
- 2-3 Days = Several Refights
- Lickert Subjective Questionaires

Operation Overmatch

- New Game Created By AMRDEC
- Ongoing Crowdsourced Game Environment
- Thousands of Soldiers
- Many Refights = Statistical Significance
- Objective Data from Analytics
- Ability to Customize Vehicles



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