Automating the Wisdom of the Crowd

A Monograph

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2018

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
05-25-2018	Master's Thesis	JUN 2017 - MAY 2018

4. TITLE AND SUBTITLE
Automating the Wisdom of the Crowd

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
MAJ Jakin J. Waldock
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Command and General Staff College
ATTN: ATZL-SWD-GD
Fort Leavenworth, KS 66027-2301

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Advanced Military Studies Program.

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release; Distribution is Unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS
See Abstract

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
(U)	(U)	(U)	(U)	44	MAJ Jakin J. Waldock US Army
					19b. TELEPHONE NUMBER *(Include area code)* 913-758-3300

Reset

Monograph Approval Page

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the US Army Command and General Staff College or any other government agency. (References to this study should include the foregoing statement.)

# Abstract

Automating the Wisdom of the Crowd, by MAJ Jakin J. Waldock, US Army, 48 pages.

The current Army Operating Concept, Win in a Complex World, describes future operational environments as complex, uncertain, chaotic, and dangerous. Under these conditions, accurate decision-making becomes a cyclical time-based competition. Commanders who can achieve situational understanding quickly enough to anticipate opportunities and threats gain and maintain a position of relative advantage over the enemy.

One way in which intelligence organizations help commanders achieve situational understanding is through the rapid collection, analysis, and delivery of actionable intelligence to the point of need. Analysts often balance two contradictory requirements to avoid intelligence failures: speed and accuracy. Failure to produce actionable intelligence in time may negate its value. Conversely, failure to vet the accuracy of the intelligence may negate its value irrespective of the timeliness.

Three factors limit both speed and accuracy: the capacity of human cognition, susceptibility to bias, and the limits of organizational knowledge. Mitigating the effects of these three constraints improves commanders' ability to achieve situational awareness. This paper examines whether a combination of artificial intelligence (AI) and crowdsourcing can help the intelligence community achieve situational understanding quicker and with more accuracy.

After a close examination of the benefits and pitfalls of artificial intelligence and crowdsourcing, this paper concludes with a "Hybrid Options" section, which demonstrates that a combination of artificial intelligence and crowdsourcing provides a path to mitigating the effects of the limits of human cognition, susceptibility to bias, and the limits of organizational knowledge. If taken into practice, this hybrid will prove an invaluable resource to operational planners.

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Acronyms

ACE	Aggregative Contingent Estimation
ADP	Army Doctrine Publication
AI	Artificial Intelligence
ARCIC	Army Capabilities Integration Center
AWCFT	Algorithmic Warfare Cross-Functional Team
AWFC	Army Warfighting Challenge
BBC	British Broadcasting Corporation
BCE	Before Common Era
COL	Colonel
DARPA	Defense Advanced Research Projects Agency
DC	District of Columbia
DIA	Defense Intelligence Agency
DOD	Department of Defense
DOTMLPF-P	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities, and Policy
EPJ	Expert Political Judgment
ESP	Extrasensory Perception
FEMA	Federal Emergency Management Agency
FMV	Full-Motion Video
GEN	General
GEOINT	Geospatial Intelligence
GIS	Geographic Information Systems
GJP	Good Judgment Project
GMI	General Military Intelligence

GPS	Global Positioning Satellites
HQ	Headquarters
IARPA	Intelligence Advanced Research Projects Activity
IBM	International Business Machines
IC	Intelligence Community
JP	Joint Publication
JTF	Joint Task Force
MAJ	Major
MANPADS	Man-Portable Air-Defense Systems
METT-TC	Mission, Enemy, Troops, Time, Terrain, and Civilian Considerations
MP	Military Police
NATO	North Atlantic Treaty Organization
NERC	Natural Environment Research Council
NGA	National Geospatial Intelligence Agency
NOME	NSG Open Mapping Enclave
NSG	National System for Geospatial Intelligence
OE	Operating Environment
OSINT	Open-Source Intelligence
OSM	OpenStreetMap
PMESII-PT	Political, Military, Economic, Social, Information, Infrastructure, Physical Environment, and Time
RAND	Research and Development
SCA	Sociocultural Analysis
SMS	Short Message Service
TRADOC	Training and Doctrine Command
US	United States

USC	US Code
VGI	Volunteered Graphic Information

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Introduction

The current Army Operating Concept, *Win in a Complex World*, describes future operational environments (OEs) as complex, uncertain, chaotic, and dangerous.[1] Under these conditions, accurate decision-making becomes a cyclical time-based competition. Commanders who can achieve situational understanding quickly enough to anticipate opportunities and threats gain and maintain a position of relative advantage over the enemy.

One way in which intelligence organizations help commanders achieve situational understanding is through the rapid collection, analysis, and delivery of actionable intelligence to the point of need. Three factors limit both speed and accuracy: the capacity of human cognition, susceptibility to bias, and the limits of organizational knowledge. Mitigating the effects of these three constraints will improve commanders' ability to achieve situational awareness.

In a digitally connected world, intelligence analysts face a surfeit of information. According to researchers at the Intelligence Advanced Research Projects Activity (IARPA), artificial intelligence (AI) shows great promise in this area.[2] IARPA identified geospatial imagery identification, and event warning and forecasting as areas in which analysts could successfully employ AI, leaving human analysts more time to devote toward making sense of the findings.

One solution to mitigating susceptibility to bias is to minimize its impact through crowdsourcing. Gathering a large quantity of human-produced judgment from a diverse population and employing it against a problem set might dilute the effects of human bias and logic errors. Additionally, tapping into the collective understanding of an external resource pool

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[1] US Department of the Army, Training and Doctrine Command (TRADOC) Pamphlet 525-3-1, *The U.S. Army Operating Concept, Win in a Complex World* (Washington, DC: Government Printing Office, 2014), 39.

[2] Robert K. Ackerman, "Blog: Seeing is Believing for Artificial Intelligence," *Signal*, August 21, 2017, accessed September 1, 2017, https://www.afcea.org/content/seeing-believing-artificial-intelligence.

helps mitigate the limits of an organization's internal knowledge. This solution also facilitates a deeper level of insight not readily available to analysts.

While these two ideas separately hold promise, there are potential pitfalls that analysts and researchers will have to consider carefully. For example, although AI is good at identifying correlations in data, it has difficulties determining cause and effect.[3] Commanders need information based on causality, not coincidence. When examining crowdsourcing options, analysts will have to consider myriad factors that can affect the validity of the information obtained, including the motives, knowledge level, and professionalism of the crowd pool. In both instances, analysts must ensure the path from information to actionable intelligence is retraceable and explainable to assuage any concerns.

This paper demonstrates that a combination of AI and crowdsourcing provides a path to mitigating the effects of the capacity of human cognition, susceptibility to bias, and the limits of organizational knowledge. If taken into practice, this hybrid will prove an invaluable resource to operational planners.

Literature Review

Research for this paper included a comprehensive literature review of relevant published material regarding the use of AI and crowdsourcing for military intelligence purposes. A wide range of media informed this study, including academic journals, books, magazines, web-based articles, newspapers, blogs, US military doctrine – both Army and Joint, strategic guidance, intelligence-related publications, psychology-related publications, technical manuals, and future-based thought pieces.

The research focused on identifying knowledge gaps in the AI-crowdsourcing field of study. The purpose was to identify key concepts, major trends, and primary relationships; assess

[3] Ibid.

strengths and weaknesses; and consider contradictory evidence. This method solidified the paper's logical foundation.

To underpin the monograph with a solid explanation of the intelligence field – the enterprise, its role in situational understanding, how it describes the OE, and its influence on speed and accuracy – research included several examples of current US Joint doctrine. This doctrine included the Department of Defense's (DOD's) Joint Publication (JP) 2-0, *Joint Intelligence*; JP 2-03, *Geospatial Intelligence in Joint Operations*; and JP 2-01, *Joint and National Intelligence Support to Military Operations*. A thorough doctrine review revealed that Army Doctrine Publication (ADP) 5-0, *The Operations Process*, provided the most useful definition of *situational understanding*. This discovery was helpful in maintaining a golden thread throughout the paper.

Research into AI focused initially on AI's history and influence on military intelligence operations, and later shifted to recent developments with important implications. Sources in this section include many news articles like Sean O'Neill's *New Scientist* article, "Human v. Machine: Five Epic Fights against AI," and Andrew McAfee and Colin Clark's *Breaking Defense* piece, "Cardillo: 1 Million Times More GEOINT in 5 Years." Web-based news articles helped capture fluctuating trends in a way that long-term studies could not. AI-related books like Erik Brynjolfsson's book, *Machine, Platform, Crowd: Harnessing Our Digital Future*, (also useful during crowdsourcing research) helped define terms and explored ideas in greater detail. Several scholarly sources provided credible research that supported ideas presented in other sources. For example, Volodymyr Mnih's 2017 research paper, "Human-Level Control through Deep Reinforcement Learning," provided academic reinforcement to Jennifer Welsh's *Business Insider* article, "Researchers Say This is the Most Impressive Act of Artificial Intelligence They've Ever Seen." Both sources supported the paper's argument that machine learning will be an important aspect of intelligence operations in the future.

Crowdsourcing research followed the same method – cutting-edge news reinforced by academic writing. Research in this section focused on historical developments, application of *explicit* and *implicit* crowdsourcing, and its influence on military intelligence operations. Scholarly publications like the *Journal for Public and Nonprofit Affairs'* 2017 study, "Intelligence and Information Gathering through Deliberative Crowdsourcing" and Consuelo López' University of California thesis paper, "An Experiment in Microtask Crowdsourcing Software Design" buttressed concepts discussed in the paper. News articles like Dominic Ponsford's 2017 *Press Gazette* piece*,* "Six Years of Syrian Civil War: 211 Journalists Killed, at Least 21 Held Hostage or Missing and at Least 26 Imprisoned," helped frame theoretical arguments with real-world examples.

Throughout the research phase, one golden thread focused efforts toward answering a single question: whether a hybrid model of AI and crowdsourcing improves the speed and accuracy with which commanders achieve situational understanding. Criteria for using evidence in the paper included relevancy (the evidence related to the research question), suitability (the evidence successfully supported or opposed the question), and acceptability (the evidence was credible).

Using the trinity of theory, history, and doctrine as a guide helped to ensure that the research was comprehensive and focused. The theorists cited in this paper are contemporary; including Daniel Kahneman, Philip Tetlock, and Robert Jervis. The history that supports these theories, however, ranges from antiquity to present-day – all supported with examples from current Joint and Army doctrine.

It is important to note that space and classification restrictions prohibit an exhaustive study of the ways in which AI, crowdsourcing, or a hybrid of both can support faster and more accurate situational awareness. Some gaps in the research (e.g., quantifiable combat results) are present due to classification restrictions. Rather, this research supports Army Warfighting Challenge (AWFC) #1: Develop Situational Understanding by exploring ways to "develop and sustain a high degree of situational understanding while operating in complex environments against determined, adaptive enemy organizations."[4]

[4] "Army Warfighting Challenges," Army Capabilities Integration Center (ARCIC) website, updated on March 9, 2018, accessed April 3, 2018, http://www.arcic.army.mil/initiatives/armywarfightingchallenges#Num1.

Section I – Military Intelligence

> All the business of war, and indeed all the business of life, is to endeavor to find out what you don't know from what you do.
>
> – Arthur Wellesley, Duke of Wellington, 1852, personal letter

The Intelligence Enterprise

The intelligence enterprise is a conceptual framework used to describe the interconnected network of people, tools, capabilities, and organizations that support situational understanding through the collection, analysis, and distribution of information.[5] Users operating inside this network are utilizing an *enterprise approach*.[6] The enterprise approach provides intelligence users and consumers access to resources produced at all levels of warfare, each with its own utility. Tactical-level units, such as Brigade Combat Teams (BCTs), gather data through local engagement. Analysts at the operational level, such as a joint task force (JTF) or a combatant command, aggregate this data to produce information about a region. Analysts at the strategic level use this information to produce intelligence products at the theater and national level. This multi-level enterprise approach is key to generating situational understanding.

The Role of Intelligence in Situational Understanding: Describing the OE

Achieving and maintaining situational understanding is the bedrock for effective planning and decision-making. Without this critical step, false assumptions can taint all subsequent tasks. Part of this first step is knowing the OE. For these reasons, describing the OE is the most

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[5] US Department of the Army, Army Doctrine Publication (ADP) 2-0, *Intelligence* (Washington, DC: Government Printing Office, 2012), 5.

[6] Ibid.

important role of intelligence in military operations.[7] JP 2-0, *Joint Intelligence*, describes the OE as "a confluence of the conditions, circumstances, and influences that affect the employment of friendly and adversary forces."[8] Although joint doctrine contains the phrases *situational awareness* and *situational understanding*, it does not provide a definition for either, and treats them as virtually interchangeable. This paper uses the Army Doctrine Publication (ADP) 5-0, *The Operations Process* definition of situational understanding: "the product of applying analysis and judgment to relevant information to determine the relationships among the operational and mission variables to facilitate decision-making."[9]

Variables to Describe the OE: PMESII-PT and METT-TC

Those operational and mission variables are characteristics of an OE that affect the ability of military forces to accomplish their mission. Operational variables are elements that influence the OE. These variables are: political, military, economic, social, information, infrastructure, physical environment, and time (PMESII-PT). Mission variables are factors that affect mission accomplishment. These include mission, enemy, troops, time, terrain, and civilian considerations (METT-TC). Analysts look at both types of variables as systems – interconnected elements that affect and influence each other in both intended and unpredictable ways.[10] The two types of variables also serve as frameworks for describing the OE. Put simply, situational understanding is the result of describing the OE through the lenses of operational and mission variables.

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[7] US Department of Defense, Joint Staff, Joint Publication (JP) 2-0, *Joint Intelligence* (Washington, DC: Government Printing Office, 2013), I-28.

[8] Ibid., I-3.

[9] US Department of the Army, Army Doctrine Publication (ADP) 5-0, *The Operations Process* (Washington, DC: Government Printing Office, 2012), 5.

[10] Robert Jervis, *Systems Effects* (Princeton, NJ: Princeton University Press, 1997), 6.

Methods to Describe the OE: GEOINT and OSINT

To describe the OE, the intelligence enterprise uses many different disciplines to collect, process and analyze information. Two of these disciplines are geospatial intelligence (GEOINT) and open-source intelligence (OSINT). GEOINT and OSINT are multipurpose intelligence disciplines – useful in both combat and stability operations.

GEOINT is a broad category of intelligence that encompasses imagery (still or moving pictures), imagery intelligence (information gleaned from the details of an image), and geospatial information (data that refers to the location and characteristics of a geographic feature).[11] The intelligence community (IC) collects GEOINT using a variety of electro-optical, infrared, spectral imaging, radar imaging, and lidar sensors.[12] Examples of GEOINT include photos, videos, image metadata, maps, demographics and topographies.

OSINT is intelligence collected from unclassified (open) sources. During OSINT collection, experts analyze doctrine, research papers, academic studies, interagency materials, newspapers, journals, media broadcasts, speeches, and web-based networking platforms or repositories.[13] The resulting OSINT helps commanders fill information gaps and provides context to classified intelligence. OSINT serves another purpose by giving analysts clues regarding where they should dig a little deeper using other collection methods.

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[11] US Department of Defense, Joint Staff, Joint Publication (JP) 2-03, *Geospatial Intelligence in Joint Operations* (Washington, DC: Government Printing Office, 2017), vii. For a full listing of definitions associated with geospatial intelligence and the National Geospatial-Intelligence Agency (NGA), see section 467 "Definitions" of Title 10 US Code "Armed Forces," accessed November 25, 2017 at http://uscode.house.gov/view.xhtml?req=granuleid:USC-prelim-title10-section467&num=0&edition=prelim.

[12] Lidar is a method of measuring distance by emitting a series of pulsed lasers and measuring the pulses' reflections. Reference sources vacillate between defining lidar as an acronym (light detection and ranging) and as a portmanteau of "light" and "radar." The former interpretation is based on the related term "radar," which was originally an acronym for "radar detection and ranging." Sensor information from US Joint Staff, JP 2-03 (2017), G-7.

[13] US Department of Defense, Joint Staff, Joint Publication (JP) 2-01, *Joint and National Intelligence Support to Military Operations* (Washington, DC: Government Printing Office, 2017), III-35.

Describing the OE: Intelligence Products

Commanders require focused and cogent intelligence products that describe the OE. Intelligence products fall into eight categories; however, the scope of this paper covers only the categories that have the most promise to benefit from advancements in artificial intelligence and crowdsourcing: general military intelligence (GMI), and estimative intelligence.[14]

GMI is an umbrella category for intelligence that broadly describes an OE in a foreign country, to include non-traditional facets of an OE such as cultural aspects and social media.[15] An example of a GMI product is an *OE assessment*, which is an in-depth summary describing aspects of an OE covering topics like military geography and demography.[16] An OE assessment sometimes includes a sociocultural analysis (SCA), which is the methodology through which the IC makes sense of behaviors of the population in the OE, and the factors that shape those behaviors.[17] SCAs are particularly useful for understanding cultural group motivations and intent.

While GMI promotes understanding in the current environment, analysts use *estimative intelligence* to help them forecast the way forward. According to JP 2-0, *Joint Intelligence*, estimative intelligence "identifies, describes, and forecasts" ways in which situations, adversaries, and population centers will develop, react, or change.[18] Products in this category typically take the form of intelligence *estimates*. Estimates are forecasts, or predictions, of how particular facets of an OE may develop, along with the implications for planning and executing military operations. Using pattern analysis, inference, and statistical probability to predict future variables,

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[14] JP 2-0, I-18. The eight intelligence product categories are: warning, current, general military, target, scientific and technical, counterintelligence, identity intelligence, and estimative intelligence.

[15] JP 2-01, III-52.

[16] Ibid., III-55.

[17] JP 2-0, GL-11.

[18] Ibid., GL-7.

estimates support situational understanding by providing commanders with an expectation of how an adversary, population group, etc. might react to specific stimuli.[19] Intelligence estimates typically also include important potential adversary actions, such as the *most likely* and *most dangerous* enemy courses of action (ECOAs). This intelligence helps provide context to behavior and events in an OE, thereby increasing situational understanding.

Influence on Speed and Accuracy

Gaining situational awareness is more than compiling data. Analysts must often balance two contradictory requirements to avoid intelligence failures: speed and accuracy. Failure to produce actionable intelligence in time may negate its value. Conversely, failure to vet the accuracy of the intelligence may negate its usefulness altogether. Three factors limit both speed and accuracy: the limits of human cognition, susceptibility to bias, and the limits of organizational knowledge. Mitigating the effects of these three constraints can improve commanders' ability to achieve situational awareness.

The Limits of Human Cognition

As technology improves and expands across the globe, the amount of available data increases. The intelligence enterprise simply does not have enough human brains to sift through an endless trove of information without unbalancing the ratio between speed and accuracy.[20] The challenge of dealing with enormous data sets, or *Big Data*, is more than just a *volume* issue.[21] Big

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[19] Ibid., I-20.

[20] Sydney J. Freedberg Jr., "Artificial Intelligence Will Help Hunt Daesh By December," *Breaking Defense,* July 13, 2017, accessed December 27, 2017, https://breakingdefense.com/2017/07/artificial-intelligence-will-help-hunt-daesh-by-december/.

[21] The *Army Data Strategy* defines Big Data as "very large, rapidly changing, and differently structured data sets that are impractical to manage using conventional data processing techniques." US Department of the Army, Office of the Army Chief Information Office/G-8, Information Architecture Division, Army Architecture Integration Center, Headquarters, Department of the Army, *Army Data Strategy*, February 2016, accessed December 10, 2017, http://ciog6.army.mil/Portals/1/Home/Tabs/Strategy/20160303_Army_Data_Strategy_2016.pdf.

Data is also rapidly changing (velocity), and structured in different ways (variety).[22] The *3V* Big Data factors (volume, velocity, and variety) are obstacles with which human brains are ill-equipped to deal, even with the help of sophisticated data processing software.

Susceptibility to Bias

Analysts sometimes rely on intuition when interpreting meaning from information, but humans are far from infallible. The emotions that separate us from machines also make us susceptible to cognitive bias that can distort intelligence indicators.[23]

An example of this phenomenon occurred during the Yom Kippur War in 1973. During the ten months preceding the war, the Egyptians and Syrians held monthly large-scale maneuvers near the Israeli border in full view of the defenders manning the Bar-Lev line. The Arabs intended to acclimate the Israelis to large troop concentrations near the borders. Concurrently, they confirmed Israeli beliefs of Arab ill-preparedness through deceptive newspaper articles and misleading intelligence 'leaks'.[24] When the attack commenced on October 6, a holy day for all participants, the Israelis were slow to act despite compelling evidence that they were under attack. Their biased assumptions led them to believe they were safe from an attack, and it nearly cost them the war.

The Limits of Organizational Knowledge

Even if the IC was comprised solely of the planet's smartest and most well-informed people, it would still have knowledge gaps. There is no single organization that can contain all the

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[22] The 3Vs are volume, velocity, and variety. "Volume" refers to the exponentially increasing amount of data available. "Velocity" refers to the accelerating rate at which people generate and distribute data. "Variety" refers to the multiple forms that data can take (e.g. social media posts, sensor readings, cell phone signals, and consumer trends), which makes aggregation difficult. Andrew McAfee and Erik Brynjolfsson, "Big Data: The Management Revolution," *Harvard Business Review*, October, 2012, accessed January 22, 2018, https://hbr.org/2012/10/big-data-the-management-revolution.

[23] Daniel Kahneman, *Thinking Fast and Slow* (New York: Farrar, Straus and Giroux, 2011), 3-22.

[24] Trevor N. Dupuy, *Elusive Victory: The Arab-Israeli Wars: 1947-1974* (Garden City, NY: Military Book Club, 2002), 392.

knowledge necessary to fully explain the complexity of human interactions in an operational environment. To fill these knowledge gaps, the IC must look outside the intelligence enterprise to alternative erudition sources. Advances in artificial intelligence and crowdsourcing show promise in facilitating this integration.

Section II – Artificial Intelligence

I, for one, welcome our new computer overlords.

– Ken Jennings, former *Jeopardy!* champion

Describing the OE is the IC's most vital role in military operations. Section I explained how the IC describes the OE by collecting, processing, and analyzing GEOINT and OSINT to produce OE assessments and estimates. This section examines the history of AI, the importance of machine learning, and the role AI can play in helping the IC describe the OE more quickly and more reliably.

History of AI

Artificial intelligence is ubiquitous. Special encoded process instructions called *algorithms* empower digital personal assistants like Siri and Alexa, guide self-driving cars, and defeat world champions in everything from *Go* to *Jeopardy!*[25]

Although AI's recent Cambrian Explosion appears to be a recent phenomenon, its history began in antiquity.[26] Man's earliest attempts at AI resulted in analog mechanisms that followed predetermined sequences. The Antikythera Mechanism, for example, was a complex machine built as early as 200 BCE (before Common Era) with at least 30 internally meshed gears, pointer needles, and concentric circular scales. It predicted astronomical positions and eclipses and tracked a variety of data including the four-year cycle of the ancient Olympic Games.[27]

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[25] Sean O'Neill, "Human vs Machine: Five Epic Fights against AI," *New Scientist,* May 31, 2017, accessed January 24, 2018, https://www.newscientist.com/article/2133146-human-vs-machine-five-epic-fights-against-ai/.

[26] The Cambrian Explosion was a brief period of rapid biological diversification about 500 million years ago. In this period single-celled organisms diversified into the complex animal phyla present today.

[27] Jo Marchant, "Decoding the First Antikythera Mechanism, the First Computer," *The Smithsonian*, February, 2015, accessed December 12, 2017, https://www.smithsonianmag.com/history/decoding-antikythera-mechanism-first-computer-180953979/.

AI development ebbed and flowed over the next several centuries, catalyzed in the 20th century by technological advancements in digital computer science. A major AI milestone occurred at Dartmouth College in 1956, when math professor John McCarthy organized the first conference on AI.[28] This conference formed the beginning of the modern conception of AI, but it also bifurcated the field. Differences in methodology and application spawned two competing schools of thought: a rules-based approach, and a statistical pattern recognition approach called *machine learning*.[29]

Rules-based AI can perform simple, task-specific actions using a series of *if-then* instructions (e.g., *if* the subject is plural, *then* the verb must also be plural). Computer scientists embed these rules into software to enable programs to do things like follow the subject-verb agreement rule.

The advent of Big Data made rules-based AI obsolete for complex tasks.[30] If-then rules do not work well with Big Data, which is too big, too peripatetic, and too diverse to control with a series of linked binary choices. For example, coders would face a Sisyphean task constructing an algorithm comprised of if-then statements enumerating all the possible pixel combinations to describe an image of a dog.

Machine Learning

Machine learning is more compatible with Big Data. It works by identifying statistical patterns in the data, and using them to form shortcuts, or *heuristics* (e.g., most dogs have four legs

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[28] Dr. McCarthy defined the term "artificial intelligence" as the "science and engineering of making intelligent machines." Andrew McAfee and Erik Brynjolfsson, *Machine, Platform, Crowd: Harnessing Our Digital Future* (New York: W.W. Norton & Company, 2017), 67.

[29] Ibid., 69.

[30] Ibid., 70.

and a tail).[31] Machine learning algorithms can identify and categorize images using *computer vision*, which is a machine's ability to make sense of images. Using computer vision, machines detect features in an image that have a high statistical probability to be present in a set or subset of objects, and then categorize objects in the image based on the accumulated probability.[32] For example, a machine might detect an object with four legs, forward-facing eyes, pointed ears, a slightly domed head, a distinctive snout, carnivorous dentition, and curly fur. The machine would compare this information with its database of labeled images to determine that a high statistical probability exists that this object is a dog.

Machine learning is either *supervised* or *unsupervised*. Supervised machine learning involves inputting labeled data sets to train the software to recognize images or assess population sentiment. By providing the AI examples of labeled items, the machine learns the characteristics of those items. It is the equivalent of showing the AI what right looks like. During supervised machine learning, developers may provide hundreds of thousands of images of dogs to train a program to correctly identify dogs in images. The size and variety of the data set corresponds directly to the AI's depth of knowledge on what it should categorize as a dog. Unsupervised AI does not use training data and must use cues from its environment to complete these tasks.[33]

An example of supervised machine learning at work is International Business Machines' (IBM's) Watson, which was purpose-built to compete with humans on the trivia game show

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[31] "Heuristics" is a term introduced by the mathematician George Pólya in his book on mathematical proof, *How to Solve It,* and adopted by early AI researchers. Heuristics continue to be an important AI method for reducing innumerable combinatorial search possibilities. George Pólya, *How to Solve It: A New Aspect of Mathematical Method* (Princeton, NJ: Princeton University Press, 1945), 112.

[32] Li-Jia Li, Richard Socher, and Li Fei-Fei, "Towards Total Scene Understanding: Classification, Annotation and Segmentation in an Automatic Framework" (paper prepared for the 2009 IEEE conference on Computer Vision and Pattern Recognition, Miami, FL, June 2009), 2, accessed March 30, 2018, http://vision.stanford.edu/pdf/LiSocherFei-Fei_CVPR2009.pdf.

[33] Vishal Maini, "Machine Learning for Humans, Part 3: Unsupervised Learning, Clustering and Dimensionality Reduction," Medium website, August 19, 2017, accessed March 30, 2018, https://medium.com/machine-learning-for-humans/unsupervised-learning-f45587588294.

Jeopardy! IBM trained Watson by outfitting it with years' worth of *Jeopardy!* data and the complete Wikipedia anthology – over fifteen terabytes worth of information in all.[34] Success required Watson to behave in a manner consistent with human behavior. Just like a human contestant, Watson had to understand human speech, recall the correct answer from memory, activate the buzzer, and deliver an answer in the form of a question. In February 2011, Watson defeated the two highest-ranked Jeopardy! champions in the show's history – beating the second-place finisher by more than 53,000 points.[35]

Watson's victory is important because it demonstrates the ability of AI to successfully apply a large amount of information to maximize a given reward against human opponents and a well-defined problem set. In military endeavors, however, the parameters are not always so clear. In scenarios where the way forward is murky, the IC helps by giving the commander a better idea of the operating environment.

Speed and Accuracy

The IC uses GEOINT and OSINT to describe the OE. Getting the description right is difficult under the best of circumstances, and operational environments are rarely optimal. The following examples demonstrate how AI can help the IC increase speed and accuracy by mitigating the effects of the limits of human cognition, susceptibility to bias, and the limits of organizational knowledge.

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[34] Ben Zimmer, "Is it Time to Welcome Our New Computer Overlords?" *The Atlantic*, February 17, 2011, accessed March 30, 2018, https://www.theatlantic.com/technology/archive/2011/02/is-it-time-to-welcome-our-new-computer-overlords/71388/.

[35] Final results: Watson: 77,147, Ken Jennings: 24,000, Brad Rutter: 21,600. Gerald Tesauro, David Gondek, Jonathan Lenchner, James Fan, John Prager, "Analysis of Watson's Strategies for Playing Jeopardy!" *Journal of Intelligence Research* 21 (May, 2013): 244, accessed March 30, 2018, https://www.jair.org/media/3834/live-3834-7061-jair.pdf.

The Limits of Human Cognition

With the advent of Big Data, the gap between the demand for actionable intelligence and the supply of human analysts continues to widen. GEOINT and OSINT are two intelligence disciplines in which there is a deluge of available information. The National Geospatial Intelligence Agency (NGA) is the largest collector of full-motion video (FMV) in the IC, and Big Data is currently their biggest challenge.[36] Scott Currie, the NGA Mission Integration Director, estimated in July 2017 that he would need to hire two million more analysts (roughly the population of Houston) to keep pace with satellite proliferation.[37] As bad as it seems, the problem is getting worse. NGA Director Robert Cardillo told a conference in June 2017, "…in five years, there may be a million times more than the amount of geospatial data we have today. Yes, a million times more."[38]

FMV is a major component of the OE assessments the IC produces to describe the OE. Unfortunately, the demand has outpaced NGA's resources such that commanders in the field may be missing opportunities to exploit time-sensitive intelligence still awaiting examination. To solve this Big Data problem, the NGA began exploring options using algorithms and computer vision.

The DOD's Algorithmic Warfare Cross-Functional Team (AWCFT), also known as Project Maven, is working on a solution.[39] Project Maven intends to use supervised machine

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[36] Colin Clark, "Cardillo: 1 Million Times More GEOINT Data in 5 Years," *Breaking Defense,* June 5, 2017, accessed December 23, 2017, https://breakingdefense.com/2017/06/cardillo-1-million-times-more-geoint-data-in-5-years/.

[37] Currie's full quote, "If we looked at the proliferation of the new satellites over time, and we continue to do business the way we do, we'd have to hire two million more imagery analysts." Freedberg, "AI Will Hunt Daesh By December."

[38] Clark, "1 Million Times More."

[39] In April 2017, the Deputy Secretary of Defense, Dr. Robert Work, created Project Maven to "accelerate DOD's integration of Big Data and machine learning. The AWCFT's objective is to turn the enormous volume of data available to DOD into actionable intelligence and insights at speed." Deputy Secretary of Defense Memorandum dated April 26, 2017, "Establishment of an Algorithmic Warfare Cross-Functional Team (Project Maven)."

learning algorithms and computer vision to automate 75 percent of the video processing, analyzing, and disseminating that NGA currently conducts.[40]

Creating this kind of capability for the IC is no easy task, and the up-front labor cost is considerable. To create the first training data set for Project Maven, humans labeled over 150,000 images.[41] In December 2017, just six months after the program's inception, the first batch of Project Maven's trained algorithms began supporting drone missions in the fight against the Islamic State of Iraq and al-Sham (ISIS).[42] Within the first few days, the AI detected and categorized items such as people, cars, and building types with 60 percent accuracy. After a few software tweaks to account for regional differences, the AI began detecting objects with 80 percent accuracy.[43] The Project Maven team anticipates this percentage will continue to rise as they introduce larger data training sets.[44] While Project Maven is still only a working prototype, the positive results displayed after only six months demonstrate enormous potential for solving NGA's Big Data problem.

Susceptibility to Bias

With the development of AI that can perform routine analysis, the IC gains a time dividend it can leverage toward higher-level sense-making. Since the days of the Antikythera Mechanism, the standard model of human-machine partnerships consigned machines to mundane chores while humans perform more judicious undertakings. The problem with this design is that

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[40] Clark, "1 Million Times More."

[41] Marcus Weisgerber, "The Pentagon's New Artificial Intelligence is Already Hunting Terrorists," *Defense One,* December 21, 2017, accessed January 15, 2018, http://www.defenseone.com/technology/2017/12/pentagons-new-artificial-intelligence-already-hunting-terrorists/144742/.

[42] Ibid.

[43] Ibid.

[44] Ibid.

humans are demonstrably bad at rendering judgment.[45] Until recent innovations in machine learning and deep neural networks upset the status quo, the standard model was the logical option. The analytic capacity of AI has advanced such that the best option may be reversing the partnership completely.

This is an important development for the IC, whose analysts rely on their judgment to forecast how adversaries or population groups will react to stimuli. The intelligence estimates they produce provide context to behavior and events in the OE but are subject to the effects of human bias. AI has demonstrated the ability to mitigate the effects of human bias in estimative intelligence.

An example of bias mitigation is the successful record of MogIA, a computer program that has accurately predicted the last four US presidential elections.[46] MogIA works on the premise that the candidate with more social media mentions, or *engagements*, has a higher probability of winning the election.[47] The program collects and analyzes OSINT from social media sites like Facebook, Twitter, and YouTube, and then aggregates the data to form conclusions based on probability. Like its namesake, Mowgli, MogIA learns its rules from the environment.[48] In software terms, this means the underlying algorithm is unsupervised – no initial training data. MogIA has baseline instructions but develops its own judgment policies using a

[45] Kahneman, 3-22. Also see the multi-decade study led by Philip Tetlock for more evidence of humans' gaucheness with judgment: Philip Tetlock, *Superforecasting: The Art and Science of Prediction* (New York: Broadway Books, 2015), 4-5.

[46] Arjun Kharpal, "Trump Will Win the Election and is More Popular than Obama in 2008, AI System Finds," CNBC Tech Transformers, October 28, 2016, accessed January 23, 2018, https://www.cnbc.com/2016/10/28/donald-trump-will-win-the-election-and-is-more-popular-than-obama-in-2008-ai-system-finds.html.

[47] Interestingly, using social media engagements as a predictor of future electoral success is another form of bias.

[48] Mowgli is the protagonist in Rudyard Kipling's *The Jungle Book*.

learning algorithm.[49] By not providing a training data set, MogIA's programmers avoid the bias inherent in creating judgment rules. Another bias mitigation is the neutral nature of the data collection. By passively collecting social media data, MogIA avoids the risk of bias posed by human pollsters interviewing other humans who may have motives for dishonesty.

MogIA's results suggest the method is working. For example, using twenty million social media data points, MogIA correctly predicted Donald Trump's 2016 US presidential election win weeks before his victory.[50] This finding was in stark contrast to the prevailing opinion of political prediction experts and opinion polls forecasting a Clinton victory until late in the evening on Election Day.[51]

The Limits of Organizational Knowledge

Former Secretary of Defense Donald Rumsfeld's *known unknowns* quote during a news briefing in 2002 illustrates the limits of organizational knowledge.[52] His remarks spoke to the difficulty of achieving situational understanding in complex operational environments. This is another area in which AI shows potential to help the IC.

For a machine, what is known consists entirely of what its designers have trained it to know through supervised machine learning or what it can learn on its own through unsupervised

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[49] Kharpal, "Trump Will Win the Election."

[50] Ibid.

[51] Mike Brown, "MogIA AI System Predicted a Trump Win Weeks Ago," November 9, 2016, accessed February 18, 2018, https://www.inverse.com/article/23472-mogia-ai-trump-win-weeks-ago.

[52] Secretary Rumsfeld's full quote: "Reports that say that something hasn't happened are always interesting to me, because as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns -- the ones we don't know we don't know. And if one looks throughout the history of our country and other free countries, it is the latter category that tend to be the difficult ones." Department of Defense News Transcript, February 12, 2002, accessed January 23, 2018, http://archive.defense.gov/Transcripts/Transcript.aspx?TranscriptID=2636.

machine learning. Programs like MogIA suggest that machines are getting better at determining environmental unknowns on their own using unsupervised machine learning.

In 2015, Google's DeepMind project developed a program that achieved human-level performance at 43 arcade games, and beat the human test subjects (professional game testers) in 29 of the games despite having no prior training on game play.[53] For each game, DeepMind's team only provided its AI with sensory input (the pixels on the screen), and basic control instructions. Then they ordered it to maximize the total score without telling it how to score points.[54] It was up to the program to determine capabilities, rewards, punishments, and tactics on its own.

Figure 1. Screen capture of Google's DeepMind agent playing Breakout. Jennifer Welsh, "Researchers Say This is the Most Impressive Act of Artificial Intelligence They've Ever Seen," *Business Insider*, November 13, 2015, accessed December 28, 2017, http://www.businessinsider.com/artificial-intelligence-playing-video-games-2015-11.

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[53] Volodymyr Mnih et al., "Human-Level Control through Deep Reinforcement Learning," *Nature* 518, February 26, 2015, 530, accessed December 28, 2017, https://storage.googleapis.com/deepmind-media/dqn/DQNNaturePaper.pdf.

[54] Mnih et al., 529.

DeepMind achieved these results using a subset of machine learning called *deep learning*. Deep learning uses complex, auto-correcting algorithms in combination with a series of classification layers known as a *neural network*.[55] Neural networks operate using nodes and connections like the neurons and synapses in human brains. Stacking several neural networks creates a *deep neural network*. Each neural network in the stack has a discrete function that increases in complexity with each successive layer. For example, one layer classifies an image as an animal, the next classifies it as a four-legged animal, the next classifies it as a canine, etc. The algorithm moves information through ascending layers, incorporating each layer's findings into subsequent layers' analysis.

DeepMind's achievements are important because they demonstrate the possibilities that neural networks represent. The development of an AI agent that can take stock of an unknown situation, use its existing knowledge of other circumstances to understand current circumstances, and then train *itself* to maximize rewards has substantial implications for military application.

Why We Still Need the Human in the Loop

Advancements in neural networks are changing the way we think about AI. What AI still cannot do, however, is think like a human. There is nothing in the AI realm that remotely approaches the complexity of the human brain. The same AI that defeated two *Jeopardy!* champions is incapable of understanding why a joke is funny. Former Defense Advanced Research Projects Agency (DARPA) director, Arati Prabhaker, adeptly described the problem in May, 2017. "The problem is that when they're wrong, they're wrong in ways that no human would ever be," she said, demonstrating her point with a picture of an infant holding a

[55] Vishal Maini, "Machine Learning for Humans, Part 4: Neural Networks & Deep Learning," Medium website, August 19, 2017, accessed March 30, 2018, https://medium.com/machine-learning-for-humans/neural-networks-deep-learning-cdad8aeae49b.

toothbrush.[56] A machine had incorrectly described the image as “a young boy is holding a baseball bat.”[57] Common sense is only common to humans. Machines cannot understand the nuanced difference between *infant* and *young boy* until developers program it to do so. Programmers are, in effect, coding in millions of years of evolutionary cognitive development one lesson at a time. Research suggests crowdsourcing can help.

Figure 2. An example of AI’s shortcomings. Andrej Karpathy and Li Fei-Fei, “Deep Visual-Semantic Alignments for Generating Image Descriptions” (paper prepared for the Institute of Electrical and Electronics Engineers (IEEE) Conference on Computer Vision and Pattern Recognition (CVPR), 2015), accessed December 15, 2017, https://cs.stanford.edu/people/karpathy/deepimagesent/.

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[56] Sydney J. Freedberg Jr., “‘Algorithmic Warfare:’ DSD Work Unleashes AI on Intel Data,” *Breaking Defense,* April 28, 2017, accessed December 27, 2017, https://breakingdefense.com/2017/04/dsd-work-unleashes-ai-on-intel-data-algorithmic-warfare/.

[57] Andrej Karpathy and Li Fei-Fei, “Deep Visual-Semantic Alignments for Generating Image Descriptions” (paper prepared for the Institute of Electrical and Electronics Engineers (IEEE) Conference on Computer Vision and Pattern Recognition (CVPR), 2015), accessed December 15, 2017, https://cs.stanford.edu/people/karpathy/deepimagesent/.

Section III – Crowdsourcing

> Crowdsourcing is the process by which the power of the many can be leveraged to accomplish feats that were once the province of a specialized few.
>
> – Jeff Howe, *Wired Magazine,* 2006

In 2010, Haiti experienced the worst earthquake in its 214-year history.[58] The upheaval killed over 200,000 people, and injured scores more.[59] Survivors were unable to contact their loved ones due to power outages and communications infrastructure damage. A shortage of relevant GEOINT blinded decision-makers and hindered relief efforts. A pattern of innovative crowdsourcing emerged within days, which helped aid workers identify and focus relief efforts on the most affected areas of the country. The Haiti earthquake was a complex problem that presented emergency management officials with multiple dilemmas. This disaster demonstrated the importance of describing the OE in domestic operations as well as combat operations.

The IC's capacity to describe the OE is dependent on its ability to rapidly collect accurate intelligence. Crowdsourcing can help by providing a means for further refinement. Crowdsourcing nests within the IC's practice of collecting, processing, and analyzing GEOINT and OSINT to describe the OE for commanders. This section examines crowdsourcing, its history, the participants and their motivations, and the impact crowdsourcing can have on the speed and accuracy of intelligence.

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[58] Ray Harris, "Satellite Earth Observation and Disaster Management – Lessons and Needs after the Indian Ocean Tsunami and the Haiti Earthquake," *Yearbook on Space Policy 2009/2010* (Vienna: Springer-Verlag, 2011), 281.

[59] Ibid.

What is Crowdsourcing?

Crowdsourcing, a term coined by writer Jeff Howe in a 2006 *Wired* magazine article, is a portmanteau of *crowd* and *outsourcing*.[60] It is the process by which an individual or organization employs the public to solve a problem or provide a resource.[61] Crowdsourcing can take numerous forms to satisfy myriad participant motivations. While modern crowdsourcing activities typically involve the internet, the practice of asking the public for help solving Big Data problems pre-dates computers by thousands of years.[62]

History of Crowdsourcing

Early crowdsourcers aimed to solve travel-related problems. In 1567, for example, King Philip II of Spain offered a reward for a method of determining a ship's longitude at sea.[63] His son, Philip III, upped the reward in 1598 to 6,000 ducats and a pension.[64] In the 18th Century, the

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[60] Jeff Howe, "The Rise of Crowdsourcing," *Wired,* 14.06 (June, 2006), accessed February 17, 2018, https://www.wired.com/2006/06/crowds/.

[61] There is no governing body regulating crowdsourcing, and as such, there is no commonly accepted definition. The definition used in this paper is succinct and useful for the purposes of this study. Benjamin Clark, Nicholas Zingale, and Joseph Logan "Intelligence and Information Gathering through Deliberative Crowdsourcing," *Journal of Public and Nonprofit Affairs* 3, no. 1 (April 2017): 55, accessed February 28, 2018, http://dx.doi.org/10.2139/ssrn.2485796.

[62] Buddhadeb Halder, "Evolution of Crowdsourcing: Potential Data Protection, Privacy and Security Concerns under the New Media Age," Digital Democracy and Electronic Government 1, no. 10 (2014): 377, accessed February 20, 2018. http://buscalegis.ufsc.br/revistas/index.php/observatoriodoegov/article/view/34341/33195.

[63] *Longitude* is a geographic coordinate that specifies the east-west position of a point on the Earth's surface. King Philip II: Martin Romme Henriksen, "Cavity Enhanced Spectroscopy on Ultra Cold Atoms" (master's thesis, University of Copenhagen Faculty of Science, 2014), 1, accessed April 2, 2018, http://ultracold-atoms.nbi.ku.dk/research/theses_conference/MRHenriksen_master.pdf.

[64] J.J. O'Connor and E.F. Robertson, "History Topic: Longitude and the Académie Royale," University of Saint Andrews website, February 1997, accessed April 2, 2018, http://www-groups.dcs.st-and.ac.uk/~history/PrintHT/Longitude1.html.

British government codified a £20,000 reward for longitude calculation in the Longitude Act of 1714.[65]

In the mid-1800s, Matthew Maury, an American astronomer, distributed hundreds of thousands of copies of his nautical guide, *Wind and Current Chart of the North Atlantic,* to the seafaring community at no cost. Maury intended for sea captains to use these charts on the condition that they return a standardized log of their voyage to the US Naval Observatory in Washington, D.C.[66] Maury used the 1.2 million unique data points he received in trade to publish *The Physical Geography of the Sea* in 1858, recognized internationally as the premier maritime navigational source of its day.[67]

Pre-digital crowdsourcing helped solve non-travel-related issues as well. In 1884, the first publishers of the Oxford English Dictionary used over 800 volunteer readers to catalogue words, and in 1957 the architect for the Sydney Opera House surfaced from a crowdsourced international design competition.[68]

These early attempts at crowdsourcing resemble modern efforts in many ways. While the nature of crowdsourcing remains unchanged, the advent and proliferation of the internet dramatically altered one's *capacity* to crowdsource. With increased capacity came increased

[65] Katy Barrett, "'Explaining' Themselves: the Barrington Papers, the Board of Longitude, and the Fate of John Harrison," *The Royal Society Journal of the History of Science*, January 12, 2011, accessed April 2, 2018, http://rsnr.royalsocietypublishing.org/content/early/2011/01/03/rsnr.2010.0089.full.

[66] Matthew F. Maury, *The Physical Geography of the Sea* (New York, NY: Harper and Brothers, 1858), ix.

[67] Christopher Cosper, "The Expert Mind in the Age of Junk Data," *Architecture & Planning, Cogent Social Sciences* 2, no. 1 (June 2016): 2, accessed February 17, 2018, https://doi.org/10.1080/23311886.2016.1198218.

[68] Consuelo López, "An Experiment in Microtask Crowdsourcing Software Design," (Master's thesis, University of California, Irvine, 2016), 6, accessed February 22, 2018, https://escholarship.org/uc/item/2904d747.

specialization: crowdvoting, crowdsolving, crowdsearching, and crowdmapping are some examples.

Explicit and Implicit Crowdsourcing

Crowdsourcing can be *explicit* or *implicit* depending on the method of conduct, and the knowledge of the contributors regarding their participation.[69] Crowdsourcing is *explicit* when contributors collaborate on tasks to solve a stated problem. Crowdsourcing is *implicit* when recipients gain information from contributors who are unaware of their participation. Explicit crowdsourcing uses standalone systems (i.e., a website), for stated purposes such as evaluating, sharing, building artifacts, and executing tasks.[70]

Evaluating

Evaluation crowdsourcing employs the crowd to provide opinions on products, services, healthcare, entertainment, restaurants, and myriad other business-related ventures.[71] Businesses rely on customer reviews on websites to build or maintain a positive reputation. It is word-of-mouth in the digital age. Many online vendors, like Amazon, build the review system directly into the product presentation. Consumers advocate or deprecate products using ratings and comments. Amazon maintains customer satisfaction by giving the consumer a voice to support or denounce products as they see fit. This crowdsourcing method creates efficiency for Amazon by employing

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[69] Anhai Doan, Raghu Ramakrishnan, and Alon Halevy, "Crowdsourcing Systems on the World-Wide Web," *Communications of the ACM* 54, no. 4 (April 2011): 88, accessed April 2, 2018, http://doi.acm.org/10.1145/1924421.1924442.

[70] Aditi Misra, Aaron Gooze, Kari Watkins, Mariam Asad, and Christopher Le Dantec, "Crowdsourcing and Its Application to Transportation Data Collection and Management," *Transportation Research Record: Journal of the Transportation Research Board*, no. 2414 (2014): 3, accessed February 1, 2018, https://doi.org/10.3141/2414-01.

[71] Fernando Ferri, et al., "KRC: Knowing Crowdsourcing Platform Supporting Creativity and Innovation," *Advances in Information Sciences and Service Sciences (AISS)* 5, no. 16 (November 2013): 3, accessed February 1, 2018, https://arxiv.org/pdf/1704.00973.pdf.

millions of their customers as product testers. Before the digital revolution, companies had to pay for this service. Now, the customer pays for the right to review products with their purchase.

Yelp.com is another example of large-scale evaluation crowdsourcing. Yelp is a website created as a repository for online business reviews. Yelp is a widely used website with over 142 million reviews, and a monthly average of 104 million unique visitors.[72] In addition to their robust crowdsourced review service, Yelp is also conducting crowdsourcing to improve its own business. The Yelp Dataset Challenge is a competition for students to "conduct research or analysis on our data and share their discoveries with us."[73] Yelp awards cash prizes for discoveries that improve Yelp's machine learning processes. These include things like compiling training datasets more efficiently, improving graph mining, and improving natural language processes.[74]

Sharing

When sharing via crowdsourcing, contributors exchange ideas, information, products, or services.[75] Websites like YouTube, Facebook, and Twitter allow users to express opinions, promote businesses, or post content intended for a wider audience. These websites are very popular due to the public's desire to connect and share – evidenced by 1 billion YouTube users collectively watching over a billion hours of video daily.[76] YouTube and Facebook are the

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[72] "About Us," Yelp website, accessed February 4, 2018, https://www.yelp.com/about.

[73] "Yelp Dataset Challenge," Yelp website, accessed February 4, 2018, https://www.yelp.com/dataset/challenge.

[74] *Graph mining* is the process of finding and extracting useful information from semi-structured data sets.

[75] Ferri, et al., 3.

[76] YouTube Website, "YouTube for Press," accessed April 3, 2018, https://www.youtube.com/intl/en-GB/yt/about/press/.

second- and third-most visited websites in the world – each with millions of visitors daily.[77] YouTube is particularly well-suited for crowdsourcing due to its video content format. The broad spectrum of human interest motivates millions of users, with skill levels ranging from novice to professional, to produce an immense body of knowledge.[78]

As of February 2017, YouTube users were watching a billion hours of content each day.[79] Visitors to the site can crowdsource user-submitted footage demonstrating everything from fabricating an Iron Man suit to carving watermelons.[80] With a substantial portion of the global population submitting content each day, the crowdsourcing potential is enormous.

Artifacts Crowdsourcing

Crowdsourcing that focuses on creating objects, knowledge bases, software, or systems is known as *artifact* crowdsourcing. An example of artifact crowdsourcing is Threadless.com. Threadless is a website where contributors submit original artwork attempting to get their work printed on t-shirts for sale on the site. Visitors to the site (including other contributors) select the winning designs by voting and commenting on their favorites. A Threadless selection team makes the final decision based on the crowdvoting, and then they print, market, and sell the winning design on their site. The winning designer receives a one-time cash award in return for signing over the creative rights to the design. The site makes public statistics on its contributors (number

[77] "The Top 500 Sites on the Web," Alexa Internet, accessed February 2, 2018, https://web.archive.org/web/20170309101510/http://www.alexa.com/topsites.

[78] Courtney Seiter, "The Psychology of Social Media: Why We Like, Comment, and Share Online," Blog: Buffer Social, August 10, 2016, accessed April 3, 2018, https://blog.bufferapp.com/psychology-of-social-media.

[79] Cristos Goodrow, "You Know What's Cool? A Billion Hours," YouTube, Official Blog, February 27, 2017, accessed February 2, 2018, https://youtube.googleblog.com/2017/02/you-know-whats-cool-billion-hours.html.

[80] Mutita Edible Art, "Simple Watermelon Flower Style – Int Lesson 1," YouTube, December 16, 2012, accessed February 2, 2018, https://www.youtube.com/watch?v=J0Ozl_SRGVE. James Bruton, "XRobots – How to Build an Iron Man Helment & Suit, Moulding, Casting, 3D Printing, Electronics," YouTube, August 22, 2014, accessed February 2, 2018, https://www.youtube.com/watch?v=8dy9tAhweeU.

of designs submitted, number of wins, amount of cash prize, etc.) with pictures of each users' contributions in their profile section. This is a beneficial practice for both the business and the contributors. The contributors get a better idea of the designs that are winning, and the business gets an opportunity to train the crowd on what is selling.

The website Wikipedia is another good example of an artifact crowdsourcing system. Wikipedia is a textual knowledge base accessible in the form of a free online encyclopedia. It is the largest encyclopedia ever assembled with over 40 million articles in 299 different languages.[81] Articles on Wikipedia are organized like research papers, including a table of contents, structured paragraphs with header titles, visual aids, citations, and bibliographies.

The US DOD adopted this practice with a website on their classified network called Intellipedia. Intellipedia is a collaborative sharing website made in Wikipedia's image that the IC uses to crowdsource secret and top secret information. This system is not available to the public for security reasons and is only accessible to security clearance holders with a need to know. The Intellipedia site allows users to add and edit information on regions, people, and issues of interest to the intelligence enterprise.

Executing Tasks

Task execution is a major impetus for people or organizations to employ crowdsourcing. Organizations execute tasks via crowdsourcing to create efficiencies or to compensate for a deficiency in people, resources, or ideas. This can include tasks like identifying text, objects, or people in images; generating ideas; and funding projects.[82]

The founder of a Kansas City convenience store chain crowdsourced a solution to his shoplifting problem. Babir Sultan's chain, FavTrip, was experiencing a high incident rate of theft

[81] "Wikipedia," Wikipedia: The Free Encyclopedia website, accessed February 3, 2018, https://en.wikipedia.org/wiki/Wikipedia.

[82] Fernando Ferri, et al., 3.

in 2017. In response, Sultan began posting security camera footage of the thieves in action to social media sites to identify the shoplifters, and shame them into reimbursing the store for the stolen items. Sultan stimulated sharing by overlaying each video with an amusing narrated description of the action on the screen. The tactic was very successful, compelling many offenders to return to the store with payment in exchange for removal of the footage. The tactic deterred potential theft as well. Sultan told a local news reporter that his *shrinkage*, a business term for theft, reduced by sixty percent because of the crowdsourcing policy.[83]

Crowdsourcing in any of these systems can be explicit in three ways.[84] The first two ways are recipient-based, and the third is contributor-based. First, recipients can ask the crowd for help directly as in the FavTrip store owner requesting the crowd's help to shame shoplifters. Secondly, users can query an existing body of crowdsourced knowledge for specific information, as in when a YouTube visitor types "how to write a monograph" in the search text box. Finally, a crowdsourced problem can be explicit when a contributor provides information to potential recipients with the goal of solving a stated communal problem. For example, servicemembers having difficulty passing the DOD's Cyber Awareness Challenge exam, an annual requirement, need only consult the website Quizlet.com, which contains answers to all versions of the test.[85]

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[83] Taisha Walker, "Local Convenience Store Using Shame, Social Media, and a Little Humor to Fight Shoplifting," KMBC News 9 website, January 16, 2018, accessed February 4, 2018, http://www.kmbc.com/article/local-convenience-store-using-shame-social-media-and-a-little-humor-to-fight-shoplifting/15300534.

[84] David Geiger, Michael Rosemann, Erwin Fielt., "Crowdsourcing Information Systems: A Systems Theory Perspective," *Proceedings of the 22nd Australasian Conference on Information Systems (ACIS)* (2011): 4, accessed February 17, 2018, https://aisel.aisnet.org/acis2011/33/.

[85] "Annual DOD Cyber Awareness Challenge Exam," Quizlet website, accessed February 4, 2018, https://quizlet.com/80158200/annual-dod-cyber-awareness-challenge-exam-flash-cards/.

Implicit

This method involves collecting data from the crowd as they participate in an activity unrelated to the crowdsourced problem. The collected information may be a by-product of the unrelated task or data about the contributor's activity as they conduct the unrelated task.[86]

In 2003, researchers at Carnegie Mellon University created an internet-based method of labeling image metadata called the Extrasensory Perception (ESP) Game.[87] Carnegie Mellon's intent was to improve the effectiveness of software that audibly describes images for the visually impaired. The software's algorithm needed labeled training data to conduct machine learning, and the ESP Game created that training data.

The game matched random players into pairs and displayed several consecutive images. Unable to communicate with each other, the partners attempted to agree on a label by typing matching answers into a text box. Each time partners entered the same word for an image, they advanced to the next word. The image, meanwhile, recycled back into the game but now with a *taboo* word – the label assigned by the previous team. When the image appeared before the next set of players, the taboo word was inadmissible as an acceptable answer. This cycle continued until players could no longer agree on a label without using taboo words. In this way, images attained a complete set of frequently-used metadata labels with minimal cost to the recipient.

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[86] Daren Brabham, "Crowdsourcing as a Model for Problem Solving: An Introduction and Cases," *Convergence: The International Journal of Research into New Media Technologies* 14, no. 1 (February 2008): 75–90, accessed February 17, 2018, https://www.webcitation.org/67BLxbafe?url=http://www.clickadvisor.com/downloads/Brabham_Crowdsourcing_Problem_Solving.pdf.

[87] *ESP* is an acronym for extrasensory perception. Angela Saini, "Solving the Web's Image Problem," *BBC News*, last updated May 14, 2008, accessed February 4, 2018, http://news.bbc.co.uk/2/hi/technology/7395751.stm.

The program labeled over 100 million pictures in three years, attracting the attention of Google, which bought the program in 2006.[88] Google repackaged the program as Google Image Labeler, and uses the process to increase image search result accuracy.[89]

Influence on Speed and Accuracy of Intelligence

The Limits of Human Cognition

Inspired by the success of Wikipedia, British entrepreneur Steve Coast created OpenStreetMap (OSM) in 2004. OSM is an open-source platform that relies on *volunteered geographic information* (VGI), a grandiloquent term for *crowdmapping*, for its data.[90] The proliferation of small, economical satellite navigation system receivers (i.e. like the kind in a smart phone) over the last decade created the capability for millions of people to become amateur cartographers. OSM taps into this capability to generate an editable crowdsourced world map. Satellites capture billions of pixels every day but making those pixels useful requires putting them into context. OSM volunteers pore over satellite imagery in a web-based interface to identify trees, parks, buildings, houses, roads, and other items of geographic interest. Local knowledge enhances the crowdmappers' ability to identify objects with more specificity.

Like Wikipedia, users can add, modify, and delete information as things change. This fluidity facilitates an adaptive system that reacts quickly to stimuli. During emergencies, OSM requests help from crowdmappers to update affected portions of the map to support relief organizations and first responders. The first responding crowdmapper, a continent removed, may

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[88] Saini, "Solving the Web's Image Problem."

[89] Google Image Labeler Website: https://crowdsource.google.com/imagelabeler/category. For more information on how the site works, see Luis Von Ahn, "Human Computation," YouTube video, posted July 26, 2006, accessed February 19, 2018, https://www.youtube.com/watch?v=tx082gDwGcM.

[90] VGI is a term created by Michael Goodchild at the University of California Santa Barbara. *Crowdmapping* is a subtype of crowdsourcing that draws geographic data from the public. Will Mortenson, "NSG Open Mapping Enclave (NOME)" (briefing presented to the NGA GEOINT Foundation Group, Washington, D.C., December 7, 2016), accessed February 6, 2018, https://s3.amazonaws.com/gpccb/wp-content/uploads/2017/01/10163403/GP_Mortenson.pdf.

only have enough information to identify an object as a building. The next volunteer, a native to the area, may update the map to designate the building as a hospital based on her knowledge. An emergency worker on the ground may revise the map further to indicate the hospital is damaged. Mobile applications like Go Map!! and MAPS.ME allow users to edit OSM maps from their smart phones, allowing updates to occur in near-real time.

Well-developed areas (e.g. Southern California) are more detailed, with intricacies like stop signs and fire hydrants. Under-developed areas (e.g. Haiti) have little or no detail. Unfortunately, disaster also strikes in under-developed areas, and a dearth of GEOINT delays response efforts. This is when crowdsourcing's surge capacity demonstrates its worth.

When the 2010 earthquake devastated Haiti, extant maps were insufficient to support relief efforts. The scale of destruction obsoleted any satellite imagery more than a day old. The private sector responded by making terabytes worth of updated high-resolution satellite imagery available to OSM.[91] OSM posted urgent requests to the crowdmapping community on their crisis response page, and they responded immediately. Volunteers from around the world mapped many of the roads, buildings, and refugee camps in Port-au-Prince days after the earthquake.[92] OSM's effort involved 640 volunteers, took less than three weeks, and cost nothing.[93] The impact was enormous; triggering a sea change in disaster response policy in the United States.

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[91] Kenneth A. Duda and Brenda K. Jones, "USGS Remote Sensing Coordination for the 2010 Haiti Earthquake," *Photogrammetric Engineering & Remote Sensing* 77, no. 9 (September 2011): 899, accessed April 2, 2018, https://doi.org/10.14358/PERS.77.9.899.

[92] Chris Anderson-Tarver, "Crisis Mapping the 2010 Earthquake in OpenStreetMap Haiti," *University of Colorado at Boulder Geography Graduate Theses and Dissertations* 80 (Spring 2015): 45, accessed April 2, 2018, https://scholar.colorado.edu/cgi/viewcontent.cgi?article=1081&context=geog_gradetds.

[93] Clark points out that crowdsourcing is not free when you factor in the costs associated with doing business: server costs, paid employees, physical property, etc. "These costs can, however, be minimized when the crowd is a willing and engaged participant. This means engaging the crowd early and often by providing feedback on how the crowd's involvement and ideas matter." Clark et al., "Intelligence and Information Gathering," 68.

Taking note of OSM's impact during the Haiti earthquake crisis, NGA and the Federal Emergency Management Agency (FEMA) began researching ways to leverage open-source material and the public to improve situational understanding in domestic disaster scenarios. Their joint enquiry led to a paradigm shift in operations that bore fruit when Hurricane Sandy struck the US East Coast in 2012. During the storm, over 5,000 volunteers categorized 35,000 Civil Air Patrol-generated images in a matter of hours.[94] (Then) FEMA Deputy Administrator Rich Serino credited crowdsourcing with making "a big difference…to help the survivors quicker."[95]

Susceptibility to Bias

In 1906, Sir Francis Galton, a Victorian-era polymath, observed 800 people attempt to win a contest by guessing the weight of an ox on display at a county fair in Plymouth, England.[96] Galton observed that while no single contestant guessed the exact weight of the animal, the median guess was 1,207 pounds – within 1% accuracy of the actual weight of the ox: 1,198 pounds.[97] Galton declined to speculate on the cause of this "curious anomaly," labeling it a "psychological question."[98]

Psychologist Philip Tetlock opined in his book, *Superforecasting: The Art and Science of Prediction*, that the wisdom of the crowd was more accurate than any individual because their

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[94] David Becker and Samuel Bendett, "Crowdsourcing Solutions for Disaster Response: Examples and Lessons for the US Government," *Procedia Engineering* 107, 2015, 29, Accessed March 22, 2018. https://doi.org/10.1016/j.proeng.2015.06.055.

[95] Aaron Skolnik, "Thank You Mapping Volunteers," FEMA website, video posted by Aaron Skolnik, November 3, 2012, accessed February 19, 2018, https://www.fema.gov/media-library/assets/videos/80995.

[96] Galton was an accomplished statistician, psychologist, anthropologist, explorer, eugenicist, geographer, inventor, and meteorologist. For more on Galton, see Michael Bulmer, *Francis Galton: Pioneer of Heredity and Biometry* (Baltimore: The John Hopkins University Press, 2003).

[97] Francis Galton, "Vox Populi," *Nature* 75, March 7, 1907, 450-451, accessed February 19, 2018, https://www.nature.com/articles/075450a0.pdf.

[98] Ibid., 451.

biases canceled each other out.[99] Undergirding Tetlock's opinions were decades of research and a recent victory in a government-sponsored forecasting tournament.

Tetlock began studying *expert political judgment* (EPJ) in 1984, with a series of small-scale forecasting tournaments. After twenty years and 28,000 questions, Tetlock found that the 'experts' were "roughly as accurate as a dart-throwing chimpanzee."[100] Tetlock discovered that individual 'experts' were no more able to overcome their biases than the rest of the population.[101]

His research caught the attention of the Intelligence Advanced Research Projects Activity (IARPA). In 2011, IARPA sponsored a tournament-style forecasting study called the Aggregative Contingent Estimation (ACE) program. Like the EPJ study, ACE participants made predictions on geopolitical events. IARPA's tournament was massive, involving thousands of forecasters and millions of dollars.[102] Tetlock's team, the Good Judgment Project (GJP), harnessed the wisdom of the crowd by calculating the average forecast of the team. This crowdsourced forecast became the official GJP entry for each question in the tournament.

In the first year, the GJP beat IARPA's control group by 60%.[103] The second year, they beat it by 78% and were so far ahead of the competition that IARPA dropped the other remaining teams.[104] This study reaffirmed Tetlock's theory that organizations can mitigate bias by employing a crowdsourcing approach.

Galton's ox-weighing competition explains the effect. Just like the contestants at the county fair, individual forecasters had their own biases and heuristics that affected their

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[99] Tetlock, *Superforecasting,* 74.

[100] Ibid., 68.

[101] Philip Tetlock, *Expert Political Judgment: How Good Is It? How Can We Know?* (Princeton: Princeton University Press, 2005), xx.

[102] Tetlock, *Superforecasting,* 90.

[103] Ibid., 17.

[104] Ibid.

judgment. Other members of the group offset individual errors when aggregated. Forecasters who swung too far from center mitigated others who swung too far in the opposite direction. Accurate predictions built on each other, increasing the overall precision of the forecast.

The Limits of Organizational Knowledge

The story of how an unemployed administrator broke a major story in the Syrian Civil War using only OSINT and his laptop suggests the potential for reducing gaps in the IC's organizational knowledge.

Eliot Higgins, a self-titled *citizen journalist* and blogger, gained recognition for his investigative work exposing developments in the Syrian Civil War from his home. Using web-based OSINT and an obsessive curiosity, Higgins became an expert in military weaponry, explosives, formations, equipment, and many other indicators of military activity. He specialized in munitions, often able to discern rocket types from the debris they caused.

Higgins first came to notoriety in 2012 by reporting that the Free Syrian Army had obtained anti-aircraft guns.[105] He was also the first to report that the Assad regime used banned cluster bombs.[106] He also revealed the use of barrel bombs, Chinese man-portable air-defense systems (MANPADS), and a cache of weapons from the former Yugoslavia that led to a story in the *New York Times* indicating Saudi financing with US knowledge.[107] British Broadcasting Corporation (BBC) producer Stuart Hughes said of Higgins, "It's very incongruous, this high-

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[105] Patrick Radden Keefe, "The Blogger Who Tracks Syrian Rockets from His Sofa," *The Telegraph,* March 29, 2014, accessed February 5, 2018, http://www.telegraph.co.uk/news/worldnews/middleeast/syria/10730163/The-blogger-who-tracks-Syrian-rockets-from-his-sofa.html.

[106] Matthew Weaver, "How Brown Moses Exposed Syrian Arms Trafficking from His Front Room," March 21, 2013, accessed February 4, 2018, https://www.theguardian.com/world/2013/mar/21/frontroom-blogger-analyses-weapons-syria-frontline.

[107] C.J. Chivers and Eric Schmitt, "Saudis Step up Help for Rebels in Syria with Croatian Arms," *The New York Times,* February 25, 2013, accessed February 4, 2018, http://www.nytimes.com/2013/02/26/world/middleeast/in-shift-saudis-are-said-to-arm-rebels-in-syria.html.

intensity conflict being monitored by a guy in Leicester. He's probably broken more stories than most journalists do in a career."[108]

What is important about Higgins' work is that he was not a trained analyst nor journalist. He had no military or investigative training when he started researching the activities of the Syrian Civil War. Higgins told a reporter in 2013, "Before the Arab Spring I knew no more about weapons than the average Xbox owner. I had no knowledge beyond what I'd learned from Arnold Schwarzenegger and Rambo."[109] What he did have was a keen mind, an enthusiastic interest, and an internet connection.

Higgins was able to research and report his discoveries more capably than professional news outlets due to several factors that favored a crowdsourced solution. First, the situation on the ground in Syria was extremely dangerous for journalists. At the time of Higgins' discovery, more than fifty reporters had died in the fighting.[110] The situation has not improved since 2013, with that number rising to at least 211.[111] In addition to the danger, the Assad regime banned the international press from reporting from inside the country, increasing the threat of imprisonment. This reduced the familiarity that comes with on-ground access, putting Higgins on an even footing with professionals.

Second, no one expected him to break a major story about a civil war in the Middle East. Unemployed at the time, Higgins was a stay-at-home dad looking after his toddler daughter. This situation provided him the flexibility to research a war zone nearly three thousand miles away

[108] Patrick Radden Keefe, "Rocket Man," *The New Yorker*, November 25, 2013, accessed February 4, 2018, https://www.newyorker.com/magazine/2013/11/25/rocket-man-2.

[109] Weaver, "How Brown Moses Exposed Syrian Arms Trafficking."

[110] Keefe, "Rocket Man."

[111] Dominic Ponsford, "Six Years of Syrian Civil War: 211 Journalists Killed, at Least 21 Held Hostage or Missing and at Least 26 Imprisoned," *Press Gazette*, March 16, 2017, accessed February 4, 2018, http://www.pressgazette.co.uk/six-years-of-syrian-civil-war-211-journalists-killed-at-least-21-held-hostage-or-missing-and-at-least-26-imprisoned/.

with less pressure than a professional reporter.[112] There were no deadlines, no editors, and no airtime to fill.

Third, the Syrian Civil War is occurring in the information age. All sides of the conflict record footage, and air it for divergent aims. Each night, Higgins reviewed 450 YouTube channels filled with videos uploaded by activists, rebels, Assad supporters, and Syrian state television.[113] These videos documented fighting, speeches, casualties, propaganda, and weaponry. From this massive trove of OSINT, Higgins was able to pull out the intelligence necessary to provide a little more situational understanding in a complex, dynamic situation.

A Note of Caution

When using OSINT and crowdsourcing, the balance between speed and accuracy is never more precarious. In disaster scenarios, where delays are most harmful, accepting risk in favor of speed may be necessary. In the face of the enemy, that option may not be suitable. Analysts must carefully consider the motives, knowledge level, and professionalism of the information pool. Additionally, the IC must contend with potential obstacles. How will the IC determine where they can accept risk in the accuracy-speed ratio? Following the Boston Marathon bombing, users of the website Reddit mistakenly identified people not involved with the bombing as suspects, who the mainstream media quickly pilloried.[114] How does the IC counter malcontents who have no intention of supporting sense-making operations? Galton observed that "the sixpenny fee deterred

[112] Google Maps, Directions from Leicester, England to Al Ghouta, Homs, Syria, Google, accessed February 4, 2018, https://goo.gl/A9nCtq.

[113] Weaver, "How Brown Moses Exposed Syrian Arms Trafficking."

[114] (Original post author deleted), "Is Missing Student Sunil Tripathi Marathon Bomber #2?" Reddit website, original post submitted April 19, 2013, accessed February 19, 2018, https://redd.it/1cn9ga. For a more in-depth accounting of mistaken identity cases surrounding this event, see Joe Coscarelli, "All the Mistakenly Identified 'Suspects' in the Boston Bombing Investigation," *New York Magazine*, April 19, 2013, accessed February 19, 2018, http://nymag.com/daily/intelligencer/2013/04/wrongly-accused-boston-bombing-suspects-sunil-tripathi.html.

practical joking."[115] Although Galton never encountered *internet trolls* who, ensconced in anonymity, attempt to denigrate the ideas of others; he may have hit on a mitigation strategy. Participants are more likely to participate in explicit crowdsourcing when they have a compelling reason to do so.[116] When not properly motivated, participants are less likely to take the endeavor seriously. The Natural Environment Research Council (NERC) experienced this phenomenon when they asked the public to help them name their new $287 million polar research vessel. The most popular suggestion, *Boaty McBoatface*, was hardly the dignified name for which they hoped.[117]

Creative ways to mitigate counterproductive activities do exist. Google introduced countermeasures to prevent players from 'cheating' the Image Labeler by giving players a commonly known test image (e.g., a picture of a dog). If players are unable (or unwilling) to correctly label the test image, the game excluded their answers from the data set. As a second layer of protection, Google only stores crowdsourced labels in the training data set after a fixed number of players agree on it.[118] This helps prevent one user from sabotaging the work of many.

Crowdsourcing has enormous potential to augment sense-making efforts in the IC, but it is not a panacea; it cannot replace professional intelligence analysts. The examples in this paper are meant to illustrate the potential for crowdsourcing to expand the IC's toolkit, not supplant it. Augmenting traditional intelligence activities with crowdsourcing can provide an additional

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[115] Galton, 450.

[116] Thomas Wagenknecht, Timm Teubner, and Christof Weinhardt, "Peer Ratings and Assessment Quality in Crowd-Based Innovation Processes," *25th European Conference on Information Systems (ECIS) Proceedings* (June 2017), 3147, accessed April 3, 2018, http://aisel.aisnet.org/ecis2017_rip/62.

[117] Katie Rogers, "Boaty McBoatface: What You Get When You let the Internet Decide," *The New York Times*, March 21, 2016, accessed February 19, 2018, https://www.nytimes.com/2016/03/22/world/europe/boaty-mcboatface-what-you-get-when-you-let-the-internet-decide.html.

[118] Von Ahn, "Human Computation."

stratum of understanding not available within the homogeny of any single organization or discipline.

Recent research suggests the best solution to augment the IC's current capacity is a combination of artificial intelligence and crowdsourcing.

Section IV – Hybrid Options

If you don't like change, you're going to like irrelevance even less.

– GEN Eric Shinseki, *National Review Online,* 2010

Operating in complex, chaotic operational environments requires a multifaceted solution. By aggregating the benefits of AI, crowdsourcing, and human ingenuity into one hybrid solution; the IC can attain a more accurate operational understanding in less time and with more precision, than conventional methods.

Hybrid Example #1 – Domestic Operations

Taking note of OSM's impact during the Haiti earthquake crisis, NGA began researching ways to leverage open-source material with the public.[119] The public proved to be a resource-rich environment. As corporations became more dependent on Geographic Information Systems (GIS) data, they increased their capacity to produce it.[120] Platforms like Wikimapia, OpenStreetMap, and Google Earth trail-blazed open-source mapping, making it cheaper and easier.[121] Among the innovations sparked by this paradigm shift was a widespread adoption of the Wikipedia crowdsourcing model. NGA entered the fray in 2015 with an acronymically-named pilot program: the National System for Geospatial Intelligence (NSG) Open Mapping Enclave, or *NOME*.[122] NOME is an initiative to leverage VGI within the IC enterprise.

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[119] Becker and Bendett, 27-33.

[120] Will Mortenson, "The 'In' Crowd: NGA Adopts the Crowdsourcing Model," *Pathfinder Magazine* 14, no. 2, June 27, 2016, 33, accessed February 6, 2018, https://issuu.com/nga_geoint/docs/pathfinder_magazine_2016_issue_2/33.

[121] Ibid.

[122] The National System for Geospatial Intelligence (NSG) is an operating framework that integrates GEOINT-related strategies, policies, and capabilities. It is a subset of the intelligence community enterprise. The NGA operates within the NSG alongside national, international, commercial, military, and

NOME incorporates three explicit crowdsourcing methods: *community*, *active*, and *passive*.[123] NOME's *community* sourcing application provides a venue for members of the IC to collaborate on shared datasets. This technique taps into the intelligence enterprise's vast collective resources. NOME *actively* collects VGI from the public by asking for help answering questions about specific features on Earth and collects *passive* VGI by providing imagery to the public for correction or enhancement.[124] By merging these three sources, NOME creates a living map. NOME is different from other crowdsourcing examples in that its designers plan to use machine learning to aggregate Big Data-levels of GEOINT. By combining the combined wisdom of the crowd with the analytic power of AI, NGA may be on the verge of a revolution in intelligence gathering. The AI aspect of NOME is still under development, but the prototype is a significant step toward gaining situational understanding in an operational environment.

The potential benefit of this AI-crowdsourcing hybrid is intriguing for the DOD's second largest component, the Army National Guard.[125] The Army National Guard, in addition to its federal mission as the Army's combat reserve, conducts disaster response missions in the homeland. Disasters are typically localized within a city or state (e.g., severe snowstorms knock out power in St. Louis), but can escalate to major disasters (e.g., Hurricane Sandy). When situations like this occur, military components must integrate with emergency management agencies, civilian first responders, and other military components. A web-based open-source

academic partners. The amalgamating theme among these partners is the production and consumption of GEOINT.

[123] Mortenson, "The 'In' Crowd," 33.

[124] Ibid.

[125] DOD's largest component is the active duty Army with 472,049 soldiers. The Army National Guard has 343,605 soldiers. Defense Manpower Data Center (DMDC) Website, "Location Report 1709," current as of September 30, 2017, accessed February 26, 2018, https://www.dmdc.osd.mil/appj/dwp/dwp_reports.jsp.

portal, informed by crowdsourcing and powered by AI, can create shared situational understanding among all stakeholders in real time.

A descriptive narrative for this hybrid approach is helpful: Following massive flooding, an Army National Guard military police (MP) battalion deploys to a flood-ravaged county to support local first responder efforts. The state-level emergency management agency liaises with National Guard representatives, and facilitates access to a FEMA-operated, open-source disaster-mapping website. The website is a user-friendly repository for all participants – victims *and* responders. For victims, the website is a Craigslist-style request site to request aid and report conditions. For responders, the website is a prioritization tool. A machine learning algorithm manages victims' aid requests arriving via social media messaging, short message service (SMS) texts, emails, and automated phone message responses. The AI-produced (but human-verified) output is a crowdsourced disaster map that commanders can use to make informed life-and-death decisions based on real-time GEOINT and OSINT.

At the disaster site, flooding restricts travel to watercraft. A joint team, comprised of sheriff's deputies and National Guard MPs, arrives at a nearly-submerged residential building via National Guard bridge erection boats (BEBs). The disaster map lists the home as *occupied*, and indicates the residents need help evacuating. After a quick search, the team locates a family on the top floor of the home – unable to evacuate their non-ambulatory octogenarian grandmother. One of the stranded family members tells the team that when the flooding rose to dangerous levels, they were unable to make phone calls. Records later reveal that cell phone users swamped local towers attempting to reach loved ones. Instead, the family alerted first responders by sending a text message to the FEMA disaster website, which reported their urgent situation to rescuers. A deputy coordinates an air ambulance extraction for the immobile patient via a National Guard satellite phone, and the team transports the remaining family members to safety via the BEBs. Just before departing the residence, an MP team leader spray paints a FEMA search and rescue code on the house and updates the disaster website with a smart phone app.[126]

Hybrid Example #2 – Expeditionary Operations

A 2017 RAND study, *Monitoring Social Media*, offers a second hybrid option. In this approach, algorithms conduct implicit crowdsourcing of social media images to help make sense of an operational environment.[127] This option combines geolocation data embedded in social media images with AI that categorizes those images and plots users' locations on a digital map. This approach contains an inherent Big Data component that is an advantage disguised as a problem. The problem is that the larger the crowd, the larger the data set. However, if algorithm designers can resolve the Big Data issue, this hybrid approach has the potential to provide an enormous amount of cultural data that, when applied to a map, provides a geographic depiction of what users in an OE think is important. Given US privacy laws, the IC can best apply this approach in overseas combat operations.

Adding an explicit crowdsourcing element, such as that provided by Eliot Higgins' citizen journalist website, Bellingcat, improves on RAND's model.[128] Again, a descriptive narrative for this hybrid approach is helpful to elucidate its usefulness: In March, 2018, the 1st Infantry Division Headquarters arrives in Poznan, Poland to take over day-to-day command and

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[126] FEMA search and rescue (SAR) codes, or *x-codes,* communicate SAR data like occupancy, the presence of danger, search status, search type, number of victims removed and number of deaths. For more information on x-codes, see Federal Emergency Management Agency, US&R-23-FG *National Urban Search and Rescue (US&R) Response System Rescue Field Operations Guide*, September 15, 2006, accessed February 26, 2018, https://www.fema.gov/pdf/emergency/usr/usr_23_20080205_rog.pdf.

[127] William Marcellino, Meagan Smith, Christopher Paul, and Lauren Skrabala, *Monitoring Social Media: Lessons for Future Department of Defense Social Media Analysis in Support of Information Operations* (Santa Monica, CA: RAND Corporation, 2017), 17, accessed January 16, 2018, https://www.rand.org/pubs/research_reports/RR1742.html.

[128] The Bellingcat website is located at https://www.bellingcat.com/.

control of army operations in Eastern Europe in support of Operation Atlantic Resolve.[129] Arriving nearly a year after the Army Public Affairs division announced the deployment, European social media is well informed of their arrival.[130] The division HQ liaises with the Defense Intelligence Agency (DIA), NGA, and Bellingcat to develop an algorithm that implicitly crowdsources social media images. Bellingcat citizen journalists provide an additional layer of clarification for crowdsourced images the AI tags as important. Helpfully, Russian troops take 'selfie' photographs against orders while encroaching on North Atlantic Treaty Organization (NATO) borders and post them on social media. The algorithm collects these images and maps their location using geo-related metadata.[131] Bellingcat citizen journalists help refine the location of images, including those taken by devices with disabled geolocation trackers.[132] The GEOINT this approach produces helps commanders discern areas of adversary activity. The approach also identifies portions of the OE most susceptible to Russian influence by mapping locations with unusually high incidences of pro-Russian imagery.

These scenarios make assumptions (e.g., wireless connectivity) that bely their infancy. They are useful as vignettes designed to illustrate how a hybrid option can benefit both domestic and expeditionary military operations – seeds to be nurtured with critical and creative thought.

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[129] John Vandiver, "'Big Red One' Deploying Division Headquarters for Europe Mission," *Stars and Stripes*, January 18, 2018, accessed February 27, 2018, https://www.stripes.com/news/big-red-one-deploying-division-headquarters-for-europe-mission-1.507085.

[130] US Army Public Affairs, "Department of the Army Announces 1st Infantry Division Deployment," US Army website, April 27, 2017, accessed February 27, 2018, https://www.army.mil/article/186751/department_of_the_army_announces_1st_infantry_division_deployment.

[131] Harry Cockburn, "Russian Military Bans Selfies to Prevent Soldiers Revealing Locations," *Independent*, October 6, 2017, accessed February 27, 2018, http://www.independent.co.uk/news/world/europe/russia-military-ban-selfies-facebook-soldiers-reveal-secret-locations-syria-ukraine-a7986506.html.

[132] Simon Ostrovsky, "Russia Denies That Its Soldiers Are in Ukraine, But We Tracked One There Using His Selfies," *Vice News*, June 16, 2915, accessed February 21, 2018, https://news.vice.com/article/russia-denies-that-its-soldiers-are-in-ukraine-but-we-tracked-one-there-using-his-selfies?utm_source=vicenewsyoutube&utm_medium=video&utm_campaign=relatedarticle.

Section V – Conclusion

We can only see a short distance ahead, but we can see plenty there that needs to be done.

– Alan Turing, *Mind – A Quarterly Review of Psychology and Philosophy,* 1950

Based on the research presented in this paper, a hybrid of AI and crowdsourcing can improve the speed and accuracy with which the IC gains and maintains situational understanding. These ideas are already beginning to gain traction in the disaster relief community. FEMA, for example, is exploring ways in which it can leverage "crowdsourced data for artificial intelligence, machine learning, and deep learning."[133] What remains is a larger push for full IC implementation in military operations. In a future operating environment dominated by technology and uncertainty, the US should utilize its innovative and industrial advantages to offset the advantages of our adversaries.

The Way Forward: Public-Private Partnership

Public-private partnerships – arrangements between a government agency and a private sector entity – are innovation catalysts. These arrangements benefit both parties. Project Maven, which became operational in just eight months after collaborating with Silicon Valley, is hardly the first to leverage civilian expertise.[134] Many of the innovations Americans rely on stem from collaborative efforts between the DOD and the civilian sector: the internet, global positioning

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[133] Sophia B. Liu, "Leveraging Crowdsourcing in FEMA-led Response Efforts" (briefing presented at the Community for Data Integration's (CDI's) monthly meeting, Washington, D.C., November 8, 2017), Slide 9, accessed February 24, 2018, https://my.usgs.gov/confluence/display/cdi/CDI+Monthly+Meeting+20171108?preview=%2F580031568%2F580039516%2FCDI+-+Leveraging+Crowdsourcing+in+FEMA-led+Response+Efforts.pdf.

[134] Weisgerber, "Artificial Intelligence Already Hunting Terrorists."

satellites (GPS), and Siri are just a few examples.[135] Initiatives like the Defense Innovation Unit – Experimental (DIUx) are a step in the right direction, but the trend should be to incorporate innovation across the Army's doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy (DOTMLPF-P). While this approach has hazards (i.e., operational security), there are obvious timeline benefits. Pursuing this strategy is a wise choice to make the most efficient use of the United States' vast material and cognitive resources.

[135] Cheryl Pellerin, "Carter Seeks Tech-sector Partnerships for Innovation," *DoD News*, April 23, 2015, accessed April 3, 2018, https://www.defense.gov/News/Article/Article/604513/carter-seeks-tech-sector-partnerships-for-innovation/.

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