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

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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 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

[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.

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.

Contents

Introduction: Megacities Initiative for Collaboration, Idea Generation, and Problem Solving

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.

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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

[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.

situational understanding; obtain freedom of movement and 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:

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[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.

- Rapid growth in urban areas will produce more demand on the infrastructure and flow systems, more waste, and increased urban density.[12]
- 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 military forces may have to contend with in the future.[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

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

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 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 intelligence.[39] A system

[23] Kozloski, Robert, "Power Through Stability."
[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."
[39] Dixon, Robert COL, "Bringing Big Data to War in Mega-Cities."

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]
- Changes in doctrine to enable the **development of knowledge experts in megacities** is needed where personnel are assigned to monitor cities.[52]

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

- 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]

[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 and DUAs?

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. This 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 within the

[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."

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]

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

[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.
[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.

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 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

[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.
[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.

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 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]

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[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.
[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."

- **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 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 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

[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."
[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."

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 are largely will be determined by 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 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

[118] Morrison, Dawn A. and Wood, Colin D., "Megacity and Dense Urban Environments: Obstacles or Opportunity?"
[119] Insights provided by MS contributors.
[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."

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 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]

[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."
[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 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

[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.
[138] Ippolito, Danielle PhD, "Assessing Physiological Response to Toxic Industrial Chemical Exposure in Megacities."

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

[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.
[150] Piekarski, Brett Dr., "Research and Vision for Intelligent Systems for 2025 and Beyond." Megacities/DUA Conference Presentation.

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.

[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.

[152] Glenn, Russell Dr., "Megacities: The Good, the Bad, and the Ugly."

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 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 paradigm shift in how medical data is defined, stored,

[153] Fisher, Nathan and Gilbert, Gary, "Unmanned Systems in Support of Future Medical Operations in Dense Urban Environments."
[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."

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 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

[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."
[172] Glenn, Russell Dr., "Megacities: The Good, The Bad, and The Ugly." Megacities/DUA Conference Presentation.

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 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.

[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.
[184] Swartout, William Dr., "Virtual Humans as Centaurs." Megacities/DUA Conference Presentation.
[185] Swartout, William Dr., "Virtual Humans as Centaurs."

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

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.

Challenges and Opportunities

A Complex Adaptive Learning System

[186] Felix, Kevin COL (ret.), "Army Panel on Megacities." Megacities/DUA Conference Presentation.

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 observable 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 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]

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[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."
[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."

- 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 of 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

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]

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[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.
[225] Insights provided by MS contributors.
[226] Kozloski, Robert, "Power Through Stability."
[227] Otto, Gustav and Besik, AJ, "Megacity Madness."

- 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]

[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	
2: Shape the Security Environment	22	
10: Develop Agile and Adaptive Leaders	19	
13: Conduct Wide Area Security	17	
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	
5: Counter Weapons of Mass Destruction	11	
15: Conduct Joint Combined Arms Maneuver	11	
14: Ensure Interoperability and Operate in a Joint, Interorganizational, and Multinational Environment	9	
20 Develop Capable Formations	9	
11: Conduct Air-Ground Reconnaissance	8	
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 Challenges megacity objectives. 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 Dense Urban Areas Conference also included over 500 individuals participating virtually through web streaming, a chat room, and Twitter: #madsci16. 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. 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 and Dense Urban Areas 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.

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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
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MR. ABE USHER	CHIEF TECHNOLOGY OFFICER, HUMANGEO GROUP,	"ADDRESSING THE CHALLENGES OF THE HUMAN TERRAIN IN 2050"	CONFERENCE PRESENTATION
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COL PATRICK DUGGAN	STRATEGIC LANDPOWER TASK FORCE, SOCOM	ARMY PANEL ON MEGACITIES	CONFERENCE PRESENTATION
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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	STORIES AND VISIONS FOR A BETTER FUTURE	CONFERENCE PRESENTATION

NAME	ORGANIZATION	IDEA CONTRIBUTION (S)	SOURCE
	ASSISTANT PROFESSOR, ARIZONA STATE UNIVERSITY		
DR. FRAN ZENZEN	ASURE CHIEF OPERATING OFFICER, ARIZONA STATE UNIVERSITY	"FRAMEWORKS FOR FUTURE CHALLENGES: UNDERSTANDING DENSE URBAN AREAS"	CONFERENCE PRESENTATION
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
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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
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MR. GARY PHILLIPS	TRADOC G-2 SENIOR INTELLIGENCE ADVISOR	DAY 1 INSIGHTS	CONFERENCE PRESENTATION
DR. KIRA HUTCHINSON	TRADOC G-29	ADMINISTRATIVE REMARKS	CONFERENCE PRESENTATION
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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

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RICHARD KNAPP	USAACE QAO	CROWDSOURCING INTELLIGENCE	ELECTRONIC SURVEY
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SCOTT GORIC	ARMY	ROBOTICS OPTICS	ELECTRONIC SURVEY
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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

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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
FRANK PRAUTZSCH	VELOCITY TECHNOLOGY PARTNERS LLC	GRAPHENE	ELECTRONIC SURVEY
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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
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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

NAME	ORGANIZATION	IDEA CONTRIBUTION (S)	SOURCE
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
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

NAME	ORGANIZATION	IDEA CONTRIBUTION (S)	SOURCE
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 MEGACITY AND DENSE URBAN AREA OPERATIONS."	PAPER SUBMISSION
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

NAME	ORGANIZATION	IDEA CONTRIBUTION (S)	SOURCE
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
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

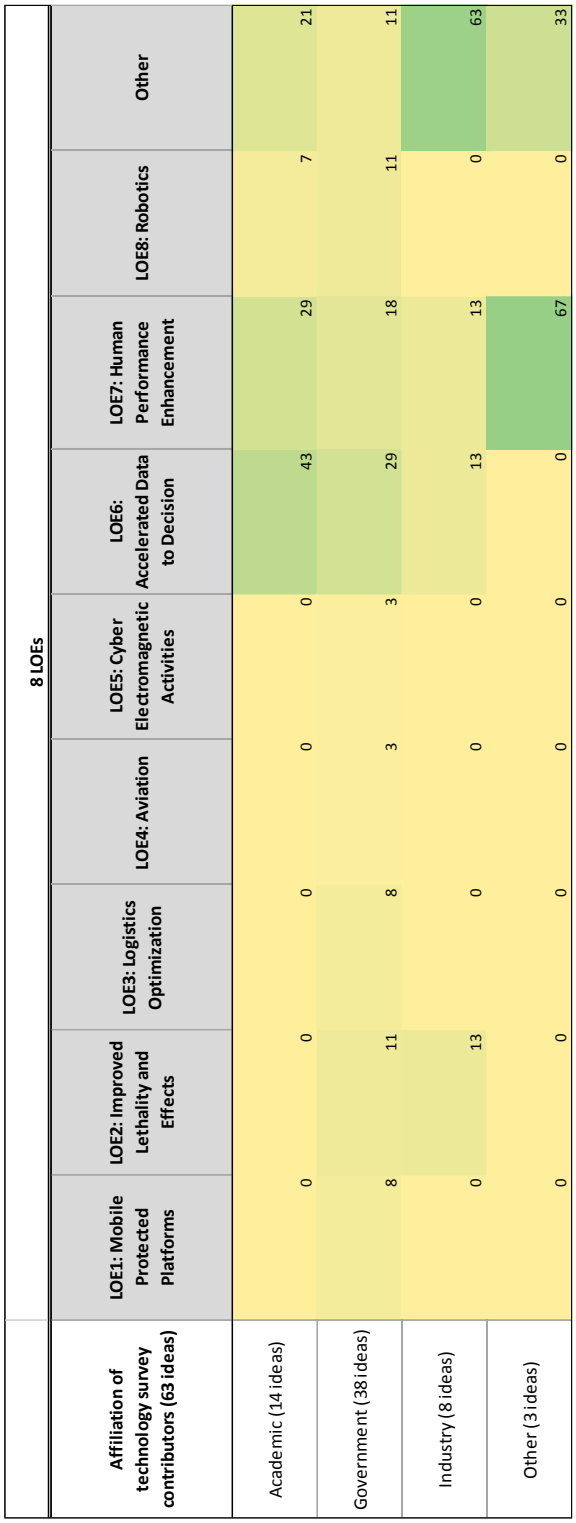
Survey Data

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).



Affiliation of technology survey contributors (63 ideas)	8 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	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		7	7	7	2	14
2: Shape the Security Environment	22		6	9	7	0	15
10: Develop Agile and Adaptive Leaders	19		8	6	5	0	14
13: Conduct Wide Area Security	17		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		3	5	3	1	8
5: Counter Weapons of Mass Destruction	11		3	6	2	0	9
15: Conduct Joint Combined Arms Maneuver	11		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		2	2	3	2	4
11: Conduct Air-Ground Reconnaissance	8		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 Dense Urban Areas 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 OE 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 OE, 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 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.
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 (OE)	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)
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 OE. (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

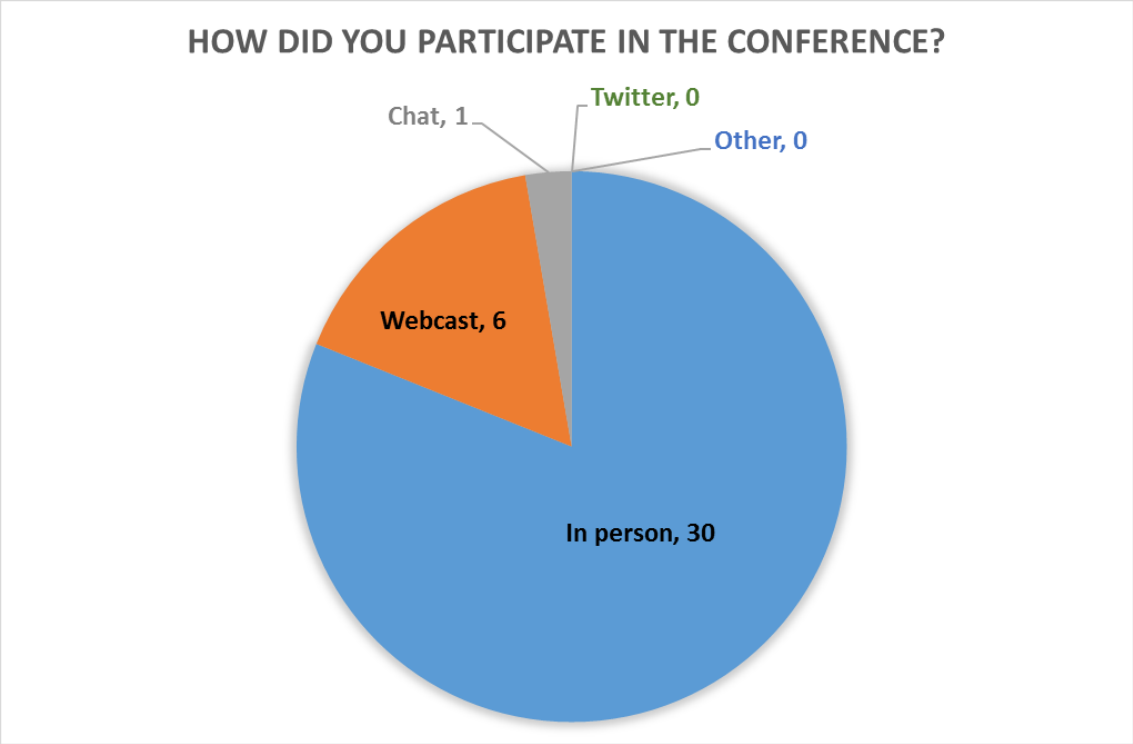
	themselves broken up by man-made features. (JP 3-06)
System of systems	A system-of-interest whose system elements are themselves systems; typically, these entail large scale inter-disciplinary problems with multiple, heterogeneous, distributed systems. (INCOSE)
Technology Imperatives	Focusing mechanism 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	OE 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 Megacities and Dense Urban Areas Conference feedback survey from 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 OE. 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 megacities 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.