Urban Futures, Technology, and Military Operations

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Abstract:

2014 marked the first year in which over 50% of the world's population lived in an urban area, and projections show that by 2050, that proportion could approach 70%. As these numbers climb, so does the probability that the US Army will be called to operate in a dense urban environment for operations ranging from disaster relief to counterinsurgency and beyond. However, even after 15 years of urban operations in Iraq, the US military struggles to conceptualize, measure, and understand cities in ways that can turn tactical innovation into strategic success. Recognizing this gap, the Army Future Studies Group (AFSG) tasked the Capstone team with developing a framework to understand dense urban areas as complex, interconnected systems. Through a literature review, extensive interviews with experts from the urban planning, data science, technology, and military fields, and a scenario-based workshop, our team has generated a framework that establishes four categories into which characteristics of urban environments might fall: human, structural, natural, and institutional. We then presented information requirements under each category, intended to provide insight to commanders on what questions are most important to ask in order to understand dense urban environments and how emerging technologies can be harnessed to answer them. Based on this framework, we developed six recommendations on ways to direct investment and optimize organizational processes to allow the Army to best leverage the current revolution in data science and improve their ability to operate in complex urban environments.

Acknowledgements & Disclaimer:

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Cover photo: Kaye (2004).

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1 EXECUTIVE SUMMARY

Even after 15 years of urban operations in Iraq, the US military struggles to conceptualize, measure, and understand cities in ways that can turn tactical innovation into strategic success. For the Army, the service most likely to undertake long-term urban operations, being able to measure the politics, health, and economic vitality of cities will be a crucial aspect of understanding the battlefields of the future.

Urban operations pose distinct challenges to effective utilization of American military power: a high density of social and organizational ties that are difficult for outsiders to understand; complex, civilian-filled terrain that extends in three dimensions; opaque networks of formal and informal institutions; and an even more severe than usual overload of information and accompanying difficulties separating signal and noise.

Cities are enormously complex systems; social scientists struggle to understand them even in peacetime. Foreign cities suffering from violent conflict or natural disasters present even tougher challenges. The degree of difficulty is unlikely to decline in the near future, but a set of emerging technologies centered on analytics and big data, artificial intelligence, robotics, autonomous systems, and mobile and cloud computing may help us see deeper into the black box of the city in ways that could be valuable to the Army when operating in dense urban environments.

Using a literature review and extensive interviews with military, academic, and civilian practitioner experts, we generated a framework for the Army to understand cities as interconnected systems. We then explored how major emerging technologies–big data, artificial intelligence, and cloud computing–could help the Army fill out that framework in the coming years. We also conducted a scenario-based workshop, bringing together a range of experts to debate the key points of disagreement we found in our research. This report covers the results of our research, the workshop, and six recommendations for the Army on how to take advantage of the emerging technologies to better understand urban operating environments.

We organized our findings and recommendations into four categories: the human, the structural, the natural, and the institutional. Each category has distinct implications for military, urban, and technological understandings of cities; corresponding information requirements allow commanders to see connectivity across issue areas rather than "silo-ing" them. While there is sometimes overlap in these categories, our team believes the ability to see such overlap is advantageous. Problematic characteristics of dense urban environments which span multiple categories may have multiple solutions, and our framework encourages users to approach those broad, cross-sectoral challenges from multiple perspectives.

Based on this framework, we have developed six key recommendations:

1) **Embrace complexity in modeling cities and focus on decomposing them into understandable, interconnected systems.**

   The Army should move away from understanding cities as monolithic, simplifiable entities which can be generally grouped into broad, like categories. Instead, we recommend that dense urban environments be considered as complex, interdependent systems that are made up of equally complex sub-systems.

2) **Create a dedicated staff section to help commanders understand the flows of the operational environment quickly and decisively.**

   The Army should create a section within battalion staffs that is dedicated to providing a commander with contextual information, intelligence, and/or relevant historical data about the battalion's operating environment, rather than being enemy-centric. This section might be a new staff "shop" or exist within the S-2 at the battalion level. The section would be responsible for bringing together data flows from military, civilian, and partner organization sources.

3) **Assess access to urban data and secure access ahead of time in likely operating environments.**

   The Army will need to undertake a survey of the relevant data available in cities were it operates, and to negotiate access to any important data that it currently lacks. This can be done ahead of time in the cities where the Army is most likely to operate, but the sheer number of potential locations makes this a major challenge.

4) **To fill in data access gaps, invest in deployable and remote sensor platforms or develop new techniques and uses for existing platforms.**

   The Army will need to ensure that it has deployable and remote sensors that it can bring to bear in cities that lack them. This recommendation builds on the traditional strengths of the US military and intelligence agencies in geospatial and signals intelligence, but it suggests that – alongside the typical focus on enemy activity – these intelligence products will be useful for mapping human and economic flows and assessing infrastructure and service delivery.

5) **Develop techniques for integrating qualitative and quantitative data.**

   The Army should invest in methods for integrating quantitative and qualitative data. This combination will help commanders and soldiers alike gain a detailed understanding of the urban environment. Effective information fusion can help sharpen potentially fuzzy or unreliable data by combining and layering information from multiple sources.

6) **Remain skeptical about the ability of technology and data to offer precise, reliable understandings of complex human systems.**

   The Army should remain cautious about relying too much on technology. While technological advancements will no doubt continue to change the face of warfare and will dictate ways that urban operations doctrine develops in the future, human intelligence should not be undervalued.

2 INTRODUCTION

2014 marked a watershed moment in human history: the UN reported that, for the first time, more people lived in cities than lived in rural areas. The move to majority urban living is merely another benchmark in the long-running trend of urbanization. Global population doubled between 1965 and 2014–in that same time, the number of cities of over one million people nearly quadrupled, and is projected to grow significantly in coming years.

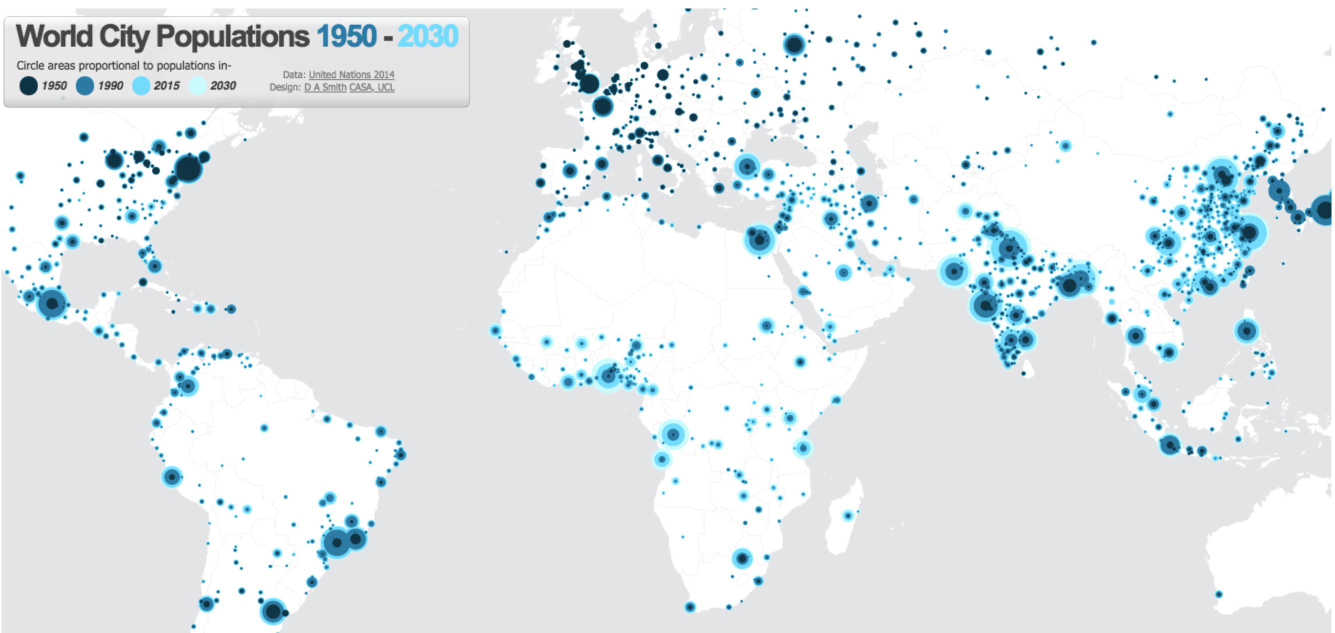

FIGURE 1: Cities have grown rapidly since 1950; larger circles correspond to more growth.[1]

As climate change and economic transformation drive more people into cities, political grievances, resource pressures, and other drivers of conflict will accompany them. Competition for power, security, and basic necessities in the coming years will inhibit efforts to effectively govern dense urban spaces, and demand for solutions that bring state power to bear on those areas will increase. The US Army (and other services) will increasingly have to contend with conducting operations in large, dense cities.

[1] LuminoCity3D (2014)

Urban operations pose distinct challenges to effective utilization of American military power: a high density of social and organizational ties that are difficult for outsiders to understand; complex, civilian-filled terrain that extends in three dimensions; opaque networks of formal and informal institutions; and an even more severe than usual overload of information and accompanying difficulties separating signal and noise.

In 15 years of urban operations in Iraq, the US military has made a number of strides in overcoming the tactical challenges cities present. From counter-IED procedures to integrating platoon-level drone coverage into tactical intelligence flows, innovation has made American troops safer and more lethal in urban areas. Yet the military still struggles to conceptualize, measure, and understand cities in ways that can turn tactical innovation into strategic success. For the Army, the service most likely to undertake long-term urban operations, being able to measure the health, political sentiment, and economic vitality of cities will be a crucial aspect of understanding the battlefields of the future.

Cities are enormously complex systems, and social scientists struggle to understand them even in peacetime. Foreign cities suffering from violent conflict or natural disasters present even tougher challenges. The degree of difficulty is unlikely to decline in the near future, but, a set of emerging technologies centered on analytics and big data, artificial intelligence, robotics, autonomous systems, and mobile and cloud computing may help us see deeper into the black box of the city in specific ways that could be valuable to the Army when operating in dense urban environments.

Using a literature review and extensive interviews with military, academic, and civilian practitioner experts, we generated a wide range of questions of interest to militaries operating in cities. We then selected the questions that we judged to have the highest value to the Army and the most potential to be answered by harnessing emerging technologies. We organized these questions into four categories of information requirements - concerning the human, structural, natural, and institutional facets of the city - and they are presented below, along with analysis of their importance and how they might be answered before and during Army operations. We also conducted a scenario-based workshop, bringing together a range of experts to debate the key points of disagreement we found in our research. This report covers the results of that workshop, as well as risks, challenges, and potential adversary countermeasures linked to the emerging technologies and techniques we cover. Finally, we make recommendations regarding the capabilities the Army will need to take advantage of the opportunities we have identified.

3 FRAMING THE PROBLEM

3.1 MILITARY OPERATIONS IN URBAN ENVIRONMENTS

The urban environment challenges commanders in that it both amplifies problems inherent to any military operations and imposes unique dilemmas that the US Army is currently not consistently training troops to face.[2] Cities compound these challenges and put stress on traditional military decision-making processes. Traditionally, the cognitive bias is that when the time comes to engage militarily in an urban environment, no amount of destruction is off the table.[3] But this does not have to be the future; short-term destructive action might solve security dilemmas, but often that redesigns the city in such a way that the military has to stay for years following, rather than sustaining the urban environment wherever possible in order to mitigate the need for long-term deployment.

Operating in Port-au-Prince, Haiti during Operation Secure Tomorrow (2004) required US military commanders to stabilize a city with few formal governance institutions, rampant criminal gangs, and a rebel force asserting its bid for control. American forces—Marines in this case—were activated with no more than twenty-four hours' notice and had very little intelligence before landing. HMMWVs, they soon found, were too wide to travel many of Port-au-Prince's narrow streets, and within three days, squads of Marines were patrolling the city on foot without much more more than a map in hand to help them understand the urban environment.

In order to address these sorts of knowledge gaps, commanders rely on data and intelligence to guide their decisions. Information flows into an operations center through various means but may not be effectively compiled to provide commanders or small unit leaders with the necessary knowledge. Additionally, intelligence priorities are usually adversary-focused and can lack a broader context. As was the case in Port-au-Prince, simply making basic data about the urban environment available–such as the width of streets so that US Marines could be reliably mobile–can go a long way for increasing probability of operational success.

In a recent interview, Colonel Patrick Mahaney (Ret.) imparted the dangers of haphazardly applying strategies learned in one theater in another without considering the unique context. In Baghdad's Sadr City neighborhood a concrete wall was built to create a protected zone separating militia activity from reconstruction areas. The Sadr City wall, by most counts, disrupted all the right systems (e.g. militia taxation of merchants) and enabled the US military to carry out its reconstruction efforts and reclaim the neighborhood.[4] According to Major John Spencer, the Sadr City wall was an accidental solution; it was put in place to cut off movement of insurgent fighters, not

[2]Spencer MAJ USA (2018).
[3]Spencer MAJ USA (2018); Kilcullen (2013).
[4]Enders (2009).

to strangle the home base of the insurgency. And while the outcome was largely positive, the reactive nature of the decision-making could have had severe consequences, and one positive outcome does not mean that building a wall is a catch-all solution—or a solution of any kind—elsewhere. Colonel Mahaney stresses that practices may not be translatable from one urban context to another. Applying strategies without a clear vision of what you are trying to achieve, without real understanding of the population's needs and preferences as well as the institutions (both formal and informal) through which those needs and preferences manifest will make matters worse. "Quick fix" solutions like hastily-built concrete walls can adversely affect the functions of an urban environment and achieve short-term successes at the expense of long-run sustainability.[5]

The Army's need to think "deeper in time" and consider resources and meaning beyond immediate violent action is evident in humanitarian emergency response as well as stability and COIN operations.[6] In both cases, strategists should take a long-term perspective recognizing that the less the Army knows going into a dense urban environment, the longer it is likely to remain engaged in that place.[7] Analysis that leans away from the enemy-centric and toward a more comprehensive, holistic understanding of the urban environment itself is an invaluable aspect of such sustainable engagement, as it will enable commanders to better predict spoilers, anticipate the future needs of the city, map human networks that could both help and harm US activity, and keep as much metropolitan day-to-day flow functioning as usual.

Understanding what challenges made urban operations unique allowed us to narrow our focus, moving away from conventional, offensive/defensive operations and limiting our work to humanitarian assistance and/or disaster relief (HA/DR) and stability operations. Offensive/defensive operations in cities are challenging to be sure, but military history is littered with precedents for success in conventional urban operations and the Army is well-equipped to implement those lessons within its core competencies. The destruction wrought by offensive/defensive operations and the ease of distinguishing conventional enemies from civilians means that these operations play to the Army's strength: finding, fixing, and defeating conventional enemy forces. As we sought to explore ways of addressing the Army's weaknesses in urban operations–understanding city dynamics and their effect on operational goals–it became clear that a focus on less kinetic missions would create the greatest opportunity for a real re-evaluation of the Army's approach to cities. Furthermore, given recent history and geopolitical dynamics, the US Army is more likely to conduct urban HA/DR or stability operations in the next 20 years than it is to be involved in a large offensive/defensive fight in a city.

[5] Mahaney (2018).
[6] Glenn (2018).
[7] Dr. Russell W. Glenn and Scott Norwood at Various (MDB in Megacities) (2018).

3.1.1 HUMANITARIAN ASSISTANCE/DISASTER RELIEF

The recent history of US military HA/DR response is indicative of the Army's likely operational tempo for the near future. From the disaster response for Haiti in 2010, to Fukushima in 2011, to Hurricane Sandy in 2012, to West Africa during the Ebola outbreak of 2014, and more recently in Puerto Rico, there has been no shortage of catastrophes requiring military assistance domestically and abroad.

Going forward, the pace and scale of urban HA/DR operations may even increase. The combination of climate change and coastal population growth place large swaths of the world's poorest people in a precariously vulnerable position.

Nations in the global south will lack the capacity to effectively react to and contain the first-order effects (and the follow-on effects) of a major emergency in one of its megacities. It will often fall to the US Army (or a sister service) possessing the global reach to prevent an unchecked catastrophe from upending stability.[8]

Information requirements during HA/DR operations include:

- **Is there effective governance?** What capacities does the host nation have? What don't they have? Is there an organized system in place for providing basic services to the populace? If not, does the capacity exist? Can services be provided in a consistent, reliable manner?

- **What are the critical institutions and what are the essential services people require to feel safe and secure?** How can commanders assess what's working and what isn't? Where is the best application of the US Army's resources? What are the essential services people deem critical for their everyday lives?

- **What constitutes "normalcy"?** What did it look like before? What does it look like now? What metrics can the Army offer policymakers to show that their "normalcy" objectives have been achieved? Can this be an opportunity to use a whole-of-government approach to help build a new normalcy? Is that something the people want or would accept?

3.1.2 STABILITY OPERATIONS

Stabilization missions may be the most complex operational environment because they consistently thrust Army units into unexpected and ever-evolving mission profiles. The so-called "Three Block War", in which soldiers may be asked to deliver humanitarian assistance, resolve low-intensity conflict among civilians, and fight a full-scale engagement in the course of a single patrol,

[8] O'Hanlon (2009).

is the trademark of urban stabilization operations.[9] Larger cities raise the stakes of every phase of stability operations and magnify dilemmas for commanders.

Because missions are diverse and goals population-centric, measuring success in stability operations requires describing complex political, economic, and social dynamics. Understanding those dynamics in cities is difficult even for local governments, much less foreign forces. Yet the Army, as the service most suited to long-term ground operations, is likely to be faced with just that challenge in future stabilization missions.[10]

The Army currently uses the PMESII-PT (Political, Military, Economic, Social, Information, Infrastructure, Physical Environment, and Time) framework to understand complex operating environments, which is comprehensive without being particularly illuminating. The framework presupposes that the Army is well-equipped to gather information about all of the PMESII-PT components, which it currently is not. As this report will detail, emerging technology offers opportunities to gather insights into some of the most opaque political, economic, and social aspects of cities.[11]

Information requirements in stability operations include:

- **What is the balance between control and management of the population?** When and how can commanders leverage forceful tactics to create a situation where control can be safely transferred to local authority?

- **What information is crucial for small unit leaders to have?** The overwhelming influx of data into a Tactical Operations Center cannot be formatted into digestible knowledge or situational understanding for commanders in a timely manner. How can commanders decide what information about the city all soldiers need to know in order to accomplish their operational goals?

- **What would be required to establish civil security?** We can already determine the size of the population and its basic demographics, but how can we understand what different groups require for that security and why they require it?

- **Who is the authority?** How can commanders identify key players/stakeholders in a densely populated city? Who is accepted by the populace and does that conflict with the mission? What is the proper way to engage with dialogue? What other organizations are available to assist (State Department, United Nations, or non-governmental organizations)? What are the other informal institutions/nodes of power that the Army needs to be aware of? How can they be quickly identified? Are they benign or harmful? Who controls them and what is their capacity for violence?

[9] Krulak (1999).
[10] Headquarters Department of the Army (2008).
[11] Ducote MAJ USA (2010).

3.2 KEY EMERGING TECHNOLOGIES

Based on an evaluation of technological trends, interviews with professionals and scholars working in science and technology, and an assessment of military operations in urban environments (as outlined above), we believe advancements in the following three key technology areas will have major implications for the US Army's capacity to understand cities: 1) Analytics and Big Data, 2) Artificial Intelligence, Robots, and Autonomous Systems, and 3) Mobile and Cloud Computing. These technologies are rapidly changing and are essential for intelligence gathering and processing (e.g. Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) applications).

3.2.1 ANALYTICS AND BIG DATA

The world now generates more data in a year than it did between the beginning of recorded history and 2004. Just by 2020, the world is expected to generate 40,000 exabytes of data, with the size of the digital universe doubling every two years.[12] In addition to readily-available data on social media posts, meteorological events, food and water consumption, traffic flow, etc., more data will come from the proliferation of Internet of Things (IoT) sensors and devices, which are expected to number between 20 and 30 billion by 2020.[13]

Big data can produce deep insights about individual behavior and perceptions, public health and needs, climate change, and a range of other economic, social, and political challenges that will be relevant to US military operations. In its simplest form, the value of this technology is its ability to find, recognize, and remember patterns in incredibly large datasets. In the immediate future, big data analysis promises the ability to begin automating simple processes and tasks currently performed by humans, and in the future, to possibly identify trends that we have not yet seen. As this trend evolves it will also improve understanding of other fields like artificial intelligence and cloud computing.

3.2.2 ARTIFICIAL INTELLIGENCE, ROBOTICS, AND AUTONOMOUS SYSTEMS

There is significant research going into the study of artificial intelligence (AI), robotics, and autonomous systems. An AI, at its core, is a computer program capable of making intelligent decisions faster and better than a human, given a set of parameters and an objective. Robots are machines capable of performing designated tasks, usually driven by computer programs. An autonomous system is any technology or device capable of independently executing its designated

[12] Gantz and Riensel (2012).
[13] Nordrum (2016).

tasks. These technology trends are all heavily dependent on big data and analytics. Simple robots and autonomous vehicles are already used for defense purposes, and in the near future, they will be able to perform increasingly complex tasks.

The combination of AI and autonomous robots have application in Manned-Unmanned Teaming (MUMT) operations, ISR operations, and other situations where sending in a manned team alone may be dangerous. This technology also has an application in transportation and logistics through improved navigation and reduction in risk to people. AI is still in its infancy, but experts expect it to mature quickly to perform several non-critical functions during operations.[14] Most importantly, AI may be able to help commanders sort through the torrent of information being collected by the Army.

3.2.3 MOBILE AND CLOUD COMPUTING

Mobile and cloud computing are transforming the way we interact with data. In the U.S., an estimated 30% of web browsing and 40% of social media use are currently done on mobile devices, and by 2030, 75% of the world's population will have mobile connectivity and 60% should have broadband access.[15] These devices, together with cloud computing, will transform how we create, store, compress, transmit, and process large quantities of data, and they will significantly improve communications, information sharing, and decision-making in military operations. The Department of Defense's investments in initiatives like Joint Enterprise Defense Infrastructure (JEDI) point to the potential of mobile and cloud computing–i.e. ruggedized, miniature servers small enough to fit in a Humvee or even a soldier's backpack, connecting "combat troops, officers, intelligence analysts, and others to a wider universe of information." [16]

3.3 RISKS, COSTS, AND ADVERSARY COUNTERMEASURES

These technologies have great promise for the US military, but they arrive with a range of risks. The inefficiencies of data-driven processes, the high cost of maintaining data quality, and the ability of adversaries to both co-opt and counteract our technological advances all threaten to undermine the benefits of the coming technology revolution. Before we discuss how emerging technologies will help the Army better understand cities, we need to examine the risks the Army will have to manage to realize future benefits from those technologies.

[14] Work and Brimley (2014).
[15] Augustyn (2017).
[16] Freedberg Jr. (2018).

3.3.1 MAKING THE INFORMATION USABLE

3.3.1.1 Information Overload

As General Robert B. Brown, Commanding General of the U.S. Army Pacific (USARPAC) has suggested, today's fog of war is too much information.[17] Each day US intelligence agencies collect more raw data than their entire workforce can effectively analyze in their combined lifetimes.[18] Most of this data is unstructured – i.e. data that is not organized according to any known rule set in image, text, signal, electronic, or other form – and stored across unintegrated databases, and a lot of it goes unanalyzed because of lack of time, short decision cycles, cognitive limitations, physical requirements, and more.[19] Greater access to the internet, more mobile devices, and proliferation of sensors will only produce orders-of-magnitude greater amounts of data at higher speeds in the future. In such an environment, intelligence analysts will need to rely more heavily on machine learning algorithms to quickly extract valuable information from the data deluge from a variety of sources and forms and will need to present and convey this information effectively.

3.3.1.2 Need for Shared Networks

Through infinite simultaneous (rather than sequential) calculations, artificial intelligence and quantum computing together will enable rapid processing of large quantities of data.[20] Datasets that were previously only analyzable by humans (e.g. satellite imagery) will become more amenable to automated analysis, meaning that it may be possible for US intelligence agencies to automatically analyze every square meter of the Earth's surface every single day.[21] This automation will be critical for analyzing persistent ISR data, but this will also require more shared networks and common technical infrastructure to link data more efficiently across agencies. A shared architecture would give AI tools access to the largest possible data sets, accelerating pattern recognition improvement and consequent intelligence outcomes.[22] As Adam Routh of the Center for a New American Security argues, data collection is not a significant challenge in US military operations; what is challenging, however, is real-time analysis enabled by information sharing across agencies.[23] Too frequently, intelligence agencies do not transmit data to other agencies in an actionable time frame due to incompatible technical infrastructure, inadequate protocols for information-sharing, or jurisdictional concerns; lack of inter-agency cooperation may pose a se-

[17] Freedberg (2017).
[18] Allen and Chan (2017).
[19] Brimley et al. (2018); Allen and Chan (2017).
[20] Brimley et al. (2018).
[21] Allen and Chan (2017).
[22] Brimley et al. (2018).
[23] Routh (2018).

rious challenge for future US military operations, especially when US adversaries are investing in highly sophisticated C4ISR capabilities and may have looser information-sharing protocols and fewer bureaucratic limitations.[24]

3.3.1.3 Keeping Humans in the Loop

In arguing that information sharing will be critical for future success, Routh underscores the need for better management of collected information.[13] With a shift towards high levels of autonomy and tip-and-cue responses, military commanders and stakeholder will need to reflect on how best to keep humans in the loop – to produce actionable intelligence and facilitate better decision-making on every level. This will certainly require organizational changes. As David Zikusoka, consultant to the US Department of Defense and former Special Assistant for Battlespace Awareness and Program Assessment at the Office of the Secretary of Defense, argues, military commanders and civilian leadership alike will need to seriously consider flipping the workforce equation.[25] According to Zikusoka, the US government currently employs more analysts than data scientists, but the future force will require a higher data scientist to analyst ratio to ensure faster and better information collection, visualization, layering/fusion, validation, analysis, sharing, and more. This type of reflection will be especially important to account for instances where autonomous systems unexpectedly and rapidly spiral out of control with potentially catastrophic consequences – e.g. the stock market "flash crash" of May 2010, which, as the US Securities and Exchange Commission reported, was enabled and exacerbated by use of autonomous financial trading systems.[26]

3.3.2 INFORMATION DECEPTION

3.3.2.1 Data Quality

In addition to concerns about there being far more potentially useful raw data than that which can be analyzed, there are obvious concerns about quality and veracity of collected data. Even without intentional deception, it may be difficult to assess the quality of data in situations where the US military does not have extensive knowledge of a city and its people, and where it has to depend on local institutions and organizations to provide information. This information may be incomplete and/or inaccurate and will naturally impede decision-making. Additionally, dependence on data collected en masse and analyzed by machines may create new vulnerabilities and deception opportunities for adversaries – through content creation and manipulation since existing and

[24] Brimley et al. (2018).
[25] Zikusoka (2018).
[26] Brimley et al. (2018).

emerging AI capabilities are not limited to just data analysis.

3.3.2.2 Content Generation

According to a Belfer Center report titled "Artificial Intelligence and National Security," existing content-creating AI capabilities include (but are not limited to): changing facial expressions and speech-related mouth movements of an individual on video in real-time; generating realistic-sounding, synthetic voice recording of any individual for whom there is sufficient training data; producing realistic, fake images based only on a text description; producing written news articles based on structured data such as political polls, election results, financial reports and other statistics; creating a 3D representation of an object based on one or more 2D images; and producing realistic sound effects to accompany a silent video. As AI applications and tools become cheaper and more accessible, it will be possible for even amateurs to generate such content at scale, leading to more forgeries that are indistinguishable from reality. This, of course, will pose challenges across industries, including military operations, and will affect the relationship of individuals to truth and evidence.[27]

3.3.2.3 Social Engineering Threats

In the future it will be harder to know what to trust as even relatively objective data, such as satellite images of a city, may be easily manipulated by adversaries. Cryptography and secure/encrypted communications channels will certainly help, but everyday social trust between individuals and organizations will be compromised as people share more fake and misleading information on social media, citing articles from unreliable and alternative media domains.[28] This vulnerability will also extend to military operations and command and control organizations in the form of social engineering threats that target people instead of computers. For instance, one can imagine a scenario in which an adversary impersonates a military or intelligence officer and orders the sharing of sensitive information or taking some undesired action. An adversary could also produce counterfeit versions of US military directives and policies and disseminate these across the internet. In addition, an adversary could produce large quantities of forged evidence alleging US wrongdoing, fomenting mistrust and anger in places where the US military is conducting HA/DR or stability/COIN operations.[29]

[27] Allen and Chan (2017).
[28] Starbird (2016).
[29] Allen and Chan (2017).

3.3.2.4 Data Pollution and Corruption

Deception will also extend beyond social engineering and will impact machine learning systems that US and allied militaries use. Since machine learning systems rely on high-quality datasets to test and train algorithms, injecting corrupt data into these datasets could manipulate AI systems into performing in undesired ways. For example, one can imagine a data-polluting cyberattack that results in even trusted sensors automatically miscategorizing a friend as enemy or an enemy as not present at all.[30] Indeed, automated analysis of polluted social media data already results in misinformation and flawed decision-making; rising levels of autonomy and greater reliance on machine learning will make deception through pollution and manipulation of data a more acute challenge.

3.3.3 ADVERSARIES WITH THE SAME CAPABILITIES

3.3.3.1 Electronic and Cyber Warfare

As the Center for a New American Security "Evolving the Future Force" report argues, "if the first step toward information superiority is securing access to mission-critical data, the second is denying one's opponent the same." In the future, US adversaries will also use AI to make sense of the massive amounts of data collected, and their data fusion capabilities will be attuned to defeating US advantage. Through electronic warfare, adversaries will be able to not only disrupt transmission of intelligence data and communications but also radio-controlled or GPS-dependent precision-guided munitions. As discussed above, adversaries will use new types of cyberattacks to disrupt or degrade US C4ISR; this will also extend to logistics; positioning, navigation, and timing (PNT); and even strike asset operations. In addition, adversaries may use cyber weapons to damage dual-use infrastructure including water and food supply, and wireless networks critical to military operations.[31]

3.3.3.2 Autonomous Systems

As commercial robotic and autonomous vehicle technology becomes widespread, adversaries will leverage this technology to make more advanced IEDs – e.g. autonomous vehicle-borne IED (VBIED) to function as suicide car bombs. Moreover, as long-distance package delivery by drone becomes more accessible and cheaper, adversaries will be able to use more precision-guided munitions and other similar devices against US military and civilian targets.[32]

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[30] Allen and Chan (2017).
[31] Brimley et al. (2018).
[32] Allen and Chan (2017).

4 OUR FRAMEWORK

It became clear early in our research that it would be impossible to say anything worthwhile about how technology can help explain cities without a framework for understanding urban environments. We delved into the modern urban studies literature, engaging competing ideas in that space, including urban ecology approaches, theories of scaling, "urban metabolism" theories, "cyborg" understandings of technology integration, discourse on smart cities, and theories of urban resilience.[33] In spite of the plethora of theory choices, a unifying feature of the current literature is a move away from classical approaches toward understanding cities that focus on chaos and balance as absolutes. Rather than seeing cities as inherently tending toward equilibrium, theorists now overwhelmingly discuss cities as complex, interdependent, entropic systems.[34]

In the modern frame, cities do not strive for some ideal balance, but instead seek to build resilience against inevitable shocks, both external and internal.[35] Shocks to complex systems–such as natural disasters, humanitarian emergencies, or urban conflict–often require external intervention while at the same time exacerbating complexity and disrupting interdependence. When the Army undertakes urban operations, it is most often doing so to bridge the gap in a city's resilience caused by the city's most recent shock.

Understanding dense urban environments and the ways they are predicted to change in the future is crucial to managing resilience and therefore to Army doctrine. This report introduces many information requirements for those seeking to understand urban environments that our team believes generate useful guidance for assessments that can produce granular, contextual, and actionable pictures of the lives of cities. While the analysis and recommendations that follow can be helpful for finding enemies or identifying a particular problem–for example, by using data for change detection–this report will focus on conceptualizing and understanding cities themselves rather than contribute to an already rich literature on identifying adversaries. By using this framework to dig into specific operational challenges, commanders can conceptualize cities and understand how the Army can and should interact with them.

We determined that the most effective way to organize this framework is to establish four broad categories into which characteristics of dense urban environments might fall: the human, the structural, the natural, and the institutional. Each category has distinct implications for military, urban, and technological understandings of cities; corresponding information requirements allow for commanders to see connectivity across issue areas rather than "silo-ing" them. While there is sometimes overlap in these categories, our team believes the ability to see such overlap

[33] Broto et al. (2012).
[34] Kilcullen (2013); Broto et al. (2012); Glenn and Christopher (2017); Spencer and Amble (2017).
[35] Ibid.

is advantageous. Problematic characteristics of dense urban environments which span multiple categories may have multiple solutions, and our framework encourages users to approach those broach, cross-sectoral challenges from multiple perspectives.

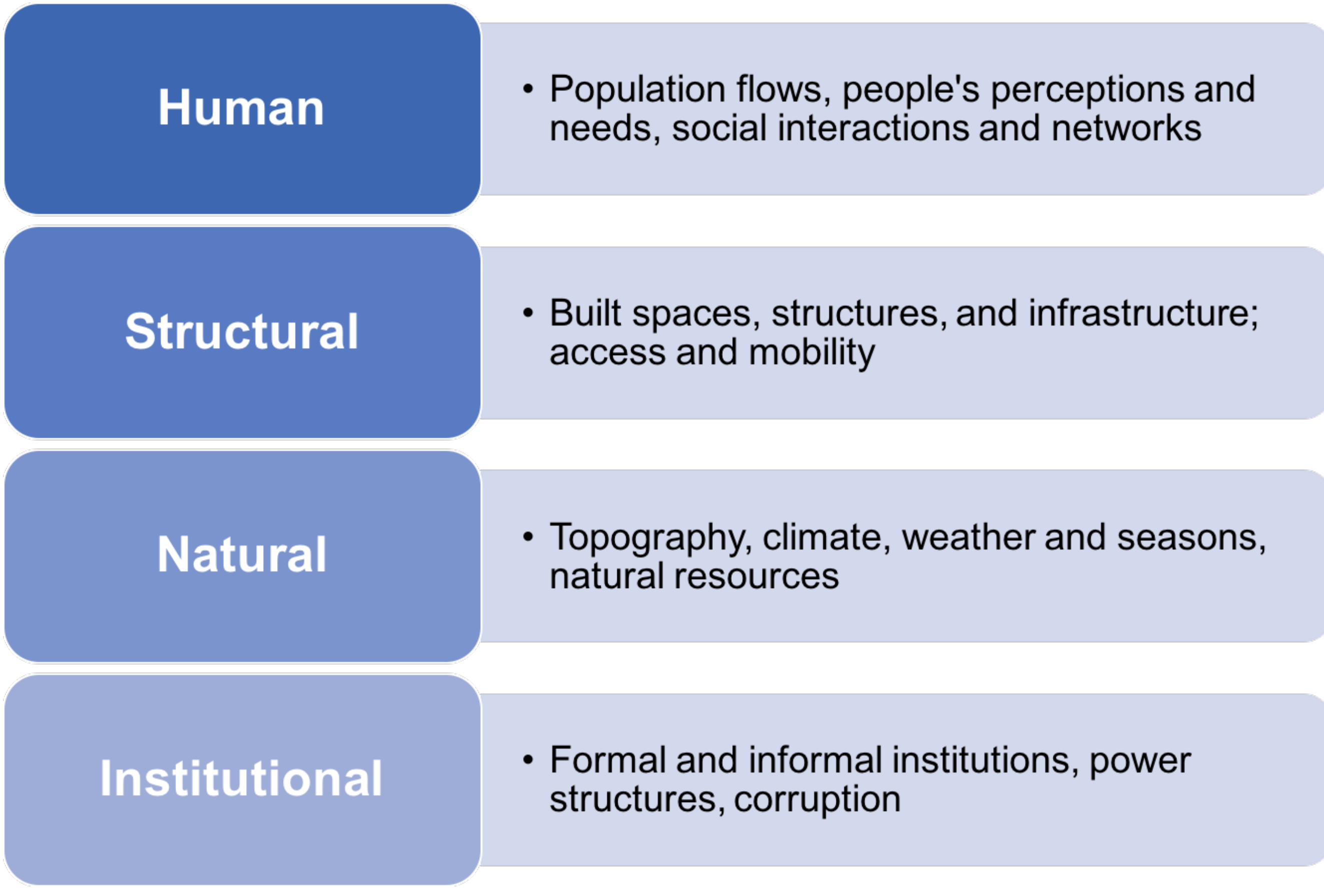

FIGURE 2: Framework

4.1 OVERVIEW: HUMAN

The human elements of an urban environment refer to the ways in which members of the population of a dense urban environment interact with each other and with the city itself. The concept of "flows" underpins cities' human and material attributes; flows illustrate how human beings access spaces, move to and from areas of interest, and navigate a city's resources. Identifying characteristics of a city's population will allow commanders to evaluate flows of people and goods, character and composition of neighborhoods, and local perceptions of the events around them.

Information requirements: How do people move within a city? How does a city's population or subset of a population perceive a given entity or event? What are the major social groups within a city and how do they interact? How do social divides manifest in the city's geography? What material goods and services do people need?

4.2 OVERVIEW: INSTITUTIONAL

The institutional elements of an urban environment refer to formal and informal human institutions. The institutional considers both overt and hidden systems which can significantly influence human or mechanical flows, governance, social networks, and markets. The invisibility of many institutional nuances makes these factors especially complex to map and analyze without human intelligence. Localized, cultural, and situational understandings based on such human intelligence should not be replaced, but there are certain technological resources that can enhance and expand upon those understandings.

Key information requirements: Where does power reside in the urban environment and how do formal and informal power structures interact? What are the security and emergency response capabilities of the urban environment and where are the gaps in those capabilities? Are formal and informal institutions functional, reliable, and trustworthy?

4.3 OVERVIEW: STRUCTURAL

The structural elements of an urban environment refer to a city's built spaces, structures, and infrastructure. Structural challenges include access and mobility, navigation of both heights (e.g. tall buildings) and depths (e.g. subterranean spaces), and the role of infrastructure in service delivery as well as disruptions to service delivery caused by shocks (e.g. non-state occupation of state spaces or damages caused by natural disasters). While the Army appears to already be well aware of the importance of urban structural factors, technological developments over the next 10-20 years are likely to enhance the ability to collect and analyze data in real time and predict the effects of the Army's actions.

Key information requirements: What is the condition/status of a city's infrastructure? What are the access and mobility conditions in the city? How can we map difficult-to-access spaces?

4.4 OVERVIEW: NATURAL

The natural elements of an urban environment refer to the environmental components of a city such as its topography, climate, weather and seasons, natural resources, and relationship between the urban, peri-urban, and the rural. Like cities' built structures, natural features are very often visible and mappable. As climate change is a key driver of urbanization, measurements of environmental futures can be utilized by the Army to predict the future needs of shifting urban spaces as well as the needs of future urban populations. Assessments of the natural can give insight into links between seasonal shifts and human behavior, limitations of infrastructural expansion, and environmental challenges posed both to and by cities (e.g. increased risk of natural disaster and food insecurity, respectively). Experts working on climate change do a great deal of predictive work around environmental futures that will be especially useful for the Army when engaging in reconstruction projects post-disaster or conflict.

Key information requirements: What do climate, weather, and geography of the region look like? How do climatological and geographical factors affect cities and the conduct of military operations?

5 KEY INFORMATION REQUIREMENTS: HUMAN

The information requirements in this section deal with how people in a city interact with each other and with the city itself. Across the spectrum of military operations in urban areas, the Army will be forced to contend with large numbers of people in small amounts of space, and being able to understand their daily patterns, basic needs, and motivations will be critical in maximizing efficiency and mitigating unintended consequences while operating in these spaces. In the case of HA/DR or COIN/Stabilization missions, where the population is just as or more important than the territory itself, this becomes even more important.

5.1 HOW DO PEOPLE MOVE WITHIN THE CITY?

5.1.1 WHY?

Evaluating movement within the city has multiple components. First, we are concerned with the broad concept of population flows–determining the primary, secondary, and tertiary arteries of the city, as well as how many people can be assumed to be moving through a given area at any given time of the week or day. On top of that, we want to know how people move around. Do they travel by bus, by train, by bicycle, or on foot?

In HA/DR operations, knowing how people ordinarily move through the city and where large groupings of people are likely to be at any given time can help facilitate evacuation routes, evaluate areas where infrastructure damage will be most disruptive to day-to-day life, and predict where people are likely to be trapped given the time of day that disaster strikes. In COIN or stabilization operations, an understanding of natural chokepoints, primary and secondary ingress/egress routes from given neighborhoods, and population flows on any given day can inform efforts to manage population movement, point to natural locations for checkpoints, and assess possible impacts of barriers or restrictions of movement on everyday market activities. Furthermore, establishing baselines for population flows in stabilization missions allows for easier identification of illicit behaviors that pose threats to stability.[36] In sum, having an advanced understanding of population flows and how they adapt to external stimuli would give the Army insight into civilian responses, intended and otherwise, to population control measures.

5.1.2 HOW?

On the most basic level, we can get information on population flows by fusing a variety of data sources and layering them onto a map. Data from cell phone locations, traffic and street cameras, toll plazas, public transit access swipes, and urban conveniences like rent-a-bike systems can be fused to map out movement within the city. This can be further integrated with real estate transaction records or land use maps, with consumer purchasing data, or with geo-located data from applications like Yelp in order to add context to observed population flows and gain insights into the breakdown of commercial, industrial, and residential areas within the area of interest. Google's use of aggregated cell phone location data to assess popular times and visit durations at known locations like restaurants, attractions, or business establishments is just one example of how data can be fused to gain insights into how and why people move around a city.[37] Furthermore, this data can be used to construct models of the city that highlight "areas of interest" or "hotspots" of human and economic activity.[38]

As evidenced by the example above, much of this is already being done across sectors. The Army itself is certainly no stranger to overlaying various data points onto spatial location data. There is, however, a critical gap in our inability to embed dynamism and real-time changes into these processes.[39] To address this, we can look to advancements in computing power and artificial intelligence, which will increase the speed at which data can be aggregated, analyzed, and modelled, making a meaningful difference in our ability to integrate real-time information into usable data sets.

Looking towards the data collection side, the increasing ubiquity of sensors integrated into urban infrastructure will offer an ever-growing range and number of inputs. However, when cities themselves cannot collect information on traffic and population flows, due to a lack of smart city infrastructure or damage from natural or man-made disasters, the Army will need to look to its own data collection capabilities. These capabilities are already substantial: the Army fields a range of aircraft, aerostats, and ground vehicles with integrated sensor arrays capable of collecting video, imaging, infrared, and other data. These techniques - understandably - tend to be focused on identifying and tracking specific adversaries, but much of the data they collect could

[36] Davis et al. (2013).
[37] Google (2018).
[38] O'Beirne (2017); Louail et al. (2014).
[39] Konaev and Kadercan (2018).

plausibly be adapted to help measure large-scale flows throughout cities as well.[40] For instance, synthetic aperture radar (SAR) and video data from the Airborne Reconnaissance Low Multifunction payload, which is already being collected to track specific vehicles, could be also be used as an input for an algorithm that counts the number of cars and people moving through major intersections at different times of day, to help build a model of the city that could be used to assess the effects of measures to control the population's movement. If these data sources do not have sufficient resolution, the Army might consider employing a distributed network of small sensors like Expendable Unattended Ground Sensor, but built to track overall flows of people around it instead of detecting and alerting Soldiers to any nearby footsteps.[41]

Furthermore, we can expect to see advancements in surveillance and imaging technology that will allow the Army to collect more data more easily. For example, the development of low-cost, miniaturized optical and LiDAR sensors, such as those in DARPA's MOABB program, will help pave the way for the development of surveillance miniature drone swarms, which could offer persistent ISR capabilities in places where typical aerial ISR platforms are difficult to operate.[42] In addition, the increased availability and resolution of optical and SAR-based satellite imagery (from both US government and private sources) may be even more crucial for data collection in spaces where the Army is denied easy access or which are simply too large for thorough ground-based intelligence collection.[43]

On the vanguard of modeling population flows and population responses to various exogenous stimuli, Virginia Tech's Network Dynamics and Simulation Sciences Lab has had great success in modelling phenomena as varied as the spread of Ebola, responses to a nuclear explosion, and the spread of civil unrest using synthetic populations derived by combining general census data from the population in a given area with more specific data from a small subset of the same population. This type of modeling is especially useful because it allows one to generate reasonably good aggregate data models without a large amount of individual-level data, which is rarely available.[44]

5.2 HOW DOES A CITY'S POPULATION OR SUBSET OF A POPULATION PERCEIVE A GIVEN ENTITY OR EVENT?

5.2.1 WHY?

Measuring people's perceptions remains one of the most critical yet most difficult components of evaluating any operating environment for a population-centric mission. In COIN and stabiliza-

[40] PEO IEWS (2018).
[41] PEO IEWS (2018).
[42] Mix (2017).
[43] Capella Space (2018); Dillow (2013).
[44] Marathe and Swarup (2018).

tion missions, it is of the utmost importance to ascertain how the population views various actors, whether they be the Army, the insurgents, or the local government, as well as how these perceptions change over time as the mission continues. One can easily imagine the utility of being able to accurately gauge perceptions within a fairly small geographic area on a day-to-day basis so as to measure change in popularity of the Army or of a governing body being empowered by the US as a function of various actions taken.

Furthermore, in both HA/DR and stabilization operations, understanding how the Army is perceived by local populations can help a commander determine how best to deliver information and assistance. During the military's response to the Ebola epidemic in West Africa, for example, sizable swathes of the population believed that the disease was either a form of witchcraft or a Western-backed population-control strategy, hindering the military's ability to convey information or encourage compliance with medical procedures.[45] A deep understanding of perceptions can further lead to an understanding of who or what constitutes a trusted source for the target population, which can inform information operations and ensure that critical information is being effectively communicated.

5.2.2 HOW?

While social media data is far from perfect–recent events have demonstrated the extent to which bots and "fake news" can infect such data sets, a trend which is likely to continue and worsen over time–analyzing trending topics and the ways in which people are discussing them on social media platforms is still an effective way to take the pulse of a given area.[46] Moreover, advances in data science have already started offering ways to automate and scale up this type of analysis, by using sentiment analysis and other natural language processing algorithms to detect how social media posters feel about the topics they discuss. These algorithms have made impressive advances in recent years; deep learning-based techniques such as Word2Vec are able to learn the relationships between words from the text itself, without external training data, and sentiment analysis has been shown to be useful for recognizing emotions, detecting sarcasm, and other applications.[47] In addition, text-based techniques are already useful for forecasting political and judicial outcomes: for example, they have significantly improved predictions of U.S. Supreme Court case outcomes.[48] The current ability of these algorithms to understand complex human attitudes is admittedly limited, but it is reasonable to assume that it will improve over the next two decades - assuming that it becomes possible to reliably detect fake and misleading social media data.[49]

[45] Cmdr Benjamin Espinosa at Various (MDB in Megacities) (2018).
[46] Nutter (2018).
[47] Zhang et al. (2018).
[48] Kaufman et al. (2018).
[49] Frank (2018).

However effective sentiment analysis eventually becomes, human processing of local news sources will always be an important complement to it. To return to the example of the West African Ebola outbreak, a simple search of "#Ebola" on Twitter or Facebook would more than likely have turned up the range of theories being thrown around–even a major Liberian newspaper published an article alleging that Ebola was a US engineered bioweapon designed for population control purposes.[50] In cities where lack of internet connectivity or nearly complete collapse of everyday life prevents the collection of this kind of data, analysis of similar historical data can still shed light on how a given population is likely to respond to certain kinds of actors.

In the case of COIN operations, it is equally important to monitor how insurgents and people sympathetic to their goals are using social media and the ways in which they are portraying or discussing the Army in their own publications, as this can add additional context in determining local perceptions.[51]

Despite the increasing availability of opinion data coming from social media platforms, almost everyone interviewed for this project–from social scientists to resiliency planners to beat cops to the former mayor of Philadelphia–continuously stressed the fact that technology will only get you so far.[52] There is no sensor that can take the place of face-to-face interactions and personally walking the streets to truly understand the character of the city and the perceptions of the people. That said, the Army tends to prefer quick operations that limit the time available to build personal relationships necessary to grasp a city's intricacies. Learning how to make the most of technological substitutes is the least worst way forward.

There are, however, ways in which technological advances can increase soldiers' capabilities during the limited time they have to walk through the streets, having those face-to-face interactions. Over the next couple of decades, we can expect to see rapid advancement in wearable translation technology, which would allow soldiers on the ground to have substantive conversations with a wider variety of people, although optimism on this front should be partially tempered by the fact that speaking the local language will not automatically make the speaker a trusted agent in a given location.[53]

The idea that "every soldier is now a sensor" has already permeated military thinking–the next step is ensuring that the right kind of data is being collected by those soldier-sensors, and that it is being fed to a central location where it can be appropriately aggregated and analyzed to inform a broader situational awareness. Increased computer processing speeds and artificial intelligence will allow units to better analyze the incoming data, as will bureaucratic innovations to overcome barriers to information sharing.

[50] Feuer (2014).
[51] Isobe (2018).
[52] Various (Capstone Workshop) (2018); Wilson (2018); Nutter (2018); Konaev (2018).
[53] Heater (2018).

Furthermore, face-to-face interaction was continuously raised by interviewees as one of the only ways of evaluating perceptions in areas chronically underserved or otherwise marginalized, where people may be less likely to have regular access to the internet, less likely to have social media profiles, or less likely to respond to metrics like surveys.[54] This not only points to a specific difficulty that both scholars and practitioners continue to face in learning about cities, but also to the broader point that attempts to learn about people and their perceptions of the world solely via tech-enabled platforms will always be vulnerable to significant data gaps–whether by missing swathes of the population not represented on the platforms in question, or by leaving you stranded in the event of a catastrophic event that wipes out those same platforms.

5.3 WHAT ARE THE MAJOR SOCIAL GROUPS WITHIN A CITY AND HOW DO THEY INTERACT? HOW DO SOCIAL DIVIDES MANIFEST IN THE CITY'S GEOGRAPHY?

5.3.1 WHY?

As explained by RAND Corporation information scientist Dr. Aaron Frank, any given city is really a collection of lots of little cities–it's impossible to understand the whole without understanding its component parts and their interactions with each other.[55]

There are a variety of reasons why being able to learn about neighborhood-sized microcosms of a city from a social perspective could be important to urban military operations. Within the context of a COIN or stabilization operation, for example, tensions, or popular support for a given entity or belligerent, can often fall along the lines of a given social divide within the city, whether economic, ethnic, racial, religious, or otherwise.

It is important to note here that identifying distinct religious, ethnic, racial, or economic groups does not automatically imply religious, ethnic, racial, or economic tensions–even if tensions exist between the exact same groups elsewhere. Relationships between social groups is highly context-dependent and is likely to change over time. As one example, a 2004 article by political scientist Daniel Posner looked at why the Chewa and Tumbuka peoples were adversaries in Malawi and allies in Zambia, directly across the border, concluding that the political salience of this cultural cleavage was entirely dependent on exogenous, national political factors, not an inherent mutual hatred.[56]

As another example, we can look to the contentious relationship between Shi'a and Sunni in today's Iraq–while this sectarian divide formed the backbone of the post-2003 insurgency, there

[54] Wilson (2018).
[55] Various (Capstone Workshop) (2018).
[56] Posner (2004).

was a time not long before the invasion when the sects lived together peacefully, and almost a third of marriages were inter-sect. Much of the sectarian tension in Iraq in the years leading up to the 2003 US invasion were the product of Saddam Hussein's weaponization of sectarian identity during the 1980-88 Iran-Iraq War.[57]

Understanding the historical and political context of social schisms in a society is important because it can inform the way outside forces respond to the tensions that they see on the ground. On a policy level, a strong understanding of the modern history of sectarianism in Iraq might have prevented the Coalition Provisional Authority from employing the disastrous de-Baathification policy, or creating a post-war government that entrenched sectarian identity over Iraqi identity.[58] In a COIN or stabilization operation where populations represent the true center of gravity, the tactical often has strategic implications, meaning that at least a basic understanding of these dynamics is important for an Army Commander as well. It has been argued, for example, that putting up walls in Baghdad separating sectarian enclaves from each other played a role in codifying the political significance of sectarian identity in post-war Iraq and damaged prospects of reconciliation, despite their tactical success.[59]

Once the military or the policy community has isolated and understood the relevant social divides in a city, however, being able to understand how that manifests spatially within the landscape of the city is critical to understanding how best to allocate resources. As stated by Dr. Russell W. Glenn during a recent conference on Multi-Domain Battle in Megacities, "Chances are you're only going to be able to put forces in a small part of the urban environment."[60] Being able to identify which physical areas correspond with concentrations of the population that a commander is interested in influencing can help determine where to send forces.

5.3.2 HOW?

The most basic method for visualizing these spatial distributions of social groups is via census data. A 2011 New York Times article published an interactive map on the city's "ethnic mosaic," using census data to visually represent ethnic enclaves throughout the city.[61] While census data is simplistic and can vary in accuracy between countries, it can still be a helpful tool for baseline analyses.

There is a plethora of additional relevant data that can be geographically represented as well. In 2011, Eric Fischer–former Google employee and "self-described 'map geek,'" created a map of the world's languages by geographically representing where people were posting to Twitter in

[57] Al-Gharbi (2014).
[58] Al-Ali (2014).
[59] Damluji (2010).
[60] Various (MDB in Megacities) (2018).
[61] Fessenden and Roberts (2011).

which languages.[62] Inspired by this, Ed Manley created a similar map for London during the summer of 2012.[63]

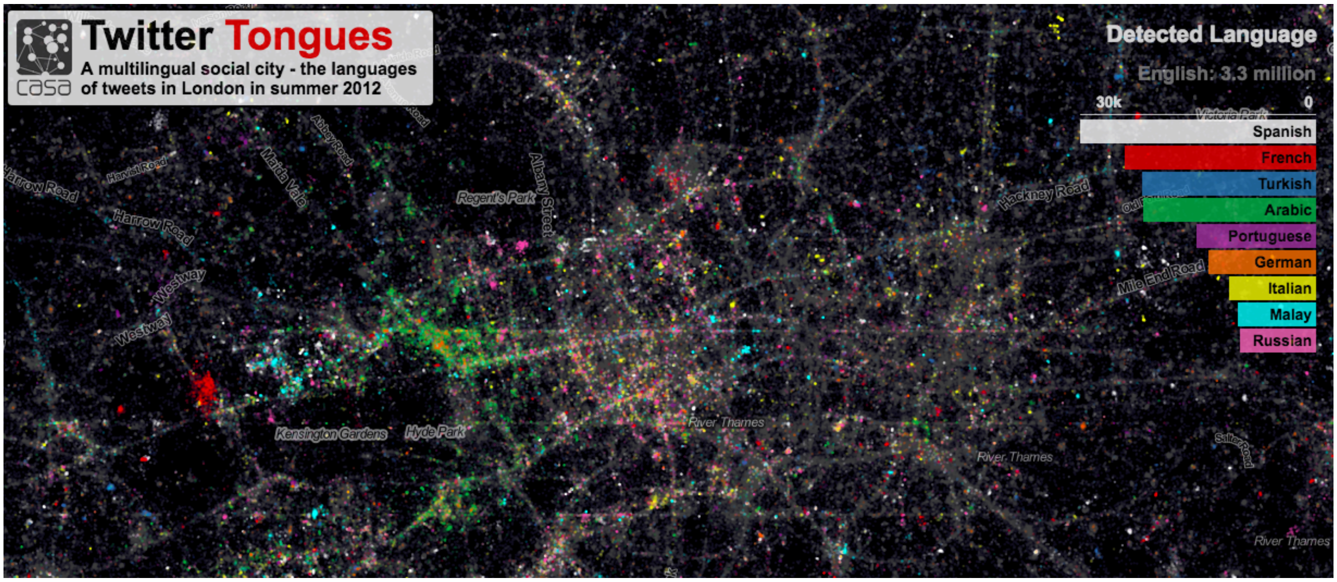

FIGURE 3: A map of the languages of tweets in London.[64]

A group of Norwegian researchers using mobile phone data to study segregation between ethnic groups–particularly looking at recent immigrant populations–used data on what countries individuals called the most as a proxy for that person's ethnicity.[65] While imperfect, this approach is particularly compelling because it allows researchers to use incredibly rich mobile phone location data, which is generally difficult to use for identity-based research as it is all anonymized and does not directly indicate ethnicity, race, gender, or age.

In addition to understanding the basic geographic breakdowns of different groups, we want to understand the interactions within and between these groups. Network analysis presents another promising methodology to tackle these questions.

Broadly, network analysis works with data that describes relationships - including, for instance, familial connections, economic links, or membership in organizations - between nodes, which can be people, institutions, neighborhoods, etc. Once the network has been built, an analyst can easily extract information about clustering, density, and the centrality or connectedness of particular nodes[66].

Dr. Frank suggested that, if it were possible to build a comprehensive set of network datasets with information about all of these types of relationships between people and groups in a city,

[62] Grandoni (2011).
[63] Spatial.ly (2012).
[64] Spatial.ly (2012).
[65] Bjelland et al. (2015).
[66] Knoke and Yang (2008).

then clustering algorithms such as stochastic block models could be very powerful in helping an analyst understand the city. With such data, he suggested, it might be possible to understand the structure of organizations (for instance, are they decentralized webs or hierarchical patron-client groups?) and to make inferences about how people within those organizations might act in response to the Army's actions. For example, an analyst might be able to recognize that what appeared to be one unified group that was hostile to the Army really had several factions with minimal links between them, creating an opportunity to split the group and weaken it; or that a group thought to be similar to another that the US knew and understood was organized in such a different way that it might be expected to respond very differently to a shock. This method is not without challenges: in particular, building a truly comprehensive network dataset of this type would be very challenging, even with unfettered access to social media, consumer, and cell phone data.[67] However, with increasing amounts of data available, building such a model for at least some types of relationships (i.e. social connections derived from cell phone metadata) is already plausible.[68] In addition, if only a small part of the population is truly of interest, but its actions are shaped by a larger population around it, analysts may be able to collect additional data on that subpopulation and then embed this network in a larger, less-detailed network created using a method such as a synthetic population. [69]

There is further work being done that specifically looks to measure issues like prejudice and segregation. Facebook and other social media sites have implemented algorithms set to detect hate speech over the past few years, and University of Rochester researchers published a paper last year on their study detecting hate speech that has been coded specifically to circumvent these algorithms.[70]

5.4 WHAT MATERIAL GOODS AND ESSENTIAL SERVICES DO PEOPLE NEED?

5.4.1 WHY?

In both HA/DR operations and COIN or stabilization operations where the population is the center of gravity, it is critical to be able to determine who needs what where. As one example, the rising death toll in Puerto Rico in the aftermath of Hurricane Maria has made it increasingly clear that individuals with chronic conditions have been the most severely affected.[71] While this is hardly a surprising fact, it points to the importance of being able to determine where those in the most

[67] Frank (2018).
[68] Cook (2017); Healy (2013).
[69] Marathe and Swarup (2018).
[70] Magu et al. (2017).
[71] Dr. Sheri Fink at Various (MDB in Megacities) (2018).

dire need are located, and what they need. In COIN and stabilization operations where the military needs to build support for either US presence or for a given entity in the local government, the Army likewise needs to understand what goods or services are essential to the population so that it can prioritize the actions that will yield the greatest degree of goodwill.

5.4.2 HOW?

The advent of social media and proliferation of internet-enabled mobile phones have sparked a new a wave of interest in ways to utilize social media data for emergency management and disaster response purposes. Citizens' use of social media during Hurricane Harvey provided a direct example of this, with numerous examples of desperate people posting their location on social media instead of enduring indefinite wait times on 911. Many of these cries for help were responded to by local good Samaritans and civilian volunteers, but others–like a Tweet from a nursing home in Dickinson, Texas–went viral and were able to be quickly addressed by first responders.[72]

With the ever-increasing ubiquity of internet-enabled cell phones–the number of mobile internet users is expected to rise to 5 billion by 2025–there are opportunities to introduce an app that would allow people to request help or record damages, either through a separate system or by tapping into their social media accounts.[73] This would allow people to circumvent the overtaxed 911 system while facilitating immediate data centralization that would make the information actionable for first responders–in this case, the Army.

A version of this idea has been put into practice by the Urban Risk Map project at MIT's Urban Risk Lab, which crowd-sources information on changing conditions in a given city during extreme weather events or natural disasters by linking with residents' Twitter accounts and syncing with existing city-operated sensor information. This information is then overlaid onto a live map that residents can use to navigate the city–the map can even be temporarily integrated into the Uber app to assist drivers in finding the most efficient routes. It has been successfully used in both Jakarta, Indonesia and Chennai, India during recent high-intensity rain events, and presents a very promising model for future development and implementation.[74]

Data from mobile phone apps can be a useful way of learning about population needs outside of HA/DR operations as well. In Philadelphia, for example, the introduction of a 311 system with an associated mobile phone application allowed the city to gather rapid, real-time data about the implementation of service delivery and the varying needs of constituents. In discussing the utility of the application, Michael Nutter, who was serving as Mayor of Philadelphia during this program's roll-out, cited the example of knowing that if a significant volume of messages from the same gen-

[72] Rhodan (2017).
[73] GSMA (2018).
[74] MIT Urban Risk Lab (2018).

eral location are coming in through the app or the phone system complaining about snow, you then know where to send the snow plows next–or at least you know to send some kind of message to that neighborhood telling them when to expect the plows.[75] Having this kind of feedback from a population as to what services they need and when they get them can be useful in both HA/DR and COIN/stabilization operations in a couple of ways: First, it serves as an implicit monitoring tool–if you see that people are having trouble with snow, dispatch snow plows, and see no improvement in people's difficulties with the snow the next day, that may indicate a problem with delivery. Second, it allows the population to indicate what services are important to them. If a crucial component of the Army's COIN mission is to build support for the local city government, then knowing that a critical mass of people in Neighborhood X have noted that lack of garbage collection is a problem can allow the Army to assist the city government in clearing garbage from that area and increase public support for the government.

Data on the price of goods–which can be crowdsourced–can point to spikes in demand for a given product, providing additional insights into what is needed in a given area and informing planning of both HA/DR and COIN/stabilization missions. Monitoring sharp changes or worrisome trends in this data over time can also provide early warning signs of economic distress and potential instability, which is crucial across the spectrum of operations. If a significant proportion of economic transactions in the city are digitized, or flow through a relatively small number of businesses or banks that are willing to share data, it may also be possible to collect data on sales and prices directly from these sources. Such a strategy would likely run into significant issues with data access, but it could work in cases where the Army is able to set up strong relationships with the right economic intermediaries.

The primary challenge with the above methodologies is their reliance on an internet connection, which should certainly not be taken as a given in the aftermath of a disaster–natural or man-made–or in a city where our adversaries have sufficient control over the infrastructure to shut down the internet.

There are, however, a few technological trends in resilient or "to-go" internet capabilities that would mitigate this risk. In the aftermath of Hurricane Sandy, New America Foundation's Resilient Communities Program launched a Resilient Networks NYC initiative, which has worked to build "community-owned mesh networks" in areas most vulnerable to storm surge. These networks "provide community-maintained, cooperatively owned critical infrastructure," thereby delivering telecommunications services able to withstand various shocks and stresses.[76] While there was concern expressed during our interviews that mesh network technology is not developing at the speed many had hoped, it is still a promising trend.[77] Furthermore, recognizing the difficulty in in-

[75] Nutter (2018).
[76] Byrum (2018).
[77] Marzi (2018).

stalling and maintaining these mesh networks, Resilient Networks NYC simultaneously developed "Portable Network Kits" (PNKs) that consist of a customizable "collection of easily configured, solar-powered wifi gear that allows you to create a hotspot–either standalone or the first module of a larger community network"–and is composed entirely of elements that can be found on Amazon.[78] In another segment of the portable internet universe, X Development's Project Loon and an Internet.org-Facebook partnership have both been working on ways to provide internet access from the sky via a network of balloons designed to travel along the edge of space and a combination of satellites and drones, respectively.[79]

FIGURE 4: A Portable Network Kit.[80]

There is also work being done that uses satellite imagery and machine learning techniques to estimate economic activity, using techniques that include counting cars at malls to predict retail success, measuring how full rooftop oil tanks are, and estimating outdoor storage of metals.[81] While these techniques are currently limited to working with relatively large and uniform objects, advances in the resolution of satellite imagery and in computer vision algorithms could allow these techniques to estimate economic flows in a more granular way.The Department of Defense certainly has the capability to reproduce what is being done by these companies, with its massive store of imagery data, and given the utility of monitoring economic activity in a given city before and during an engagement, it should seek to build on these techniques.

Independent of self-reported data on what people need and where they need it during and im-

[78] Byrum (2018).
[79] Robarts (2014); X Development, LLC (2018).
[80] Byrum (2018).
[81] Orbital Insight (2018).

mediately after a crisis, analysis of census data can provide insights into areas of the city with high concentrations of vulnerable people. The Center for Disease Control maintains a Social Vulnerability Index, which uses data from both the regular American census and the more specific American Community Survey to map out which census tracts are the most or least vulnerable given a range of social variables.[82] For example, a highly vulnerable neighborhood might be classified as such because of large percentages of elderly or disabled people, people living under the poverty line, people who don't speak a lot of English, people who don't have a vehicle, or people who live in structures with a high number of units (i.e., a densely populated area). Not only do mapping tools like these help focus responders' attention towards the most vulnerable populations, but they inform how assistance should be provided in those areas. As Dr. Sheri Fink indicated in her lecture at a recent conference, in areas with a high percentage of elderly or disabled people, you can't just drop supplies at the door–you have to physically go in and walk them upstairs. In areas with a high percentage of non-English speakers, you should send a translator.[83]

6 KEY INFORMATION REQUIREMENTS: STRUCTURAL

The questions in this section relate to a city's physical spaces, structures, and infrastructure. A deep understanding of these elements of the city is important to a wide spectrum of military operations. For instance:

- Issues with access and mobility are relevant to all types of operations, and are uniquely challenging in cities;
- Subterranean spaces, tall buildings, and dense, unofficial settlements pose particular challenges for mapping urban terrain;
- Understanding the status of infrastructure is crucial for delivering services in stability operations and/or HA/DR missions.

Development and proliferation of smart city technology over the next 10-20 years will enhance our ability to collect and analyze data in real time in response to shocks to urban systems.[84] It is important to note, however, that the smart city sensors and data required to achieve these gains may not be present in all of the cities where the Army operates; therefore, this section focuses on solutions that the Army could plausibly deploy into cities with limited existing data collection and communications infrastructure.

[82] Agency for Toxic Substances & Disease Registry (2016).
[83] Various (MDB in Megacities) (2018).
[84] Newcomb (2014).

6.1 WHAT IS THE STATUS OF THE CITY'S INFRASTRUCTURE?

6.1.1 WHY?

Having functional city infrastructure - and knowing when and where it is not functional - is important to the Army for several reasons. First, it is clearly a central concern in HA/DR operations: the Army needs to know where damage has been done and which essential services have been suspended for parts of the population in order to know where it needs to direct its recovery efforts. Similarly, in stability operations, knowledge of the status of infrastructure may be valuable for directing "hearts and minds"-oriented service delivery efforts.

In higher-intensity conflict, the Army will want to know when and where infrastructure has been damaged by its adversaries or by the army itself.

Finally, the Army has a strong interest in detailed knowledge of the condition of roads and bridges to assess access and mobility, especially when these conditions are changing rapidly due to a natural disaster or violent conflict. This topic will be dealt with in greater detail below.

None of these reasons listed above are likely to be news to Army commanders who have spent years engaged in urban counterinsurgency, but the distributed sensor networks of smart cities may make it possible to collect more accurate information more rapidly and with less manpower.

6.1.2 HOW?

The methods used to monitor infrastructure vary, but one instructive example is assessing damage to bridges. Traditionally, structural health monitoring of bridges was done using manual sensors and displays installed on bridges and checked intermittently by technicians.[85] More recently, some of these systems have been replaced with units that could wirelessly transmit information, allowing for constant monitoring without manual inspection.[86] However, such technology may not be present in many of the environments where the Army operates, or it may not be functioning after violent conflict or a natural disaster. Fortunately, remote sensing technologies for monitoring bridge health are now becoming available, which may allow the Army to collect and process information even in environments with minimal existing structural monitoring capacity.[87]

These remote sensing techniques include close-in techniques such as photogrammetry and LiDAR, which both can be used to produce 3D point clouds of the bridge surface using sensors mounted on vehicles, as well as very long-range techniques, such as synthetic aperture radar and multispectral imagery from satellites. These remote techniques - especially those using satellite data collection - all currently have limitations on the resolution of the images they produce, but

[85] Federal Highway Administration (2014).
[86] Federal Highway Administration (2014).
[87] Liu et al. (2017); Ahlborn et al. (2013); Phares et al. (2013).

improvements in space-based sensing over the next twenty years, as well as the higher resolution of satellite imagery available to military users, should make these techniques viable. In addition, some of these techniques take a significant amount of time on-site to collect and process the data (for instance, producing ultra-high-resolution panorama of bridges can take several hours), which reduces the value of such techniques, especially in combat environments. Advances in computing power should reduce these time requirements to some extent, but they still suggest that satellite and aerial imagery may be the most appropriate remote sensing methods when there are significant force protection concerns.[88]

Other promising infrastructure monitoring technologies cover water systems, gas distribution and storage, and electrical power. In some cases, such as intelligent power distribution systems, these sensors must be installed in distribution systems by utility companies, making it impractical for the Army to deploy them into a city if they are not already present.[89] Although costs for these technologies are already dropping rapidly, their adoption is currently limited even in wealthy countries such as the United States, and it would be unreasonable to expect that they would be present in all of the cities where the Army is most likely to find itself operating.[90]

However, some types of distributed sensor networks can be built from the bottom up instead, and these may see faster adoption or be easier to rapidly build once the Army is operating in a city. Bottom-up networks may be as simple as the people of the city reporting infrastructure issues to their government with a phone call or a mobile app, and the city combining this information into an easily-accessible database; these platforms are already in place in many cities around the world, and they will likely continue to spread (Forbes; Socrata/NYC; Nutter interview).[91] In the future, these networks may be augmented by data from IoT devices in people's homes, such as smart gas and smoke alarms.[92] These devices, again, have seen limited adoption so far even in wealthy countries, but if they become cheap enough, this could change - although securing access to data from many different devices produced by a variety of private companies could be challenging. In addition, in cities with sufficient communications infrastructure, such devices might be faster and easier for the Army to distribute throughout the city than centralized monitoring solutions that require comprehensive updates to power, water, and gas systems.

6.2 WHAT ARE THE ACCESS AND MOBILITY CONDITIONS IN THE CITY?

[88] Ahlborn et al. (2013).
[89] Smartgrid.gov (a); Sensus (2018).
[90] Smartgrid.gov (b); Tomas (2017).
[91] Brown (2017); Nutter (2018); NYC Open Data (2018).
[92] Saeed et al. (2018); Talari et al. (2017).

6.2.1 WHY?

Moving rapidly and safely through dense urban environments is an important challenge for the Army, as discussed above. For example, ground vehicles may find it difficult to operate on narrow, winding streets and roads and bridges may not be able to safely support their weight, while rotary-wing assets may have their access impeded by tall buildings and a lack of clear, flat ground. In cities where the United States has a long lead time before an operation and has a strong relationship with local authorities, it may be possible to gather a great deal of data ahead of time and to make plans and deploy assets well-suited to the city in question. However, in cities where the Army is less prepared to operate, where even the local authorities have limited knowledge or control of the mobility conditions in the city, or where the city has suffered significant physical damage from violent conflict or a natural disaster, the ability to rapidly collect and analyze data on access and mobility could be extremely valuable. Coming advances in technology may be able to help the Army confront this challenge.

FIGURE 5: Marines conducting a mounted/dismounted patrol in the narrow streets of Port-au-Prince during US operations in 2004.[93]

In addition, advances in autonomous and remotely controlled systems may make it possible to

[93] Kaye (2004)

reduce the number of human-crewed vehicles needed, paving the way for smaller, more nimble vehicles that can navigate narrow urban streets.

6.2.2 HOW?

Much of the answer to this question is covered in the previous question: there is a wide array of sensing techniques available for assessing the condition of bridges and roads. While the techniques that would be the easiest to deploy in a city with minimal "smart" capacity are not fully mature, they will likely improve over the next ten to twenty years.[94] In addition to being used to assess the condition of transportation infrastructure, technologies such as photogrammetry and LiDAR can be paired with machine learning algorithms to build 3D models of cities along roads - like those already available for many cities in Google Street View - to help the Army assess which streets are wide and clear enough to use.[95] Depending on the city, this data may well already exist, although getting access to it could be challenging. If such data does not exist, the Army could collect it, but comprehensive Street-View style mapping could be very time-consuming and difficult, especially in hostile environments. Fortunately, the Army already fields LiDAR sensors as part of packages like ARL-M, and imagery sensors as part of many others.[96] In the future, these sensors could plausibly be placed on the unmanned ground systems that the Army is already developing to carry soldiers' loads and provide enhanced situational awareness, especially if advances in the relevant technology allow for miniaturization, acceptable resolution at higher movement speeds, and better tolerance for large numbers of moving objects in the environment.[97]

Alongside the technologies discussed above, there are numerous sensors available for tracking road traffic that could be useful to the Army in navigating cities. Some are static pieces of centrally-managed sensor networks, such as red light cameras, license plate cameras at tolls, and in-road sensors.[99] These sources can offer easily-accessible data to the Army if it is working in close cooperation with civil authorities, but it may not be available in all cities. On the other hand, mobile phone location data may be more difficult to access in some cases, as it is typically not publicly owned, but it is already used in products such as Google Maps to provide real-time traffic information[100]. The usefulness of this data depends on relatively high levels of smartphone ownership, which may not always be present, but with high and growing mobile phone penetration even in some of the world's poorest countries, it will only become more valuable. (In 2017, for instance,

[94] Ahlborn et al. (2013).
[95] Babahajiani et al. (2017).
[96] PEO IEWS (2018).
[97] U.S. Army TRADOC (2017); DARPA (2018); Ahlborn et al. (2013).
[98] AerotecUSA (2018)
[99] Connectivity (2018); Wang Ph D et al. (2012).
[100] Stenovec (2015).

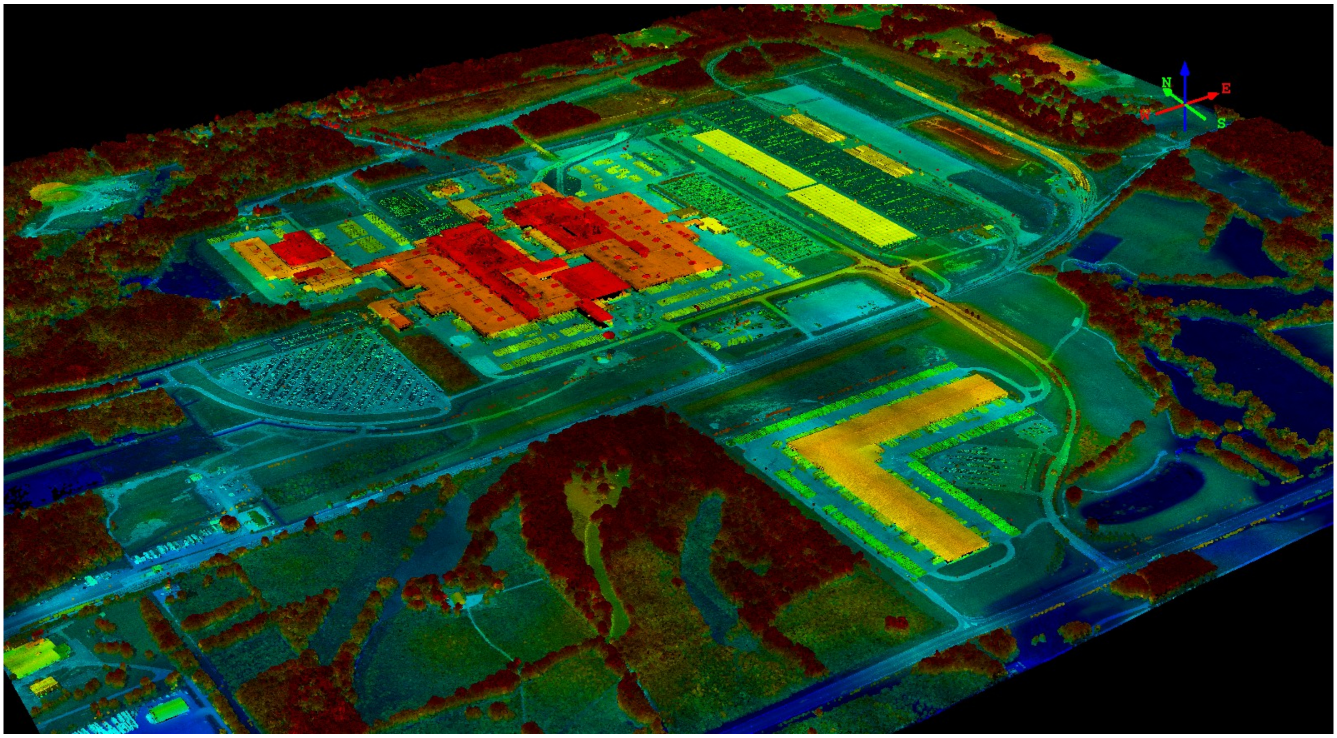

FIGURE 6: A 3D model built using LiDAR.[98]

Africa had 995 million mobile phone subscriptions, amounting to 81% of the continent's population, although many of those subscriptions were not for smartphones.[101])

6.3 HOW CAN THE ARMY MAP DIFFICULT-TO-ACCESS SPACES?

6.3.1 WHY?

Large cities include high concentrations of complex, dynamic, poorly-mapped spaces, which pose particular challenges to situational awareness. Subterranean spaces are perhaps the most challenging of these types of spaces, but slums and skyscrapers also pose significant challenges.

This knowledge is important across the spectrum of Army operations. In an HA/DR mission, for instance, being able to rapidly map subterranean systems - which may have changed significantly as a result of the disaster - may be crucial for rescuing survivors and restoring services. In a kinetic operation, on the other hand, the Army would need thorough knowledge of these spaces in order to deny access to adversaries and operate in them at an acceptable level of risk.

Once again, while the Army appears to be well aware of these challenges, there may be ways to use emerging technologies that have not yet made their way into the Army's arsenal.

[101] We Are Social (2017).

6.3.2 HOW?

In recent years, several efforts have emerged aimed at mapping the underground spaces of major cities, which may prove useful to the Army if such data is available for cities where it operates. However, building such maps from scratch during operations in a large city appears less plausible.

These efforts have faced challenges both in acquiring data and in combining different sources of data into comprehensive maps. On the data acquisition front, for instance, geophysical methods can offer a low-cost way to map spaces about which there is little existing information, but different types of soil and underground infrastructure require different methods; experts therefore recommend a mix of ground-penetrating radar, shallow seismic, EM mapping, and other methods. This mix can complicate and lengthen the data collection process.[102] However, the UK's "Mapping the Underworld" program is currently developing a mobile, multi-sensor device that will combine several sensing technologies. This data is then combined with (often imprecise) administrative data on infrastructure location, using Bayesian statistical methods made possible by recent improvements in computing power, to infer the most likely positions of underground utilities.[103]These developments could make such mapping during military operations somewhat more plausible.

Data fusion can also be challenging for both technological and institutional reasons. In the aftermath of 9/11, for instance, plans to integrate data on underground utility infrastructure in New York City acquired new urgency, but the project still stalled thanks to security concerns on the part of utility companies.[104] New standards for geospatial data integration from the Open Geospatial Consortium have already been useful in providing a technical framework for data fusion, but they can do little in the face of institutional intransigence[105].

Mapping slums presents a different challenge: instead of integrating data from advanced sensors, authorities must collect information from residents of informal settlements, who may not trust the local government (much less the US Army) or have the means to provide GIS information even if they do. However, there are several NGO initiatives in place aimed at crowdsourcing maps of slums, enlisting residents to contribute information about roads, buildings, and businesses to platforms such as OpenStreetMaps.[106] The Army could plausibly use similar strategies to map informal settlements, or perhaps work with the State Department to do so through NGO partners. If such a strategy proved impractical in a given case, mobile phone location data paired with machine learning algorithms may be helpful for inferring the structure of slums without explicit local

[102] Rashed and Atef (2015); Boulanger (2018).
[103] Bilal et al. (2018); Mapping the Underworld (2018).
[104] Milner (2017).
[105] Boulanger (2018); Open Geospatial Consortium (2018).
[106] Blakemore (2016).

knowledge.[107]

7 KEY INFORMATION REQUIREMENTS: NATURAL

This section covers a wide array of natural factors which affect cities and urban operations ranging from topology to climate to weather and seasonal cycles. These elements are worth Army commander's attention in urban operations primarily because geographical or topological features of a city influence how the city is formed, how the city manages harmful natural phenomena, and, in turn, how the Army should operate in the urban area. The assessment of these natural factors is an important key to various kinds of operations. For instance:

- Understanding long-term climate trends affecting urban cities give the Army hints to make better predictions on where social unrest will be observable and where future operations will take place;
- Evaluating seasonal cycles or weather patterns of an urban area helps the Army see what the area of operation will look like and what kinds of limitations it will face;
- Assessing the effects of long- and short-term climate change on a city offers a window into the foundational resource management issues the city is likely to face.

Even though the Army has considered geography and weather conditions as crucial elements to be assessed in operation planning, there are several factors missing from commanders' considerations which are crucial in urban operations. These natural factors affect city layouts, emergency response procedures of civil institutions, and human behaviors on the ground. Fortunately, the combination of existing and emerging technologies will help the Army fill in the gaps and enhance its situational awareness.

7.1 WHAT DO CLIMATE, WEATHER, AND GEOGRAPHY OF THE REGION LOOK LIKE?

7.1.1 WHY?

Understanding both long- and short-term natural trends is key to preparedness of the Army for future urban operations. In the long term, it helps the Army make educated guesses on where it is likely to operate. The rise of sea level driven by global warming will render some countries with low elevation, such as the Netherlands, more vulnerable to water hazard and require Army

[107] O'Beirne (2017).

deployment for HA/DR operations. As for stabilization operations, desertification will decrease arable land on the Earth and increase a number of "climate refugees," creating social disorder which makes it easier for terrorist groups or local powers to commit illegal activities.[108]

Another reason why long-term climate matters in Army operations is that it will provide each combatant command with a better picture of what kinds of threat the commanders will face and what kind of capability they have to develop beforehand, which vary depending on the region for which they are responsible. For example, while Pacific Command needs to be wary of recurrent earthquakes and tsunamis due to tectonic plates weaving around the Indo-Pacific region, Africa Command has to pay attention more to drought and desertification because of the hot and dry climate in the African continent.[109]

Short term environmental concerns, which include weather patterns and seasonal cycles often drive tactical decisions. If an earthquake hits a city in a rainy season, there will be more likelihood that loose ground will trigger landslides or damaged infrastructure will cause flooding.[110] Throughout the long-lasting war in Afghanistan, the Army has observed that the seasonal cycles affected the battle cycle of Afghan insurgents; the arrival of spring brings a considerable increase in insurgent violence due to improved weather conditions and the end of opium poppy production. Geography also plays a crucial role in executing military operations.[111] The topographic bowl in which Kabul sits keeps a thick layer of smog in the city and significantly reduces visibility for aviation operations within the city.

7.1.2 HOW?

One of the tools that will help the Army understand long-term climates in each region is climate modeling. Climate modeling is a quantitative method to predict future climate trends and interactions between different weather variables, such as atmosphere, oceans, and land surface, that determine climates. The International Panel on Climate Change (IPCC), a scientific research body backed by the United Nations, provides a dataset of temperature, precipitation, and cloud distribution and creates visual maps based on these data.[112] Since long-term environmental concerns have an impact at the strategic level rather than at the operational or tactical level, there is less necessity for the Army to have its own climate modeling system. At least, however, the Army needs to be aware of who has the dataset and be capable of integrating it into strategic planning.

Some methods for measuring short-term climate factors overlap with what we have discussed in the previous chapters. Climate modeling will be useful for understanding short-term weather

[108] Smith (2012).
[109] Moroney (2013); Smith (2012).
[110] Mahr and Sharma (2015).
[111] Koven (2017).
[112] Intergovernmental Panel on Climate Change (2018).

conditions or seasonal cycles in a specific area where the Army is expected to operate. Cameras or sensor arrays installed in a city will indicate how local populations respond to weather events. Even if a city where the Army operates does not have such monitoring devices, remote sensing technologies will help collecting climatological data necessary for the conduct of operations.

As for topographical or geographical mapping in an urban area, the Army can rely on existing technologies. The Army has a robust mapping capability, supported by the National Geospatial-Intelligence Agency, to draw on in understanding the geography in the area of operation. Although these visual materials are sometimes insufficiently detailed for operational or tactical use, technological improvements to sensing devices in the next decade will upgrade the information gathering systems in terms of accuracy and granularity.

7.2 HOW DO CLIMATOLOGICAL AND GEOGRAPHICAL FACTORS AFFECT CITIES AND THE CONDUCT OF MILITARY OPERATIONS?

7.2.1 WHY?

In addition to tracking long-term climate change and seasonal cycles themselves, the Army will want to be able to draw conclusions about how people will respond to changing conditions. Drought or harsh weather conditions, for example, usually lead to food insecurity and increased tensions among people–a recipe for political instability. The rainy season, which periodically occurs in Southeast Asia and East Africa, loosens soil and makes muddy ground, which could limit the Army's vehicle maneuverability. These effects or limits brought by natural phenomena significantly affect decision-making of field commanders.

Furthermore, increasing our understanding of how local institutions measure and address climate effects is important also because it will be valuable and reliable source of information that the Army might be unable to collect by itself. Maj. Gen (Ret.) Isobe of the Japan Ground Self-Defense Force (JGSDF), based on his experience of commanding a Joint Task Force in HA/DR operation in Japan, points out that local governmental branches have sensors and surveillance systems on which rescue units can rely to increase situational awareness about how a natural disaster occurred and what is actually happening on the ground.[113]

7.2.2 HOW?

Social media will play a large role in generating data on human responses to climate events. In addition to traditional information gathering through monitoring devices, direct input from local people will be useful source of information to observe and measure climate-driven weather

[113] Isobe (2018).

events. In the 2011 flood in Thailand, about 40% of message exchanged through Twitter among Thais during the disaster was situational and location-based information telling the users which infrastructures became unusable and how higher water levels got in certain areas.[114]

A downside of collecting information through social media is that commanders or analysts might be overwhelmed by the excessive amount of information that they have to process and evaluate. There are already so many useful data points being generated by Internet of Things devices or sensors, which allow the Army, to a certain extent, to gain real-time view of what is happening on the ground. At the same time, however, there is also always a need for more computing power to take advantage of all collected information. Quantum computing technology will be a potential problem solver for the big data issue and help the Army streamline a massive amount of information gathered through different channels, including social media, sensors and mapping systems.

8 KEY INFORMATION REQUIREMENTS: INSTITUTIONAL

At the most macro level, understanding institutions is a vital component of understanding where power resides in the urban environment and how various power structures interact. Both formal and informal institutions make up the civic fabric of cities. While the formal is likely to be more visible and more easily mapped, many scholars argue that the informal is more important to understanding dense urban environments and the complex interdependence of the three previously-described factors.[115] Tracing formal and informal power–and, by extension, the points where the formal and the informal meet–is useful for establishing situational awareness prior to entering an urban environment, utilizing existing networks during disaster relief or combat, and rebuilding urban life post-disaster or conflict.

Often, the informal attributes of cities are seen as threats. They can be unpredictable in the way that they interact with the formal, and there is a rich body of research which highlights the complex interconnectivity of the informal as well as the risks of always equating "informal" with "enemy."[116] Jamison Medby, in a 2002 RAND report Street Smart: Intelligence Preparation of the Battlefield for Urban Operations (co-authored with Dr. Russell W. Glenn) introduced the "continuum of relative interests." Medby and Glenn advise that analyzing groups in the urban environment on a continuum is useful because limiting such groups to either "friendly," "neutral," or "enemy" categories can erase the role of factors like manipulation or interdependence.[117] The level of threat or utility posed by various groups can be considered along this continuum, and fights what

[114] Kongthon et al. (2012).
[115] Maj. John Spencer at Various (Capstone Workshop) (2018).
[116] Nordstrom (2004); Staniland (2012); Bdeir et al. (2017).
[117] Medby and Glenn (2002).

Major John Spencer has called a fallacy of the COIN mindset.[118] The assumption he refers to is that when carrying out stabilization missions, the population in question prefers the government in power rather than considering that governance at an informal level might be just as good–if not better–for the broader population, and preferences will vary from one subset of the urban environment to the next.

While the Army is aware that institutions are important, there is also recognition that the invisibility of many institutional nuances makes these factors especially complex to map and analyze without human intelligence. A deep understanding of these elements of the city is important to a wide spectrum of military operations. For instance:

- Understanding of community-level loyalties, power holding and sharing, and various forms of governance can help the Army to quickly and effectively distribute disaster relief responsibilities, identify local allies or adversaries, and assess communities' abilities to access or provide services during or after shocks;
- Quickly assessing capabilities of public, private, and non-state security forces and emergency response mechanisms is necessary when responding to urban shocks in order to minimize response gaps and maximize resource allocation.

Localized, cultural, and situational understandings based on such human intelligence should not be replaced, but there are certain technological resources that can enhance and expand upon those understandings. One important overarching point within institutional understandings in the future will be an acknowledgement that what the Army may know as "informal" and/or "ungoverned" are actually formal and/or governed; to understand them otherwise is simply to misunderstand the form they are taking.[119]

8.1 WHERE DOES POWER RESIDE IN THE URBAN ENVIRONMENT AND HOW DO FORMAL AND INFORMAL POWER STRUCTURES INTERACT?

8.1.1 WHY?

Questions of overt power and influence often seem clear, but in fact humans create deeply complex layers of power and control based on any number of personal, cultural, or political ties. Likewise, what may appear on the surface to be one comprehensive system is certain to have multiple subsystems nested within.[120] While the "formal" (e.g. state) institutions may stand at odds with

[118] Various (Capstone Workshop) (2018).
[119] Richard Plunz at Various (Capstone Workshop) (2018).
[120] Dr. Glenn at Various (MDB in Megacities) (2018).

the “informal” (e.g. non-state), often the two work symbiotically. The complexity of these systems’ relationships to one another can cause analysis to become bogged down in understandings of “legitimacy”; however, this report advises against the use of such a subjective term. Instead, mapping institutional features such as service provision can identify primary leaders and leading institutions in any given area of a city, whether or not that figure or institution has official, state-bestowed or internationally recognized power. Such an approach also allows for recognition that formal institutions often break down in emergency situations and should not be considered infallible.[121]

The Army’s ability to understand these power distributions is directly linked to its ability to predict political and social loyalties and therefore assess likelihood of allyship or hostility in an operating environment. Soldiers can maximize their efficiency in dealing with local allies if they know which power holders to communicate with in a given neighborhood. If a foreign, state actor–such as the US Army–enters an HA/DR or stabilization environment without understanding local governance at a variety of visible and invisible levels, it risks subverting local governance by completely taking over or misplacing responsibility on local structures that may be severely limited by conflict or disaster. Additionally–especially where informal structures are concerned–understanding who holds power and why is important when foreign actors are transitioning out of an area affected by an emergency. Because “institution building” is often such an integral part of foreign-led or aided post-emergency reconstruction projects, intervening forces like the US Army should be especially wary of instituting new leadership or power structures that exclude the less visible but often no-less-respected “informal” governance institutions.

8.1.2 HOW?

As previously mentioned, institutional analysis and the situational understanding necessary to avoid undermining less visible systems of power in dense urban environments are most accurately analyzed using human intelligence and creative thinking. Commanders can look at data on formal systems and impute that the gaps observed there represent informal systems. The Army should be wary of relying too much on technological solutions in this case, as complex political questions that necessarily centralize human subjectivity (e.g. those around ultra-subjective definitions of legitimacy) may be oversimplified without the nuance allowed by human intelligence. Partnerships and information-sharing with localized grassroots organizations, civil society, and international agencies is one way to mitigate misunderstandings of power structures. However, both existing and emerging technologies can be used to supplement human intelligence and form a more holis-

[121] At Fort Hamilton’s April 2018 conference, Dr. Sheri Fink highlighted the extreme and ultimately deadly breakdown of operations at Memorial Medical Center, asking her audience, “When does a hospital become not a hospital? When do you start to turn people away?”

tic, detailed understanding of complex institutions in dense urban environments.

Concentration of resources often indicates concentration of power. Sometimes this reality is overtly observable simply by walking through city neighborhoods and noting changes in the sizes of homes or the quality of roads. But often things are much more complex than that. While the state is often assumed by foreign actors in situations of crisis to be a trusted or vulnerable entity, that perception may not be shared by local communities. One way of using technology to determine perceptions of or trust in the state is to track who and how much of the population opts in to optional government services. In the case of a state with strong record-keeping institutions, the Army could simply use those records to make this assessment. In cases of cities with weak record-keeping abilities, satellite imagery can be employed to track state resources such as waste management. In both cases, data that is available would reveal not only areas of formal institutional strength but also intimate for which services people turn to informal institutions, by virtue of what is missing from the data.

8.2 WHAT ARE THE SECURITY AND EMERGENCY RESPONSE CAPABILITIES OF THE URBAN ENVIRONMENT AND WHERE ARE THE GAPS IN THOSE CAPABILITIES?

8.2.1 WHY?

Whether responding to a humanitarian disaster, violent conflict, rising insurgencies, or disease outbreaks, local institutions will have to be called upon to respond alongside international interveners. Understanding what capabilities are already in place before arriving can mitigate overlapping deployment of resources and personnel; such overlap can result in over-attentiveness to some areas and no attention to others and, in the worst case, cause serious increases in casualties. Doctor Joel Montgomery, in a recent lecture at Fort Hamilton, emphasized the importance of understanding local perceptions of health issues as well as military figures because if there is a lack of trust and understanding between locals and external interveners, situations can escalate dangerously and pose a risk to all involved.[122] Liaising with local organizations and networks can also quickly identify gaps to know what additional resources need to be pulled in, such as mobile laboratories as part of the US military's response to the Ebola outbreak in West Africa.[123]

[122] One example of this is the riots that broke out during the initial Ebola response in Monrovia, Liberia.
[123] Joel Montgomery at Various (MDB in Megacities) (2018).

8.2.2 HOW?

These questions are most likely easily answered through communication with host governments or local organizations. The Army can draw on the expertise of its allies, tap into its own historical knowledge, and increase inter-organizational engagement so that webs of networks are not lost as new people are cycled through posts every few years. Emergency resources and community responses to security concerns are particularly ripe areas for the Army and its allies to engage with local organizations. Establishing trust will also be essential in this area. In emergency situations, social media scraping, discourse analysis, and liaising with local experts can all be used to establish trust, all while holding community-based human networks primary.[124] Social media analysis can also be utilized to discern and address rumors like the population control conspiracy theory that spread across West and Central Africa during the 2014 Ebola outbreak.

As evidenced in the recent Houston (2018) and New Orleans (2005) disasters, local networks and informal means of communication are often more useful for mobilizing quick, life-saving responses. In both cases, flooding necessitated employment of private citizens' personal boats to pick up those who were trapped or in need of medical assistance.[125] In Houston, formal emergency response mechanisms were overwhelmed by calls from citizens needing rescue. City officials quickly recognized this and got on the radio to call upon private citizens with boats to help with rescue efforts. In the case of New Orleans, emergency responders were similarly overwhelmed but advised citizens not to use social media or other informal means of calling for help; the option they were then left with was to endure being placed on hold with 911 indefinitely, all while their phones slowly lost battery. In the end, people used social media to call for help regardless, but because the formal responders had rejected the informal response, they had no control over the situation, nor were they tracking the informal emergency responders.[126]

8.3 ARE FORMAL AND INFORMAL INSTITUTIONS FUNCTIONAL, RELIABLE, AND TRUSTWORTHY?

8.3.1 WHY?

One recent framework for understanding the urban environment ranks cities' levels of integration.[127] While this report presents a different means of analyzing urban environments, the concept of integration remains useful for analyzing the efficacy or reliability of institutions. Infrastructure that is vastly spread out, unpredictable, regularly needing maintenance, or generally

[124] Greta Byrum at Various (Capstone Workshop) (2018).
[125] Dr. Sheri Fink at Various (MDB in Megacities) (2018).
[126] Ibid.
[127] US Army Strategic Studies Group (2014).

damaged is likely indicative of a less integrated institutional environment than infrastructure that runs well and on time would be.

If local institutions typically run well, that will affect disaster or conflict response. Capitalizing on still-functional institutions can relieve pressure on outside interveners and allow for more efficient addressing of all kinds of emergencies. In the case of public transit in an environment experiencing a natural disaster, knowing that subway trains typically run on time can help to more accurately and quickly determine how much of the population has escaped the most dangerous disaster zones as well as estimate how many people may be trapped on trains in those zones. On the other hand, if the institutional nature of such services is generally known to be unreliable, the Army will face significantly more challenges in short-term responses and will likely have to disproportionately fall back on human intelligence rather than technology.

8.3.2 HOW?

The Army can consider the resources allocated toward public institutions such as budgets and the number of employees in a given institution. It can hold public institution capabilities up against private institutional capacity, assuming that the private sector may, like informal structures, be addressing a gap created by a lack of public institutions. Another means to identify where trust and perceptions of reliability lie is to look at alternative services offered.[128] For example, if a high number of people in a given city choose to use mobile banking over more traditional banking services, that tells the Army something about the perceived reliability of physical banks. To ascertain such information, with the rise of cellphone use and mobile banking, would not be difficult. Its collection could be used not only to determine rejection of more formal or traditional structures, but could also be used to track social networks through monetary sharing across a cashless network. The Army can also tap into social media data, sentiment analysis, and social network analysis to gauge when and where there is an uptick in complaints made by the public via social media.

8.4 HYPOTHETICAL

One possible way that the US Army–or any intervening force/organization–could track power dynamics and service delivery is to look at electricity provision. If a natural disaster were to hit a city like Yaounde, Cameroon and knock out the electrical grid, restoration of that service would be a priority for responders. A city like Yaounde, however, will have had inconsistent electricity provision pre-disaster. Mapping these inconsistencies can quickly help responders to determine areas that are likely to have informal systems for service delivery in place and those which may

[128] Credit for this idea belongs to Professor Dipali Mukhopadhyay at SIPA.

need more urgent restoration of electricity in order to mitigate larger scale damage to the neighborhood. Varying definitions of vulnerability and recognizing informal institutions underpinning areas that may ostensibly seem weak (and then capitalizing on and supporting those institutions) can help the Army and its local partners maximize their resources.

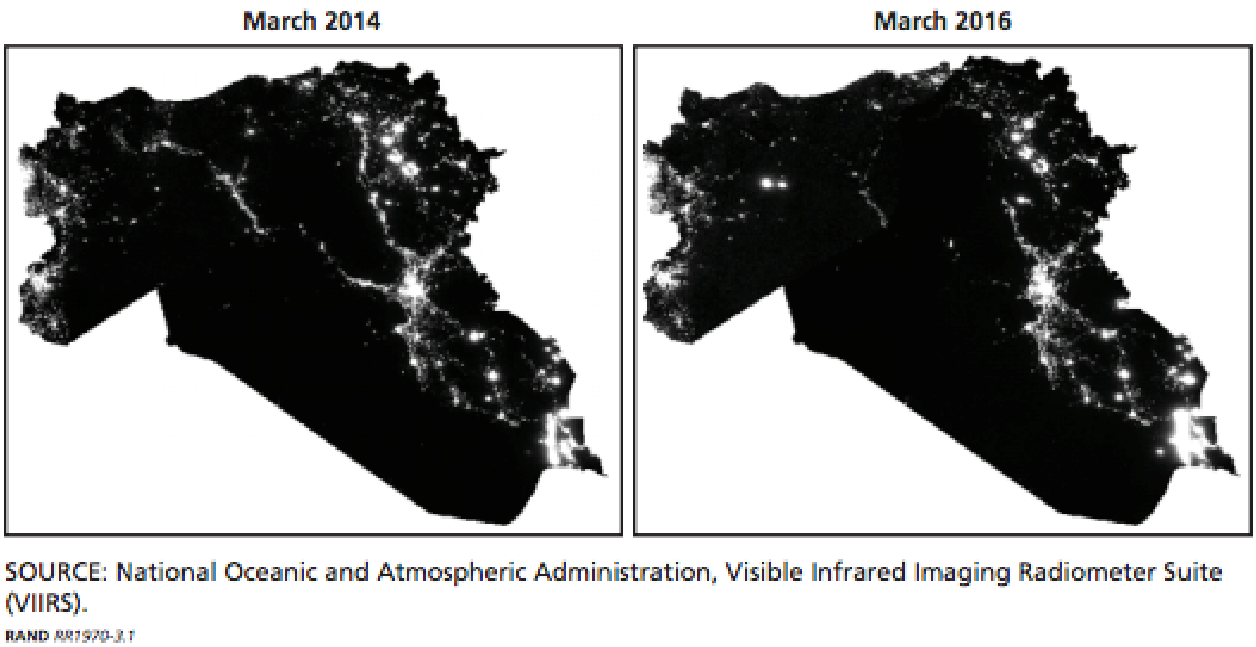

FIGURE 7: Nighttime lighting in Iraq and Syria, March 2014 and March 2016.[129]

Areas that are already accustomed to dealing with unreliable resources such as frequent power outages are unlikely to have institutions in their neighborhoods which rely on those resources–at least not on a formal level. In cases of disaster response, the Army can use satellite images to quickly assess which parts of the city might need prioritized electricity restoration for anything from food refrigeration to security (street or house lights) to the continued functioning of neighborhood institutions like hospitals, schools, or food vendors. Because such institutions normally rely on electricity, to leave them too long without will only exacerbate the disaster situation with continued disruption of daily life, decline in neighborhood security, or large-scale food waste and shortage, to name a few examples.

Though an outsider's immediate assessment may be that neighborhoods with unreliable service provision from formal sources may be more anarchic, the reality is that those spaces are likely full of informal systems and practices covering the range of basic services like security and food preservation. It is critical, however, to note that this approach should be carefully considered on multiple levels because too much prioritization of service restoration in wealthier or more pow-

[129]Robinson et al. (2017)

erful subsets of the urban environment can project further neglect of already-neglected populations. Just because a hospital, for example, does not typically have consistent electricity does not mean that it would not benefit greatly from speedy provision of triage resources.

9 WORKSHOP SCENARIO: DISASTER IN CITY X

We spoke to a wide range of experts during our research, and each of them offered recommendations and insights specific to their particular area of study. As we worked to synthesize their responses into a broader framework for understanding future opportunities in urban operations, we wanted to see these experts interact and put their ideas to the test in a wargame environment. To accomplish this, we organized a day-long workshop at Columbia, bringing together thirteen leaders in fields from emergency response to machine learning to confront a hypothetical, future urban operation. The workshop produced fascinating results, and participant responses played a crucial role in informing our ultimate recommendations.

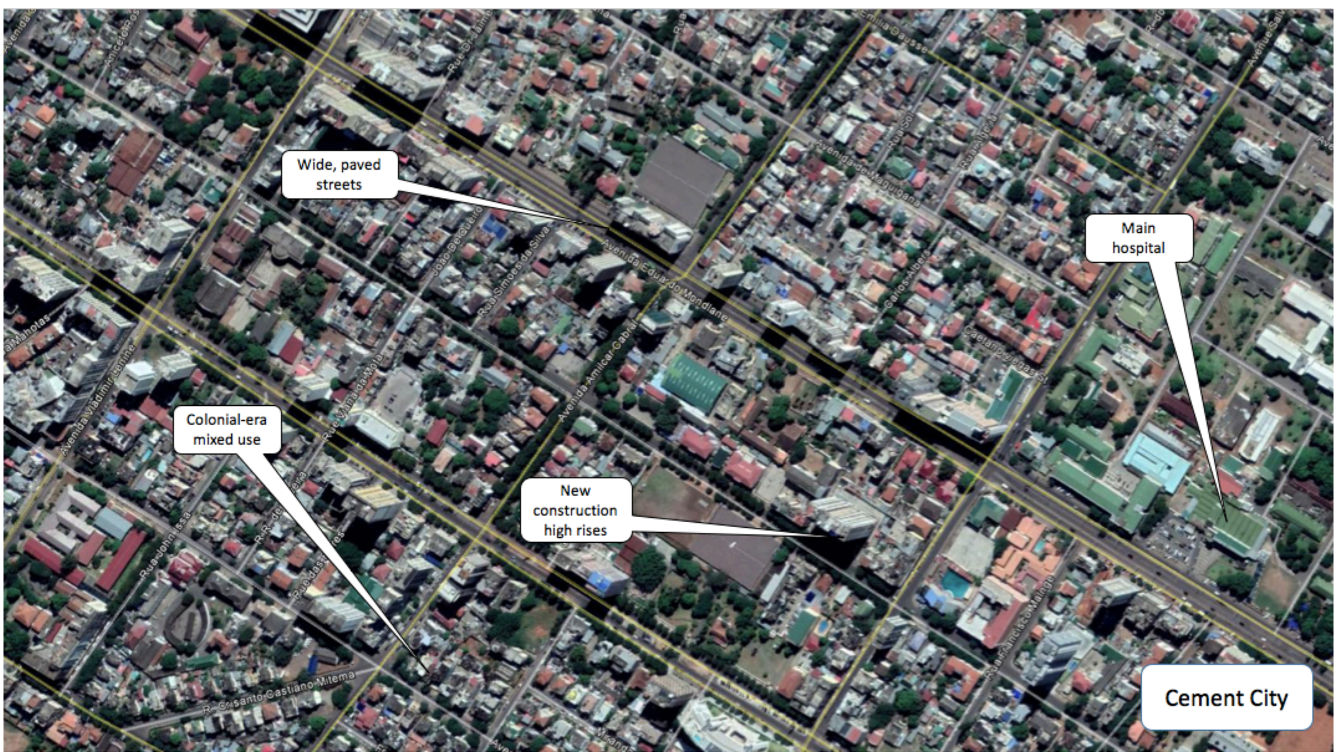

FIGURE 8: The ”Cement City” region of City X.[130]

We built the workshop around a scenario which brought participants to the year 2030 and City X, a fictional city based on modern-day Maputo, Mozambique. After an earthquake struck City X, capital of the fictional country of Tiko, the Tikan government requested assistance from the US military to help in the recovery. In response, the US sent two US Army brigade teams and an airborne division, along with a logistics command and accompanying naval support. We assigned workshop participants to work in the detachment's intelligence shop and charged them with determining the questions American intelligence assets should seek to answer in an urban Humanitarian Assistance/Disaster Relief (HA/DR) operation and the methods used to answer them.

Unbeknownst to the workshop participants, Tikan anti-government rebels saw a disaster-struck City X as a target of opportunity. Halfway through the day, what had been an HA/DR operation turned into stability operations when fighters from the Tiko National Resistance launched a series of IED attacks against Tikan soldiers and police in the center of the city. Workshop participants then had to suggest intelligence goals and methods for a short-term stability mission.

9.1 MAIN THEMES

Participants brought their array of perspectives to bear throughout the day, generating ideas for how the Army can see the city that were insightful, original, and sometimes in conflict. Overall, however, two overarching themes came through. The first is that all the experts were much more confident that emerging technology would provide major gains in understanding cities' physical infrastructure than in understanding relationships among people and between people and institutions. On the infrastructure side, participants took as a given that, by 2030, the US military will have near-real time mapping capabilities and sensors that will offer clearer pictures of building interiors and subterranean spaces.

On topic of measuring human networks, however, optimism was harder to come by. As RAND Corporation information scientist Dr. Aaron Frank put it, "there's the bread [physical infrastructure] that we're really good at, and the circus [social mapping] that we're really terrible at." People like Dr. Frank and New America Foundation's Resilient Communities Program director Greta Byrum, whose work centers on questions of how to understand community dynamics, expressed deep skepticism that future technology alone will allow the Army to penetrate social network structures. The lack of quality data on things like intra-institution communication and the ease with which adversaries might manipulate social media data complicates the idea that technology can solve long-standing problems of how to model complex human interaction, they warned.

The second overarching theme was that, across all domains, the data use that experts were most excited about was setting baselines and measuring shocks. In a world where satellite data can offer a comprehensive, accurate view of electricity distribution or trash pickup in City X before the earthquake and generate a real-time overview of the state of those services after the disaster struck, disaster response can run more efficiently and effectively than it does today. Furthermore, in a world where cashless societies allow us to easily measure the sale price of weapons in a given area and track sudden price increases, we may be able to see social shocks that our current in-

[130] Map constructed for workshop by authors.

telligence gathering capabilities miss entirely. Data baselines will almost certainly become more easily available over time and offer major insights into locations and sectors we currently know little about.

9.2 INTELLIGENCE CAPABILITIES

Discussions in the workshop focused largely on the methods for urban intelligence gathering that will be available to the Army by 2030. In particular, four emerging technologies caught the lion's share of attention: parasitic intelligence gathering; pop-up communications infrastructure; real-time, 3-D mapping; and social science research on community structure.

9.2.1 PARASITIC INTELLIGENCE GATHERING

As RAND Corporation senior defense policy analyst Peter Wilson put it, the greatest intelligence arbitrage opportunity of the coming years will come in the form of "parasitic intelligence" – adapting non-military data caches to offer insight for military operations. The most obvious non-military data caches are the data generated by online social networks. These constantly updating, individualized data flows have, in theory, a huge potential to offer real-time intelligence on specific events and relations between people. TRADOC Plans and Policy director Dr. Russell W. Glenn summarized the future information environment succinctly: "George Orwell's 1984 was precocious."

The capacity to do large-scale scraping of social media accounts in a dense urban area–and, crucially, the digital storage space to maintain the data for long-term analysis–will likely be a key military capability in the near future. Workshop participants discussed applying social media data to questions ranging from identifying missing people during a natural disaster to understanding how insurgents talk about themselves within their own group to measuring daily flows of commuters through a city, and many in between.

There is good reason to believe that parasitic intelligence will shed light on these and other questions, but, as noted above, concerns were also raised. Parasitic intelligence gathering amounts to massive electronic surveillance, which produces both ethical and practical obstacles. If, as Ms. Byrum pointed out, different cultures have different tolerances for digital surveillance, in some cases the process of gathering parasitic intelligence might be more damaging to operational outcomes than the intelligence itself would be helpful.

Parasitic intelligence also begs another, more fundamental analytical question: does additional data actually improve our understanding of complex urban systems. Dr. Frank urged caution on this point, warning of the potential for "bifurcation" in which analysts receive more, and more up-to-date, information but still cannot understand what the information means in the context of the operation. “The theory [of the city] has to evolve along with the technology”, Dr. Frank noted– without valid models of the structures and institutions we are attempting to learn about, added data is unlikely to produce better analysis.

9.2.2 POP-UP COMMUNICATIONS INFRASTRUCTURE

A second focus area, related to parasitic intelligence gathering, was the ability to import communications networks to an area that had lost its native telecommunications capacity. As Mr. Wilson pointed out, by 2030 low earth orbit telecommunications infrastructure will allow for both 3G and internet access in areas that lose terrestrial communications infrastructure. Even before then, Dr. Frank responded, mobile communications infrastructure should be able to fill gaps in service caused by natural disasters.

The ability to guarantee continued telecommunications service allows for greater communication among communities, between communities and institutions (including the Army), and continued social media information flows to scrape. Data from the Iraq War suggests that improving telecommunications access during COIN operations helps counterinsurgents more than it helps insurgents.[131] Even though insurgents are better able to coordinate their actions when they have easy access to cell phones, cell phone penetration makes it harder for insurgents to control information flows from civilians to counterinsurgents. In a situation where information access is crucial, guaranteeing and expanding information flows is a foundational goal that technology will soon allow the Army to achieve.

9.2.3 REAL-TIME MAPPING

The same physical infrastructure that can guarantee telecommunications infrastructure also enables the workshop’s third area of focus: real-time mapping technology. A combination of satellites, aerostats, and terrestrial sensor arrays can house everything from cameras to emerging sensing technologies that marry electromagnetic and LiDAR sensors to create accurate images of subterranean spaces. With the processing power to turn those sensors into real-time maps that all relevant units can access, the Army can solve reconnaissance and information distribution problems simultaneously.

Dr. Glenn, however, sounded a note of caution regarding real-time mapping. “In cities in particular”, Dr. Glenn said, “your eyes can lie to you.” Accurate information on the physical state of the city can still lead to inaccurate conclusion about how the city functions. City X’s main hospital was still intact after the earthquake, but that was no indication that it could care for patients. With

[131] Shapiro and Weidmann (2015).

doctors and nurses dealing with damage to their own homes, transportation infrastructure damaged, and looters threatening medication supplies, the hospital may be out of commission despite being physically undamaged.

9.2.4 SOCIAL SCIENCE RESEARCH

Finally, workshop participants expressed real interest in how social science research could help describe the models of close human interaction that define urban systems. One insightful suggestion in this vein came from Ms. Byrum, who pointed repeatedly to the work of Dr. Kate Starbird, an Assistant Professor in the University of Washington engineering department who studies social media responses to large-scale shocks like natural disasters, as an example of research that could point a way forward on separating signal and noise in parasitic intelligence. Dr. Starbird's research traces the flow of information and misinformation on social media in crisis situations, allowing her to draw conclusions about how people produce beliefs in pressurized situations.[132] In addition, Dr. Starbird deals explicitly with the role of intentional misinformation in crowded information environments–a key challenge to drawing conclusions from social media data.[133] Research in these areas is likely to gain steam in coming years and will play a key role in enabling intelligence professionals to evaluate the validity of their analyses.

Another area of social science research that participants discussed was developing measures of social vulnerability–metrics that account for social factors of community resilience to predict vulnerability to external shocks.[134] Historically, our measures of vulnerability were largely infrastructure-based. A town with a hospital was inherently less vulnerable than a town without one, the thinking went. Social vulnerability, however, allows for the kinds of factors that restrict a community's capacity to adapt to challenging circumstances–lack of wealth, lack of education, or crowded housing, for example–to shape our predictions of response to shocks. As we gain more granular data about neighborhood characteristics and a better understanding of how communities deal with disaster, our models of social vulnerability will improve. With it, our ability to undertake effective disaster response with little lead time will increase as well.

10 CONCLUSION

The breadth of the information requirements presented above and the challenges of fulfilling them underscore the incredible complexity of urban systems and the difficulty of conducting urban military operations. However, research strongly suggests that emerging technologies will

[132] Starbird (2017).
[133] Starbird (2017).
[134] Agency for Toxic Substances & Disease Registry (2016).

help the Army collect and analyze the data that it needs to better understand urban systems and to predict how people within them will react to the Army's actions.

To help the Army best take advantage of the coming advances in data science, artificial intelligence, and autonomous systems, we make the following the recommendations:

1) **Embrace complexity in modeling cities and focus on decomposing them into understandable, interconnected systems.**

   The Army should move away from understanding cities as monolithic, simplifiable entities that can be generally grouped into broad, like categories. Instead, we recommend that dense urban environments be considered as complex, interdependent systems that are made up of interconnected sub-systems. In doing so, these environments can be assessed by their cross-cutting features, and multiple subsets of one city can be considered as differing from one another rather than falling under the same central identifier. Components of such urban understandings include acknowledging human and material flows within and between urban and peri-urban areas, mapping of the reach of technological and service delivery systems, recognizing the reach and limitations of both social and market networks, and predicting shifts in the natural environment that will directly and indirectly affect urbanization and the built institutions of cities.

2) **Create a dedicated staff section to help commanders understand the flows of the operational environment quickly and decisively.**

   The US Army has yet to grasp the complexities of the urban environments in which it will operate. Dense urban environments have layered flows, numerous competitive groups, and varying levels of institutions; as such, they may prove overwhelming for fluid military operations without proper management and sound IPOE (Intelligence Preparation of the Operational Environment). Advances in technology and data inputs can elucidate some aspects of urban areas and will hopefully will allow commanders to formulate decisions and avoid misplaced, or even catastrophic, uses of force.[135]

   There is currently no staff member dedicated to providing a commander with the type of context proposed in this report. Some would argue that S-2/J-2 (Intelligence) already provides this level of context. At the battalion or brigade level, S-2 has the capability to provide this information but, only if the commander identifies it as a mission priority in his/her Commander's Critical Information Requirements (CCIR).[136]

   Battalion S-2 shops are not equipped to generate the type of analysis highlighted in this report and would realistically have only the available manpower to prioritize enemy warfight-

[135] Training and Doctrine Command (TRADOC) (2017).
[136] Headquarters Department of the Army (2017).

ing capabilities.[137] Specialized intelligence personnel are assigned to the brigade level and higher. Specialists like a HUMINT team or GEOINT analysts might be assigned to lower level commands for specific purposes or missions. Otherwise, any specialized intelligence at the battalion level is generated from higher and disseminated through intelligence summaries (INTSUM/GRINTSUM).[138]

The US Army is aware of this shortcoming and has tried to compensate with small, specialized teams or experimental programs. The Human Terrain System (HTS) was a limited-run attempt to infuse academic analysis into COIN operations in Iraq and Afghanistan.[139] Alternatively, CoIST or Company Intelligence Support Teams, are small-unit intelligence teams designed to inform the commander of the effects of the weather, enemy, terrain, and local population on operations and to reduce uncertainty while aiding decision making. HTS was mired in controversy and abandoned in in 2014. CoISTs have been described as underutilized or improperly integrated.[140]

The Capstone team recommends that the US Army create a section within the command staff that is dedicated to providing a commander with contextual information, intelligence, and/or relevant historical data. This section might be a new staff “shop” or exist within the S-2 at the battalion level. Focusing on the battalion level is important because it is the lowest level of command with an assigned intelligence section. If battalion commanders on the ground have this type of organic asset, they can formulate better CCIRs for their subordinates as well as better RFIs (Requests for Information) from higher.[141]

The training requirements for this section might include focused specializations in academic research and all-source analysis. Reporting responsibilities should be standardized and used to disseminate useful information throughout the chain of command. Most importantly, the function of the section, and its soldiers, should be institutionalized doctrinally. The US Army should create new CoIST-inspired Military Occupational Specialties (MOS) with a mandated career apparatus complete with official training requirements and disseminated guidance for operational integration to all levels of command.

3) **Assess access to urban data and secure access ahead of time in likely operating environments.**

While the Army will be able to directly collect some of the data it needs to meet the information requirements discussed in this report, much of the data will only be available (or will be avail-

[137] Federation of American Scientists (2018).
[138] Chairman of the Joint Chiefs of Staff (2017).
[139] Sims (2015).
[140] Morris (2015).
[141] Headquarters Department of the Army (2012).

able at far lower cost) from other organizations. For instance, smart-city infrastructure data will typically come from foreign governments; social media and IoT data will be in the hands of private companies; and data on populations with limited trust for and links to the local government may come from local NGOs.

Dependence on outside parties for data means that the Army may face challenges with data access and integration. First, privacy, business, or trust concerns may make potential partners less willing to share data. The Army will need to undertake a survey of the relevant data available in cities were it operates, and to negotiate access to any important data that it currently lacks. This can be ahead of time in the cities where the Army is most likely to operate, but the sheer number of potential locations makes this a major challenge. Second, the Army should be prepared to integrate and use a wide variety of different types and formats of data. In the short run, these efforts may rely on existing data integration and analysis tools such as the Army's Distributed Common Ground System (DCGS-A). In the long run, the Army may benefit from using and supporting open data standards, such as the work of the Open Geospatial Consortium discussed in Section 6.3.2, and by acquiring data infrastructure in the future that focuses on interconnectivity and flexibility.

4) **To fill in data access gaps, invest in deployable and remote sensor platforms or develop new techniques and uses for existing platforms.**

   While smart city technology is expected to spread significantly over the next twenty years, adoption is sure to be uneven, particularly in the less-developed countries where the Army is most likely to undertake HA/DR and stability operations. Thus, alongside data access and integration, the Army will need to ensure that it has deployable and remote sensors that it can bring to bear in cities that lack them. This recommendation builds on the traditional strengths of the US military and intelligence agencies in geospatial and signals intelligence, but it suggests that – alongside the typical focus on enemy activity – these intelligence products will be useful for mapping human and economic flows and assessing infrastructure and service delivery.

5) **Develop techniques for integrating qualitative and quantitative data.**

   Related to the above recommendation on gaining access to and integrating important outside data, the Army should invest in methods for integrating quantitative and qualitative data. This combination will help commanders and soldiers alike gain a detailed understanding of the urban environment. While quantitative data can give us information about what is happening in a city – e.g. movements on the ground, it cannot always tell us what these movements mean for a city and its various systems. Integrating qualitative information (e.g. ethnographic research, behavioral indicators) can fill in these gaps in understanding and point to the deeper, more obscure, and unexplored challenges. "Effective information fusion" can help sharpen potentially fuzzy or unreliable data by combining and layering information from multiple sources.[142] This fusion, as Dr. Nigel G. Fielding of University of Surrey's Department of Sociology argues, is critical to applying the snapshots provided by quantitative methods to the process tracing afforded by qualitative work, and vice versa.[143]

This type of information fusion will, of course, require the Army to gain access to more raw qualitative data (in addition to quantitative data), which will entail many of the same challenges articulated above. Even before that, however, it will require the Army to invest time and resources into assessing what kind of qualitative data is available to them, what is missing, and to whom they should turn to locally for this information. Regardless of whether the data is quantitative or qualitative, the Army will need to support efforts and investments in technologies that seek to link different data sources and information – combining human intelligence with that of machines.

Investments in artificial intelligence and machine learning will obviously continue to be important for information fusion, but so will more research into "new or nontraditional technologies and methods" for understanding individual behavior and social networks.[144] For instance, using computational social science and agent-based modeling, George Mason University's Center for Social Complexity is investigating potential responses of individuals and their social networks to a nuclear attack in a megacity.[145] Supporting such social science research, in tandem with advancements in artificial intelligence and machine learning, will help improve information fusion and sharpen the Army's conceptualization of a city and its people.

6) **Remain skeptical about the ability of technology and data to offer precise, reliable understandings of complex human systems.**

The Army should remain cautious about relying too much on technology. While technological advancements will no doubt continue to change the face of warfare and will dictate the ways that urban operations doctrine is developed in the future, the value of human intelligence should not be undervalued. The risk of information overload will increase as more data becomes available from an increasingly varied array of sources. More information is not always better when it is not coupled with a clear idea of how that information is being processed at multiple societal levels and integrated into decision-making both inside and outside of the Army.

Additionally, human relationships and trust have significant impacts on disaster response and

[142] Davis et al. (2013), p.xxxiv.
[143] Fielding (2012).
[144] Davis et al. (2013), p.xxiii.
[145] Rogers (2017).

stability operations, both of which form organically over time.[146] While technology is a component of measuring these through methods like social media scraping, behavioral analysis, and social vulnerability mapping, we urge the Army to use the integration of qualitative data and human sources as a means to engage with local populations wherever possible.[147] This serves two main purposes: first, integrating a variety of sources (per Recommendation 5) lessens risks by correlating multiple factors to ascertain stronger signals, and second, minimizing reliance on fallible technologies that rely on network connection or a power supply, or are susceptible to hacking can mitigate the damage caused by unexpected system failures.

The US Army's push to better understand urban environments puts it in good company at the forefront of social science. The black box of urban systems holds some of our biggest questions about how humans collaborate to create societies, and the prospects for illuminating the box through the use of emerging technologies is tantalizing. Yet the Army, as the American military service most likely to see long-term engagement in cities in coming years, bears a special responsibility to make progress in understanding cities and to operationalize its understanding with care. Military interventions, even in humanitarian assistance missions, are shocks to the cities that experience them. Following the recommendations in this report will allow the Army to better mitigate the shocks it responds to and the shocks it causes and grow its capacity to act as a buttress for urban resilience.

[146] Greta Byrum at Various (Capstone Workshop) (2018).
[147] Agency for Toxic Substances & Disease Registry (2016).

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A CONTRIBUTING ORGANIZATIONS

- Columbia University – School of International and Public Affairs
- Center for a New American Security
- Joint Task Force Empire Shield – New York Army National Guard
- The Modern War Institute – U.S. Military Academy
- MD5 - The National Security Technology Accelerator
- The National Center for Urban Operations
- The New School – Digital Equity Laboratory
- New York City Fire Department
- RAND Corporation
- U.S. Army Future Studies Group
- U.S. Army Training and Doctrine Command
- Urban Design Lab – The Earth Institute – Columbia University

B FURTHER SUGGESTIONS FOR INSTITUTIONAL COLLABORATION

- Columbia University's Center for Spatial Research "Conflict Urbanism: Aleppo" project
- Dataminr
- Google Jigsaw
- Google Sidewalks Lab
- (Google) X
- MIT Human Dynamics Lab
- MIT Media Lab: City Science, Human Dyanmics, Signal Kinetics, and Social Machines
- OneWeb
- OpenAI
- Pew Charitable Trusts' "State of the City" project
- PlanetLabs
- Project Loon
- Santa Fe Institute
- SETO Lab
- SparkCognition
- Urban Risk Map project from MIT's Urban Risk Lab
- Virginia Tech's Network Dynamics & Simulation Science Laboratory

C TEAM BIOGRAPHIES

Gretchen Baldwin is a second-year SIPA student studying International Security Policy. Her areas of focus include gender & political violence, non-state armed actors, and authoritarian states. Gretchen spent the summer of 2017 in Kigali, Rwanda conducting interview-based research for an ongoing project analyzing the role of post-genocide commemoration in the formation of Rwandan nationalisms. Prior to enrolling at Columbia, she worked with a peacebuilding NGO in the eastern DRC and was a 2014-2015 Fulbright Research Fellow in northern Cameroon. Gretchen was also a 2016-2017 AC4 Graduate Fellow and a 2017 board member of SIPA's Gender Policy and Conflict Resolution working groups.

Elise Guarna is a second year International Security Policy student with a specialization in the Middle East, pursuing her Masters as part of a five-year BA-MIA dual-degree program. She has worked on U.S. Syria policy through internships with USAID and the Office of the Undersecretary of Defense for Policy (ISA/Middle East), focusing most recently on post-ISIS stabilization planning for Raqqa. After SIPA, Elise will spend seven months furthering her study of Arabic in Oman on a Boren Fellowship.

David Kaye is originally from Massapequa Park, New York and has a BA in History from Penn State University. Currently, David is a Master of Public Administration candidate at SIPA concentrating in International Security Policy and specializing in Conflict Resolution. Prior to SIPA, David served in the United States Marine Corps as an infantry mortar section leader where he deployed in support of contingency operations in Port-au-Prince, Haiti (2004) and and then to Anbar Province, Iraq in support of OPERATION IRAQI FREEDOM (2005). David then joined the United States Army where he served as a UH-60L Blackhawk pilot and an aviation operational planner. He deployed twice to Regional Command- East, Afghanistan in support of OPERATION ENDURING FREEDOM (2011, 2014).

Shohei Kubo is a second-year student at SIPA focusing on International Security Policy and East Asia Studies. He is an active duty tank officer of the Japan Self-Defense Force with two years of experience as a tank platoon leader. Prior to SIPA, he was a research associate at the National Defense Academy of Japan. His areas of interest include East Asia security and US military strategy.

Zaib Rasool is a Master of International Affairs Candidate concentrating in International Security Policy and Conflict Resolution. Her areas of interest include arms trade, illicit networks, and sanctions with a regional focus on South Asia. Prior to SIPA, she worked at Microsoft as a Corporate Strategy and Development Manager, conducting research on emerging technologies and outlining areas of strategic investment, partnership, and acquisition. While at SIPA, she has worked at the United Nations Development Programme's Innovation Facility and the Council on

Foreign Relations' Program on International Economics.

Sam Ratner is a second year student at SIPA studying security policy, quantitative analysis, and African affairs. In 2017 he spent three months in Mozambique working as a security correspondent for Zitamar News and conducting research on Mozambique's post-civil war DDR program for the Columbia Global Policy Initiative. Prior to attending SIPA, Sam was a research assistant at Harvard's Belfer Center, where he worked on projects covering nuclear negotiations with Iran and American coalition leadership in Iraq and Afghanistan. Sam was a 2016-2017 International Fellow at Columbia, and is founding co-president of SIPA's Progressive Security Working Group.

Siddhey Shinde is an Indian second year at SIPA focusing on Economic and Political Development. His core interest lies in working with specialized technology (eg: defence, space, biomedical) trade and development. He has a background in strategic electronics, specializing in Satellite Communication and Radar Navigation. He has worked on projects like RF Ablation and Microwave Filter Design.

Robert Ward is a second-year International Security Policy student at SIPA, focusing on defense policy, conflict and stability operations, and quantitative research methods. Before attending SIPA, Robert worked at the Tobin Project, a nonprofit organization that catalyzed, supported, and disseminated academic social science research on pressing public problems. He has also interned at the Government Accountability Office and several foreign policy think tanks, including the Brookings Institution and Stimson Center. He has a BA in Political Science and English from the University of Chicago.

D ACRONYMS AND DEFINITIONS

- AI - Artificial Intelligence
- CCIR - Commander's Critical Information Requirements
- COIN – Counterinsurgency Operations
- CoIST - Company Intelligence Support Team
- GEOINT - Geospatial Intelligence
- GRINTSUM - Graphic Intelligence Summary
- HUMINT - Human Intelligence
- INTSUM - Intelligence Summary
- IPOE - Intelligence Preparation of the Operational Environment
- ISR – Intelligence, Surveillance, Reconnaissance
- LMTV - Light Medium Tactical Vehicle
- LP/OP – Listening Post/Observation Post is a temporary or fixed position from which soldiers can watch enemy movements or direct fire
- LZ/PZ - Landing Zone/Pickup Zone
- MDMP – Military Decision-Making Process (per FM 101-5-1) is a doctrinal, analytical process used for problem solving and provides a common methodology for commanders developing and estimating military plans
- MOS - Military Occupational Specialty
- MRAP - Mine-Resistant Ambush Protected tactical vehicle
- MTOE - Modified Table of Organization and Equipment
- MUMT - Manned Unmanned Teaming
- PMESII-PT – Methodology for analyzing the conditions of a strategic environment consisting of eight variables (Political, Military, Economic, Social, Information, Infrastructure, Physical Environment, and Time)

- RFI - Request for Information
- S-2/J-2 - Intelligence staff section of a military command