The Great Preset

Remote Teams & Operational Art

EDITED BY

Daniel A.
Friedman

Richard J.
Cordes

The Great Preset

Remote Teams & Operational Art

EDITED BY

Daniel A. Friedman & Richard J. Cordes

Cognitive Security & Education Forum (COGSEC)
www.cogsec.org

This hardcover edition, 2020

Includes works cited for each chapter and appendices where relevant. Citations in PLOS format, metadata was produced using a reference manager and may contain errors. All images used were generated by the writers, public domain, or attributed under fair use. Some images may be blurred.

ISBN 978-1-7364269-0-6

1 2 3 4 5 6 7 8 9 10

I have written for all,
with a profound love for my own country,
but without being engrossed by France
more than by any other nation.
In proportion as I advance in life,
I grow more simple,
and I become more patriotic for humanity.

—Victor Hugo, *Les Misérables*

CONTENTS

Such an enterprise,
to be worth anything,
must be built on the foundations
laid by others,
and indeed, my debts are diverse

—Eric A. Havelock, *Preface to Plato*

ACKNOWLEDGEMENTS

The Michaels; JM; 61; JLark; Derisk-David; all of the contributors to the work cited and built on—we stand on both the shoulders and smolders of giants; the 2020 cohort of COGSEC Contributors, Group_3; Team_Comm; ActInf Lab; and to Complexity Weekend for making it happen.

For Daniel, a special thanks to:

My Nestmates: family, friends, and colleagues. Deep appreciation as well for the known and unknown heroes: those who consecrate the world by tending to each trimtab with diligence and vigilance.

For Richard, a special thanks to:

The Alessio Family, The Sabiston Family, and The Murphy Family for being warm hosts and facilitating healthy breaks from writing; Mom for encouraging writing; Grandma for encouraging reading; Dad for facilitating interests in military history; Achilles and Socrates; Dr. B & Dr. B; Dr. Deviance and Son; O-4 Al; The Monk of Malta, Keyboard Theologian; The Meteorologist; The Neurobiologist; The Warrior Monk; Enreg; The Trader; The Bureaucrat; The Merc; Little Tesla; mCrew Alliance Squad; an Owl; and King Finn.

CONTRIBUTORS

Richard J. Cordes. Richard is a co-founder of COGSEC and currently a non-resident fellow at the Atlantic Council on appointment to the GeoTech Center. He contributes research to a variety of working groups and committees across Department of Defense programs, the IEEE, and the Private Sector on topics like gray zone warfare, knowledge management technology, optimization of human learning, remote team performance, and complex systems. He is especially interested in unifying concepts within narrative design, intelligence analysis, science and scholarship, engineering, and pedagogy under the domains of sensemaking and knowledge management.

Daniel Ari Friedman. *(BSc: University of California, Davis, 2014, PhD: Stanford University, 2019).* Daniel is currently a postdoctoral researcher at the University of California, Davis. His PhD research focused on the genetics and epigenetics of collective behavior in ants. His postdoctoral projects involve using modern computational techniques to address key questions in myrmecology and evolutionary biology. He is also interested in the areas of cognitive security, online teams, active inference, and Synergetic geometry.

Mikel Maron. *(Evolutionary and Adaptive Systems Master's Program, 2004, University of Sussex, England; BA, Computer Science, 1996, UC Santa Cruz, United States).* Mikel is the leader of the Community team at Mapbox, helping to grow the adoption of open geo data in humanitarian, government, and education organizations, and advancing work with OpenStreetMap. As Presidential Innovation Fellow at the U.S. State Department he drove OpenStreetMap adoption across federal agencies. He is co-founder of the Humanitarian OpenStreetMap Team, co-founder of Map Kibera and GroundTruth Initiative, and Board member of the OpenStreetMap Foundation.

Ivan Metelkin. *(Engineer Master's Program, 2005, The Bonch-Bruevich Saint Petersburg State University of Telecommunications, Russia).* Ivan is a Methodologist at the Systems Management School, Moscow, Russia, studying the impact of project management tools and techniques to improve the efficiency of online teams. His research has also included a focus on conceptions of well-being in cities, spatial-social dependency, and how cities are changing in the context of rapidly developing technology, climate change, and global pandemics and how these changes affect people's lives. His current work includes applying a systems engineering approach to complex urban projects.

Alexandra Mikhailova. *(Bachelor of Science in Neurobiology, Physiology and Behavior, 2014, University of California, Davis, United States).* Alexandra is a PhD Candidate in Neuroscience at UC Davis, studying the role of immune signaling in early brain development. Her previous research explored how the adult and developing brain recovers from stroke injury. She is driven to explore the developing brain as a complex system, at both the molecular level and the social and interactive level. She is also interested in using Active Inference as an approach to improving education and building inclusive online spaces.

Steven E. Phelan. *(Doctor of Philosophy in Computational Economics, La Trobe University, Australia).* Steven is a Distinguished Professor of Entrepreneurship at Fayetteville State University in North Carolina, where he teaches business strategy, entrepreneurship, and innovation management. His research has focused on solving complex problems in business and economics, including agent-based models of industry competition, behavioral game theory, and the application of complexity theory to entrepreneurship. He current research focuses on new models of innovation management and revisiting the socialist calculation debate in the era of big data.

Alexander Vyatkin. *(Information Systems Engineer Master's Program, 2005, St. Petersburg State Transport University, Russia).* Alexander is a Researcher at the Systems Management School, Moscow, Russia, and an independent Systems Engineering Consultant. His research interests lie in applying transdisciplinary approaches based on Systems Thinking and Complexity Science to the field of online teams and organizational behavior.

EDITORS' FOREWORD

2020 was a singular year for the Cognitive Security & Education Forum (COGSEC, cogsec.org), as it was for many others. In light of this paradigm-shifting year, we leave it for future dates and other authors to digest the proceedings of 2020. Rather than a recap of momentous events, this foreword's contribution will be the contextualization of the book you are reading now: "The Great Preset: Remote Teams and Operational Art". This edited volume is a compilation of the traces that COGSEC and collaborators left during 2020. In this foreword we will briefly review the initial and updated intentions of COGSEC, then distill the contribution of each chapter, before closing with intentions for 2021 and beyond.

The original intention of COGSEC in early 2020 was to improve the state of knowledge management through developing computational tools related to user interfaces, databases, and filetype standardization. Over the course of our early research, we came to understand that knowledge management is a fundamentally social and collaborative process. So, while computational tools and data standards are indeed enabling factors for successful knowledge management systems, they are part of a much larger constellation of essential system attributes. Our investigations into this larger constellation initially led to topics such as narratives, memetics, team life cycle studies, and organizational psychology. Later, we began to include perspectives from physics, anthropology, mathematics, and complexity science. What had begun as a private sequence of product development design sprints, over the course of the year evolved into a research program with global participation. Along the way, we "learned by doing". Through practice and collaborators, we came to new realizations about our system of interest: online organizations. The chapters of this book are ordered chronologically, and if published elsewhere, include a note accompanying the abstract.

In Chapter 1, "Emergent Teams for Complex Threats," we searched for insights into knowledge management and team dynamics from the area of counterterrorism efforts. We found that the capacity to reorganize rapidly, maintain resilience, and integrate new information channels are instrumental for both successful terrorist and counterterrorist activity. These flexibilities and feedback processes are especially important when dealing with complex threat surfaces, which are characterized by their potential to induce non-linear and cascading failure modes if exploited.

In Chapter 2, "Infinite Games for Infinite Teams," we explored the intersection of online teams, memes, and games. Cognitive overload and adversarial dynamics beset online teams of all kinds, whether they be professional research groups or emergent cliques on anonymized forums. The open question is how to design online or hybrid spaces that are healthy and participatory. Our contribution here was the exploration of role-based group improvisational and cultural dynamics in the context of rapidly assembled modern online teams, and the provision of several initial "Infinite Game" structures with application in research, development, and citizen science domains.

In Chapter 3, "Active Inference & Behavior Engineering for Teams," we approached online team design with insights from systems engineering and the emerging physics-based framework of active inference. Active inference frames the dynamics of goal-seeking systems in terms of their actions, as oriented towards reducing uncertainty about the statistical regularities in their niche or operating environment. Our contribution here was to bring together the areas of engineering, narrative communication, multiscale systems thinking, and active inference, with an eye towards developing new tools and modes of work for online teams.

In Chapter 4, "The Facilitator's Catechism," we reviewed the historical development of the Operations Order (OPORD) from antiquity to the modern day. We found that historically, changes in technological and organizational complexity necessitated novel formats and applications of OPORDs. Taking stock of recent developments in research & development, we presented a novel "Facilitator's Catechism" that builds on the Heilmeier Catechism and is designed to catalyze the development of emergent research teams in various settings.

In Chapter 5, "Reimagining Maps," we surveyed recent developments in geospatial mapping techniques, in the context of various types of extra-cartographic "maps" such as genetic, mathematical, and informational. Our contribution here was to find the challenges in common between various mapping domains and how they are being or have been addressed in order to reveal paths to solutions which may be generalizable.

In Chapter 6, "The Innovator's Catechism," we traced the history of OPORDs in the business context, from the early programs in entrepreneurial education through the current day's drive for integration in early-stage startups. We highlighted the value of fusing approaches derived from large high-reliability organizations and small agile startups. We also presented an initial version of the "Innovator's Catechism", an interactive document that derives from the "Facilitator's Catechism" and is modified to include features relevant for today's entrepreneurial ecosystem.

Building upon the research of 2020, we will initially consider the detection, classification, and design of Narrative Information

Management (NIM) systems. Narrative Information Management is the process of tracking, detecting, compressing, and storing information about narrative and memetic content. As an entry point to our study of NIM systems in 2021, we intend to explore communities of practice that are using platforms that act as ad hoc NIM systems. Our aim will be to find methods of expediting and stabilizing sensemaking, especially in the domains of education, research, communication, and innovation.

As the sun sets on 2020, we can look to what 2021 may bring for the collaborative nexus that is COGSEC. We strive for rigorous, productive, and meaningful collaborations. In early 2021 or any future moment, we are calling for collaborators who are interested in helping to build a more resilient future (see cogsec.org for updated information on participation).

ΑΘΕ

CHAPTER I

Emergent Teams for Complex Threats

Richard J. Cordes & Daniel A. Friedman

ABSTRACT

While the underlying, fundamental principles of warfare have long remained unchanged, recent social and technological developments have necessitated new approaches to conflict management. Specifically, the introduction of nuclear weapons and the maintenance of large military budgets during peacetime in the latter half of the 20th century have changed the risk calculus of conflict among state and non-state actors. Consequently, the operating environment has changed. Extant, centralized actors have experienced new adversities such as ideological warfare and sustained low-intensity and gray zone conflict while new, decentralized participants have emerged and evolved. Nation states, as a part of normal operations, now have to contend with the potential for novel, emergent hazards in a myriad of, littoral and other environments. In this chapter we introduce the concept of a Complex Threat Surface to capture these non-linear failure modes of small and large organizations. We highlight how Complexity Science has been of use in the analysis of Complex Threat Surfaces in the military and within civilian organizations, particularly High Reliability Organizations or HROs. This paper also discusses the intersection of Complexity Science and Military Science by focusing on analysis of counterinsurgency and counterterrorism operations. We highlight rapid reorganization, pooling collective expertise, and the assembly of novel organizational components as a potential basis for developing spontaneous expertise, actionable intelligence, and solutions to the aforementioned emergent hazards of Complex Threat Surfaces.

Introduction

This paper uses a Complexity Science framework to investigate the relationship between the rapid assembly of teams and the success of counterinsurgency and related efforts. Beginning with a vignette of the 2008 attack on Mumbai by Lashkar-e-Taiba, general ideas and trends in Military Science related to counterinsurgency efforts and Complex Threat Surfaces will be discussed. This introduction of Complex Threat Surfaces will be followed by a discussion of Complexity Science as an approach for modeling and de-risking Complex Threats. In alignment with literature on both High Reliability Organizations and Complexity Science, reorganization and adaptation are addressed as potential avenues for responding to novel, emergent problems. Finally, Rapid Team Assembly is presented at the intersection of Complexity and Military Science as a basis for developing spontaneous expertise, actionable intelligence, and solutions to novel, emergent problems. We conclude with a discussion of best practices and opportunities for future work.

Lessons from Mumbai

To understand how Complexity Science, rapid assembly of teams, counterterrorism, counterinsurgency, and other related efforts are linked, we begin with a recollection of the 2008 attack on Mumbai. On November 23rd, 2008, ten men in their early twenties left the Pakistani port city of Karachi by boat. This group carried light armament, some fire-starting material, fake passports, and satellite phones [1,2]. They set out for Mumbai, the seventh most populous city in the world, a mega-city of more than fourteen million people, the capital of the Indian State Maharashtra [3]. Enroute, the group hijacked a fishing vessel registered in Mumbai, murdered its crew [1,4], and forced the captain to re-introduce the vessel into normal fleet traffic [5]. On November 26th, seven kilometers from Mumbai's coastline, the captain was killed. With the vessel fully under control, the ten men begin their approach toward the shore. By 8:10 p.m. that evening, the group of ten split into two groups, one going ashore and the other continuing by boat. By

8:30 p.m., both groups had fragmented again, resulting in five teams. Now dressed in casual clothes to blend with the local population, each of the five teams made their approach toward their respective targets [1,4,6]. By 9 p.m., improvised explosive devices (IEDs) had been left in the taxis which transported the individuals to these locations [7]. Upon arriving, they maneuvered and fired indiscriminately into restaurants, train stations, and social establishments near their respective locations. At 9:38 p.m., a pair assaulted the Taj Mahal Hotel from the main lobby, killing twenty non-combatants within the first few minutes [7].

By 10 p.m. there were explosions at gas stations, civilians had been taken hostage, and police, accompanied by three senior counterterrorism agents, had not only been counterattacked but successfully ambushed before even arriving on the scene. The van they were ambushed in was then hijacked and used to carry out attacks with a surviving officer sitting paralyzed in the backseat [1,8]. It is around this time that Zabiuddin Ansari, a phone-operator working from a command post in Pakistan made a call by satellite phone to a subunit which was hardening its position in a hotel. It is on this call that he states the following: "Tell [the Indian Media] this is just the trailer. The real movie is yet to come" [1,2,7,9,10]. This message, in retrospect, could be viewed as hauntingly accurate. Despite the deployment of a counterterrorism force which had superior training, equipment, and support, the attackers, acting as semi-autonomous groups with minimal equipment, managed to keep a city of over fourteen million people under siege for three days. By the end of the conflict, 172 people were dead and 308 were wounded [1]. Some background on the group and the basis for their relative success will be discussed.

The group responsible for training the young men in the attack was Lashkar-e-Taiba [1], meaning "The Army of the Pure" [11,12]. Lashkar-e-Taiba is primarily concerned with removing Indian military presence from Jammu and Kashmir and is composed of religious radicals affiliated with an ultra-orthodox form of Sunni Islam. In compliance with their beliefs, the group is known for foregoing suicide missions, in favor of "dare-devil" missions [1]. Despite being a banned terrorist organization within Pakistan, they maintain multiple training and operational camps in the Pakistan-controlled sub-regions within Kashmir [11] and their operations frequently result in links to the ISI, or Inter-Services Intelligence, the primary intelligence agency of Pakistan [13–17]. This is unsurprising, given the ISI's involvement in the dismantling of the Soviet occupation of Afghanistan and the resulting close ties with liberation movements and guerilla operations in the region [15,18].

ISI has nurtured a thriving market for illegally trafficked goods for decades, even going as far as using the National Logistic Cell (NLC), a logistics company nationalized by the Pakistani Army which was used to supply arms to the Mujahideen in Afghanistan, to run drugs over the same routes [18,19]. Intelligence estimates in 1992 suggested that Pakistani drug dealers had amassed the world's largest stockpile of opium and heroin [15,18]. As indicated by their use of the NLC, ISI does not just passively allow this environment of criminality, they are an active part of it. Apprehended drug traffickers and scouts from Norway and Japan admitted that their handlers had close ties with generals in the region [18,19]. The insurgencies in the neighboring regions made the arms trade lucrative, and, as stated earlier, ISI has been involved in trafficking directly. While access to funding, munitions, and armament, and lack of meaningful government oversight in the regions in which they operated, enabled Lashkar-e-Taiba's operations in 2008 [1,11], they were not the primary factors in the group's success. Across all notable analyses reviewed, there was a conclusion in common regarding the causes of their success: superior information and exploitation of OSINT, or open-source intelligence, as a basis for rapid, spontaneous planning and for reorganization [1,6–8,20].

The group made notable efforts prior to the event to develop actionable intelligence and a working knowledge of the intended area of operations. The terrorists applied for jobs in the kitchen, booked rooms at the hotel, and visited and mapped buildings. Most of the information they used to plan and modify operations was open-source and available to the public. The groups made use of back entrances and corridors not open to civilians and barely known by the reacting counterterrorism force and used these areas, discovered in prior reconnaissance, to counterattack the counterterrorists, ambush civilians, and escape and evade when outmatched [6,8,21]. During the event, a command center in Pakistan was in contact with the group using satellite phones. The command center used live news and Twitter to inform decision-making and to inform personnel on the ground of counterterrorism operations [20]. In one notable incident, a tweet with a picture posted by the BBC revealed the position and intent of a counterterrorism unit on the ground in real-time, resulting in a counterattack [6]. Marc Goodman, an authority on terrorist use of open-source data, in a talk on the topic, noted that while terrorists had used public-access tools such as Twitter and Google Earth before, this was the first notable event in which they mined social media data in real time and did so at such a scale [20]. The groups confirmed potential high value targets by using Google and social media, remapped operations using tweets, GPS devices, and Google Earth, and even intercepted communications at the hotel, alerting the terrorists to room numbers of high-value targets [7,20,21].

In contrast to Lashkar-e-Taiba's OSINT-informed improvisation and spontaneous planning, counterterrorist forces were continuously delayed by lack of flexibility. The Indian emergency planners had planned for scenarios similar to the 2008 Mumbai attack, but "lacked a modular and flexible structure when it came to communicating and responding in a non-routine fashion" [22]. In some cases, the lack of a QRF (quick reaction force) in Mumbai was noted as a basis for failure, however, this may be misleading, as various QRF elements were available but unused. Among other examples, the Indian Navy had assets stationed in Mumbai at the time of the attack but lacked the necessary signed release to use military assets in civilian domains [6], and a special forces unit with the Indian Army was delayed due to the lack of "their own air assets" to travel to the site [6,23]. It may be important to note that the Indian Government had access to all of the same information the terrorists did but failed to assemble specialists who could have made use of the data and funnel analysis to the individuals who could have leveraged incoming information [1,6,20]. Shivshankar Menon, India's Prime Minister at the time of the attack, noted afterward: "[the key was rapid analysis]… we didn't have it." [9].

While traditional metrics for readiness and capability might indicate that the conflict was significantly asymmetric in favor of the counterterrorists (e.g. monetary value of equipment, personnel count, extent of training), this vignette supports the findings of other analyses on asymmetry, which indicate that such metrics may not necessarily be representative of the balance of power or indicate probability of outcomes, especially in modern contexts [24,25]. Asymmetry in resources having little correlation with success in conflict is acknowledged as a recurring phenomenon and is an important characteristic of conflict which developed in the latter half of the 20th century, [24] the reasons for this emergent characteristic will be discussed further.

Complex Threats in the Gray Zone

The introduction of nuclear weapons and the maintenance of large military budgets by the remaining geopolitical superpowers after the conclusion of World War Two [26] created an environment which changed the risk calculus of conventional conflict [27,28]. This shift in risk is sometimes interpreted as a cause of a "Long Peace" [29] or "Nuclear Peace" [28], which, at a glance may be supported by data on battle deaths per year [30]. Though this may be true of direct, conventional, interstate warfare, this has not necessarily been true for military conflict in general. Instead, its "timing, intensity. and [outcomes]" have changed [24,28]. Governments have adapted the way they conduct conflict, and as a result, nurtured a new domain of operations often referred to as "The Gray Zone" [31,32]. Actions which are aggressive in nature but moderated in order to prevent triggering formal change in diplomatic status (e.g. declarations of war) vis-a-vis Article 5 of the North Atlantic Treaty or Article 51 of the

United Nations Charter are classified as Gray Zone Warfare [32–35]. Intelligence agencies of many nations, not just superpowers, managed conflicts through proxy warfare and by sponsoring non-state actors with aligned goals [36]. Often assisted by training from state actors, non-state actors used guerilla tactics and operated in a decentralized, networked fashion in the interest of self-preservation. One of the results of this decentralization has been a deep embedding of these non-state actors in local networks, including governments, illicit trafficking operations, and religious groups; this embedding blurs the line between licit, criminal, and guerilla networks, allowing groups to use this embedding as a form of camouflage and a basis to acquire resources without sponsors [1,5,11,15,18,19]. As centralized state actors learned to react to the new tactics being used against them and to practice deterrence, decentralized non-state actors continued to evolve, solving complex informational problems such as the imperfect monitoring of cells, inter and intragroup communication of activities, and reducing risk and cost of operations [37,38]. The smaller size and limited resources of non-state actors required them to become resilient and adapt where larger nations may have reinforced. More importantly, it required them to become more innovative in finding opportunities and exploiting weaknesses [39].

Based on analyses of the events in Mumbai, the attack can be characterized as a successful exploitation of what are defined here as "Complex Threat Surfaces". In hardware security, attack surfaces are defined as "the sum of all possible security risk exposures" [40] and in practice refer to domains of risk exposure often described in layers [41]. The term may have equal value in describing surfaces of attack in Military Science and the study of counterterrorism [42]. However, non-adversarial events are also of interest to National Security, such as the response to natural disasters, pandemics, or even post-terrorism clean-up operations such as hazardous material removal [43], so for the purposes of this paper, "attack" is replaced by the more generalizable term "threat". Further, in complex adaptive systems, where "the whole is not equal to the sum of the parts", the common threat surfaces, such as those exploited by terrorist groups, may be difficult to defend using linear methods and offer the potential for difficult to quantify, non-linear, cascading failure-modes. To this end, the prefix "complex" is added to threat surfaces to separate them from the kind of security threat surfaces that are considered in risk analysis in hardware. Complex Threat Surfaces are thus introduced and defined as surfaces that have one or more of the following characteristics:

- Produce non-linear impact
    - If exploited, yield the potential for novel and cascading or nonlinear failure modes
- Require non-linear and/or adaptive and anticipatory defense
    - Cannot be effectively defended or de-risked linearly, intuitively, or by using linear planning mechanisms

For example, it is likely that the vessel exploited by Lashkar-e-Taiba could not have been made much more resilient against a hijacking of this kind without preventing it from operating effectively in its normal role. After being hijacked, the vessel allowed the group to circumvent the linear measures implemented by Mumbai and national littoral, port, and customs security. Thus, the fleet of fishing vessels represents an archetypal example of a Complex Threat Surface. In this paper we introduce and discuss Complex Threat Surfaces rather than "attack surfaces" to emphasize the need for an integrated management approach to various kinds of non-linear failure modes. As stated earlier, terror and insurgent groups have become more innovative in their approach to exploiting weaknesses. Groups are incentivized to maximize impact while minimizing risk and cost. This has resulted in a focus by terror and insurgent sects on identifying and targeting Complex Threat Surfaces, as their inability to be effectively defended linearly, intuitively, or by using certain established legacy measures minimizes cost of operations and risk of discovery or intervention [1,22,31,33,39], as evidenced by the failure of counterterrorism measures which successfully red flagged behavior by Lashkar-e-Taiba [6] to deter or reduce the efficacy of the Mumbai Attack. In addition to reducing cost and risk, because Complex Threat Surfaces represent opportunities for cascading, non-linear impact, they also offer the opportunity to maximize the impact of operations [44–46]. We now turn to a discussion of the interdisciplinary paradigm of Complexity Science and highlight the role of rapidly assembled teams in responding to Complex Threat Surfaces.

From Complex Threats to Complexity Science

The science of Complexity, or Complexity Science, is the study of systems that are composed of many interacting subunits [47–50]. Complex Systems, such as brains or battlefields, often exhibit characteristics such as adaptive capacity, radical historicity, self-organization, and non-linear dynamic behavior. To manage and de-risk these challenging attributes of Complexity Science is an interdisciplinary field that studies the patterns and principles of complex adaptive systems (CAS) in general and specific [47,50–52]. Robert Maxfield, a trustee of the Santa Fe Institute, which was founded to study complexity, at a symposium on complexity for the National Defense University stated that: "The scientifically significant results [of Complexity Science] are so far mostly in the physical and biological domain, but the metaphors have proven to have tremendous appeal and utility in studying humans and human social systems" [53]. Indeed, recent decades have seen increased interest in research and applications of Complexity approaches in Military, Informational, and Geopolitical contexts [54,55]. Specific examples here illustrate the point that Complexity Science approaches can add significant value, reflected by unique explanations or predictions, when considering Military Science [49,56], counterinsurgency approaches [57,58], and team formation approaches.

Complexity Science has been used to help model and characterize the behavior and structure of insurgencies and terrorist organizations. As noted by Maxfield and others, the results of these analyses provide utility in understanding their nature [53]. Work has been done to model insurgencies and terrorist organizations as complex adaptive systems, revealing evolutionary tendencies already modeled in natural and computational systems [38,59]. Beyond terrorist groups, Complexity

Science has been used to model domestic military forces as well, such as interpreting frigate crews, littoral (coastal) forces, and air forces as complex adaptive systems [60–62].

Across different types of military forces, the manifested collective behavior or "phenotype" of a group arises emergently from the interaction between the guiding principles of the group and the specifics of the environmental context. The variable expression of underlying characteristics of terrorist groups provides them with adaptive flexibility across environmental context. In order to help predict surfaces of attack and tactics, strategists must identify both essential characteristics of a group and relevant elements of the environment. For example, terrorist groups with similar characteristics are more likely to engage in frequent violence in regions which have higher press access [63]. Here there are striking parallels to the findings and implications in the literature on genetics and epigenetics [64–67]. This "epigenetic" spread of insurgencies thus may be modeled as following principles found in collective behavior models [68,69], resulting in patterns of spread and behavior that look remarkably similar to the results of ant-colony optimization algorithms [70–73].

Decentralized terrorist groups appear to have self-organizing and autopoietic (self-meaning-generating [74,75]) characteristics. These attributes are especially apparent in recruiting spaces, littoral environments, and volatile battlefield situations [5]. Where leadership of terrorist groups is highly centralized, surgical removal of the central leadership may result in the collapse of the organization. For example, the offer of an amnesty deal to the leaders of Al Aqsa by the Israeli Government caused a nearly immediate, systemic collapse of the organization [63]. In contrast, destroying the central leadership of a primarily decentralized organization may just result in loss of cohesion, fracture, and increased complexity, causing the group to fracture along hidden ideological or methodological lines just as easily as they might fracture on a basis of geography [63,76,77]. Separation from intellectual or political leadership can result in groups over-imitating their parent organizations, resembling well-studied social and psychological phenomena such as cargo cults and over-imitation, leading to senseless violence increasingly detached from the original objectives [63,76,78–80]. Understanding the autopoietic and self-organizing nature of these groups prevents a false sense of security which can so often come from material victories, such as the breaking of a stronghold or the assassination of leaders [77], as fractured groups or groups which remain operational despite fractured leadership or the completion of the explicit goals they were formed with are not uncommon. For example the Stern Gang (LEHI) remained active after the creation of the state of Israel, as did the IRA after the establishment of the Irish Free State, and the Ku Klux Klan in the United States after leadership left the organization [63].

Future work in the spirit of Complexity Science could elaborate and formalize the intersection of well-modeled natural phenomena (epigenetics, collective behavior), modern computational techniques (network analysis, machine learning) and counterinsurgency efforts. Such a cross-sector framework for understanding behaviors may lead to the ability to influence outcomes (e.g. through the use of control theoretic approaches) and eventually even the ability to design distributed counterinsurgency systems [6,81,82]. We hold that Complexity Science can thus provide useful direction to those who hold responsibility for operations and force design to be mindful of the complexity of the operating environment [53,61,83]. We now turn to an investigation of rapid team assembly in located, remote, and hybrid contexts, from the perspective of Complexity.

Emergent Teams and Rapid Reorganization

Within various civilian domains, some of which overlap with military, High-Reliability Organizations (HRO) have to contend with Complex Threat Surfaces as well [84,85]. These domains include air traffic control, power grid management, wildland firefighting, and intensive care units [84,86,87]. Similar to their military counterparts, these domains are often areas where failures cascade and victories accumulate, where small errors can create macro-level impacts that are not necessarily proportionate to the perceived severity of the error viewed in isolation [88–90]. In these environments where minimizing chance of failure is key, optimization can be interpreted to come at the cost of fragility [91]. As a consequence of the importance of reliably managing Complex Threat Surfaces, a robust literature exists on these environments [85]. Work from a Complexity perspective on collective behavioral algorithms highlights the relevance of ecological factors such as degree and type of variability, and threat of catastrophic disruption [48,92,93].

While most early work on strategies within HROs focuses on co-located groups, HRO research has adapted over the years to include remote and hybrid paradigms. Work has been done to integrate remote organizational components and even nonhuman or unmanned assets into HRO frameworks [94–96]. In a modern information workspace and battlefield, AI-augmented human actors, and autonomous AI systems, play an increasingly important role. A key strategy found in the analysis of HROs and related work on emergency response is the maintenance of organizational fluidity or the ability to rapidly pool collective expertise, share information, and reorganize in order to respond to emergent problems in the operating environment [43,85,96,97]. In oil and gas production, flexible, horizontal mechanisms are used to rapidly reorganize and integrate operators and supervisors into "tiger teams", groups of experts that are assigned to solve specific problems relevant to the background of personnel [96]. In the auto-manufacturer Toyota, "swift market analysis response teams" (SMART) were organized around customer complaint content based on background relevance and reorganized on completion to greatly increase turnover on errors and handle recalls safely, this was successful to such an extent that elements of the role reorganization process were built into SCRUM, a widely used project management framework [85]. It is important to note that in both cases personnel were not required to be co-located in order to participate [85,96]. This transition toward more distributed frameworks aligns research on civilian HROs with research on complex adaptive systems, the challenges militaries face, and potential best practice. These same attributes of organizational fluidity and flexibility are echoed in military literature on force design, counterterrorism, doctrine, and counterinsurgency as well [60,62].

In respect to force design, organizational fluidity has been acknowledged as essential in modern militaries. Special attention has been paid to littoral warfare, where land, water, and amphibious forces are faced with the paradox of maintaining flexibility while being composed of assets which are the result of decades-long investment cycles [60,98]. Modern littoral environments are often characterized by the myriad of Complex Threat Surfaces that can be exploited by local insurgencies and related groups. These Complex Threat Surfaces include the surface of the water itself in the form of mines, unmanned vehicles, and submerged vessels, as well as attacks from the air via drones [62,99].

To this end, it is difficult to design a perfect system to ensure that any specific vessel, given any single configuration of crew and equipment, would be capable of deterring every threat [60,98,100,101]. As described in a Complexity-informed analysis of rapidly-assembling teams on frigate ships, "it is not reasonable to expect a linear response as circumstances will dictate specific actions"—in such cases, operators on the ship operate semi-autonomously and teams emerge in response to threat assessments [60,62]. For such situations, pre-planned responses help maneuver the crew into positions from which they can confidently follow or diverge from doctrine. This ability to rapidly reorganize is especially important given terror and insurgent groups' tendency toward mimetic transfer and copy-cat attacks, trading and adapting strategies that worked for other groups [99]. Organizations in this space have had notable successes in the exploitation of Complex Threat Surfaces present when military and civilian ships operate in littoral environments [8,99]. In response to these dangers are projects like STANFLEX, which is a modular ship design implemented by the Danish Navy, offering the capability of hot-swapping modular weapons, sensor, and staging platforms while in port in order to rapidly reorganize equipment and crew configurations [60,102].

Rapid Reorganization of leadership in counterinsurgency efforts has been documented to be impactful. The Malayan Emergency (Malay Peninsula, 1948-1960) is frequently looked to as a subject for case studies of successful counterinsurgencies [103,104] and will be discussed briefly. Though the counterinsurgency had many failures at the beginning, there was a reorganization of top leadership to include civilians. This structure, once allowed to proceed, quickly replicated at provincial and district levels resulting in a decentralization of intelligence and local operations [104]. With increased information sharing and the inclusion of locals, less focus was given to combatting the rebels and organizations took significant steps to begin addressing the social, economic, and political problems which drove rebel support instead [103–105]. These emergent, cohesive civilian and military management apparatuses robbed rebels of public support and contributed significantly to the war effort at remarkably low costs [105]. This style of reorganization and rapid assembly of organizations or teams with the inclusion of populations in the area of operations was replicated in Iraq in 2003 and was viewed as imperative to operations in the region, especially due to the complexity of the operating environment [96,106–108].

New York Landmarks Plot 1993

To close, as well as provide an optimistic contrast with the Mumbai events, we relate a vignette from 1993, when a group of terrorists affiliated with Al Qaeda planned to put into action a multistage attack to exploit Complex Threat Surfaces across the island of Manhattan in New York City [3,109]. The terrorists intended to storm the island in watercraft [8] and split into several tactical teams. The group's plan included bombs at key locations like landmarks and transport infrastructure such as the Lincoln and Holland tunnels and the ferries in lower Manhattan. Simultaneously, other teams intended to raid hotels such as the Waldorf-Astoria, St. Regis, and U.N. Plaza with the intention of finding high-value targets and inflicting as much damage to soft-targets as possible [8,109]. Similar to the pre-planning in Mumbai, the group in New York did on-site reconnaissance in advance, taking detailed notes of stairwells, cameras, and security personnel location and attire [8]. The FBI, upon discovery of the plot, began to coordinate multiple, previously-unconnected individuals, such as controlled informants from previous operations, terrorism task forces, and local government and police. With this reorganization in place, it was decided that they would allow the group to centralize their operation in relative safety in order to prevent fracture. When the group began building explosives, their safe house was raided, eight arrests were made, and the plot was foiled with no loss of life [109]. This New York vignette, contrasted with the eerily similar Attack on Mumbai, illustrates how rapid reorganization and assembly of teams in response to novel, emergent threats can meaningfully impact outcomes in counterinsurgency operations.

Conclusion

In this paper we have used the interdisciplinary approach of Complexity Science to introduce and highlight Complex Threat Surfaces as a key variable for counterinsurgency efforts and other gray zone efforts in today's cyberphysical battlefield. We highlighted key principles that differentiated event outcomes, such as the ability of opposing forces to rapidly reorganize, propagate information, and reassemble teams. As teams in the modern operating environment become increasingly remote, new challenges are presented, but also new advantages can become realized [96]. The definition and identification of Complex Threat Surfaces highlights the need for further work at the intersection of information sharing system design [97], decentralized intelligence or OSINT [108,110], and other topics. Conceptual models and innovation technologies arising from this integrative approach may prove useful in service of counterinsurgency efforts now and in the future.

CHAPTER II

Infinite Games for Infinite Teams

Daniel A. Friedman & Richard J. Cordes

Infinite Games for Infinite Teams was written in response to and published through DARPA Polyplexus Citizen Science Incubator: Inventing a Remote Culture to Deal with Pandemics (Incubator-ID 399).

DRIVING & INSPIRING QUESTIONS

- How are global online narratives constructed and received in 2020? Why are the processes of narrative design and culture production so important for security and governance? What is possible now or soon that was not possible before?
- What approaches could catalyze assessment, design, and deployment of online narratives in real-time? Why is it so important to have meme-detection systems that are culturally-aware, interlingual, intermodal, and human-in-the-loop?
- What does it look like to take a Complex Adaptive Systems (CAS) approach to the neuromemetics of narrative co-construction and agenda-setting? How could a CAS approach be used to support specifically-defined cultural/institutional/national/global interests? How do we find, formalize, and quantify goals or outcomes within a CAS framework?
- How can we diagnose, perturb, and create narratives through gameplay? What might a "design science for memes" look like?
- How is this present work continuous with and contrasting with previous work in innovation, generative games, and LARPing? How can music, sound, art, and other techniques amplify narrative impact?

Introduction

Disturbing and destabilizing online narratives can be described as complex threat surfaces that have the potential to impact the entire world. Quite simply, the "Internet is real life", cybercrime, peer-to-peer abuse via social media, and sophisticated propaganda have real-world implications. To grasp the heterogeneity and incompatibility of online narratives available today, we can consider the user experience of a web-searcher with an honest inquiry into the biological basis and origins of SARS-CoV-2 (the virus associated with the disease of COVID-19 [1]). Depending on which search terms are used, media are followed, or friends are asked, this seeker might conclude that the origins and spread of SARS-CoV-2 were due to some wild animal [2,3], natural genomic mutations [4,5] (or not [6,7]), the spread of millimeter-wave "5G" technology [8–10], long-running vaccine research programs funded by Bill Gates-related international organizations [11,12], or Bioterrorism from China, the USA, or some non-State actors [13]. Disinformation and "fake news" aside, the ability to make sense of legitimate information streams online has become untenable.

Where in the past, organizations tasked with knowledge management and sensemaking often had the problem of getting data and analyses, now the problem is parsing it. Novel online-native frameworks (with theoretical models and deliverable tools) are required to deal with this complex situation [14]. Here we use "meme" and "narrative" interchangeably to refer to a broad set of cultural products that "influencers" or "content creators" might make, that includes the image templates that fit the popular cultural definitions of a "meme" as well as videos, songs, hashtags, copypasta [1], songs, stories, posts, pages, themes, and styles that also act as vehicles for the transmission of narrative. These viral videos and movements can contribute to the failure of states and institutions, and such directions can be expected to increase in frequency in the near future. Large and legacy institutions

[1] Copypasta refers to copy-pasted blocks of narrative text

find themselves challenged in the modern narrative ecosystem, in part due to the novel non-linear dynamics of global techno-memetics and narratives. The modern memetic ecosystem calls for unconventional, non-linear, and online-native strategies [15–19].

The human memory system is characterized by its ability to self-organize and reorganize, allowing for spontaneous expertise, even when dealing with novel phenomena [20]. This capability allows humans to succeed in grasping extant and emergent links between memetic materials that might be entirely missed by Artificial Intelligence (AI) [21]. The reason for this is that even when documents and memetic objects are fully indexed by an ideal and complete data architecture, it can be difficult for AI to understand content and impute context, let alone recommend effective interventions. It is challenging to design a "perfect AI" to stop such objects in the public space, as it is a game of whack-a-mole that often has collateral damage (for example, Twitter's attempts at fact-checking) [22,23]. In areas of national security, public health information, and questions of social justice, unintentional consequences of AI-based curation can be devastating [24,25]. Fundamentally, this arises because modern AI systems are having trouble detecting links between memetic material, other datasets (big data), the metadata (big metadata), and causal models of the world (big mechanisms) [26,27]. The reason why we need curated knowledge networks rather than co-occurrence matrices here, is analogous to why we need curated path discovery (via Geocaching, Ingress, Niantic) rather than just total movement data.

With the information ecosystem in this current condition, we ask: what directions for platform design and Remote Team research might be beneficial?

Instantaneous Remote Teams

Culture production and agenda-setting are effective, and even magical, within communities composed of small teams (e.g. music scenes made of multiple bands, academic disciplines composed of labs, book subcultures reflected by separate reading groups). Communities of small teams are the "last mile" of culture production and consumption. Nowadays, such teams and communities are increasingly all-online or online-native. We refer to online-native teams as Remote Teams, whatever their form or function. In cases where Remote Team formation is rapid or instantaneous (as opposed to Remote Teams with low turnover), we introduce the term Instantaneous Remote Teams (IRT). Instantaneous Remote Teams (IRT) are essential for function, adaptability, and resilience in conventional as well as non-conventional institutions [33].

Collective attitudinal states and beliefs can propagate themselves through time during Fiction generation, role-playing, and other kinds of Games [34,35]. Examples of this mode of narrative creation can be found in moderated and unmoderated role-playing games [36–39]. Games can be used as a device for therapy and serve as a basis for abstract task transfer in and out of game. Games can affect users off the platform in very real ways (weight loss, psychology, voting). Generative games (e.g. Minecraft, D&D) are often played via placing individuals in a (cyber) environment with tools, threats, and constraints and can result in creative or practical collaboration and organization even when there are no obvious directions or objectives given to the participants. Collaborative Games can lead to a playful and flexible view of the self, team, and world.

Collective attitudinal states and beliefs can propagate themselves through time during Fiction generation, role-playing, and other kinds of Games [34,35]. Examples of this mode of narrative creation can be found in moderated and unmoderated role-playing games [36–39]. Games can be used as a device for therapy and serve as a basis for abstract task transfer in and out of game. Games can affect users off the platform in very real ways (weight loss, psychology, voting). Generative games (e.g. Minecraft, D&D) are often played via placing individuals in a (cyber) environment with tools, threats, and constraints and can result in creative or practical collaboration and organization even when there are no obvious directions or objectives given to the

participants. Collaborative Games can lead to a playful and flexible view of the self, team, and world.

The many iterations of the popular Massively multiplayer online role-playing game (MMORPG) World of Warcraft (WoW) offer an instructive case study in IRTs. While much of the game can be played alone, the most valuable rewards WoW has to offer its players requires the coordination of IRTs composed of both familiar actors and strangers. When a group of players commit a scenario in which adversaries are generated by the Game's environment ("PvE Content" reflected by antagonistic Non-Player Characters), players rapidly assemble teams composed of 5, 10, 20, or 40 individuals capable of both distinct and overlapping roles. These IRTs are tasked with complex challenges which cannot be done alone. These group goals cannot be completed without cooperation, communication, and trust [40]. The temporary and task-focused nature of these PvE teams meets criteria for rapid cultural transmission [15,41]. Where players committing to "PvE content" rapidly assemble teams prior to engaging with tasks, players engaging with "PvP content", or content in which adversaries are other players, may become a member of an IRT as a consequence of being in the proximity of other players (formation around shared mutual threat). The outcome of such IRT vs. IRT encounters will be influenced by the capabilities, strategy, mission and understanding of the situation by each IRT [42]. In both PvE and PvP engagements, rapid cultural transmission occurs through conversation and call-outs of bad behavior. Over hundreds of iterations, guilds and communities of WoW players learn not only tactics, strategy, in-game lore, and jargon but also narrative, transferable skills, and a sense of identity. These players are receiving gradual initiation into the moral order and praxis of a Game, despite a clear lack of distinct curriculum or even a consistent cast of characters [43].

Research and experience converge on several themes that recur in IRTs from the classroom to the operating theater to the aircraft carrier. Here we highlight several common features or best practices of IRTs that are relevant here. Resilient IRTs are able to rapidly find emergent best practices (e.g. customized solutions that are reached via improvisation). IRTs benefit from cultural competencies, transferable skills, and effective communication protocols. In many cases, the most rapid form of communication is shared mindset (instantaneous coordinated action via independent response to stimuli). High-functioning IRTs draw from a community of culturally-competent, pre-adapted, flexible agents. Increasingly not just humans are involved in IRTs—in online settings, augmented and artificial agents are common. The study and practice of IRTs can involve both qualitative & quantitative approaches, so diverse team perspectives and transdisciplinary approaches are crucial for maximal impact [30,44].

Communities of IRTs, almost as a rule, cannot escape disintegration by "returning to the good ol' days", nor by utopianism alone. Rather, community disintegration is averted when novel approaches to IRT reassembly and renewal are implemented [39]. The Hero's Journey is a common model of Self-renewal used both in product user experience as well as game design [45,46]. Similar renewal processes can be seen in other complex systems such as cultures, insect colonies, and economies [47–49]. Individuals, IRTs, and communities may find paradigms of renewal to be of special importance during moments of uncertainty and rapid change.

Infinite Games in the Gray Zone

Infinite Games are those that have no distinct end state, and have the potential to be played forever, by the same or a rotating cast of actors. Infinite Games have many possible outcomes, an air of possibility, and a balance of tradition and novelty. The term "Infinite Game" has been used by Simon Sinek to describe the modern paradigm of management and leadership [50]: open-ended, endlessly-challenging, and more like a marathon than a sprint. Sinek highlights that Infinite Games succeed when the team has a just cause, a worthy adversary, a vulnerable team, courageous leadership, and an open playbook [51]. Albeit with slightly different terminology, Biology has long focused on "Infinite Games" in nature, such as Red Queen coevolution and winnerless competitions

(Evolution can be seen as the "Transfinite Game" in that it is open-ended regarding how open-ended it is [52–54].). Infinite Games are also a useful framework for considering other innovation spaces such as culture creation, agenda-setting, research & design, improvisation, LARPing [2], SciFi, etc.

"Infinite Teams" are the organizational analog to Infinite Games, teams which have open-ended and evolving composition. The turnover rate of Infinite Teams can be rapid (e.g. improv games, IRT's), or slow (Academia, Church). The process by which Infinite Teams evolve are system-specific (e.g. a rapidly-assembling World of Warcraft team vs. a slowly-changing corporate bureaucracy). To convey the space where Infinite Teams play Infinite Games, we use the gestalt term "Gray Zone", to capture the ambiguity, uncertainty, stochasticity, and chaos in the blur between formally defined domains. To survive the growing influence of Gray Zone activities, communities and governments in 2020 need to be adaptive, flexible, and responsive at both local and global scales.

Infinite Games can be, and often must be, played in the Gray Zone. Infinite Games, like life itself, may or may not feature ambiguous goals, partially-understood scenarios, and emotional engagement. While the aforementioned Infinite Games refer to games with a Game Theoretic tone, such as evolution and management practice, what would be traditionally defined as games are still valuable to consider. Games (e.g. board games, video games) have demonstrable value in facilitating users in the learning of history, soft skills, and technical ability [55–59]. As stated earlier, "The Internet is Real Life"—all games have the potential to have real world impact. In many cases they present very real opportunities for citizens of various backgrounds to contribute directly or indirectly to society and science [60].

---

[2] LARP refers to "Live Action Role-Play"

Infinite Games, like the world as seen from the CAS perspective, are fundamentally transdisciplinary [61,62]. This is because when Games (or conversations and research paradigms) are Infinite, there is no final limit to the type of topics that enter the fray. Few theoretical or applied studies have considered the unique improvisational dynamics of "Infinite Games for Infinite Teams". Work in this area could draw from fields as disparate as wearable neurofeedback devices [63,64], video game strategy [65], and military science [33,66,67]. Perhaps in the future, Infinite Games designed to impact the world could draw the large player-bases that Eve Online or World of Warcraft have, and be designed to facilitate solutions to emergent problems which require crowd-effort or rapid cultural transmission.

Two Visions of Infinite Games for Infinite Teams

Polyplexus, a research acceleration platform developed in part by DARPA [3], uses game like approaches to cataloging scientific claims and concepts, and could be an inspiration for a platform for Infinite Games of all kinds, or evolve to be such a platform itself (culture creation, narrative evolution, research & development, etc.). Here we build off of previous collective and improvisational approaches such as Cadavre Exquis, LARPing [68,69], and PPPiP [4] [62]. While most historical work on the improvisational dynamics of culture production by in-person teams, much of the work transfers naturally to IRTs. Here we will explore how a Polyplexus-like platform might be able to host Infinite Games for Infinite Teams. These two independent visions stem from the intersection of culture creation ("memestreams") and online-native Instantaneous Remote Teams ("teamstreams").

[3] DARPA (Defense Advanced Research Projects Agency)

[4] PPPiP Partner Pen Play in Parallel, a framework for improvisational co-creation of art [62]

Idea 1. Formal Memetics (e.g. ontology, controlled vocabulary, systematics, pipelines, taxonomies for memes and narratives).

A Formal-Informal interface allows for the co-evolution of narrative and formal aspects of a SciFi story through the use of an API/metadata/ontology/structure, A Polyplexus-specific format could be used, or it could be more general [70,71]). The more technically-minded people on the platform can focus on the formal yet also creative aspects of "world building"—not by writing in art/captions/prose, but by proposing values for parameters about the world, culture, or individual in the narrative (i.e. "Planet $planet.name orbits $sun.name, so the temperature there changes there according to the Temperature(space, time) distribution annually, leading to a social regime phase space described by Government(space, time) dynamics").

Prose-, caption-, sound-, and art-oriented participants on the platform can co-evolve narratives along with this programmatic specification of the world/culture/individual. There is a Division of cognitive labor in the co-construction of the total world model. This formal-informal hybrid approach to world building also allows the introduction of "story seeds" or constraints/opportunities for the world, for individuals to explore within. Also this approach allows hierarchical recognition of stories yet unwritten, perspectives yet untold. It is a collective distributed learning process, by teams who evolve their composition, knowledge, and skills.

By setting rules for contribution, such as those found in world-building games like Microscope, the construction of world-narratives of fictional societies faced with constraints and boons can be paired with the assignment of historical examples and scientific principles may have the potential to yield discovery and analyses of potential threats to real world societies [36]. Real-world, fictional, and simulated worlds and memes can be compared and contrasted through "phylomemomic" approaches drawn from evolutionary biology.

Idea 2. A case-management-like system for knowledge mapping, enabling a cooperative "Cadavre Exquis" role-playing game played by Infinite Teams.

There are three roles in this Infinite Game: **Red**, **Green**, **Blue**.

- Red proposes "sword" memes
- Blue proposes "shield" memes
- Green integrates sword & shield memes into communicable (deliverable, coherent, structured, comprehensible, accessible, enjoyable, meaningful) narratives or paths.

Where Red and Blue focus on evidence and logic (logos, ethos, authority), Green focuses on evocation of emotion, anecdotes, and narrative (pathos and ethos, appeals and authority). Green introduces kairos in the system, that is an understanding, sense, and sequence to the memes in a space. The Green role might also be able to eventually access in-field or Mechanical Turk-like experiments to test the relative efficacy of different approaches.

One or many individuals are assigned to each role. Individuals are all roles then enact a "checks & balances"-type Infinite Game, related to some scenario or seed idea. It is a decentralized Hegelian Memetics, an Internet-native Glass Bead Game, an endless conversation that is waiting for your input. People who are familiar with the Game could generate authentic and just-in-time modifications to the game, as well as supplements, variants, and subcultures.

Teams are composed of stable or rotating casts of individuals acting under different identities. A user can create any number of identities. These identities are characters with some background, field, political leaning, subject matter of projects, titles, callsign, and a set of symbols to use in lieu of an avatar. Users agree to make great effort to approach subject matter in a way that is appropriate to this identity. A user can sign into any identity they wish and enter a "workspace". A "Workspace" is a saved "project" of sorts. A new workspace is initialized with a "Seed-Meme". This might be the central argument of a paper they are writing or a hypothesis they are trying to investigate. For example, "Chimpanzees may evolve to use tools" or "AI can be used to detect hate speech". Once a Seed-meme is chosen (along with the constraints of the space), it becomes the "meme in focus". The goal of the Game is then to participate in a process of memestreaming / weltanschauung / argument narrative co-evolution. Primary perspectives and supporting material can be added by players, and extant information can be linked, mutated, contextualized, refuted, supported, communicated, and subjected to feedback loops. Roles can be rotated among players, augmented via AI systems, and even filled by AI. Players can switch between two modes:

- In **Explore mode**, all team members can see all information, to maximally catalyze research and collaboration.
- In **Exploit mode**, each team member is assigned to only one role. This encourages them to embody the role entirely, and to play whole-heartedly.

Red Role Guiding Questions

- What would be the most true and accurate phrasing of what I want to say?

- What would be an effective approach to changing people's mind, not just informing them or "raising awareness"?
- How can messages be designed or hardened to survive the inevitable political/informational attacks against them?
- What is the most direct and devastating attack on the ignorance surrounding this topic?
- What is the most interesting thing about the topic, or least-understood?
- How can this topic be tied to other cultural touchpoints?

Blue Role Guiding Questions

- What ambiguities or subtleties might be imagined by a skeptical viewer?
- How might the meme or narrative be instantly and transparently debunked?
- How might someone from a different perspective/identity perceive the Meme?
- What might the intentional and unintentional influences on this meme be?
- How can this meme or approach be smeared, countered, disproven, or tested?
- What is a socially-acceptable or unacceptable response to this meme?
- What is a "Yes, and…", a "Yes, but….", and "No, because…" response here?

- What have previous thinkers/movements/stories done to counter this meme?
- How can the response to a meme be tied to action, identity, and mindset?

Green Role Guiding Questions

- How can ideas be communicated to multiple audiences?
- How might the same messaging be effective across audiences & media formats?
- How can narratives be accessible, productive, inclusive, comprehensible, and powerful?
- How can the discourse be sharpened as to be unambiguous and shareable?
- How will emergently-generated narratives, deliverables, and IRTs be influenced by variation within/among countries in technical capacity, internet connectivity, and cultural backgrounds? (See Figure 1).
- How can the effect of this specific meme be quantifiably measured or assessed?
- How can we model a hypothetical meme's potential ability to penetrate or propagate bias, ignorance, hate, or fear?
- What is the role of passive vs. action modes of narrative engagement in this domain?
- How can national and global goals be quantified and achieved? (See Figure 2).

Discussion

Hermann Hesse, in his 1943 book The Glass Bead Game (Das Glasperlenspiel), characterized a dismal "Age of the Feuilleton", one in which "the life of the mind [was like] a degenerate plant which was squandering its strength in excessive vegetative growth". In the book, the unhealthy mental experiences characteristic to the "Age of the Feuilleton" were inflamed by a media ecosystem of "scandal" [5] and "passive" infotainment [6]. Today in 2020, we find ourselves in an Internet-based "Age of the Feuilleton", full of (in modern terms) disinfo, conspiracies, psyops, fake news, echo chambers, funnels, and silos. Rather than the fanciful terminology of Feuilleton, we might refer to this scenario as the Gray Zone in 4th generational warfare [72,73] and find the potential for prevention of negative impacts in information and cognitive security [74,75].

In Hesse's work as in our current world, the path out of an "Age of the Feuilleton" is challenging, though not all is lost. In the grand tapestry that is human history, the recognition of the depths of an "Age of the Feuilleton" is also the spark, the seed, the impetus of something new. Hesse wrote that the recognition of an "Age of the Feuilleton" occurred at the moment when a society was "...already on the verge of

---

[5] "If the bearer of an aristocratic name was involved in a scandal, the readers of many thousands of feature articles at once learned the facts. What is more, on that same day or by the next day at the latest they received an additional dose of anecdotal, historical, psychological, erotic, and other stuff on the catchword of the moment. A torrent of zealous scribbling poured out over every ephemeral incident, and in quality, assortment, and phraseology all this material bore the mark of mass goods rapidly and irresponsibly turned out."

[6] "In those days the citizen of a medium-sized town or his wife could at least once a week (in big cities pretty much every night) attend lectures offering theoretical instruction on some subject or other: on works of art, poets, scholars, researchers, world tours. The members of the audience at these lectures remained purely passive… People heard lectures on writers whose works they had never read and never meant to, sometimes accompanied by pictures projected on a screen. At these lectures, as in the feature articles in the newspapers, they struggled through a deluge of isolated cultural facts and fragments of knowledge robbed of all meaning."

that dreadful devaluation of the Word...". In the Glass Bead Game, what eventually leads to the visionary place of Castalia, is when "at first in secret and within the narrowest circles, that ascetically heroic countermovement [began] to flow visibly and powerfully, and ushered in the new self-discipline and dignity of the human intellect". Perhaps our current Age of the Feuilleton could be collectively ameliorated by global Infinite Teams, playing Infinite Games for the benefit of all.

Chapter II
Figures

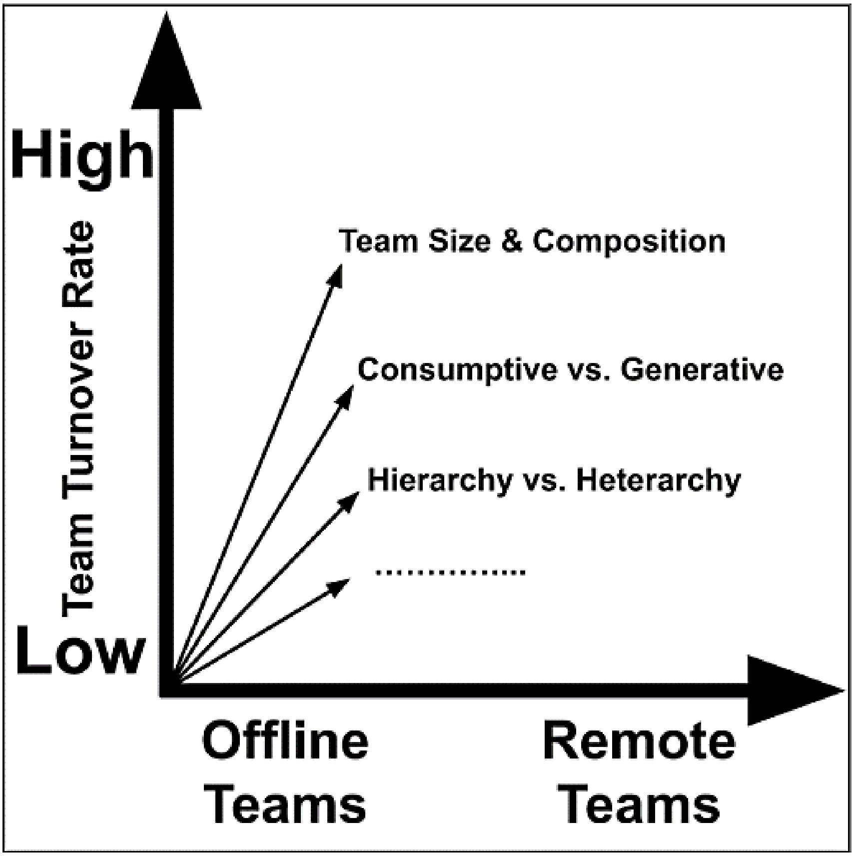


Figure 1. Multidimensional Framework for Teams and on two main axes: extent of team remoteness/distribution (X-axis) and rate of team turnover (Y). Other axes of team variability are shown as accessory dimensions to the primary two.

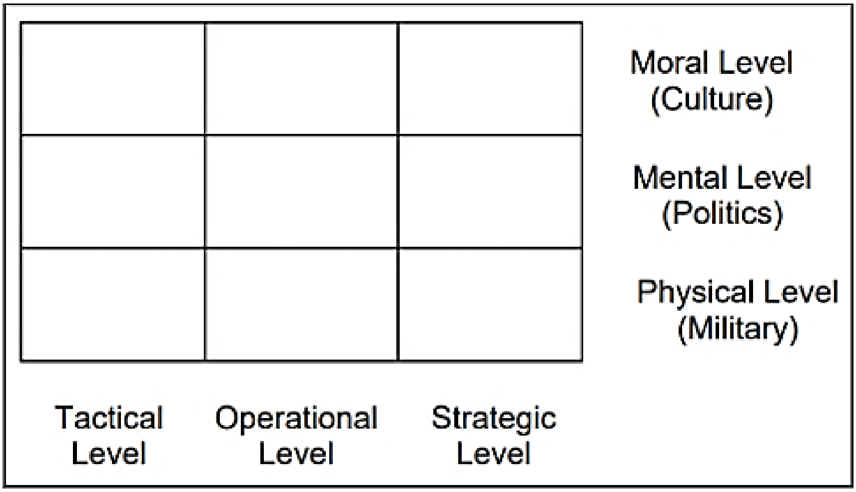


Figure 2. *According to the authors, "This figure was drawn by William S. Lind during the interview on 27 January 2005." Lind was one of the most important figures in modern military theory [66,76], and it is interesting to note that he placed the Moral (Culture) above the Mental (Politics) and the Physical (Military). An "Infinite Games for Infinite Teams" approach might be relevant to the Tactical, Operational, and Strategic levels, in the arenas of Politics and Culture (the top 6 boxes). From [72].*

CHAPTER III

Active Inference & Behavior Engineering for Teams

Alexander Vyatkin, Ivan Metelkin, Alexandra Mikhailova, Richard J. Cordes, & Daniel A. Friedman

ABSTRACT

Comprehensive frameworks for Teams should include various functionalities and structures in order to capture the broad range of affordances available for modern Remote Teams, including, but not limited to, synchronous & asynchronous communications, memes, geospatial maps, hardware/software use, and contact escalation. We suggest that Systems Engineering provides guidelines to define the functions of Ontologies, Narratives, Formal documents, and Tools (ONFT) within the context of the life cycle of any System of Interest. Following this ONFT assessment it is possible to break out to sub-systems levels and mechanistic analysis. In this paper we explore how a new generation of ONFT for Remote Teams could be based on Active Inference, a process theory related to the Free Energy Principle. Effective ONFT based upon Active Inference could lead to the realization of lightweight and powerful epistemic tools to guide everyday decision-making in an embodied, enactive fashion. Such a technology for Remote Teams would lead to fundamental changes in various aspects of Team function, for example the efficiency of a Team's production of artifacts or self-reported "phenomenology of the working day".

CONTRIBUTIONS

- Communication is fundamental in natural and designed teams; effective communication systems are needed to facilitate the organization and function of complex multi-agent systems.
- Alignment on Mission, Narrative, and Ontology is tied to team performance.
- Under the Free Energy Principle (FEP), previous work has synthesized Active Inference (ActInf) with domains such as Narratives [1], Ontologies [2] and extended cognition in multiscale biological systems [3,4].
- Using the ActInf framework, here we explore various kinds of Communication in located teams and all-online Remote Teams (RT).
- Online work and RT are promising systems for theoretical study and direct applications of the ActInf framework, because all states and updates in digital systems are observable.
- Here we bring the FEP-ActInf-Narrative nexus together with the applied approach of Systems Engineering (SE), to begin the work of formalizing the processes of RT formation and lifecycle management.

DRIVING & INSPIRING QUESTIONS

- How could we consider the coherence, narrative, and identity function of communication at the individual scale, as well as the scale of Teams & organizations?
- What kinds of methods for Teams (analytics, user interfaces, etc) could be deployed to address basic and applied questions of interest?
- How could we apply multi-scale Active Inference frameworks to Systems approaches such as Ontologies, Narratives, Formal documents, and Tools (ONFT)?
- How could we address concepts and models for epistemic values within the context of ONFT for Remote Teams (epistemic foraging)?

- How could Teams ensure narrative reliability? How can the epistemic and goal-oriented ends of foraging be jointly optimized by individuals and teams?
- What we could take from concepts and works on niche construction to aid development of ONFT approaches for modern, global Teams?
- Could we define approaches for personal behavior engineering by using ONFT in Teams communication?

Teams are about Function & Communication

Work is performed by teams, human and non-human (e.g. ants) [5–7]. The concept of Division of Labor describes how system subunits interact with each other and perform work [7,8] in Complex Adaptive Systems regulated by agent-agent and agent-environment feedback systems [7,9–11] (also see Task Allocation [12,13], Heterarchy [14–16], and ant semiotics [6,17,18]). In the context of remote and located Teams, heterarchical subsets of members and stakeholders allocate tasks based on practices (norms) and Roles (identities or assignments). Team members not only perform work, but they also send signals, exchange results, and contribute to shared and documented models in extended cognitive tools [19,20]. Tools can help both long-lasting and rapidly-assembling Teams deal with challenges which can't be solved or resolved by any single person. For example, good Team documentation software enables efficient usage of distributed expertise & transdisciplinary cognition by allowing the affordance of interacting with the wisdom of previous teammates [21,22].

For humans, narratives are aspects of individual and shared generative models of the world [23]. For teams, multi-scale narratives emerge as individuals build a generative model of their team. We highlight the phenomenological experience of an individual worker as they investigate high level narratives (Why does this company exist? What problems is it solving or impacting in the world?) as well as team-level narratives (Why does this team exist? Why is our part of the project important to the whole company?). Narratives become memetic when they can be shared and understood in common, this process of communication leads to alignment based upon shared values and mission.

Modern Teams are Remote Teams

There is a need to define Team communication in a more formal fashion, ideally drawing on insights from transdisciplinary theoretical (e.g. Complexity Science) and applied (e.g. Systems Engineering, Systems Innovation) approaches [24,25]. Modern Teams are composed of sets of human, collective, or non-human agents [26–29], often with high turnover rate (see Definitions) [21,30,31]. Today's Remote Teams (RT) are physically distributed, and increasingly use the internet to coordinate action and informationally connect team members [24,32,33]. When working with Instantaneous Remote Teams (IRTs), one also needs to consider the timing at a very fine scale – in IRTs, each team member could participate in different Teams in different capacities during one working day or even a single hour [31].

High Reliability Organizations (HROs) are organizations that contend with volatile environments in which many interactions can be considered non-routine. HROs are increasingly reliant on small, physically distributed, and sometimes temporary or rapidly assembled teams as a means of solving novel, complex problems [34–37]. Examples of these Teams include "tiger teams" in the oil and gas industry [34], and "swift market analysis response teams" (SMART) in the auto industry. Key rituals, protocols, and strategies for these IRTs have been incorporated into SCRUM and Agile Development frameworks for rapid development of software as well [37]. The rapidly assembled, or sometimes "instantaneous" remote team, is an emergent solution to a set of emergent problems. Human knowledge has expanded exponentially, consequently, fields of expertise began to divide into specializations as a basis to reduce time-to-application and learning requirements [38]. This sub-specialization has achieved its goals at a cost: generally, no single individual and often no single team holds all of the knowledge and skills necessary to solve the novel problems emerging from the complex threat surfaces with which HROs contend, and as a result, reconfiguration is becoming a more normalized response [25,39,40]. This solution isn't unique to industry: National Navies are organizations which contend with complex threat surfaces in littoral environments, with the additional constraint that equipment repertoires are the product of decade-long investment cycles [25,41,42]. Consequently, many National Navies have converged on the same outlook: that no single team or equipment configuration is adequate for the future of expeditionary warfare and indeed remote work [41–43].

Where emergent teams of any type are created in response to novel, complex problems, they cannot rely on effective informational compression via inflexible protocols, as the team situation and even composition may be a moving target. Rapidly-forming teams sometimes are precluded from relying on compression via long-term bonding as would be found in traditional high performance teams. As such, it should be unsurprising that high performance, emergent teams responding to novel, complex problems generally rely on shared organizational culture, mission, and narrative [25,31,37,44–49]. In the context of both internet communities & in-person protests, memes can serve as rallying points as well as symbols that communicate mission-critical narrative information to team members [25,31,50]. Organizational culture in remote and located teams can be defined as the shared beliefs and values of an organization, as well as its collective processes, cognitive and physical [51–53]. Mission has three primary connotations: military [54,55], religious [56,57], and corporate [58,59]. In all three usages of "mission", mission-relevant narratives and symbolic (or even esoteric) communication are used for the purpose of compressed goal-setting.

In the context of team communication, narratives are dynamic, and in constant adjustment [38,60,61]. Narratives become recognizable through shared or attuned semiotics, iconology, and totemization [47,62–66]. Narratives can be created, perturbed, and managed [63] through the production of physical artifacts [67] as well as through ritual [68–70]. Narratives are a form of memetic compression, for example Linn's reduction of three centuries of American military philosophy into three "camps": Guardians, Heroes, and Managers [71]. This concept of "narrative as dynamical analogy" is about finding the stable mappings within complex systems that allow for effective action, as is sometimes used in physics [72], computer science [73], and in memetics itself [74,75].

Rapidly formed teams and IRTs come together with clear limitations, the most important of which is the social cohesion and trust necessary for organizational sensemaking. Effective formation of small teams leads to optimal utilization of collective intelligence, and generally positive performance [37,76–81]. Conversely, failure to develop mutual trust and social cohesion can hinder performance [80,82–84]. When opportunities for a team (startup, governmental, research, or otherwise) are dynamic and require rapid reorientation, failures of team formation can be lethal [37,51,84,85]. Teams have both implicit and explicit organizational structures & networks of communication. These defined or undefined team structures (representations of networks of roles, positions, signals) have direct implications for the efficacy of communication and production of Team artifacts (physical, software, narrative, memes). Functional small teams can be argued to belong (exclusively or non-exclusively) to at least one of three classifications characterized by the means by which members reduce uncertainty about the signals and actions of other members, presented here:

> ONTOLOGICAL ALIGNMENT
> The first kind of group is composed of organizations which depend on very strict, clearly defined, compressed ontologies paired with strict processes that limit the potential for signal-error, creating high expectations of trust between individuals who do not necessarily know each other or even expect to interact again, such as operating rooms, or air traffic control [34,51,86–88].

> INTIMATE TRUST ALIGNMENT
>
> The second kind of group is found within organizations which depend on team bonding and practice over very long periods of time in order to create high-trust and "short-hand" communication that is very highly compressed even if ambiguous or indiscernible to external actors – this group includes organizations which create a "collective mind" during operations such as special operations units, fire departments, sports teams, aircraft carrier flight decks, and non-human cooperative hunting groups such as wolves [44,51,87,89,90].
>
> NARRATIVE ALIGNMENT
>
> The third is composed of organizations which are aligned on organizational culture, narrative, or mission [31,37,46,91,92]. These groups can be anonymous, and dynamic in composition or focus.

Here, by defining Teams in terms of their communicative structure, we include many informal groupings (internet chat rooms, crowds, protests, spontaneous public meetings) not classically considered as Teams. Our Team definition here is oriented towards capturing the diversity of communicating systems, rather than just the explicit organizational structures. In modern contexts, teams assemble and disassemble over short timescales, and are often composed of not just of humans but also non-human facilitation agents [26–29,93]. What is not a team, under this conception? The short answer to this question, which will be explored later in the context of Team Markov Blankets, is that non-communicating entities, or entities that are not part of the same informational niche, are not part of the same team. Non-communicating entities may still have alignment of values, mission, or even behavior—but they are not on the same team because they are in non-overlapping informational niches. All of these examples point to the need for a formalized system for today's RT that can meaningfully cope with all of these strategic and tactical challenges.

Systems Engineering Provides Frameworks for Life Cycle Management of Complex Systems

To take a field from theoretical speculation to applied utility, we need a set of tools for defining and interacting with a System of Interest (SoI). In this case we are interested in behavior engineering of team communication structures. Engineering is always about changing something in the world, and so behavior engineering in teams is no exception. Engineering can benefit from the Complexity Science perspective, but a conceptual approach alone is incomplete for the designing and implementing of real systems. To quote from the definitive Systems Engineering (SE) Book of Knowledge:

> *"Systems Engineering (SE) is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on holistically and concurrently understanding stakeholder needs; exploring opportunities; documenting requirements; and synthesizing, verifying, validating, and evolving solutions while considering the complete problem, from system concept exploration through system disposal"* [94].

SE frameworks define usage of Division of Labor for life cycle management based on different functional Roles for each stage. For each task to be performed, Practices (e.g. architecture, development, testing) are supported through technologies relevant to each Role. SE defines "Practices" as the combination of discipline, work, products, tools and activities [95,96]. To provide actionable solutions to pressing needs, Systems Engineering defines the "functions" and objects of attention during work on SoI life cycle [95,96]. In SE, functions are also a key unit of analysis. These functions can be carried out by multiple humans, or one human may have multiple roles/functions. Thus the design imperative, within a Division of Labor context, is to configure the roles in order to produce functional outcomes. This refocuses the discussion away from spurious communication, and toward task-oriented or performance-oriented outcomes. The pursuit in SE of expected team outcomes is akin to the cybernetic idea that complex self-regulating systems must be goal-seeking in order to survive and thrive [97–99].

We draw on the OMG Essence framework [100] to explore the use of Alphas (Abstract-Level Progress Health Attribute), which are uncertainty-reducing sets of States and Checklists for that track changes in the performance of collective work. Teams, at any given moment, are focused on a single Alpha that rises to the level of group attentional awareness [101], akin to the emergence of high-level salience in hierarchical systems [4,102]. The Essence framework identifies seven Alphas as objects of attention in every software engineering project: Stakeholders, Opportunity, Requirements, Software System, Team, Way of Working, and Work [100]. These seven categories also apply well to RTs. In the course of the project the status of the team undergoes small and large changes, passing through states as work is performed. These states of teams and products are observable, in contrast to Alphas, the states of which we can only judge "by instruments"—by the state of artifacts.

It was proposed in Systems Engineering Essence framework [95,96] to expand applications of Alphas from software projects only to hardware and sociotechnical projects by changing Requirements and Software System to System Definition and System Realization. To capture some of the useful ideas from SE, we summarized several recent summary documents of Systems Engineering (Table 1 & Table 2). Despite the fact that SE approaches well established and have been used widely in the last decades it is still the general opinion that SE needs to interface with people outside the scope of a system, even though there is no way to directly engineer their behavior. One possible solution to this challenge of integrating internal and external SoI dynamics would be to set patterns and rules for internal and external communication [103]. We now turn to the enactive framework of Active Inference to provide inspiration for the design of communication patterns for RT that would facilitate modern teamwork.

Active Inference in Teams

Active Inference (ActInf, see Definitions) is a formal framework that frames goal-seeking behavior as an actor-centric dynamic feedback between internal and external states, mediated by sense and action [104–106]. ActInf is a process theory (as opposed to a state or variance theory [107,108]) based upon the Free Energy Principle [102,109] (Figure 1). In ActInf, generative models about the world (as opposed to descriptive, reactive, or analytical models) support ecologically-relevant functions of real systems [3,97,110]—for example a person trying to catch a ball will move towards where they predict the ball will intersect with their trajectory, and motor saccades of the eye during reading are related to real-time predictions about which visual information will be most informative [111,112]. ActInf captures informational and statistical aspects of these generative models and how they are updated and communicated by multiscale far-from-equilibrium systems [104–106,113,114]. ActInf thus presents itself as a promising approach to the quantitative study of complex system behavior [3,97,110]. In this paper our focus is on situating team communication as a case of Active Inference, and exploring various avenues where ActInf approaches could be useful for modern teams.

Here we briefly review several recent developments in the ActInf literature that are relevant for our use case of RT. The topics of communication, narrative, and culture have recently been contextualized within the context of ActInf and the FEP [116–119]. Communicating systems such as the brain [120,121] and improvising dyads [122] can be formally cast within the ActInf framework, making these varied systems amenable to powerful physics-based analyses. For humans, the study of semantic interpretation of text is known as hermeneutics, which lies at the base of many forms of communication. ActInf captures how multiple interacting agents perform improvisational hermeneutics at the behavioral timescale (via e.g. micro-scale turn taking [122]), scaffolded within cultural niches that play out at much longer timescales [123]. The expected status of communication within human teams is cooperative, facilitating the emergence of effective work on large and complicated projects [115].

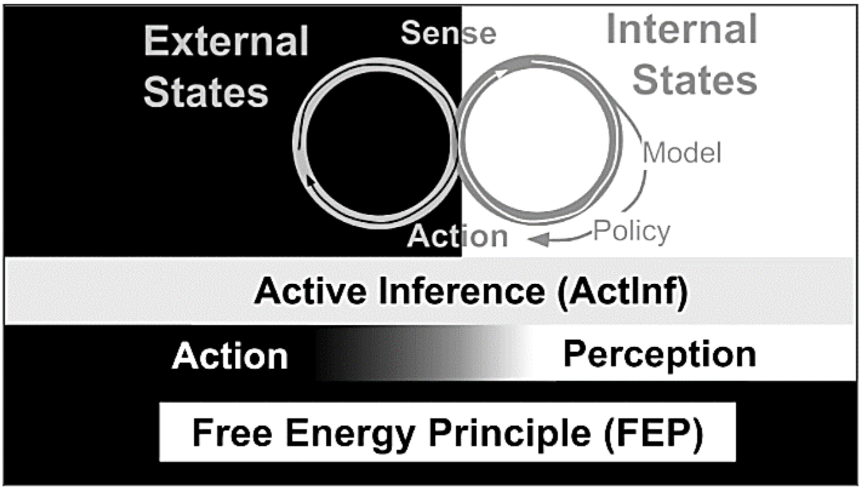


Figure 1. Active Inference (ActInf) is built upon the Free Energy Principle (FEP). Internal states (generative model and policy selection) are linked to external states (world states), via a Markov Blanket (border between dark and light) which is pierced by Sense and Action states.

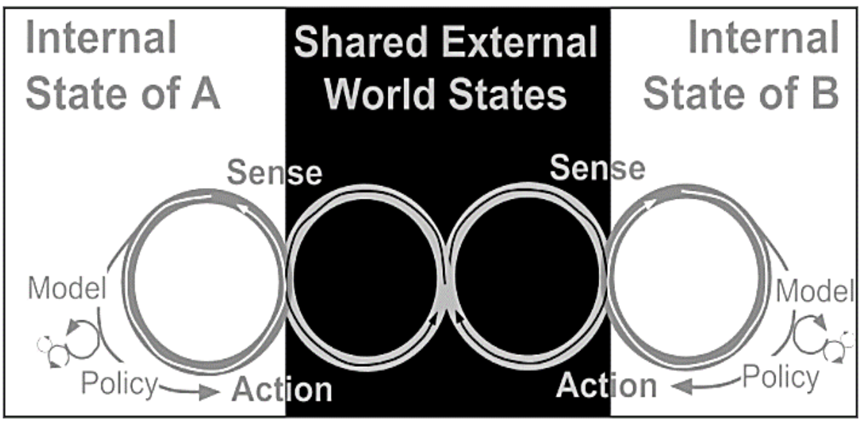


Figure 2. In the case of interacting systems, ActInf casts the commonly-accessible external world states as an epistemic information niche [115].

In the case of goal-oriented team work, ActInf explores how agents communicate with each other in order to reduce each other's uncertainty about internal (mental) and external (world) states. In order to coordinate at higher scales, agents must be connected through communication channels (shared epistemic niche) as well as have the Bayesian prior belief that attunement or alignment is a desirable outcome (desirable since it would reduce uncertainty about achieving preferred future sensory states) [115]. Over evolutionary time, the priors that communication among similar agents is cooperative becomes entrenched through selection (assuming that coordinating agents have higher fitness) [4]. These evolutionary and developmental expectations about social interactions are enacted and shaped through real-time experience – giving a formal sense to the classic phrase "through others we become ourselves" [124,125]. We can adapt this phrase here to consider how teams form and perform, e.g. "through communication with others we become a team", or "though reducing our uncertainty about the future we achieve our shared goals".

The rest of this paper is dedicated to exploring the features and implications ONFT for teams, using SE and the ActInf framework. We focus on the multiple levels of communication that teamwork entails (within and between teams), and some of the special aspects of modern Remote Teams (for example rapidly changing composition and augmented or non-human teammates). We explore the possibility of creating protocols for RT communication to succeed in the development of SoIs, based upon optimized message passing systems inspired by ActInf. This perspective for computational communication of RT extends naturally from recent work on ActInf in enactive and encultured communication.

SE Approaches to Implementing Active Inference in Remote Teams

Here we highlight the Remote Team (RT) as a tractable "model system" for studying the processes of Communication, Narrative co-construction, collective intelligence, organizational sensemaking, and organizational management online. The design of successful RTs, now more than ever, is essential for the health and productivity of modern society circa 2020. We use the multiscale action-oriented framework of ActInf to consider the communicative, psychological, and techno-social dynamics of RTs [4,97,112]. We consider how recent developments in online organization, gamification, and platform accessibility make formal systems for RT & Instantaneous Remote Teams (IRTs) a relevant technology for research and implementation [25]. Overall we aim towards Ontologies, Narratives, Formal documents, and Tools (ONFT) for RT within the ActInf framework.

We recast the generalized ActInf setting of Figure 2 into the specific case of two (or more) interacting team mates within a shared team informational niche (Figure 3). We use the concept of a Markov Blanket (MB, see Definitions) and communicating systems to define a team as the set of human and non-human agents that share a specific informational niche (Figure 4). In ActInf, the MB reflects the separation between internal and external system states, pierced by active and sensory states [126–128]. In the context of team communication, the MB is enacted by the informational boundaries of the team, though there may also be permanent or transient internal subdivisions [129], especially in large organizations with reconfiguring subteams. Communication among team members in RT can take various forms (Figure 5), including audio-visual relay (video chat), text messages (chat), file sharing, and other forms of information transfer (sensors, biofeedback, geospatial information).

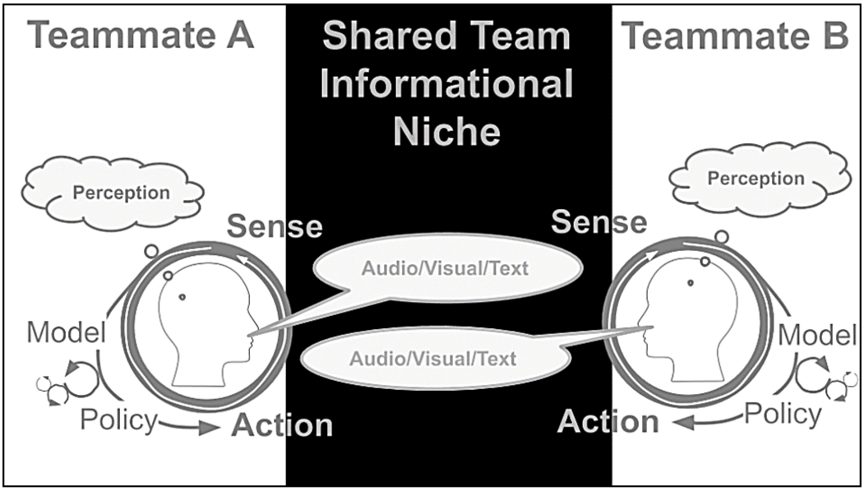


Figure 3. The Team consists of multiple interacting agents, sharing a joint informational niche. Each team member is engaged in sensemaking and the performance of work through the process of Active Inference.

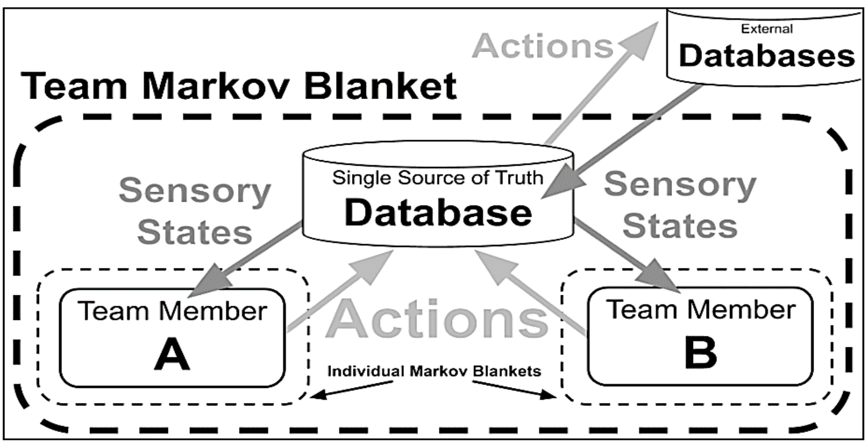


Figure 4. From a communicative perspective, Teams are defined by their coexistence within a Markov blanket. Individuals also possess their own Markovian boundaries, highlighting the need for multiscale formulations that are flexible enough to encompass diverse types of agents. The team is defined by its composition, shared informational niche, common internal model of the world, and affordances for external action.

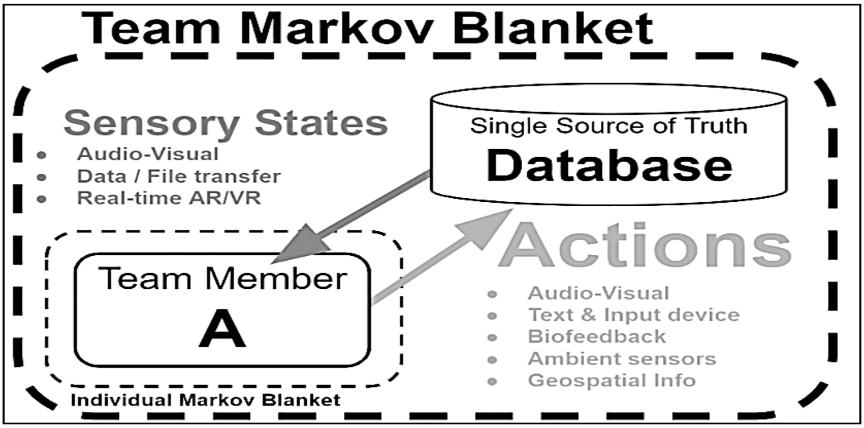


Figure 5. Here are the types of communication between a user and the Single Source of Truth (SSoT) Database. Within the scope of Team communication, a single team-mate may experience various kinds of sensory inputs, and participate in various action affordances. Not visualized here are communicative features such as synchronous/asynchronous dynamics, multiple team-mates, or other attributes of RT.

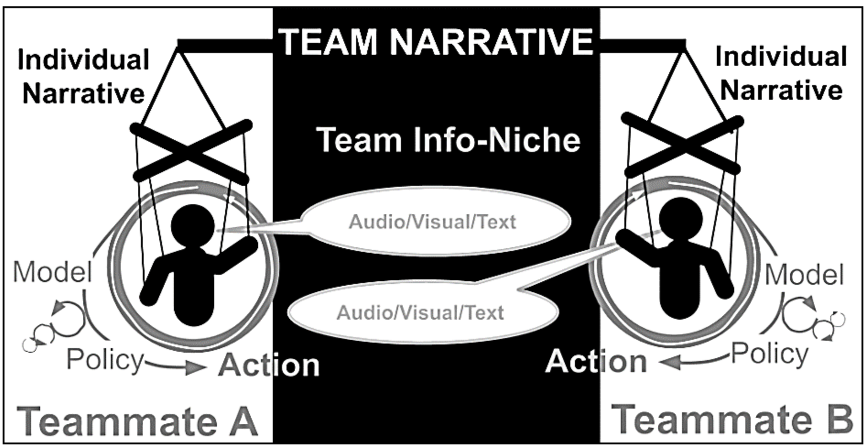


Figure 6. Team narratives are like a fulcrum or leverage point that shapes the observable communication patterns of teams. Multiscale Team narratives contextualize internal model and policy decisions of individual team mates, which influence their behavior (thus feeding back into the team informational niche and altering the narrative itself).

We consider narratives as tools that have functional roles in Teams (Figure 6). At the same time narratives can be generative models (enacted or latent generative dynamics). Our focus is on team behavior, in that we want to attune communication in the interest of achieving certain results. This focus on quality production of artifacts will be behaviorally accomplished in real teams through the design of effective communication and regimes of attention. This is consistent with recent developments in ActInf which frame cultures (of organizations, teams) as "cultural scaffolds" and "regimes of expectations" [97] that through communication are able to achieve higher-order goals [105].

Remote Teams (RT) are especially tractable for formal analysis of any kind because most state transitions in the team are observable. In located teams, it can be challenging to capture the nuance of important communication techniques such as space use or body language. Conversely in an RT, while body language and other qualitative ostensive cues may still be critical, an observer can be sure that they are at least capturing all of the signals being exchanged (unlike, for example, a video camera in a conference room which may be able to capture where each person is in the room, but not what each person sees). Continuing with this mapping between RT and other far-from-equilibrium message passing systems graphs that perform Active Inference, we can consider all agents (human or non-human) as nodes that are connected via communicative edges. The structure of this graph is the realized communication system of the team, and thus the boundaries of the work-performing aspects of the team. Nodes that are informationally connected may be formally related (e.g. via an Org chart) or they may be organizationally unlinked.

Different kinds of communicative edges may reflect different types of relationships such as informant or close interpersonal linkage (friendship or "buddyship", reflecting a highly synchronized shared generative model). In the RT, because all communications are via online transfer, this exocortex is a key Enabling System [130,131]. This means that we can define the Enabling System in terms of all communication events (in Online space), and for each event provide defined roles & protocols. Narratives for communication are essential for all sorts of team relationships. Narratives can be social functions that create a cognitive niche, thus reducing collective/individual uncertainty [115,132]. Within the context of a narrative that sets the team goal and function, there is a process of exocortex-driven Division of Labor. Functional ontologies are relevant for the role-assignment stage, whereas the System-level ontology steps in to help workers make sense of what they should do.

We see Active Inference as something like a "two stroke engine" for Remote Teams (ACT –> INFER –> ACT –> …), accomplished through the communicative structure or "Syntax" of the RT (also see OODA loops [133,134]). In all cases, everything is based upon, or supported by tools. This means that work is performed through observable sequences of Events (taking place at a specific time with specific syntax/grammar) which result in meaningful progressions of events (narrative semantics). For an event to exist, there must be a measurable change in a system state or Alpha [135]. From the perspective of the team members, communication about narratives is of the utmost importance, as narratives set the stage for interpretation of subsequent signals. Narratives are strong enough to serve as nucleating or rallying points for located protests as well as all-online IRTs, underlining the need to understand how memes and narratives interact in modern informational ecosystems [25].

Discussion

Here we use the framework of ONFT to highlight specific areas where ActInf could be applied:

> ONTOLOGIES
>
> Active Inference could inspire action-oriented ontologies for Remote Teams, describing team composition, communication systems, work performance, informational channels, hardware/software, and more. This leads to the idea of interoperable RT from different organizations (e.g.

using standards for metadata that allow for data transformation and Business, Operations, Legal, Technical, and Social inter-team communications and situational awareness such as those proposed through work on Coalition Battle Management Language [136–138])).

Required ontological information for team communication could include (Date, Time, Sender, Role, Alpha). Optional information could include (Seals, Symbols, Context, and Signposts for regimes of attention).

An ActInf-based ontology for Narratives would allow the design or control of narratives in RT. This might be facilitated by tools like Sentiment analysis, visualization techniques, and machine learning of social media data. Other researchers have sketched out common cases where narratives for online teams already exist, how could a formal structure make this more manageable?

In terms of Team membership and informational ingresses/emissions, ontologies for multi-agent systems and Markov Blankets might allow for the design of internal and external representations of work performance [2].

NARRATIVE

Narrative alignment is dynamic and grows between members of teams through peer or "horizontal" bonding [84]. Organizations which consist of many teams may experience narrative alignment via both horizontal and vertical bonding, that is, bonding with team-mates and members of other teams as well as bonding with supervisors [84]. The highest level of narrative alignment might be best described with the military term "esprit de corps", where mutual sense of mission, trust, ideals, culture, and shared threats allow alignment to transcend self-interest, specific unit membership, and limits on intimate relationships [84,139–142]. Narrative alignment associated with "esprit de corps" creates behavioral ideals, objectives, heroic tradition, and culture or "regimes of expectations" for individuals to align and conform with in order to cope with high levels of uncertainty [1,4,71,83,97,142,143]. ActInf frameworks for RT could promote a digital "esprit de corps" that is observable and also tractable to interface with.

The value of communication patterns in the RT could be quantified in terms of value for the team narrative, as proxied by novel evidence for (updated distribution of) shared generative models. This is similar to how backpropagation training of neurons in an artificial neural network updates parameters based upon contribution to error, or how Numer.ai rewards machine learning models proportionally to how they contribute to the success of an automated trading bot [144].

At different levels, we can associate different functions for different generative narratives of interest. We need to be able to name, trace, and document the states of narratives (as well as capture pluralistic interpretations of multi-person narratives).

A focus on function and role performance within a narrative context could improve the performance of work and the experience of team members. This is because narratives are functions that provide Identity and Meaning across multiple scales. From a SE perspective, Narrative is just another SoI that we can reduce our uncertainty about, towards the end of system design and cybernetic control. Just as with other Complex control questions, we are able to design/control at the Systems level by making the right abstraction for coarse-graining (here, Markov Blankets that allow us to ignore hidden internal states).

FORMAL DOCUMENTS

ActInf could inform the design of documents that relate multiscale event frameworks. Each event has prerequisites, inputs/outputs (functionalism), consequences & outcomes, roles, problems in focus, expectations, and predictions. Formal documents capture which engineering metadata needs to be present (e.g. reference data format) in order to perform life cycle analysis on SoI.

Formal Documents for the work day and week could improve the experience of workers:

- Morning documents: providing narrative alignment and informational update for the day.
- End-of-day documents: providing closure to the day, filling out information about progress.
- Monday documents: providing narrative Alignment for the week (mission, culture, identity, collective sense-making, where are we in the bigger niche?)
- Friday documents: providing closure for the work week.

TOOLS

Tools are required in all of the above domains so that professional, innovative, effective, inclusive Remote Teams can implement effective ActInf frameworks of any kinds. Current common (and often free) tools include chat, file-sharing, voice/video, CRM, Single Source of Truth software, etc. Such tools will be helpful for ActInf-based teams, and also new kinds of tools may be required. Given the total observability of RT, toolkits such as SPM [145,146] and multiscale analytics could help attune RT communication towards desired products. Human-in-the-loop machine learning systems based upon ActInf could allow for actions and perceptions to be designed and controlled in real-time at a fine scale [104,147].

For RT communication across platforms, it would be helpful to design common database formats that link protocols, for example using an API connector like Matterbridge [148]. This would allow for the effective management of the tradeoff between centralized, private, and decentralized backends that use custom metadata, and user-facing platforms with customizable UI/UX and dynamic data updating. This kind of "total comms" understanding, and ability to design effectively within the space of possible RT, would reduce platform fragmentation and increase worker effectiveness.

Inspiration from nature (biomimicry) could provide new tools and perspectives on how different work functions could be performed by different cognitive niches [6,149]. Computer-assisted design (CAD) Tools for communication charts would allow the formalization of "Markov communicative blankets". This could facilitate the formation of collective cognitive entities that can then be understood, compressed, templated, optimized, and reconsidered from multiple perspectives [150]. Tools for regimes of synchronous & asynchronous attention would allow for the optimal design of ostensive cues and salient epistemic signals—"events only happen when the listener is paying attention".

The future of the Free Energy Principle and Active Inference is bright but uncertain. Through our cybernetic communication and actions in the now, we reduce our uncertainty about the hereafter.

Chapter III
Tables

System Fundamentals	System
	Behavior
	Complexity
	Emergency
Representing Systems with Models	Model
	Model-based Systems Engineering
	Modeling Language
Engineered System Context	Product Systems
	Service Systems
	Enterprise Systems
	System of Systems
	Cyber-Physical Systems
Systems Engineering Standards	Modeling Standard
	Related Standard
Generic Life Cycle Stages	Concept Stage
	Development Stage
	Production Stage
	Utilization Stage
	Support Stage
	Retirement Stage
Systems Engineering Management	Planning
	Assessment and Control
	Decision Management
	Risk Management
	Configuration Management
	Information Management
	Measurement
	Quality Management

Table 1. Description of SE Knowledge Areas, adapted from [151]

This Page Intentionally Left Blank

Alpha	State	Description
Stakeholders The people, groups, or organizations who affect or are affected by a system.	Recognized	Stakeholders have been identified.
	Represented	The mechanisms for involving the stakeholders are agreed and the stakeholder representatives have been appointed.
	Involved	The stakeholder representatives are actively involved in the work and fulfilling their responsibilities
	In Agreement	The stakeholder representatives are in agreement.
	Satisfied for Deployment	The minimal expectations of the stakeholder representatives have been achieved.
	Satisfied in Use	The system has met or exceeds the minimal stakeholder expectations.
Opportunity The set of circumstances that makes it appropriate to develop or change a software system	Identified	A commercial, social, or business opportunity has been identified that could be addressed by a software-based solution.
	Solution Needed	The need for a software-based solution has been confirmed.
	Value Established	The value of a successful solution has been established.
	Viable	It is agreed that a solution can be produced quickly and cheaply enough to successfully address the opportunity.
	Addressed	A solution has been produced that demonstrably addresses the opportunity.
	Benefit Accrued	The operational use or sale of the solution is creating tangible benefits.
System definition A set of core technical activities of systems engineering, including the activities that are completed primarily in the front-end portion of the system design.	Conceived	It is clear how the system will be defined.
	Consistent	Consistent System definition has been created.
	Coherent	The requirements provide a consistent description of the essential characteristics of the new system.
	Used for Production	System definition is used for system production.
	Used for Verification	System definition is used for testing.
	Used for Operation	System definition is used by stakeholders for operation.
	Used for Disposal	System definition is used for system disposal.

Table 2. *Continued next page.*

System Realisation The activities required to build, integrate elements, and ensure that a system both meets the needs of stakeholders and aligns with the requirements.	Raw materials	Raw materials for system realization are available and allow manufacturing of the parts with required properties.
	Parts	Parts have been produced and are ready for integration.
	Demonstrable	The system has been assembled from the parts and is ready for testing.
	Ready	The system (as a whole) has been accepted for deployment in a live environment
	Operational	The system is in use in an operational environment.
	Retired	The system is no longer supported and disposed and/or recycled.
Team A group of people actively engaged in the development, maintenance, delivery, or support of a specific software system.	Seeded	The team's mission is clear and the know-how needed to grow the team is in place.
	Formed	The team has been populated with enough committed people to start to pursue the team mission.
	Collaborating	The team members are working together as one unit.
	Performing	The team is working effectively and efficiently.
	Adjourned	The team is no longer accountable for carrying out its mission.
Way of Working The tailored set of practices and tools used by a team to guide and support their work.	Principles Established	The principles, and constraints, that shape the way-of-working are established.
	Foundation Established	The key practices, and tools, that form the foundation of the way of working are selected and ready for use.
	In Use	Some members of the team are using, and adapting, the way-of-working.
	In Place	All team members are using the way of working to accomplish their work.
	Working well	The team's way of working is working well for the team.
	Retired	The way of working is no longer in use by the team.
Work Activity involving mental or physical effort done in order to achieve a result.	Initiated	The work has been requested.
	Prepared	All pre-conditions for starting the work have been met.
	Started	The work is proceeding.
	Under Control	The work is going well, risks are under control, and productivity levels are sufficient to achieve a satisfactory result.
	Concluded	The work to produce the results has been concluded

Table 2. Alphas and their states, adapted from [86] and [100]

Chapter III
Definitions

Active Inference. Active inference (ActInf) is an action-oriented process theory that is related to the formal multiscale framework of Free Energy Principle (FEP) [3,109]. ActInf posits that action-perception cycles link external and internal systems, through sensory and active states that bidirectionally constitute a system-specific boundary known as a Markov Blanket (MB). ActInf is related to areas such as Cybernetics [152], Niche construction [110], Information foraging [111], linguistics [105], Variational Bayesian machine learning techniques [104].

Engineered System. (1) An open, concrete system of technical or socio-technical elements which is the focus of a SE life cycle. Its characteristics include being created by and for people, having a purpose and satisfying key stakeholders' value propositions when considered as part of a broader system context [94]. (2) An engineered system is a system designed or adapted to interact with an anticipated operational environment to achieve one or more intended purposes while complying with applicable constraints [153].

Systems Life Cycle. The evolution of a system, product, service, project or other human-made entity from conception through retirement [95,154].

System of Interest. **SOI**. The system being considered, whose life cycle or attributes are the subject of interest [154].

Team. (1) A set of communicating nodes, where nodes represent actors (people, augmented people, computers). Teams with coherence (of communication, narrative, or function) tend to be involved in a shared work. The performance of this functional work is in feedback with Team informational connectivity, as well as the extent of attunement of shared beliefs, policies, goals, values, and worldview among stakeholders. Team composition and mission are all subject to continuous change, this paper begins to address how formal systems for complex systems could be deployed in remote teams, to maximize desired ends amidst constraints and uncertainty. Instantaneous Remote Teams (IRTs) are generative online-native teams that can have rapid evolution of mission, personal composition, skill set, and approach. Team members are engaged in task allocation, using different practices, and managing the group's lifecycle, exchanging results are relevant for the operation of the System of Interest (SoI), within the common Markov blanket, using shared Ontologies, Narratives, Formal documents, and Tools (ONFT).

Chapter III
Coda

As empirical results we want to show some examples of Team_Comm's work on this paper. Team_Comm is an all-online Remote Team which joined forces to achieve a result which was not possible individually (at least in the same timeframe) due to the interdisciplinary nature of the research. This team originated unpredictably, following the independent actions of members in a shared information niche (Discord server of the Lex Fridman podcast). Subsequently the team's communication moved to the platform of Keybase which allowed for the construction and development of a private informational niche. Several of the topics addressed in this paper can be unpacked here in relationship to how we carried out this work:

Division of Labor. Different members of the Team_Comm have backgrounds in academia, Complexity Science, Systems Engineering, and Remote Team management. We thus treated the paper as a System of Interest, and through work on its life cycle our communication was able to prepare the paper in accordance with best research and SE practices.

ONFT. We were working explicitly with FEP/ActInf and SE Ontologies, figuring out places of interconnections/interconnection of concepts from different domains. At online weekly meetings we communicated and aligned shared Narratives on different levels: about motivation working on these domains, to rise and address questions about information we lack, about future application of such approach. We were using different tools to support coordination, communication and activities of Team_Comm, as well as to create our own information niche and SSoT, based on Discord, Keybase channels and sub-teams (public Keybase team @karlfriston.freeenergy, shared Keybase username: @ActiveInference). We created an external informational presence for Team_Comm activities around ActInf which includes Twitter (handle: @InferenceActive), YouTube, and a website (activeinference.org).

Alphas. We were training to focus on different aspects at any given time, following the SE approach with Alphas for Strategy and Governance, using this article as an artifact and SoI.

CHAPTER IV

The Facilitator's Catechism

Richard J. Cordes & Daniel A. Friedman

ABSTRACT

This paper discusses the origins and evolution of Operations Orders from antiquity to modern times and the impact of Operations Orders on organizational sensemaking. Perspectives from research on Complexity Science, Organizational Psychology, High Reliability Organizations, Memetics, Logistics, Knowledge Management Systems, and Active Inference are used to consider the historical, contemporary, and future requirements and constraints of Operations Orders. Examples of traditional military Operations Orders and their civilian counterparts are detailed in context with their respective environments and requirements. Key characteristics of survivability, contemporary and future requirements, and current limitations of extant Operations Orders are addressed in order to inform the proposal of a new Operations Order format for use by Process Facilitators of military, intelligence, and civilian teams: the "Facilitator's Catechism".

Introduction

In this article we begin with a discussion of the origins and histories of Operations Orders. We will then explore a few key factors of high-performance teams that are generalizable to reflexive systems with agency: ongoing recalibration, goal-setting, and sensemaking. We then discuss how the development of the Operations Order through time and space reveals general principles of team organization, situational responsiveness, and adaptation to changes in the environment. Historically, shifts in operational reach, environmental uncertainty, and mission ambiguity have led to major transitions in the functional role and expected format of in-field Operations Orders. This recognition leads to a formulation at the end of this work of a "Facilitator's Catechism", a first presentation of a new variant of an Operations Order for military, intelligence, and civilian teams that builds upon previous formats and also catalyzes teams in situations where the mission may be unclear, team composition may be dynamic, and where novel online affordances are available.

Origins and Histories of Operations Orders

Operations Orders (OPORDs) are traditionally described as a formatted, written deliverable that describes explicit instructions for a military unit to enact [1–4]. OPORDs are different from simple requests in that OPORDs are accompanied by expectations regarding execution and tend to have a specified format, use a codified ontology, and convey the scope of the mission or situation. There can be found references to OPORD-like documents in a number of classical works on military theory and history, such as those by Caesar, Livy, Polybius, Tacitus, and Clausewitz, but they are rarely discussed as an object of interest [5–12]. Classical works do not seem to indicate rigorous adherence to a single type of OPORD format as a norm, but the existence of formatted operations orders is often argued to be obvious and in some cases is verified directly [9]. Given that the Roman Army has so often served as the source of ideals for modern militaries to replicate and given its clear status as the common root from which modern military theory springs, it is an obvious first-candidate for an analysis of the origin of OPORDs [9,13,14].

Roman Origins of the OPORD

Analysis of the Roman Army yielded the earliest examples of actual order formats with clearly defined organizational requirements in both their generation and execution [9]. It should be noted that some of the practices of the Roman Army were "so long employed and so well established that no one could find evidence for [their] beginning" [9,15]. Livy notes the use of the Roman "tessera", a tablet on which short messages might be passed, which was used to transmit orders as early as Roman conflicts with the Etruscans in 310 B.C.E. [9,10]. Tessera included simple commands to be executed such as "May every man (miles) fortify himself first with breakfast, then with weapons" [9]. Polybius notes the rigid procedures by which passwords and instruction are circulated amongst sentries in Roman camps—protocols built in such a way as to allow commanding officers to detect discrepancies or small errors [9,11]. Given that these rigid processes required literacy and that there is clear evidence that sentries were drawn from the ranks of common soldiers rather than a designated corps, the sentry order has been argued as evidence that most soldiers in the Roman Army were literate [9,12,16]. While, at first glance, the notion of a majority of Roman soldiers being literate may seem surprising, it should be noted that the Spartan Army was formalized long before the Roman Army and was highly literate (despite being described as "uneducated" by the Athenians), and required its soldiers to interact with documentation as a matter of course [9,16–18].

Roman sentry orders demanded rigid format in regards to their informational content, typically including just communication instruction in the form of passwords to be used, whereas general orders passed via tessera within Roman camps seem to have demanded clarity and concision not by order of doctrine but by constraints on the medium (tessera tablets were small and not very easily inscribed) [9–11,15]. Given the limited number of legions to guard such large expanses of frontier, communication via oral instruction and inscribed tablets became nearly synonymous with "operational reach" as defined in modern military literature [1,19,20]. It is clear that consistent and reliable communication of "service orders", or requests for reinforcements and supplies, were what allowed the Roman Army to maintain operations despite asymmetries between the available soldiers and the size of the frontier as well as the number of incursions and internal rebellions [6,19]. The ability to transport troops was secondary to the ability to inform officers as to where their troops were needed. Efficient and reliable military communication defined the operational reach of the Roman Empire beyond the border-forts and rivers which marked the edges of its territories [19].

Modern Transformations of the OPORD

Operations Orders developed significantly between the time of Rome and the late 19th century. The most substantive developments in OPORD format were likely driven by a renaissance in military theory guided by European and American military academies between the 17th and 19th centuries [21–23]. During this time, European commanders began to cohere to rigid standards for descriptive language in situation reports and OPORDs, such as the phrasing: "From reports received it seems probable that the enemy intends to…" which was common amongst German officers [23]. The convergence upon interoperable and standardized OPORDs during this period was possibly enforced by cultural norms, or "regimes of expectations", rather than by explicit doctrine [23,24]. However, these cultural norms were subjected to unforgiving environments that did not indulge maladapted behavior or over-imitation [25–27]. For example, the French Armies of the Republic of the 1870s used OPORDs which consisted of multiple pages of minute details, which "accounts of the battles show were not carried out" [23]. In contrast, the march on Paris in 1870 by German troops by General Helmuth von Moltke was specified in only eighteen lines, and accounts suggest that "not a battalion crossed another in its march, went hungry, or [camped in vulnerable positions]" [23].

Eben Swift's Format

1. Information of the enemy and general situation
2. Your own plans
3. Your disposition for carrying out your plans
4. Destination of the trains[1]
5. The position of the commander

[1] Trains is a general term which refers to the vehicles by which supplies are moved, such as a wagon, truck, or mule train.

Figure 1. Eben Swift's 1897 OPORD Format, adapted from [23], expanded in Appendix A.

After adaptation for reliability and survivability in the crucible of centuries of regular, organized European conflict, the common elements of the "field order" form and then conform to such an extent that they are identified and then formalized by U.S. Cavalry General Eben Swift [4,23]. General Swift submits a standardized format for OPORDs in 1897 (see Figure 1 and Appendix A) based on his analysis of German "Command and Control" (C2) doctrine which was primarily developed by Generals Moltke and Griepenkerl during the Franco-Prussian War [4,28].

Swift based his OPORD format on the German, mission-oriented OPORDs, arguing that task-orders must be written with very limited jargon, short sentences, legible hand-writing, and with no unnecessary information [3,23]. He specifically noted that apology, conjecture, expectations, and reasoning should be absent and suggests that the German officers corps separated out conjecture, expectation, and reasoning by issuing what was called "Orders of the Day", which rarely concerned logistical orders regarding the movement of troops; rather the documents of this kind "read like the army column of a newspaper" [3,23]. During the American Civil War, General Meade offered his "Circulars" in a similar fashion [23]. Swift's innovation, or distillation from German C2 doctrine, was to frame the OPORD as entirely separate from the situation report by making it an action-oriented document that focuses on objective, conveying only the necessary details regarding the context and tactics of the situation [23]. Swift also noted that the specificity of the order is proportionate to the level of command and thus the "information of the general situation" section of a commander's OPORD may be long and may sometimes read on its own as a "situation report" [3,23]. His basis for arguing the necessity of action-oriented OPORDs was two-fold. First, he suggested that only preventative and recalibrative action can prevent cascading failures across large organizations induced by minor perturbations. Second, he thought that complicated, lengthy documents increase the risk of perturbations and miscommunication rather than lessen it [3,23]. Using modern parlance, we can say that military communication is a complex threat surface because it offers many intuitive and unintuitive potential failure modes [3,23,29,30].

Swift's format was accepted as a valid formalization and incorporated into U.S. Army Field Service Regulations [31,32] and later was modified for its use in World War I by American Expeditionary Forces (see Figure 2 and Appendices B and C) [33,34]. The format became far more compartmentalized and detailed relative to the form originally proposed by Swift. It could be argued that these modifications were the result of a U.S. War Department that had begun to develop a view of war that was becoming increasingly professionalized and mechanistic, developing a view which did not allow for the messiness of small teams exercising agency on the battlefield: all orders would have to be carried out exactly as written with very little room for interpretation [22,35]. Military theorists of the early 20th century imagined apocalyptic battles of tens of thousands of cavalry and hundreds of thousands of men in concerted charges, battles in which single, perfectly orchestrated maneuvers would determine the whole of a war with immediacy [22]. It was argued that operations such as trench warfare would require many rehearsals long in advance with an exact process of executions [3,22,35]. However, the prevention of agency on part of the field officers often led to miserable disaster during the war, examples of such disasters are present in accounts of the infamous Battle of the Somme in which the French and British used some elements of this mechanistic philosophy to plan a joint offensive that eventually succeeded in achieving territorial gains, but did so at extreme cost [22,36].

WWI Suggested Trench-to-Trench Attack Order

Paragraph No. 1. Information of the enemy. Our supporting troops. Our flanking troops. General plan for our forces.

Paragraph No. 2. Mission of the battalion. Zero day and hour. Limit of the zone of operations. Objectives.

Paragraph No. 3. [Fire Support] (a) Artillery support. Time of its opening. Rate of advance of barrage. Where and when barrage will settle… Assignment of a Liaison

Paragraph No. 4. Plan for occupation of captured ground. Orders to each company. Assignment of a Liaison.

Paragraph No. 5. (a) Supply. Individual equipment and supplies. Additional communication trenches to be dug or connections to be made with trench system of old positions. Munitions...

Paragraph No. 6. Position of battalion commander and his headquarters during the advance and in the conquered position...

Figure 2. Suggested WWI Field Order adapted from [34], expanded in Appendix B.

Single OPORD issuances affected many sub-organizations with different objectives and methods of execution, this greatly increased the length and detail of the OPORD and required the assignment of a liaison to serve as a bridge between groups [34]. In many cases, the orders were so detailed and took so long to prepare that they would often arrive after they were needed, thus failing to provide guidance at critical moments [3,4]. No one lower than a battalion commander was allowed to issue a formal field order, and once ordered, they could not change [3]. Orders used during this period ordinarily took six hours to reach a platoon from a division headquarters [3]. Small teams during the Somme were acting asynchronously and were commanded to use an inadequate map of the world built on mechanistic expectations of support and alignment from and with other teams; a quality they could not remedy due to limitations on communications technology and protocol [22,36]. This inflexibility, or fragility, in the context of changing local circumstances lead to unnecessary loss of life.

The adapted OPORD in Figure 2 was used by American Expeditionary Forces in World War I, but was subjected to evolution and adaptation in the field [4,37]. The nature of this adaptation has been suggested to have had a relationship with the proficiency of the units in their operations: the length of OPORDs progressively became shorter, less restrictive in terms of coordinating logistical instructions, and more precise as units became more exposed to combat [4,37]. In later analyses, it was shown that the successfully adopted modifications "adhered closely" [4] to Swift's original proposed format, evidencing its practicality and utility as well as the suggestion that Complex Threat Surfaces do not indulge conformity to and over-imitation of maladaptive behavior [4,37].

The order which results after these adaptations during the war is sometimes said to have remained relatively unchanged through multiple wars, excluding minor details, until the American war in Vietnam (See Appendices D and G) [4]. However, many order formats were experimented with between World War I and the Vietnam War, including many concurrent versions in accepted doctrine for specific use-cases such as "attack, defend, and development" (See Appendices E and F) [3,38]. In these new experimental order formats, we see, especially in mobile units, the highly mission-oriented standards developed by von Moltke and Griepenkerl after the Franco-Prussian

War. This reflects an evolution of military thought toward emphasizing the unpredictability and complexity of warfare as well as de-emphasizing mechanistic expectations of subordinate echelons and of the OPORD format itself [3,21,22,39–42]. These "mission-type orders" no longer optimized for detail or technique but instead for mission, narrative clarity, and "minimum time for issuance" [3]. The experimental order formats used between World War I and the Vietnam War, regardless of use-case specific format, all demanded that the following information be provided to subordinate commanders:

- What the commander issuing the order wanted to accomplish.
- What limiting or controlling factors must be observed.
- What resources and support have been allotted.

[3]

Between World War II and Vietnam this use of separate situational and logistical OPORDs ends, and a return is made to a single order that again adheres to the fundamentals of the five-paragraph structure Eben Swift originally suggested [3,4]. This new post-World War II format is essentially the one in use by the U.S. Military today (see Figure 3 and Appendix G) [43].

```
U.S. Five Paragraph Order Format
1.  Situation
2.  Mission
3.  Execution
4.  Administration and Logistics
5.  Command and Signal
```

Figure 3. The American Five Paragraph Order [1,43,44], expanded in Appendix G.

OPORDs for Operational Art

There was a temporary divergence from the Five Paragraph Order during the American War in Vietnam (1955-1975) [3]. The Vietnam War was characterized by extreme uncertainty given that even sensemaking based on geography was unstable due to extensive tunnel systems [45], hidden insurgencies [45–47], and challenging terrain which could change with the weather [48–50]. While the official OPORD standard in doctrine was unchanged for the whole of the Vietnam war [4], the five-paragraph order was reduced to three paragraphs in field use (See Figure 4 and Appendix H) [3].

In such a chaotic environment, where situational awareness and territorial gains can be illusory [47], evacuation details became far more important than they had been previously or in predictable environs. The field-modified Three Paragraph Order used in Vietnam is unique among all modern OPORDs in its emphasis on an exit plan (see Appendix M). The need to plan amidst fundamental uncertainty in Vietnam appears to have served as a catalyst for several distinct changes within the U.S. Military [47]. First, the embodied culture around the OPORD took a turn to be much more pragmatic and flexible, for example by allowing for more inclusion of symbols, graphics, and overlays [3]. Second, during this period, unconventional warfare (or 4th Generational War [51,52]) and special operations became commonplace, requiring the joint improvisational capabilities commonly used by small special forces teams in the field. These high performance teams are noted in some works to be "masters of chaos" and, in stark contrast to the mechanistic views on war of the early 20th century, are referred to as "operations artists" [1,53–55]. In other words, the 20th century sees the metaphor of advanced warfare evolve from that of large teams of engineers, to small teams of artists.

While "Operational Art" is a modern term, this view on flexible, adaptive warfighting as an art-form begins with the earliest and most widely recognized treatise on military philosophy: "The Art of War" by Sun Tzu [56]. Both warfare and art include elements of tradition and heterodoxy, passion and patience, skill sets and teamwork, and preparation and improvisation. Historically, cavalry were typically given very generalized orders and allowed to exercise a great deal of agency in the field [30,57]. Late 19th century analyses of the American Civil War described the leaders of the Confederate Cavalry, such as General John Morgan or General Jeb Stuart, in a way similar to artists [30].

The descriptions of the “artistry” of cavalry in the 19th century indicate that they were performing similar roles as modern operational artists within U.S. special forces: disruption of supply lines and communications, destabilization of fortifications, psychological operations, and reconnaissance all at, or beyond, the edge of their parent army’s operational reach [30,57]. Reconnaissance, and this action at the limits of an army’s operational reach in general, are often referred to as “art” directly as well [57]. General Morgan for example, is characterized to be something of a self-educated savant, who was highly “improvisational” and adept at bricolage in the field beyond the reach of conventional support [30]. A summary of one of General Morgan’s raids notes that he discovered and captured a telegraph agency while in the process of being cut off from the army and used it to reroute enemy troops and intercept messages about his position [30]. Further confirming his ability to improvise in the field, a field summary of his ”first” raid suggests that he leveraged the psychological impact of his success to recruit new soldiers: "He started with 900 men, lost ninety and returned with 1,200, was absent twenty four days, traveled 1,000 miles, captured seventeen towns, destroyed all the government supplies and arms in them, dispersed 1,500 home guards, and paroled 1,200 regulars" [30]. A mechanistic OPORD, such as the one later used by American Expeditionary Forces during World War I [4,22,35], would have denied Morgan and other Civil War cavalry officers such successes by denying agency to act on opportunity. However, it should be noted that Morgan is eventually captured. Morgan’s failure can be attributed to poor situational awareness, an inability to communicate with the main force, poor discipline, and a lack of an evacuation plan [30].

```
U.S. Three Paragraph Order Format

Paragraph 1 - Unit mission and concept
of operation complete in all available
detail

Paragraph 2 - Additional essential
information to include enemy, support
available, terrain, and command and
communication details

Paragraph 3 - Essential supply and
evacuation details
```

Figure 4. U.S. Vietnam War Three-Paragraph Order, adapted from [3].

A century later, we find echoes of Morgan's failure and successes in the deployment of OPORDs used by Israeli Defence Forces. Where many European OPORDs conformed to U.S. standards during the Cold War (with limited variation observed even in the Soviet OPORD, Appendix I), Israel's OPORD form diverged significantly (see Figure 5 and Appendix J) [3]. Israel's OPORD formats placed far more emphasis on the commander's intent, both in the culture and techniques associated with writing the OPORD as well as in the format itself [3,58]. The Israelis, aligned with the views of Moltke, Swift, and Griepenkerl by embracing the agency of small tactical units in the field [3,58] and in doing so, earn a "worldwide recognition for excellence in mobile warfare" [3]. The Israeli Defence Force operated under the presupposition that "a detailed plan is only good until the first bullet is shot" [3] and placed emphasis on a metaphysical doctrine defined by "individual daring (heaza), maintenance of aim (dvekut bamatara) and resourcefulness (tushia)" [58]. Moshe Dayan, former Defense Minister of Israel, noted in his war diary:

> *"To the commander of an Israeli unit I can point on a map to the Suez canal and say: 'There's your target and this is your axis of advance. Don't signal me during the fighting for more men, arms, or vehicles. All*

> *that we could allocate you've already got, and there isn't any more. Keep signaling your advances. You must reach Suez in forty-eight hours'" [59].*

The Israeli Defence Force used this focus on commander's intent in order to develop strong narrative alignment [60] between units in the field in a way that strongly resembles the German concept of "Auftragstaktik", a concept deemed essential to the success of the German Panzer Korps during World War II [39,58,61,62]. Auftragstaktik translates, roughly, to "Mission-Type tactics"; it is a term representative not of a particular set of maneuvers but instead of an organizational culture which was developed over the course of "three wars: the Danish-Prussian War of 1864, the Austro-Prussian War of 1866 and the Franco-Prussian War of 1870" [61,63]. This organizational culture revolves around taking initiative in the field based on "grundlegende Lageänderung"—fundamental changes to the situation in the area of operations [28]. The formalization of the organizational culture of Auftragstaktik begins with the same General Helmuth von Moltke from which Eben Smith derives his formalization of the Five Paragraph Order [3,64]. Moltke, a disciple of Clausewitz, argues that decentralization, agency, bricolage, asynchronicity, individual and team initiative, and narrative alignment are the basis by which wars will be won in the future [61,64]. Most important to Auftragstaktik is a sense of Esprit de Corps, a narrative alignment not just between individuals but between individuals and the "spirit" and collective ideals of an organization as a basis for overcoming limitations on the development of intimate relationships, maintaining trust in the organization and comrades, and prevention of disintegration or route [25,29,60,65–68] Moltke comes to these conclusions while holding command positions in a Prussian Army which had recently failed to achieve consistent success during the Napoleonic Wars [61,64]. It should be unsurprising that Eben Swift, a cavalry officer who served in the American Indian Wars [69], a series of conflicts which had conditions similar to those Americans faced a century later in Vietnam, would find value in Moltke's analysis and conclusions [22,47,48].

The first Israeli experiment in extreme agency experienced some failures however. During the 1967 war, “entire battalions became lost in the sand dunes”, as limited control over units acting at the limits of the army’s operational reach resulted in the same sort of “misadventure” [3] that led to General Morgan’s capture [30,58]. Post-1967, the Israelis experiment with an “optional control” system that offered a more pragmatic approach to Auftragstaktik allowed for subordinate leaders to take maximum initiative while allowing for command to intervene [58]. This system experienced failures as well, but these failures have been deemed to be more likely the result of an over-centralization of command structure, lack of planning, and poor intelligence collection, analysis, and distribution [58]. The conclusions regarding the basis and impacts of poor intelligence practice during the Israeli’s 1973 War is consistent with expectations formed by modern research on the impacts of knowledge management systems on organizations [29,58,59,70–72].

Israel also experienced wild successes in their allowance of “operational art”, achieving “lightning fast”, significant victories likened by experts to that of Germany’s capture of France and Napoleon’s successful campaigns [73]. In the same 1967 war in which “entire battalions became lost in the sand dunes” [30,58], the IDF was also internationally declared to be a textbook example of the expression of all classical principles of success in warfare: “speed, surprise, concentration, security, information, the offensive, [and] above all training and morale” [3,73,74].

Israel’s renown for artistry in the sort of highly flexible, mobile operations that were (correctly) expected to be the norm in future warfare made their OPORD (see Figure 5 and Appendix J) the subject of study in the late 1980s on the basis that it might provide insight and inspiration for the basis of a new OPORD for the United States [3]. Instead, the United States Military kept the five paragraph order, but seems to have embraced the concept of “operational art” as it is now contained in many doctrine publications in use across all branches of service of the US Military, in some cases, even in the foreword, as a defining context for doctrine [1,20,75]. A key element of this modern operational art is the notion of being able to rapidly adjust maneuvers around new "centers of gravity" (COGs) in the area of operations, these COGs have similar characteristics to "strange attractors" in dynamical systems theory [1,76,77]. The modern U.S. Military's Five Paragraph Order allows for adjustment of an OPORD to respond to new COGs through the use of a "Fragmentary Order" or FRAGORD [1,78–82]. The FRAGORD has the same format of a Five Paragraph Order but the writer only includes changes to the OPORD to which it is tied, allowing it to act as an ad hoc overlay over the original [1,78–82].

```
The Israeli OPORD

1.   Friendly Forces
     a.   Intent or aim of the higher.
     b.   Unit Mission…
2.   Terrain
3.   Enemy
     a.   Intentions
     b.   Deployment and strength…
4.   Commander's intention
5.   Method
6.   Combat Support
7.   Administrative and logistics
8.   Control [and communication]
```

Figure 5. Israeli OPORD Format, adapted from [3], expanded in Appendix J.

OPORDs in the Modern Gray Zone

In the late 20th and early 21st century, OPORDs became the subject of plans for development in the interest of making them machine-readable, through research on “Coalition Management Battle Language” [83–88], This planning is in response to difficulties in all aspects of managing operations composed of units which are embedded in varied hierarchies, such as those coming from different branches of service during special forces operations or those from different nations in peacekeeping or coalition operations [1,70,89]. Despite this planning and the rapid changes in technological affordances, OPORDS have not been subject to any recent significant changes [1,43,44]. This may be misleading however, as this is only the case if we require OPORDs to have purely military purposes. Given our discussion of the origins and histories of OPORDs, it would appear that the key criteria for a document to be classified as an OPORD would be that it intends to communicate a “mission” or task to some object that intends to interpret and execute and is accompanied by expectations of completion informed by a regime of expectations, such as the one provided by a commander-subordinate or other formal relationship. Inclusion of components which confer situational awareness are not criteria for classification as an OPORD, but instead increase the likelihood of successful execution by offering an effective regime of expectations and therefore shape behavioral affordances and collective outcomes [24,60,90]. Given these criteria, we suggest that there are civilian counterparts to the military OPORD.

Related to OPORDs in uncertain contexts, there is a long history of non-military operations orders for engineering projects, commerce, and teams. As early as 500 B.C.E. there are written, compartmentalized joint venture agreements in the Levant and North Africa which carry expectations of execution and include components that note what it is that the members of the party shall execute (mission) as well as context (situation) [91]. Machine instructions for operating systems in computer science have been described as commands or collections of commands which a computer can interpret and execute [92]. The modern practices of business and project planning converge on similar

OPORD-like documents to communicate mission, expectations for execution, and situational awareness [93–97].

The "Heilmeier Catechism" is an OPORD format which exists in the gray zone between military and civilian application (see Figure 6 and Appendix K) and is used by The Defense Advanced Research Projects Agency (DARPA) in the direction of research activity [98–100]. The chaos of the American war in Vietnam effectively transformed DARPA (originally known as ARPA) to make it much more focused on supporting the Department of Defense, thereby heightening requirements for reliability [98]. In 1975, an engineer, military history buff, and former Department of Defense Fellow [101] named George Heilmeier became the director of DARPA [98,101]. As director, Heilmeier had to contend with the paradox of managing needs for military efficiency while also allowing for ambitious innovation in the pursuit of the high-risk/high reward research outcomes in short time scales which were required by its mission [98,102]. Heilmeier thought of DARPA as a "mission agency" and sought to align all projects with the mission to support the Department of Defense [98,102]. Heilmeier led DARPA with a "heavy hand", but didn't micromanage operations, opting instead to review all DARPA projects to check for clearly articulated objectives and milestones [98]. Heilmeier introduces a set of questions that he described as a "pre-flight checklist" for launching complex research projects [101] which he preached as a catechism" [98,101,102].

A catechism is traditionally a set of questions or prompts with defined answers, used as a basis to express or teach spiritual doctrine to rapidly build narrative alignment among members of an organization [60,103]. Where the 17th century "Westminster Catechism" attempts to build narrative alignment between the members and leaders of the Church of Scotland and that of England by asking and answering questions like "What is the chief end of man!" [103], the Heilmeier Catechism (see Figure 6 and Appendix K) is a template to build narrative alignment between members of research teams and the mission of DARPA by asking questions like "What are you trying to do?" and "If successful, what difference will it make?" [3,58,60,61]. The open question-response format of the catechism elicits participation, inclusion, joint ownership, and innovative team impact (as opposed to an inflexible or memorized creed, which may promote identity or alignment but rarely satisfices as an action plan).

The Heilmeier Catechism

1. **What are you trying to do?** Articulate your objectives using absolutely no jargon.
2. **How is it done today?** What are the limitations of current practice?
3. **What is new in your approach?** Why do you think it will be successful?
4. **Who Cares?** If successful, what difference will it make?
5. **What are the risks and the payoffs?**
6. **How much will it cost? How long will it take?**
7. **What are the milestones for success?**

Figure 6. Heilmeier Catechism, adapted from [98]

The Heilmeier Catechism is well aligned with the philosophy behind the OPORDs inspired by the organizational culture of Auftragstaktik and especially well aligned with the Israeli OPORD in that it gives a great, almost metaphysical emphasis on unit agency [3,98] There are many qualities which make the Heilmeier Catechism unique in relation to other OPORDs. First, the Heilmeier Catechism is written by the team which intends to execute the order and presented to DARPA for interpretation and acceptance. This is in contrast with the traditional "top-down" pattern of commanders writing and presenting orders to the subordinate teams. DARPA releases information regarding the nature of their current mission and teams (subordinate) that are interested in supporting that mission create proposals, built using a Heilmeier Catechism (OPORD), for a DARPA program manager (commander) to evaluate [98,102]. Second, OPORDs and OPORD-like documents such as the American Five Paragraph Order or its sibling the "PLANORD" (Planning Order) have require a relatively large amount of supplementary material to ensure that they are prepared properly [1,43,70,75], whereas a Heilmeier compartmentalizes using simple questions—nullifying any need for supplementary material. If the questions within the catechism are successfully interpreted and answered, there is no checklist with which one must comply in order to ensure it's been prepared correctly. Finally, because of this rearrangement of the OPORD process, the flexibility, and ease of preparation of this format, we posit that the Heilmeier Catechism is an OPORD that allows for emergent remote research teams to practice operational art in civilian settings.

OPORDS for Goal-Setting & OPORDs for Sensemaking

We now turn toward contemporary research on Complexity Science, Active Inference, and High Reliability Organizations, to set a basis for examining the impact of OPORDs on organizational performance. The modern context of online and hybrid remote teams, distributed over large geospatial areas, provides new challenges and affordances for strategy and OPORDS. The modern digital operating theater requires the adequate distillation of the common features of OPORDs in context with the basis for their impact.

"High Reliability Organizations" (HROs) are multiscale systems where, due to the high potential for errors to cause cascading, non-linear impact, errors must be controlled to an extremely high level of stringency [27,29,104,105]. This high potential for cascading system failure modes is a product of the Complex Threat Surfaces that HROs, such as Aircraft Carrier Crews, Firefighters, and Emergency Medical Treatment Teams, must reliably manage [25,27,29,106]. Complex Threat Surfaces are a key feature of systems in which cause and effect relationships exist, but may be mechanistically complicated (e.g. a body), conditional, or otherwise difficult to quantify and predict [29]. As a consequence, they often cannot be de-risked linearly and the threats which emerge from them can be extraordinarily difficult to predict or model effectively and present the risk of nonlinear failure modes if exploited [29,107]. Systems in nature are adapted to display a tremendous resilience to the kinds of difficult to predict perturbations which are caused by interactions with Complex Threat Surfaces [108–111]. The development of precision instrumentation for the monitoring of Complex Threat Surfaces is challenging due to confounding variables, problems with observability, and the fundamental difficulty of simulating appropriate counterfactuals for multiscale missions [29,41,112,113].

HROs are sometimes noted to be "nearly error-free" [106,114] or characterized by low rate of error, but this may be a misleading designation as it requires a definition of "error" which is synonymous with failure [27,106]. From this: fault detection, real-time diagnosis, tolerance to variability, and similar metrics of resilience can often be more useful metrics than "error-rate" in defining the functional reliability of complicated systems like hardware and complex systems like organizations [27,105,106,115,116]. The basis for creating fault tolerance in hardware is largely determined by good design principles [115,117] whereas reliability in organizations is generally determined by situational awareness, rapid information sharing, and, most importantly, the ability to recover and recalibrate [25,118,119]. In both hardware and sociotechnical systems, engineering toolkits can provide scaffolding and protocols for sensemaking and effective intervention and policy design [60].

Military organizations are tasked, not only with the monitoring and derisking of Complex Threat Surfaces, but also with the creation and exploitation of them, and regularly serve as the subject of case studies on HROs [27,29,104,106,120,121]. From a systems engineering perspective, the OPORD is a tool which is iteratively developed over time to contribute to the factors of team success most dampened by the environment [60]. For example, the late 19th century formalization and inclusion of "situation" in the OPORD appears to be a response to feedback from environments requiring good information about constraints in the locale, such as those found in the American Indian Wars which rewarded agency in the field by officers and punished inflexibility [22,23,30,57,58] The inclusion of this section about constraints obviously intends to rapidly communicate situational awareness in uncertain environments. The emphasis on an evacuation section in the American's make-shift Three Paragraph Order during Vietnam (see Figure 4 and Appendix H) intends to heighten the ability to recover from errors in an environment where, due to extreme uncertainty, error was inevitable [3,45–47]. The OPORD, in all its forms, has the potential to enable or enhance information sharing where the environment or situation would make traditional communication via utterance difficult or unfeasible (e.g. communication across long distances, communication of orders from a single commander to hundreds of subordinate organizations) [9,19]. Further, the OPORD may also contribute generally to the ability of organizations to calibrate and recalibrate.

Ongoing recalibration is fundamental to reflexive systems of all scales [106,122–125]. Maintaining coherent activity through time, for an ant colony, body, military or government, requires the system to respond to perceived errors, as well as to the future potential for errors [123,126]. For example, one might find a jacket in their house if they were cold as a response to deviation between current state and ideal state, or if they were planning to go out into the cold soon as a response to a prediction of potential deviation between some future state and its ideal. This continuous self-regulatory or cybernetic perspective applies to biological systems, HROs, and Artificial intelligence algorithms [127]. The process theory of Active Inference (a physics-based framework that describes how goal-oriented systems interact with their surroundings) describes the general relationship between goal-seeking systems and their informational niche [124,128,129]. Active Inference casts the question of system behavior as a relational mapping between internal states (generative models of the world) and external system states (the causal structure of the outside world). External states influence internal states through sensory cues, and updated internal states are differentially likely to engage in different action affordances. Internal generative models provide natural and engineered systems actionable insights from sparse sensory data, by engaging in action-oriented sensemaking [125]. Active Inference may be a relevant framework for developing advanced team education, communication, and performance characteristics [60]. In the Active Inference framework, conformity to policy and regular communicative norms are argued to be strategies to cope with uncertainty [24].

Given that this process of ongoing recalibration is fundamental to reflexive or "intelligent" systems of all scales, there is an opportunity to investigate collective intelligence through the use of dynamical analogy. Dynamical analogy is the creation of analogies to the dynamics and mechanisms of better understood systems in order to reveal avenues of approach for the investigation of those which remain enigmatic [130–132]. Dynamical analogy allows for the discovery of patterns that transcend single levels of analysis, thus expanding the range of possible system framings or intervention approaches in complex systems. Here we will explore the potential for dynamical analogy between individual and collective intelligence, to understand how high performance is achieved in multiscale cognitive systems.

Literature from the human and collective intelligence fields converge on the idea of controlled novelty, or balanced openness, in navigating the explore-exploit tradeoffs intrinsic to organization [133,134]. In the Five-Factor or "Big-Five" personality traits model, there is a factor denoted as "Openness" which is described as being associated with openness to novelty, diversity of thought, creativity, and intellect [135]. While the link between trait openness and crystallized intelligence is sometimes debated [135,136], it would seem that there is, at the least, a relationship between "openness" and the resiliency of crystallized intelligence against aging and trauma [137,138]. The existence of such a relationship forms a stable dynamic analog to collective intelligence, given that there are indications of non-linear relationships between the diversity and tolerance of temporary employees within HROs and the number of innovations produced [99,119] as well as between diversity within spontaneous, endogenous social networks and the survivability and virality of the memes and ideas they generate [139,140]. Further, the adjectives that describe organizations capable of "operational art", such as intelligence agencies and special forces, are the same adjectives which have high correlations with trait openness [20,70,141,142]. Openness is not the only component of Five-Factor analysis which may offer insight on the personality and intelligence of organizations—as analyses of the organizational equivalents of components such as neuroticism and conscientiousness have been done as well [143,144].

Following this mapping between intelligence of individuals and intelligence of teams, there is a literature on "Goal Setting" which has been used as a dynamical analogy to catalyze the development of Artificial Intelligence [145]. The individual goal-setting should be of use for understanding team function, within the context of the idea of extended multiscale cognition. Literature on goal-setting is primarily concerned with the success of individuals in reaching their end goals and, consequently, the characteristics of self-perception which enable them to do so [146–149]. The general consensus within literature on goal-setting is that when an individual's confidence in their own skillset maps well to actual competence within a domain and this "self-efficacy" [146,147,150] is paired with team or individual objectives that are clear, consistent, and relevant, progress can be reliably achieved [146,147,149,150]. Self-efficacy might be described as an internal state which coherently maps a regime of expectations or field of affordances with coherent objectives [24,151]. Another perspective on self-efficacy from the Active Inference point of view might be that agents become successful within a niche when their "regime of attention" correctly maps internal causal models of the world to possible agent policies (and affordance) and outcomes in the world [24,123]. There is a strong overlap between the individual-focused conclusions within the literature on goal-setting, narrative-focused conclusions on the impacts of ideal-setting in religious narratives [152–156], the organization-focused conclusions on course of action analysis in joint operations planning [1,20,157], and work-flow focused conclusions in software project management [93,94,158], as well as the more broadly applicable, systems-focused conclusions such as those on policy optimization and divergence minimization in Active Inference [24,125,159]. This overlap is described well by a systems engineering approach [60] wherein a set "goal" can be characterized as a stable, coherent, communicable conception of an ideal from which outcomes might deviate, allowing for recalibration in environments where uncertainty makes expectations and outcomes difficult to reckon or reconcile.

Adaptations of the OPORD and the conditions under which these adaptations occur conform with this analog between individual and collective intelligence. Like organisms existing in ecological niches, information-processing & sensemaking entities must finesse their affordances in order to stay successful amidst uncertainty [24,126]. This goal-drivenness of self-organizing systems is essential for their ability to act and thrive in challenging settings [160,161]. As previously noted, the organizations implementing OPORDs recalibrate the format to better match environmental pressures and demands, thereby recalibrating their own basis for action in response to error and potential for error [3,4,23]. The behavioral engineering of teams is suggested to require Ontologies, Narratives, Formal documentation, and Tools (ONFT) [60]. In this ONFT framework the OPORD can be described as a formal document which incorporates a codified ontology in order to efficiently and reliably convey a narrative. This narrative rapidly aligns an organization with a regime of expectations prior to operations and is used after operations as a basis for reconciling the difference between expectations and outcomes. Even in very early examples of OPORDs, there is clear intent to use OPORDs as a tool to not just orient action but also to gauge its success. Roman sentry orders were designed to be compared with specific outcomes as a means of detecting impropriety, negligence, or malfeasance [9,11]. Post-war analysis of military history is also generally done with the intent of driving changes in military philosophy, and is achieved using a combination of OPORDs and situation reports as a basis for gauging success and failure [22,23,36].

The U.S. Military has designed processes for managing this process of reconciliation in shorter time-scales, one of which is the "After-Action Review" (AAR) [78]. An AAR is described as an opportunity to turn any event into a training event to "improve individual and collective task-task performances to meet or exceed [standards]" [78]. The AAR is an analysis done immediately after an OPORD directed event in the interest of both reporting failures and successes to stakeholders as well as to help the involved parties better understand the divergence or alignment between the OPORD and the outcomes to adjust future goal-setting and course of action analysis [27,78]. The AAR has clear civilian counterparts as well, such as the "sprint retrospective" in the software development framework SCRUM [162].

A precursor and ongoing constituent of meaningful goal-setting, course of action analysis, and policy-making is sensemaking, which is described as the act of "organizing sense data until the environment becomes sensible or is understood well enough to enable reasonable decisions" [1,118,157,163]. Through the lenses afforded by the Active Inference, sensemaking might be described as the processes by which a system creates useful internal models of the world based upon the organization and integration of sense-data from external sources [164,165]. The quality of the sensemaking is related to the mapping of the external and internal states, as determined by the mapping between predicted and actual outcomes of actions informated by internal states [163]. Organizational sensemaking is the collaborative process by which sense-data about external states is integrated into a coherent, shared model that facilitates collaborative action [60,106,118,166]. Good organizational sensemaking requires that participants have a sense of self-efficacy and mutual trust [25,27,29,118,163]. Thus sensemaking depends on reliable, accessible, manageable information streams and a clear understanding of what resulting decisions intend to accomplish [25,29,106,118,167,168].

Maintaining a single source of truth (SSoT) for protocol, ontology, objectives, and workflow-related knowledge is a solution used by HROs to maintain integrity, reliability, and clarity in the information environment [27,60,169–171]. An SSoT may be temporary or interminable, for example the "product backlog" used in the software development framework SCRUM is temporary when tied to the launch of a product but interminable when tied to the maintenance of one [162]. The Military has an interminable SSoT in the form of "Doctrine Publications" [1,20,70,75,82,172]. We argue that the OPORD acts as both a temporary and interminable SSoT: it is a transient SSoT related to the objectives of an organization prior to and during operations, but after operations it serves as an SSoT on what the objectives and goals of the organization were from the time of its issuance to the time of its success or failure. In its capacity as a temporary SSoT, the OPORD, in offering compartmentalized information on what support will be available, what the rules of engagement are, what constraints exist in the locale, and what the organization needs to accomplish, greatly expedites sensemaking by defining a bounded informational niche [24,173]. While the boundaries of this informational niche only remain stable in preparation for operations, positive impacts extend into the theater of operations by contributing to self-efficacy and, as previously noted, by providing a coherent ideal to move toward [27,146,150,154].

Toward a New OPORD

From the examination of the origins and histories of OPORDs and the discussion of organizational sensemaking and the dynamical analogies between (a) intelligence in individuals and collective intelligence and (b) between reflexive recalibration of systems in general and high reliability organizations, we can conclude that the following features are critical to the success of HROs and greatly enhanced by the usage of an appropriately formatted OPORD:

- Ongoing, feedback-driven reflexive recalibration of process and capability.

- Clear alignment of participants on values, narrative, goals, and identity.
- High quality distributed & multilevel sensemaking.

We also find a number of emergent patterns within the discussion of OPORDs consistent with these conclusions. Evidenced by adaptations in both the OPORD and the culture surrounding it in response to increased uncertainty and mobility in battle over the course of the 19th and 20th centuries:

- The faster that new centers of gravity may emerge in the operating theater, the more flexibility that is required in the OPORD.
- When the nature of warfare undergoes structural changes, and/or there is unprecedented levels of uncertainty in the operating theater, the necessity for a new OPORD emerges.

Significant changes to the nature of communication and team performance since the late 20th century (e.g. the internet, 4th generation warfare, social media, COVID-19) necessitate a redevelopment of the norms of OPORDs as other socio-technical changes have altered the nature of warfare in the past. Specifically, previous iterations of the OPORD have characteristics which limit their ability to easily frame key aspects and challenges of a virtual theater of operations. Additionally, pre-online OPORDS are generally unable to take advantage of some of the new affordances and strategic possibilities in the modern era, such as versioning, compression, and fluidity in team composition.

The Heilmeier Catechism is currently recommended for use as an OPORD by research teams as a result of its success at DARPA and because it helps to answer questions that are important to appraising the usefulness of research in general [98,174–176]. The Heilmeier Catechism is the obvious best starting point for work of this kind as it was built to orient exploratory action within uncharted territory. However, the Heilmeier Catechism has limitations for its use in this new operating theater of IRTs. Specifically the Heilmeier Catechism assumes organizational alignment prior to issuance as well as a fixed team composition. Both of these implicit assumptions of the Heilmeier Catechism are regularly violated by modern online settings [177]. In online informational and narrative war and wargames the Centers of Gravity are not geospatial but exist in abstract or memetic space, as a consequence, teams must be afforded a great deal of flexibility, and their team agents must operate with skill, agency, and autonomy [177]. Team communication in online teams can run the gamut from constant interfacing to absolute radio silence in wildly uncertain informational environments—yet even one false positive or false negative communication can prevent the team from achieving its mission [29,177].

A new type of OPORD is required to address the novel characteristics of online teams, such as the potential absence of command-subordinate relationship, fully programmable communication systems, narrative ambiguity, memetic transfer with adversaries, and dynamic team composition. Such an OPORD would need to both synthesize the battle-tested elements of past-OPORDs which would invariably contribute to team success in the described environment and introduce elements and processes which allow it to circumvent the described limitations of previous OPORDs. Given that no prior OPORD found accounted for lack of extant organizational alignment or potential for dynamic and unknown team composition, this appeared to be the most difficult limitation to overcome.

Organizations have three primary means of developing rapid alignment: well codified ontology, intimate trust, and narrative [60]. Some IRTs are unable to rely on intimate trust by merit of their being just recently formed [60,177]. If the IRT lacks prior organizational, professional, or cultural alignment, they cannot rely on codified ontology, they must rely on shared narrative or shared regimes of expectations and affordances [24,60,151,177]. In situations where the scope of possible expectations, affordances, and objectives are very narrow, such as good Samaritans passing a motorist in danger [178–

180] or a group of players encountering a shared threat in a virtual game environment, IRTs may form without the presence of systems engineering tools [177], in absence of such narrow scope, behavior can be modified via ONFT in order to increase the likelihood of organization and collaboration [29,60].

In joint operations planning, a common solution to this problem of scope is the assignment of a liaison that has an understanding of the operation or problem being faced and makes regular personal contact to build and maintain mutual understanding, trust, and a unity of purpose and action [34,43]. The private sector has converged on a similar solution, with a common job title being a "Customer Success Manager", whose job is to maintain alignment of the goals of their company's teams with those of their clients [181]. In the Scrum framework for software development, the “Scrum Master” manages a very similar role [182]. However, as the environments in which companies operate become more complex, the role appears to conform more with their military counterparts. The company Palantir is an HRO which helps militaries and other HROs contend with Complex Threat Surfaces by offering tools related to knowledge management and discovery [183]. Due to the nature of the companies with which they work and the complex environments in which those companies operate, single solutions rarely generalize, so every consultation can be expected to be considered non-routine [27,184–186]. Palantir appears to have coined the term Deployment Strategist to describe a liaison position between the company’s teams and those of the served organization [184–186].

While each job has its own industry-specific requirements, the abstracted requirements of the liaison, Customer Success Manager, Scrum Master and the Deployment Strategist all find overlap within the requirements of the role of “Process Facilitator” [187]. Process Facilitators are most notably associated with the management of meetings [187], but Process Facilitators can also help to manage collaborative work, problem solving, and research tasks by helping groups align with objectives and process [188–190]. The primary requirement of Process Facilitators, such as Customer Success Managers, liaisons, Deployment Strategists, SCRUM Masters, and meeting facilitators, are to maintain group state attributes which lead to persistent action through successful management of process [27,181,184–190]. Process Facilitators have to practice behaviors, take on roles, and stage interventions to develop situational awareness, narrative alignment, coordination, and accountability in order to maintain successful communications, workflow, production, and external interaction (see Figure 7) [181,182,186,187].

Given that Process Facilitators have been used as a solution to overcome limitations regarding extant organizational alignment and potential for dynamic and unknown team composition, and because Process Facilitators are already being deployed to handle tasks in the domains in which a new OPORD is needed, we argue that an OPORD built to overcome such limitations and to be applied in these domains should be built for use by Process Facilitators such as Deployment Strategists.

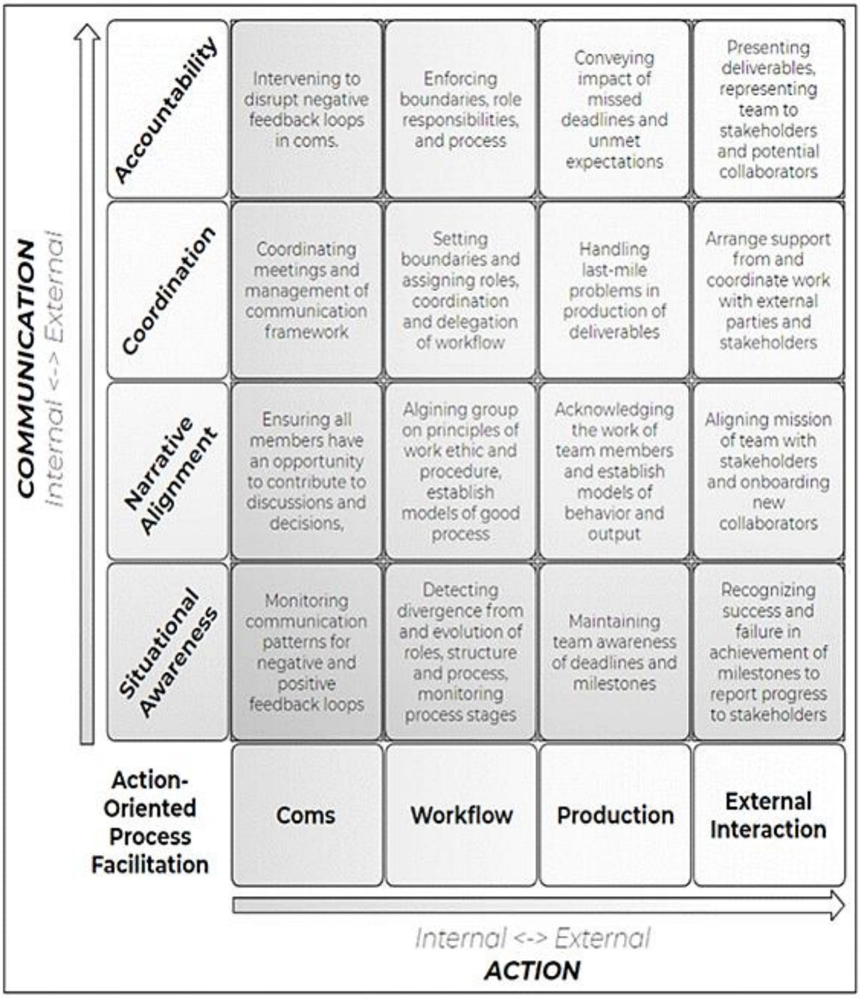


Figure 7. Action-Oriented Process Facilitation [1,27,34,43,181,184–190]

The Facilitator's Catechism

Here we propose the "Facilitator's Catechism", building on the long developmental history of the OPORD by distilling essential characteristics of military and civilian OPORDs through time and offering novel elements to overcome their limitations. The Facilitator's Catechism contains a Header, Footer, and six sections: (1) Situation, (2) Mission, (3) Potential Avenues of Approach, (4) Milestones, (5) Implications for Outcome, and (6) Administrative, Logistics, and Communications. Building from the success of the Heilmeier Catechism, each section is paired with questions which, if answered with rigor and in good faith, will ensure a format-valid order without the need for supplementary materials. The subtitles facilitate both the reading and the writing of the OPORD, informing the reader of what to expect to be answered in the section and the writer of what they are expected to answer. These questions can be treated as subcompartments and answered directly or the writer of the OPORD may answer them in written paragraphs. The OPORD can also be issued from command to subordinate, from subordinate to command, or in absence of a command-subordinate relationship. It is also built to be versioned but does not implement rigid formatting of text as would be required by coalition battle management language [83–88]. The Facilitator's Catechism is built on ONFT and Systems Engineering approaches to circumvent limitations of prior OPORDs, especially where:

- Team Composition is not necessarily known prior to writing.
- Organizational and narrative alignment of members is not necessarily achieved prior to writing.
- The first task, upon team formation, is course of action analysis on how to approach a complex problem which requires novel solutions, operational art, and bricolage.
- Due to potential for conflict in the political alignments of members, there is a need for strict boundaries on nature and

length of affiliation (such as what was required of workshops between the IEEE and USSR during the Cold War [191,192]).

- The OPORD itself may need to act as a "call for collaborators" to which potential members may respond in order to join.

Header

The Header of the Facilitator's Catechism is included as the first item in the document and contains a full title of the project followed by seven items:

1. Unique Project Callsign
2. Team Name
3. Facilitator
4. Facilitator Contact Information
5. Date of Announcement
6. Call for Collaboration End Date
7. Intended Date of Completion

The requirement for a short Unique Project Callsign (UPC) and Team Name was selected in the interest of giving the project an easily searchable identifier (TeamName-UPC) if the OPORD and related materials and deliverables are digitized, much in the same way written DARPA presentations and research deliverables can be searched for through the use of a Broad Agency Announcement (BAA) number contained both in the announcement of interest and in the resulting written deliverables [193]. Even if the OPORD is being used to facilitate an IRT or to make a call for collaborators, giving the team a name creates a symbol around which culture and esprit de corps may be developed [60,66,154,156,194], it also allows for the option to keep the team intact after project completion. The Facilitator and Contact Information are listed so that stakeholders, potential collaborators, and interested parties are aware of who is responsible for execution and how to contact them. A Date of Announcement, Call for

Collaboration, and Intended Date of Completion allow potential collaborators to get a sense for how long the project has been active, how long they have to submit a request to collaborate, and how long they should expect to be working on the project.

Footer

The Footer is included at the bottom of each page in the document and contains three items:

1. The current version of the Facilitator's Catechism format in use, preferably with an embedded hyperlink to the repository where the version specification is held.
2. The current version of the project's Facilitator's Catechism, preferably with an embedded hyperlink to where other versions are held.
3. The Page Number of the document

The Footer is an essential component of the Facilitator's Catechism, as it ensures that the reader can ascertain the current version as well as find and compare updated versions.

Situation

Building on the battle-tested success of the Five Paragraph Order, "Situation" is the first paragraph of the OPORD, and should be used to develop a narrative that conveys a situation, problem, or threat to a potential collaborator, stakeholder, or interested party. Adapting Eben Swift's notion of the length and detail of this section being proportionate to the level of command [3,23], we suggest that the length of this section be commensurate with the complexity and nuance of the situation requiring the assembly of a team. It is subtitled with a set of questions to be answered:

1. What is the nature of the situation or problem the team is being formed to address?

2. If there are traditional methods which would normally be used to address the situation or problem, what are their limitations and why are they inadequate?
3. What makes the situation novel?
4. What will happen if this situation is not resolved or addressed?

Mission

Following the format of many modern OPORDs [3,4], "Mission" is included as the second section of the Facilitator's Catechism. Using situation and mission in order follows key principles of necessary scene-setting prior to the identification of an ideal as a basis for narrative construction and survivability [152–154,177]. Mission asks only one question:

> "Given the situation, what are the team's explicit objectives?"

The answer to this question should incorporate the principles of military staff writing: brevity, clear emphasis, mechanical accuracy, readability, simplicity, and coherence [43]. If there is more than one explicit objective, the objectives are recommended to be compartmented and clearly separated. Mission is heavily emphasized in accordance with our conclusions regarding goal-setting and the success of mission-focused OPORDs. This question is resilient to future changes in group personnel or even the inclusion of adversarial team members—as long as the objective is maintained and achieved.

Potential Avenues of Approach

The third section of the Facilitator's Catechism is drawn from the "Course of Action Analysis" found within literature on joint operations planning [80]. From the point of view of ecological psychology or Active Inference, the Course of Action analysis is equivalent to the assessment of a "field of affordances" and evaluation of the team's preference over this field [151,173]. Course of Action analysis is generally done when situational awareness of potential resources (such as the skill sets and knowledge of potential collaborators) is limited and there may be many paths toward solving a problem or achieving a mission [80]. However, instead of using the Course of Action Analysis methods provided by military literature on joint operations planning, which require a great deal of checklists and supplementary material to create a format-valid deliverable, the Potential Avenues of Approach section of the Facilitator's Catechism asks a series of questions which, if answered with rigor, will provide a deliverable which is fairly similar to that of traditional Course of Action Analysis methods. Additionally, for all-human teams or mixed human-computer teams, the Course of Action Analysis of the future may include specific reference to action-oriented machine learning models. To prompt meaningful engagement with the challenging area of Course of Action Analysis, the Facilitator's Catechism asks:

1. Given the situation and the mission, what are the potential avenues for approach?
2. For each approach:
    a. What tools, techniques, or expertise alone or in combination are required?
    b. What are the risks?
    c. What are the potential limitations?

The Potential Avenues of Approach section allows the writer to develop necessary structure for project execution without assuming resource availability. The Potential Avenues of Approach section of the Facilitator's Catechism is unique among OPORDs because it assumes digitization and versioning (previous OPORD formats were simply innovated in a time before widespread file-versioning tools such as Git and Wiki). Once a team has been assembled and an avenue of approach has been decided, the section is renamed to "Approach" and the potential avenues of approach are replaced with the chosen approach. The state of this section in context with other sections and the header provides potential collaborators with valuable information, allowing them to identify what stage of development the team is in, the likelihood of success, and the length of time the project will likely take.

Milestones

The Milestones section of the Facilitator's Catechism is inspired by the "Milestones for Success" section of the Heilmeier Catechism. Like the section on Mission, the Milestones section asks only one question:

> "Given the situation, mission, and the avenues of approach, what are the milestones that would best indicate the mission's progress?"

This area is left flexible as the standards for what constitutes a milestone and how they should be written are substantially varied by domain [1,80,95,98]. If the avenues of approach in the previous section are widely varied in terms of their deliverables, methods, and progression, it is recommended that their milestones be separated and labeled with their respective approaches. It should also be noted that, like some spatial missions, the milestones in online missions might be reached in a different order than the one listed in the initial OPORD. Considering our earlier conclusions regarding the importance of achievability in goal-setting and that process facilitation can apply to very long term projects, the Milestones section affords the team opportunities to identify and rally around successes and calibrate in the short-term. As milestones are completed, they may be marked as completed on the document to inform potential collaborators of the progress and status of the project. If used in conjunction with a change-tracking tool such as Git, these changes can be labeled and used to produce after-action reports without the need for any additional reporting requirements.

This area is left flexible as the standards for what constitutes a milestone and how they should be written are substantially varied by domain [1,80,95,98]. If the avenues of approach in the previous section are widely varied in terms of their deliverables, methods, and progression, it is recommended that their milestones be separated and labeled with their respective approaches. It should also be noted that,

like some spatial missions, the milestones in online missions might be reached in a different order than the one listed in the initial OPORD. Considering our earlier conclusions regarding the importance of achievability in goal-setting and that process facilitation can apply to very long term projects, the Milestones section affords the team opportunities to identify and rally around successes and calibrate in the short-term. As milestones are completed, they may be marked as completed on the document to inform potential collaborators of the progress and status of the project. If used in conjunction with a change-tracking tool such as Git, these changes can be labeled and used to produce after-action reports without the need for any additional reporting requirements.

Implications of Outcome

The fifth paragraph of the Facilitator's Catechism, "Implications of Outcome", is drawn from the highly unique "Who Cares?" section of the Heilmeier Catechism, which presents an opportunity to clarify what the impact of a successful mission might be. The "Who Cares?" question is considered critical to the success of projects in DARPA, given that if it cannot be answered directly or communicated clearly, it is likely the case that the project isn't relevant or helpful [98]. The Implications of Outcome sections asks:

If all or some of the milestones were achieved?

1. What does the success mean to the stakeholders, situation, and team?
2. What else might be affected?
3. What work will come next?

This section helps potential collaborators align on the impact and importance of the mission and provides a stable attractor for meaning of action in context of the project and team. It is a powerful motivator to ground a project in terms of its long-term implications, and how they will specifically impact the lives of stakeholders [154].

Administration, Logistics, and Communications

Following the battle-tested standard set by most modern OPORDs, the last section of the Facilitator’s Catechism is Administration, Logistics, and Communications. This section provides a single area in which all of the supporting details necessary to the coordination and management of the project may go. It asks the following questions:

1. Who is the facilitator responsible for the project’s completion?
2. Who, if anyone, is the team accountable to?
3. What resources and support elements are required?
4. What resources are already available and how can they be accessed?
5. What are the requirements for participation?
6. How will the group communicate?
7. Where and how will the work be done?
8. Under what circumstances will the project close and the group disintegrate?

For various kinds of IRTs and online projects, Administrative, Logistical, and Communications details, such as technical requirements, tools, and affordances, are essential specifications that, much like the previously noted standards for milestones, will vary substantially across domains [1,80,95,98]. Questions are thus left fairly flexible, allowing the writer to use them as a foundation from which they might ask themselves domain-appropriate questions like:

1. What projects has the facilitator run in the past?
2. Who is the client and project manager?
3. How much money will be required?
4. How do users access the document library?

5. What kind of clearance is required for project participation?
6. What contact escalation schemes will be used to manage bringing engineers or other specialists onto a call?
7. What chat platform will be used?
8. How long do we have before a proposal must be submitted?

Discussion

To conclude, the Facilitator's Catechism is intended to serve as a tool for the systems engineering of action-oriented organizational behavior by structuring the formation, communication, function, narrative, and strategy of online teams [60]. This tool's design incorporates the battle-tested elements found within the discussion of the origins and histories of OPORDs from antiquity to 2020 and presents novel ones in context with the cultural influences of various militaries and conclusions from analysis of modern research on topics like Collective intelligence, Organizational Sensemaking, Active Inference, and the Systems Engineering of organizational behavior. In accordance with the clear pattern of technology-driven, structural changes in the expression of warfare driving the generation and adaptation of OPORDs, this OPORD is designed to overcome the limitations of its predecessors (see Appendix M) to meet the requirements of modern military, intelligence, and civilian IRTs and small teams [29,60,177] in an environment which has undergone significant structural changes due to factors including, but not limited to, the emergence of new Complex Threat Surfaces related to terrorism [29], availability and adoption of new technology, and the 2019 Novel Coronavirus (COVID-19) [195–199].

Considering that the impact and adoption of this order is difficult to predict, a consequence of the complexity of organizations and the difficulty of prediction in complex systems in general [112,176,200–202], it is not assumed that the Facilitator's Catechism presented here will be the final version. The Facilitator's Catechism presented here will be housed in a GitHub repository[1] with a flexible license, such as the Attribution-ShareAlike 4.0 International License [203], from which new versions and variants may be produced and distributed. In addition to the difficulty in predicting the impact, the impact may also be difficult to study and measure for the same reasons as well problems of comparability and collection of samples. In terms of comparability, productivity across domains in general is challenging and is especially challenging in domains where the work is knowledge intensive or dealing with innovation [204]. In high reliability and research organizations in which the Facilitator's Catechism might be most useful, comparability of performance between even individual tasks within the same organization may be difficult to attain given that these are organizations which are characterized by their engagements with novelty and generators of novelty such as Complex Threat Surfaces [29]. Even if comparability of performance were achieved there would be problems attaining the number of samples necessary to glean meaningful insights. IRTs and small remote teams may be formed instantaneously or rapidly but perform over longer periods that may be as short as minutes or as long as years [29,177]. In a future where ONFT and Business, Operational, Legal, Technical, and Social use-case reasonable data standards become commonplace, we argue that the challenges of sample size and comparability in measuring performance may be greatly reduced.

In the absence of such standardizations, we recommend the use of Serious Games applied through tools like collaborative case-management software and events like hackathons [177] as a basis for overcoming challenges of sample size and comparability. Serious Games narrow scopes such that state and outcome can be made comparable while also reducing the time-scales of performance to allow for collection of a larger number of samples [177,205]. From a pedagogical and developmental perspective, serious games can also

---

[1] https://github.com/COGSEC/FacilitatorsCatechism

offer a variety of real-world benefits to participants such as skill training and real-world impact which offer incentives for participation [206–211] while also providing an opportunity to develop authentic and impactful communities of practice

CHAPTER V

Reimagining Maps

Richard J. Cordes, Daniel A. Friedman,
& Mikel Maron

Reimagining Maps was written in response to and published through a National Geospatial-Intelligence Agency Incubator, of the same name, hosted on the DARPA platform Polyplexus (Incubator-ID 488).

DRIVING & INSPIRING QUESTIONS

- Can emerging knowledge in mathematics, perception, design, and other related disciplines help us make better, more flexible, more understandable maps and governance? What is possible now or soon that was not possible before?
- What if we suddenly found ourselves forced to explain where things are or how to get from A to B without historic maps? How would advances in abstract mathematics, psychology, cognitive neuroscience, art, augmented reality, and other technologies and disciplines be used to inspire cartography if it were a new field?
- Can map systems accommodate various users and facilitate modern action affordances?
- Can maps be dynamically customized using emerging knowledge in mathematics, perception, design, and other related disciplines?
- Can best practices in computer science fuse with insights from phenomenology and ecological psychology to make human-computer interactions healthy and meaningful?
- Can governance of datasets and map generators be transparent, effective, and secure?
- Can responses to disasters be rapid, contextual, and human-in-the-loop?
- What is possible now or soon due to changes in the use and availability of geospatial hardware and software technologies?

Introduction

The field of cartography sits at the intersection of applied mathematics, engineering, geology, geography, user experience, and graphic design. Methodologies and concepts from cartography have been creatively applied in a variety of fields, such as the application of spatial mapping techniques to information in knowledge management, or the use of itinerary visualization methods in non-spatial journeys such as learning maps in learning management systems. These fields have been subjected to their own forms of development and evolution leading to new methodologies and concepts somewhat removed from their origins [1]. Cartography itself has undergone a great deal of technology-driven development [2] but would look very different today had it been developed as a new field through the creative application of methodologies and concepts from those it inspired. As the modern information and logistical context presents new challenges and thus new demands for maps, we propose a "reimagining of maps" through an interdisciplinary synthesis inspired by the interdisciplinary origins of maps themselves.

While geospatial mapping has traditionally fallen solely within the scope of cartography, this relationship is subject to a number of common misunderstandings. The most general of these misunderstandings may be the assumption that cartography is a field which is solely concerned with the preparation of geospatial maps. Modern cartography is indeed concerned with geospatial representation, but the origins of the practice are primarily found in the production of maps that were non-geographic, such as maps of the stars, maps that informed cultural and religious practice, and maps that stressed relationship and categorization over precision in spatial representation [3–5]. Further, there is a misunderstanding that, historically, maps were in regular use for navigational purposes in transit, which was rarely the case [1,6]. In actuality, medieval and ancient maps were considered "precious" artifacts [5] often used for archival purposes and interdisciplinary (military, geopolitical, scientific, and commercial) reference but most parties traveled by itineraries that were informed by maps or by those with knowledge of them [1,6]. Histories of cartography indicate reasonable efforts taken by their authors to ensure clarity when discussing the subject, regularly using terms like "geographical", "maritime", and "terrestrial" [7,8] to indicate what kind of map is being spoken about, as each came with its own quirks and utility [1,7–9]. The objectives of spatial mapping are not always about explicit representations of territory, instead, the contemporary and historical focus is often more aligned with the connection of data to the missions and needs of other disciplines, in order to accomplish goals through primarily static, graphic representations of space and time.

In this paper we define the key dimensions of the Geospatial Problem Space before drawing associations between the traditional foci of cartography (the production of maps and archival sets) and fields such as abstract mathematics, complexity science, and information governance. The objectives of this paper are to first consider the key dimensions of the Geospatial Problem Space and the limitations of the field of cartography in its current state and at its cutting edge, and then to consider the objectives, strengths, and limitations of diverse fields adjacent to cartography such as applied mathematics, engineering, and digital pedagogy. These adjacent fields are intended to serve as a basis for exploration of the potential future of cartography. Finally, direction is provided for future research activities, specifically concerning the development of integrative frameworks for geospatial intelligence production and user experiences involving: (a) Rapid generation and customization of user-aware maps, (b) Signal processing techniques, (c) Role-based access systems for collaborative production of artifacts, (d) Open-Source Intelligence (OSINT), (e) Next Generation Analytics, (f) Artificial Intelligence (AI) in the Loop with Humans & Humans in the Loop with AI, and (g) Action-oriented usage of geospatial artifacts.

Part I
Current State of Geospatial Maps

Recent changes in medium, mobility, data availability, and infrastructure have greatly impacted the field of cartography. These technological evolutions have accordingly changed the strengths, limitations and objectives of maps, reflected by developments in the affordances that cartographers are able offer to users through their map products. Here, we consider the strengths, limitations, and objectives of modern Cartography in the context of ongoing technological changes, before exploring areas of non-geospatial mapping to understand where insights for geospatial maps may be gleaned. First, we reflect on the current state of maps, with focus on ecological, social, and COVID-19-related use cases and challenges of 2020 (Figure 1).

Interoperability

The availability of spatial data online is increasing rapidly, largely through catalogs or standalone APIs. These data catalogs fit into traditional map production workflows: beginning with the sourcing, cleaning, and organization of data, followed by careful cartographic manipulations and stylings, resulting in an end product that is a static or standalone interactive map (see Figure 2) [14]. The specifics of how this pipeline is carried out, depend on the specific features of the situation such as the volume of data, update frequency, security model, end user platform specifications. At best, the data manipulation processes are shared and documented within a code repository like GitHub. This transparency and reproducibility help make tools and datasets more useful across situations, and thus more interoperable. Large, complex datasets often need custom pipelines in order to be transformed into useful and interoperable formats. With limited standards for aggregation of data prepared without Geospatial consideration (flexible attachment to grid, locations, or boundaries) or assessment frameworks for geographic coverage, consistency, and change in value over time (related to user dynamics of different source mobile apps), the potential power of heterogeneous datasets has not been realized or leveraged. If the work is collaborative or intended to be auditable, it is essential that data manipulation processes are shared and documented within a code repository framework such as GitHub.

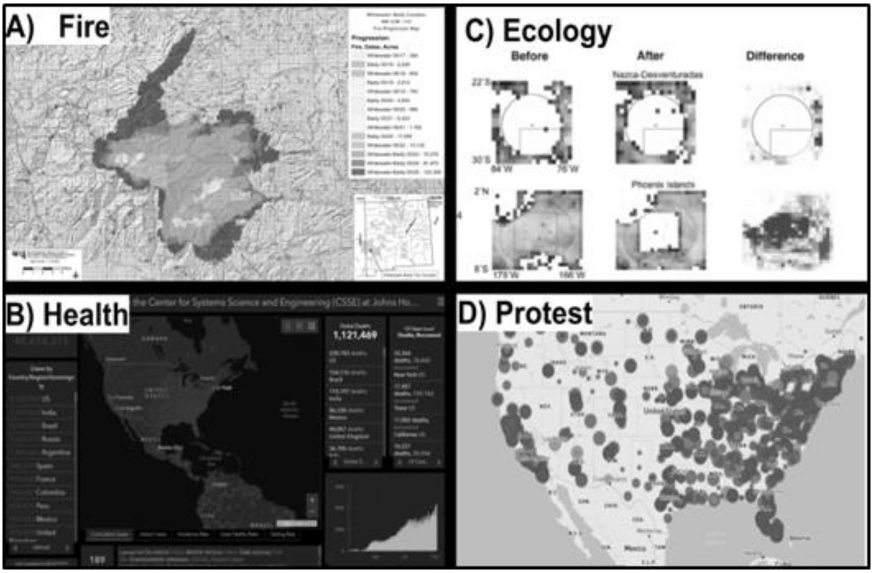


Figure 1. Use cases for maps in 2020. A) Fire map image from [10] . B) COVID-19 case map from [11] (10/20/2020). C) Marine conservation maps From Figure 2 of [12]. D) Map of protests around the United States from [13], last updated June 16th, 2020.

The global COVID-19 response in 2020 has accelerated several trends related to the processing and sharing of private sector aggregated location data. Governments and companies such as Facebook, Mapbox, Simtable and SafeGraph are involved in map products that summarize population movement, and data from these efforts have been leveraged by researchers to study various outcomes, including relating epidemiological outcomes with compliance with movement restrictions, with an eye towards developing a leading edge prediction of viral resurgence. This urgency and heterogeneous uptake across different areas has led to significant challenges related to interoperability as well as privacy. COVID-19 has revealed both problems and opportunities regarding institutional trust and data sharing. The value of individual health data in helping governments and civilians plan for and react to the spread of disease is inarguable, but the lack of a standardized framework for individual governance of personal data has led to mixed sentiments regarding sharing, which is potentially related to the success of national governance in combating the pandemic [15–21].

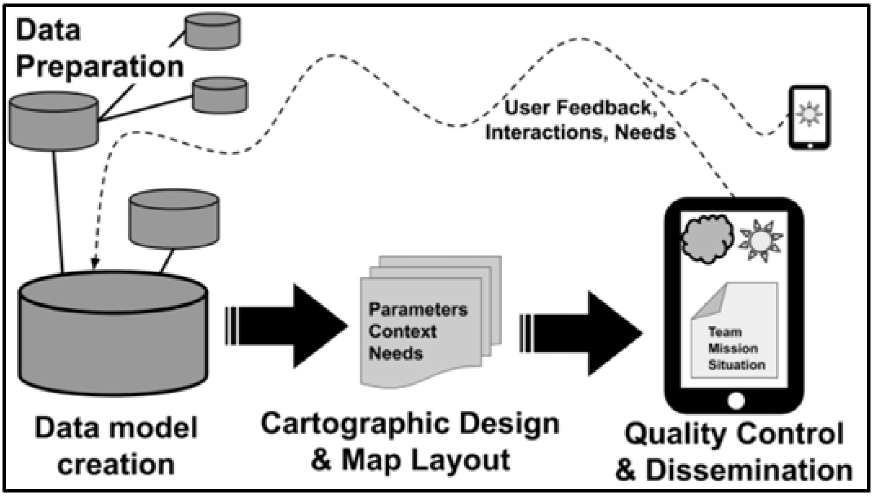


Figure 2. Map Production Pipeline

Skill Gaps

The computer science and artificial intelligence communities are often concerned with best practices for "mapping" data from one structure to another to take advantage of efficiencies or advantages of one representation of the data versus another, but the GIS trained workforce is broadly unprepared to implement these best practices or work with code, databases, or Artificial Intelligence (AI) [22]. Due to the specialization silos and changing hiring practices that emphasize machine learning, computer, and data science backgrounds, the GIS workforce may be in danger of simply being displaced by software developers. For example, common general questions facing developers using tools by the company Mapbox are: "how is our data loaded into the client side for manipulation?" and "how will we pre-process this data on our platform into vector tiles [1]?". Expertise in cartographic methodologies and practice are rare to find in the aforementioned communities [24–27]. The resulting lack of synthesis in the best practices among the domains of computer science, data science, and GIS, as well as those between these domains and graphic design and user experience engineering (UX), has notable impacts on the consumers of maps, who are liable to be overwhelmed with volume of data or misled by its presentation. Existing processes and complicated delineations of responsibility may, at the least, cause general misunderstandings about course of action analysis, and, at the worst, lead to tragic failures such as those caused by errors in emergency (US 911, UK 999) dispatch orders or motorists being left stranded in deserts [28–31]. The skills needed for modern cartography are those that facilitate the answering of these questions.

User Awareness

Overly prescriptive, robotic guidance systems are among the worst signal-to-noise ratio offenders in everyday life (e.g. frequent and salient "false positive" notifications reduce user vigilance and thus impair navigation). At this point, navigational guidance has limited intimations of human-level experience and understanding, for example providing ambiguous guidance during complicated maneuvers, or being disconnected from obvious surrounding phenomena in situations encountered on a daily basis. These systems have a limited ability to incorporate users' cognitive awareness, and any introduction of existing knowledge as a filter would vastly reduce the cognitive load for navigation. Further, likely due to a lack of trust in both intent and capability of users [32], there are limited affordances for users to update details about their environment in order to improve the experiences of others and where these affordances exist they often don't implement

[1] A data standard for terrain and traffic data [23]

best practices on crowd sourcing [33], consequently generating a variety of complex threat surfaces for the purposeful and accidental introduction of uncertainty [34].

Mapping Uncertainty

There is the eternal challenge of determining whether blank spots on the map represent absence of presence or lack of knowledge. In OpenStreetMap, an empty place may have already been surveyed for structures and none were found, or it is possible that it was never evaluated before or recently (and thus may actually have or not have a structure at that location). During the 2014-2015 Ebola response, West African communities that expanded rapidly in recent decades were found to be unmapped, a challenging situation for public health and resource allocation. The urban edge and new settlements are ever expanding, particularly in newer cities of Global South. We need to track the meaning of blank spots globally, perhaps through the use of generative models that take uncertainty into account. Some techniques do exist that allow for inference in unmapped or poorly-mapped areas, for example approaches that soften the boundaries of point and vector data [35]. However, the approaches for mapping uncertainty thus far have not lent themselves to meaningful to action facilitation in challenging situations [36].

Existing infrastructure is rapidly overturning as well in response to crisis from climate, conflict, and public health emergencies. The impact of COVID-19 lockdowns on business closures means that wide parts of our existing maps are suddenly out of date. It should be feasible to identify entire districts that have overall less certainty of continued function. The inability to handle uncertainty, combined with larger volume of diversified source data, in rapid production, makes maps more vulnerable to unintentional or maliciously injected noise.

Threat Actors

In a global world, the security, governance, and trust of maps and data becomes even more important. Fundamental data such as GPS is vulnerable to spoofing [37]. Intentional map data spoofing has occurred in augmented reality games such as Pokémon Go and games which use real-world spatial data to generate their environments, such as Microsoft Flight Simulator, both have been known to show distorted segments of OpenStreetMap [38,39]. An increasing fraction of real-life is enacted online in "social media", in the gray-zone between games and reality. The Ukraine/Russia conflict presents a (possibly apocryphal) story about the introduction of intentional changes in OpenStreetMap to divert forces into less strategic points on the landscape. More well-known are the security risks of wearable GPS-enabled trackers, which can leak information about sensitive assets [40]. In cities and military operations, where maps are in constant use to facilitate decision making, the consequences of inaccurate maps can be dire. As user-input influenced maps become spaces for conflict themselves, there is a critical need for map quality assurance, based upon data and pipeline trustworthiness.

Volume of Data

Implementation of user-informed systems that account for quality assurance and trustworthiness means leveraging huge volumes of data in a manner that is sufficiently responsive to on the ground situations (e.g. within the expected timescale of interacting with a smartphone app, less than seconds). The need for fast decisions means that analysis of data must also in part migrate to the edge of the computing network, away from centralized server farms and towards the end-user's networks and devices. Increasing power of devices and geospatial processing libraries means less round-trip travel for gathering insights. Some projects are beginning to explicitly address these challenges, for example the US Wind Turbine Database [41] calculates power capacity using Turfjs [42,43].

As the data environment becomes more complex, along with a growing necessity to leverage new open sources, the ability to communicate data certainty and chain-of-custody to the end product is paramount. The pursuit of these goals has led to problems in data analysis as an ever-increasing number of sensors and information-producing devices is making data volumes expensive or untenable to store in totality. This necessitates action-oriented, privacy-preserving, and flexible low-dimensional representations of data, a topic returned to later in the paper. In 2020, location and environmental sensors are becoming embedded into our devices, vehicles, infrastructure and objects in the logistics flow. These sensors are proliferating in number, reporting time-tagged location data to multiple aggregators. In 2019, hundreds of millions of GPS chips were in use, most commonly attached to a networked device, reflecting a market of around $100 Billion USD. New geo-positioning systems are coming online in all of the major powers. Nearly all new vehicles ship with GPS and network components. With a vehicle fleet turnover of 15-20 years [44], it is safe to predict that a majority of vehicles will be generating location data by the end of the 2020s, either through onboard sensors, or smart devices carried by passengers.

Accessibility

As technological platforms increase in scale and intricacy, accessibility for users and institutions is a key concern. Many contemporary projects are making significant strides in spatial mapping reach and accessibility however there is still a long way to go. To provide a few examples: the NOAA Big Data Program makes very large and ever-growing imagery and analysis projects accessible directly in networked cloud computing environments [45,46]. Other maritime use-cases of large geospatial datasets are also becoming increasingly important for global ecological and legal governance [47–49]. Leveraging specifications like Cloud Optimized GeoTIFF (Geospatial Tagged Image File Format) [50] enables the efficient utilization of large data stores by offering the ability to share select views of raster data available over the network. Simple specifications like Spatio Temporal Asset Catalogs [51] can solve the problem of manually searching for needed geography, time and quality over many different holders of satellite imagery, both commercial and government.

These developments in software and database technology are all occurring within the landscape of proliferation of government and corporate sensor platforms, in particular, large constellations of small satellites like Planet [52]. CARTO's BigQuery Tiler [53] eases the flow from massive data storage and analysis to map production through automated transformation of results into efficient network centric formats like Vector Tiles [23]. ML enabler [54] reuses the common distribution format of web maps (spherical Mercator tiles) to standardize and scale ML processing and integration into collaborative mapping tools. Edge data capture and processing. "Pixel8.earth" uses commodity mobile phone hardware to capture 3d point cloud models [55]. The Mapbox VisionSDK allows for on-device image segmentation and extraction of real time street level view [56]. These projects and others are pointing the way towards accessible and powerful geospatial platforms for use by citizens, researchers, and policymakers.

Key Challenge Areas

Here we distill the challenges listed above into three key contemporary challenge areas for geospatial mapping, where significant technological advances would not only be plausible and provide remedy for current limitations, but may also offer opportunity for a transformative reimagining of the potential for the capabilities and generation of maps in the future:

RAPID GENERATION OF RELEVANT MAPS

> The challenge of generating relevant maps is linked to the difficulty of integrating user-specific analytics with multidimensional, real-time information about the world, local ecosystem, mission, and team. Maps are used for missions, but when map information is outdated or is inaccurate when compared with reality, the use of the map can become counterproductive. The wider the gap between the map and the territory (due to outdated or otherwise incorrect information), the more risk there is for missions. The purpose of maps is not just to provide information about

a user's environment, but instead to provide relevant information to facilitate action—if each user or team involved in a mission has different roles to perform, then maps need to be rapidly rescoped and regenerated in order to properly to optimize communication of information, uncertainty, and affordances relevant to each of their respective tasks.

INFORMATIONAL COMPRESSION & USER EXPERIENCE

The users of maps are humans—spatiotemporal technologies reflect a case of human-in-the-loop augmented collective intelligence systems. Even the "right map at the right time" needs to have the correct informational compression for the appropriate user (e.g. an evacuating family, a grocery delivery driver, a recreational gamer). Too much information presented to the user at once, or unintentional noise in the representation of the data, can be cognitively expensive or distracting, thus contributing to risk of misinterpretation, analysis paralysis, or mission failure. The fundamental challenges of sensemaking and semantics are fused with the unique strengths and weaknesses of large datasets in the spatial mapping paradigms of today and tomorrow. Additionally, maps are geopolitical conflict spaces, which means they are often influenced by threat actors engaged in the strategic generation of deliberate noise and perturbations.

SECURITY, GOVERNANCE, & TRUST OF MAP DATA

The increasing reach and accessibility of maps is highlighting problems related to governance, privacy, and security. In some cases, the tension between user-annotated and automatically-annotated features can decrease trust in the entirety of the mapping processes and data sets. At the same time, generative algorithms are being used to create novel data, to extrapolate what street level view is like from satellite imagery [57], or intentionally deep fake landscapes and infrastructure [58]. Google's Kartta Labs is looking to recreate historic street scenes employing a combination of crowdsourced historic maps and deep learning [59]. Research in the domain of computer vision is yielding frameworks that are becoming more competent at extracting meaning from imagery. Notably Facebook produced global population data sets [60], and road networks for integration into OpenStreetMap [61]. Despite this increase in reach of automated annotated map products, in an internal Mapbox study, it was found that within a package of over 100 million Machine Learning derived building objects released by Microsoft for geospatial use cases within the US, there were notable cases of natural features, such as boulders and ponds, being incorrectly labeled as human structures. In all these cases in others, questions about the security, privacy, and governance of data are front and center. Without reliable and authenticated data, stored in well-governed repository frameworks, complex mapping projects will be difficult to collaborate on and potentially untenable or insecure.

Spatial maps aren't just geospatial. We can "Reimagine Maps" and find cartographic insight by understanding various types of maps outside the traditional reach of map-making.

Part II
Maps in Other Fields

In order to understand where we can go with maps, we need to consider the state of progress in various fields. Here we review disparate areas in which "maps" are applied, and consider examples, objectives, and limitations of each area. Across fields and use cases, the map is a tool that facilitates rapid reduction of uncertainty, often by conveying narratives, objectives, constraints, and threats [9]. We can consider an abstract map as a relation between data, information, and goals. In this light, similarities between geospatial maps of various kinds (archival and reference or itinerary) and non-geospatial maps can become apparent and provide actionable intelligence for reimagining the future of maps. For each section, we discuss the goal of the mapping system in focus, in relation to stakeholder requirements, and then inadequacies are addressed or identified.

Process Mapping

Process mapping is the application of spatial metaphors to the design of models of "relationships between activities, people, data, and objects" [62]. Where geospatial maps intend to inform the optimization of movement of objects in literal space, process maps intend to optimize organizational outcomes by helping to navigate the process of the production of a deliverable [63,64]. Process mapping has been applied inward, to the development of process maps themselves, resulting in a variety of methodologies [62], such as the Cobra six-stage method [63], BPR (Business Process Reengineering) project-stage-activity framework [65], and BPI (Business Process Improvement) [66]. Many navigation-oriented artifacts may be described as process maps, such as Operations Orders, which are used in Military, Intelligence, and Civilian teams to navigate toward successful missions [67–69], travel itineraries, communications frameworks, server architecture and distributed computing [70,71], and software. Process mapping has been noted to be of crucial importance to the improvement of the efficiency, reliability, and auditability of business operations [62–64,66,72–76]. The strict mapping of the passing of precursors and products-in-development to end-deliverables has allowed for the development of methodologies that help to clarify to map-readers exact expectations of input and output as well as variability and uncertainty at each stage of the process being described [77,78]. However, process mapping also has strong limitations, such as its linearity and inability to rigorously deal with complex systems beyond the scale of the process mapper's scope. The value of the process map has an inverse relationship with the complexity of the process and the potential for novelty and may contribute to a false sense of knowing about the nature of the business processes they intend to represent [62], leaving organizations vulnerable due to the lack of preparation for novelty.

Software and Software Development

This potential for novelty in process mapping is not so much a limitation in the description of software and business logic, where process maps are composed of algorithms and strict data structures for the reliable exchange and manipulation of data with expectations for linearity and reproducibility at each stage of the process [79]. In these domains, process mapping languages such as UML can be incredibly expressive [80]. This has resulted in wide adoption in the computer and data science communities to express software in development and have been adapted in the SCRUM and AGILE frameworks to express the workflow of developing the software as well as the software itself [81,82]. These communities are not immune from all of the limitations associated with process mapping languages however, such as the notoriously steep learning curves, strict standardizations, and lack of interoperability between not just the standards themselves but between models produced by them. This is exacerbated by the lack of codified or interoperable ontologies for the state and mechanisms of the systems they wish to model [83–85]. A common comment is that it can be more difficult to code the representation of abstract objects in process languages than it is to code the abstract objects themselves [83]. The standard in common use for UML is hundreds of pages long [86] and interpretations of the standard are often debated, making it inexpressive to individuals who are not already familiar with the standard.

As software projects become larger and include components beyond the scope of the development team (e.g. open-source libraries used as dependencies), process maps can create more burden than they relieve. Where process maps for business processes leak value proportional to the complexity and potential for novelty within a process, process maps for software see diminishing returns and, after some threshold, negative returns. This reduction in value is related to the level of complication of the process being described. In the engineering of complicated systems, it is best practice to institute a separation of concerns regarding the various mechanisms within the system [87]. In order to meet this demand, many UML maps would have to be generated in order to maintain low signal-to-noise ratios for developers working on their sections of a project. At the cutting edge of process mapping are solutions to these limitations, embedded in frameworks like cadCAD [88]. In cadCAD, the entire modeling process can be mapped and simulated, and maps can be generated rapidly with scope defined to any particular mechanism or the flow of state between them. The cadCAD package was developed in the interest of providing a generalizable framework for the modeling of Complex Systems but can apply to other systems as well.

Complex Systems

In Complexity Science, the "map" is a nomadic metaphor that relates actors and actions of various kinds [89]. The idea of a map is applied across systems and scales, in order to highlight analogies [90–94]. Some shared methodologies across these use cases include Bayesian modeling, network science, and predictive/counterfactual approaches [95,96]. The objective of these maps is to enable understanding, control, and design of large emergent or autopoietic systems [97,98]. These kinds of maps are used qualitatively as metaphors or homologous structures that suggest system leverage points for control. These maps can variously take the form of system engineering diagrams [99,100], complex system modeling platforms [88,101], or causal "world modelers" as per several recent projects, but also can be used as quantitative tools. Causal diagrams are often used in complex systems maps because these kinds of models can lead to reduced uncertainty about key leverage points for action. Similar to the geospatial problem space, interoperable encoding of complex ontologies and pipelines for transformation of data seem to be key limiting factors within these domains.

Communications

In the gray-zone between Geospatial and process maps lie the applications of mapping metaphors and methodologies to represent communications. Communications maps which intend to represent connectivity in physical locations have had to overcome key limitations of two- and even three-dimensional Geospatial representations in order to include non-terrestrial entities such as satellites which are never static in position and are not fixed in position to the Earth. Methods to remedy this have included three-dimensional colored overlays, re-rendering the map based on timestamp, and including supplementary non-spatial maps [49,102,103]. These accompanying non-spatial maps are especially important to understanding the flow of maritime communications, where most of the communication is being done between a series of objects which are in motion and communicating information which needs to be routed to a variety of destinations over a variety of channels. Some of these destinations are spatial, such as a Port Authority, but many destinations can be abstract, such as the set of all servers within a company which can parse some kind of incoming sensor data from a vessel. Key challenges of this mapping are a lack of data standardization and a pileup of low-integrity data from the introduction of Internet of Things (IoT) sensor-technology producing billions of data points per vessel annually [49].

Communications maps are being implemented as a part of workflow maps in other domains which also have abstract, non-spatial paradigms, such as in server architecture, distributed computing tasks [70,71], and in the embodied and remote information processes that are increasingly enacted in the small-group online settings (research, education, innovation, etc.), where novel individual and collective affordances are available [34,104]. In such situations, team communication maps are network representations of the channels of information flow among teammates [100]. Team communication maps can be reflected visually as a graphical layout, or using other visualization techniques from topology, network analysis, and big data analytics. The objectives of team communication maps are several-fold: to clarify how collaborators are informationally connected, to design improved paradigms for teamwork, and to reduce redundant or spurious links within a group. Team communication maps are specifically designed to deal with the challenges of many interacting agents, some aligned and some adversarial/external teammates. Modern team communication protocols are primarily through the internet, though can also be through other electromagnetic spectrums or physical objects. Current limitations of team communication mapping tools include the scarcity of usable yet flexible tools, and friction with integrating such tools into current team tech stacks and behavioral repertoires.

Knowledge Management and Information Systems

Knowledge mapping has a variety of definitions, but all reference common objectives, which include the facilitation of exploration, discovery, navigation, and recovery of information [105–107]. Knowledge maps help to connect ideas and observations within a framework that allows for disciplinary (e.g. accounting, legal) or interdisciplinary teams (e.g. research, military) to make sense of the relationships between topics and concepts. Knowledge mapping is generally a qualitative, visual task composed of adding and arranging different ideas on a canvas to suggest new associations to make, or analyses to perform. Knowledge mapping of this kind has become popularized as a note-taking tool under the name "mind-mapping" for individuals who are looking to improve their work-flow in business, research, and education contexts [108,109]. Enterprise Knowledge Management Systems (KMS), such as those employed by Palantir and similar companies, include the generation of maps that can be extremely quantitative and formalized, especially in specific subfields or where extensive semantic data already exist [104,110]. The creators and users of these maps generally face the same challenges as those found in cartography and software development: learning curves, generalizability of data, requirements for versioning, access control, and the need for rapid generation of new maps in order to allow for separation of concerns or scope for mission by the reader. Enterprise KMS have overcome some of these challenges by creating mechanisms for interoperability and versioning, and by creating query systems which regenerate maps based on stated objectives of the user and the information they're already aware of, but these systems require a great deal of work in initial set-up and data integration in order to become feasible.

In the relatively new domain of Open-Source Intelligence (OSINT), knowledge mapping is being implemented in order to facilitate the opening of the intelligence production cycle to include both members of the public and sources of information which are available to the public [111]. The "eyes and ears" model which dominated most domestic and foreign intelligence operations prior to the 20th century was successfully implemented at global scale by the city state of Ragusa around the 15th & 16th centuries [112], but the style of implementation is not amenable today given the number of individuals and amount of information sources available. While OSINT is often noted to be solely concerned with the inclusion of public resources in the intelligence production cycle, its focus on aggregation and interdisciplinary collaboration has led the domain to create a set of methods which help to fuse a variety of traditional intelligence gathering methods (see Figure 3) into a generalized framework for organizational sensemaking at a scale that traditional implementations of the eyes and ears model cannot [112,113]. Knowledge mapping in OSINT faces many of the same challenges as those found in enterprise KMS with the added difficulties from lack of affiliation and pre-existing trust between collaborators, as well as concerns with the inclusion of sensitive and highly technical materials in workspaces and individuals who have various levels of clearance and disparate domain expertise. It has been recommended that challenges of this kind may be overcome through the use of role-based access, user-aware workspaces, better data standards, and gamification of tasks [100,104,114].

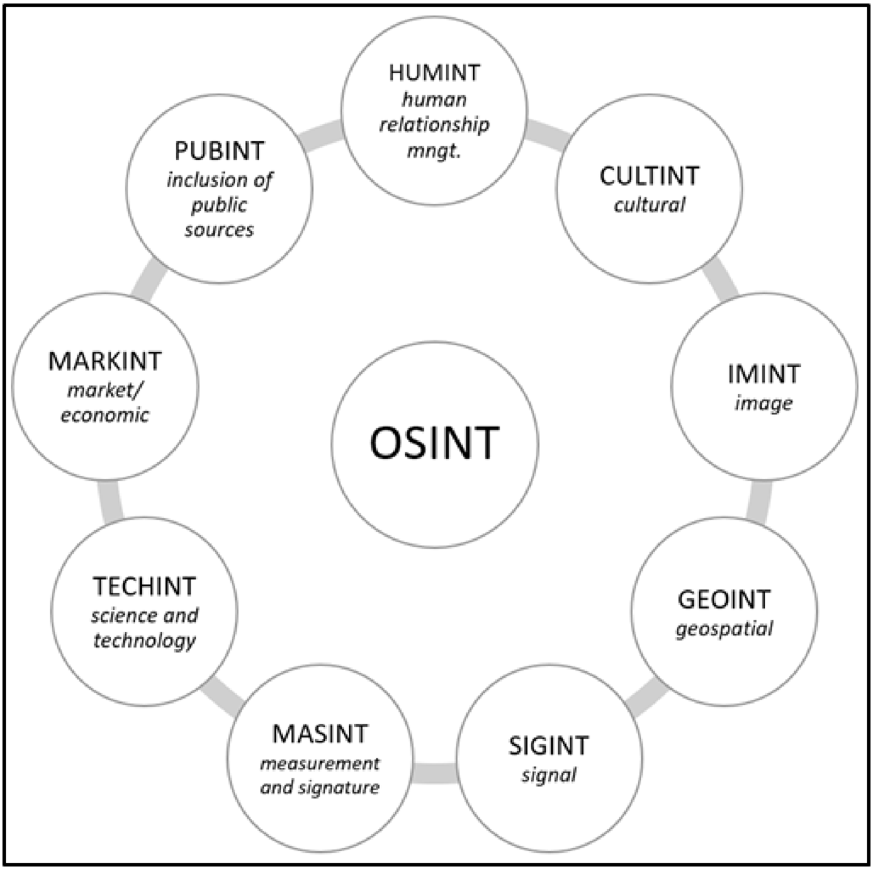


Figure 3. OSINT Fusion adapted from [113]

Education, Curriculum, and Learning

At the intersection of process mapping and information mapping are mapping metaphors in the domains of education, continuing professional development, and human resources. The ability to communicate competencies and knowledge attained and mapping them to the requirements of roles and continuing education has been becoming increasingly difficult as fields of study, roles, and credentials become more specialized, which is consistent with early 20th century predictions [24–26,115]. The effects of this increasing granularization of specialization are exacerbated by two major factors. First, learning has become more personalized and decentralized, often being done online and outside the context of the traditional classroom. Second, deeply tied to the problem of specialization silos themselves, is that the communities concerned with the development of education and personnel data standards are generally composed of individuals who have a strong background in computer science with limited understanding of pedagogy or vice versa. As a consequence, many competency standards such as xAPI [116,117], SCORM [118], and LOM [119] are highly linear and inflexible. Attempts to update these standards have generally caused the standards ecosystem to become only more byzantine, causing problems with adoption.

The objectives of many of these efforts was either to optimize competency development by rapidly generating and monitoring personalized learning pathways in order to identify and overcome skill and knowledge gaps, or to integrate approaches found in research from outside the realm of traditional organizational psychology in order to develop organization-level competencies and performance [120], such as "serious games" [104,120] and collaborative creative work [121]. In order to overcome current limitations to achieve these objectives, it has been suggested that research be directed toward developing mechanisms for crowd-sourcing the cataloging of learning resources and relationships between learning resources and competencies, managing incentivization of crowd-sourcing through microtransactions, managing trust within crowd-sourced networks, and better understanding self-forming human networks, rapid optimization of collaborative work, and rapid formation of virtual organizations [120,122,123].

Ecology and Biology

The natural world, and the study of it, can inform the study of maps. Maps are used in Ecology to map species distributions [124], ecosystem services [125], and regulated areas for human use through space and time. In basic or theoretical ecology, maps exist as abstract or idealized spaces in which processes like succession, gene flow, and guild formation occur. For applied or conservation ecologists, maps are essential in providing information on corridors for animal movement, information on the location of genetic diversity, and potential sensitivity of different populations to projected climate changes. The objectives in ecological studies of maps are to determine how features or aspects of ecosystems such as their patchiness or resource distribution, influence biodiversity, system resilience, and organismal behavior [126,127]. Other goals of ecosystem mapping include characterizing the dynamics and (informational, geospatial, ecological) components of the niche. Modeling of ecological niches can assist in sampling for conservation or utilization. Ecological analyses are often at the regional or global scale, and increasingly being used in conjunction with sensor or GPS data, to regulate maritime and terrestrial activity [48]. Machine learning schemes based upon biogeography are transferable into other domains, perhaps because biogeographic maps integrate multiscale spatial and temporal phenomena, and can integrate predictive and Bayesian methods. [128].

Some limitations of ecological modeling include microheterogeneity of the niche (e.g. temperature at one level of the rainforest different from temperature on the ground), and accurate historical/future prediction of climatic trends. Microheterogeneity of the niche can confound regional-level predictions, for example in the case where local temperature highs/lows can be outside the confidence interval of the larger area, it is unclear whether the confidence interval of the larger area should be expanded, or how to otherwise include this information on variability. The challenge of past and future projections of climate, used in niche occupancy prediction models [124,129], are similar to issues arising in large-scale climate modeling [130]. At the cutting-edge of addressing these challenges in ecology, are large consortium projects, globally-replicated long-term experiments, and spatiotemporal analytics algorithms borrowed from other fields [131]. In behavioral ecology, dynamic network representations are mapping out the interaction patterns of agents in systems like ant colonies and schools of fish [132,133]. Beyond ecological cases, there is a long history of "map" metaphors in developmental and evolutionary biology, such as the case of Waddington's epigenetic landscape [134], the genotype-phenotype map [135,136], and fitness landscapes [137–139]. Map metaphors for biological systems are linked to causal analyses (e.g. mapping between cause and effect) and therefore influence policy and culture [9,140,141].

Mathematics

Maps in mathematics often take the form of metaphors for projections of data or the results of functions onto visual planes, but these metaphors are tied to a generalizable ontology and set of methods for managing transformations of data between planes [142,143]. Functions are kinds of maps that connect inputs to outputs, for example, the function $y=2x$ maps values of y onto values of x that are twice as large. Metaphor, ontology, and methods alike provide helpful lenses for application and understanding the nature of functions and their domain (the objects and values which can be acted on) and range (the objects and values which can be produced) [143]. The ontology within the mathematics mapping domain diverges a great deal from other mapping domains described, most notably in the definition of the term "map" itself. The "map" does not refer to the visual projection of data on "Plane Y" from data sourced from "Plane X", instead, the "map" is the function through which "Plane X" data are passed in order to generate or locate the data which sit on "Plane Y".

Mathematical mapping methods have been well generalized to work outside the realm of theoretical math and abstraction in physics and applied engineering. For example, in the gray-zone of computer science and mechanical engineering, these methods allow the "map" to be an algorithm, enabling the mapping of complex, n-dimensional objects, an example being the mapping of stress-tensors [2] to any other measure of strain [145]. These kinds of maps enable interoperability between standards without the addition of new standards or frameworks as well as enable the rapid generation of visualizations and models [145]. These mathematical intimations regarding maps overcome the limitations found within other map domains described, as maps become "generators" of visualizations rather than the visualizations themselves. Freed from focus on fixed products, mathematical maps can be linear, non-linear, chaotic, stochastic, or whole computer programs with humans in the loop, such as AI, and can contain multiple layers of maps contained within Markov blankets [146,147]. This is akin to modern paradigms in cartography where "maps" are increasingly becoming user-informed and user-aware, and being presented in terms of dynamical connectors, rather than simply being low-dimensional projections of higher-dimensional data.

The application of mathematical maps represents the cutting edge of a number of fields. For example, underpinning the field of cryptology, which is concerned with the security and encoding of data, is the ontology and methodology associated with maps [148,149]. The "hashing" of an object, or the reproducible, algorithmic conversion of data into a string of a specified length of random characters is a type of "non-homotopic" data transformation or mapping. Non-homotopic transformations are those which occur using a map for which there is no defined inverse or reciprocal (we can transform the data from plane XY onto plane WZ, but there is no defined map that will project the resulting WZ data back into its original position on the XY plane). Where reverse transformations are implausible or computationally intractable, non-homotopic mappings can be used as a one-way encryption, or hashing, technique. On the other hand, the encryption of data is an explicitly "homotopic" transformation in which there is one map for encoding data into cipher-data and another

[2] Tensors are high-dimensional objects that used in machine learning across different domains through transferable algorithms and frameworks such as TensorFlow [144]

for conversion from cipher-data back to its original state. Underneath the business logic of advanced data manipulation and integration frameworks, such as those used by Palantir, are transformations described as "isomorphisms", which are structure- and order-preserving maps [150,151], and transformations over special kinds of maps like "functors", which allow for the coherent transformation of objects from one set or category to another [152,153]. In cases where mapping transformation is able to convey some knowledge about the strategies available for a specific the starting state and action (e.g. "this account has enough money to pay the bill") while strongly protecting other dimensions of the data (such as specific amounts or previous transactions), the relationship is known as "zero knowledge". Zero knowledge cryptographic proofs are increasingly relevant for Internet of Things (IoT) [154] and cryptocurrency uses [155,156].

Part III
Reimagining Maps

The application of mapping metaphor and methodology in many of the domains and subdomains described have converged on some combination of the three key areas of limitations of modern spatial maps raised in the Introduction. However, each domain has approached the development of next-generation solutions to their shared limitations in unique ways, and these advanced approaches will be considered in the reimagining of maps with respect to each key area of limitations.

The Map is Not the Territory

Many of the domains described faced similar requirements for the necessity of rapidly generated maps for managing detail and scope, producing maps for a variety of users and stakeholders, viewing maps at a variety of scales, and managing the integration of changing parameters, user input, and constant flows of real time data. Mapping paradigms in mathematics and at the cutting edge of the mapping of complex systems and workflow, are potentially helpful conceptions and methodologies for the rapid generation of relevant Geospatial maps.

The application of static reference maps in many tasks is now outdated, as reference data living in databases can simply be projected on command to any number of visualizations or directed to analysis frameworks. Now that the data can more easily live at their source or in accessible collections, they are frequently used or updated through transformations into a more fit for purpose data structure. This fundamental turn in cartography towards dynamic data structures moves beyond the practice of the mapmaker as collecting data to their workspace for human evaluation, to the mapmaker applying cartographic transformations to ever updating sources outside their control. The static map no longer serves a single arbiter of truth.

Rather, mapping can now primarily consist of sculpting the processes by which user- and mission-specific maps are generated and delivered. This shift toward holding the map in the data allows for the interactive visual representations of complex or mechanistically complicated systems where no single static representation could possibly communicate all of the meaningful components or processes without overwhelming the user.

Using conceptions of maps from within mathematics, where maps are generators of the projection rather than the projection itself, paired with the gamification and temporary, Instantaneous Remote Teams (IRTs) of experts found at the cutting edge of OSINT practice [34,100,104]. The traditional mapping procedure of data preparation, model creation, cartographic design, layout, quality control, print, and dissemination [14] could be greatly expedited and more easily delegated to a variety of teams of collaborators and contributors. For each encountered map request, temporary teams could be formed from domain experts and relevant stakeholders to produce generators for the transformations and projections necessary at various stages of the procedure [104]. Prioritizing the production of generators rather than the production of visualizations has already led to a great deal of progress in the enterprise mapping community, converting more organizations to this prioritization and creating non-proprietary standards for generators as well as the data which they use could yield a great deal of value. In addition, the use of Instantaneous Remote Teams (IRTs) helps to overcome previously stated problems regarding the difficult to attain skill combinations required for successful navigation of the entire procedure by a single team or individual. Select data scientists and domain experts can be enlisted to focus on case-specific generators for the often non-routine data preparation and model generation or be considered the generators themselves, and cartographers and graphic designers can focus temporarily enlist the help of software developers or data scientists in generators of layout and projections without these skill-sets dominating these areas of the procedure.

User/Role/Actor-Centric and Mission-Aware Maps

With the correct generators, systems can have a model of the end-user built-in and use a map production procedure that not only takes end user characteristics into account, but also their objectives and feedback through the use of gamification. This gamification, through playful mechanisms found in Pokémon Go can be used to incentivize crowd-sourced development of features and notable improvement of mapping products. In the domain of linguistics, Duolingo, a language learning platform, has mechanisms to allow expert users to help adapt and add to curriculum as a part of their own language learning. However, these user-contributed additions are slowly adapted for larger populations by more trustworthy users and staff—these mechanisms could be used to help inform trust management in crowd-sourced development of catalogs and map products as well.

A key generalized objective across all mapping domains is hodological facilitation: they need to facilitate pathfinding and sensemaking for users intending to orient themselves or their assets toward action. Within the domain of this generalized objective are benign use-cases, such as finding a place to buy an iced coffee or trying to circumvent traffic where failures are measured in minutes wasted, alongside far more serious use-cases, such as evacuation during forest-fires, avoiding riots and roadblocks during civil unrest, and ambulances circumventing traffic, where failure is measured in human bodies and success in lives saved. In critical modern use-cases, maps must be generated just in time, not with just a visual layout, but rather with a mission-aware interface providing a sculpted set of representations and options that will either have outsized impacts on mission-success or quickly incorporate feedback from failures to do so.

BOLTS

Across nearly every mapping domain reviewed, there were limitations at the cutting edge concerning, not the availability of data, but the ability to rapidly integrate it. At the cutting edge of each of these domains, there appears to be an overwhelming consensus that standardization of data is prerequisite to the rapid generation of maps. Synthesizing the requirements from each domain indicates a need for data specifications which are reasonable for Business, Operational, Legal, Technical, and Social (BOLTS, see Figure 4) use-cases.

One of the primary obstacles to developing such standards in the past has been adoption and the inflexibility that, axiomatically, accompanies the introduction of hard-coded standards. Universal standards for the exact schemas of all data objects that could be of use is unachievable, however, borrowing from concepts regarding transformations within mathematics may provide interesting insights. It is not necessary that all data be universally fit to specific schematics in order to be BOLTS reasonable, instead, all that is necessary is that the objects referenced within a data object (maritime vessels, individuals, documents), the instantiated data object itself, and the schematic which is used are accompanied by metadata in order to inform transformations. Standards regarding this type of meta-data would allow for greatly increased data sharing and cross-platform compatibility while also enabling the highest standards of privacy and governance if the standards were paired with encryption and decentralized consensus protocols.

Just as mathematics defines maps as the functions which project the data, rather than the projection itself, BOLTS standards have the potential to provide an infralanguage by providing the standards for metadata to inform access and rapid transformation of data across frameworks. The presence of such an infralanguage and clear metadata would also allow for easier integration of AI into workflows to facilitate cross-referencing, discovery, and production, and transformations into varied, lower-dimensional forms while maintaining sourcing and context.

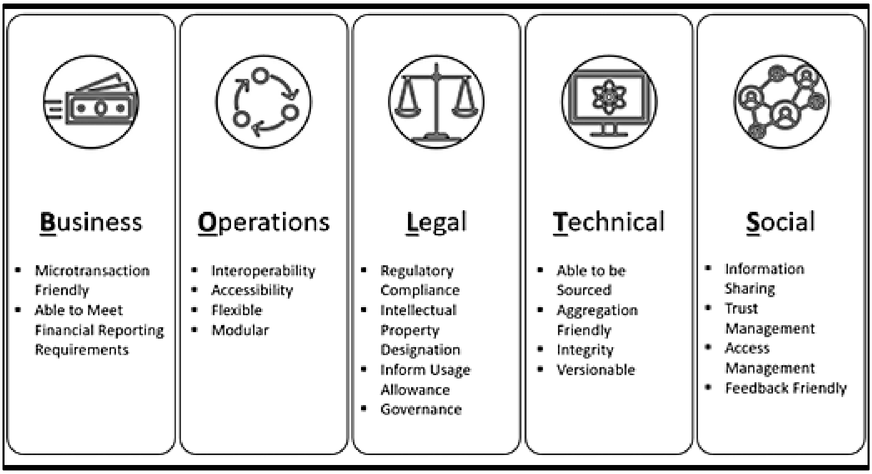


Figure 4. BOLTS

Fuzzy and Incomplete Data

One of the great challenges to universal data catalogs is the presence of disagreement over not only what should be present in the schema, but also on how to handle disagreements and uncertainty within the data itself. This extends from somewhat benign cases of "what version of the book are we referring to in this library?" to "where is this national border?", the practical impacts of these disagreements can range from dangerous to meaningless. Future data and metadata standards should incorporate the potential for disagreement and heresy within collections and acknowledge sourcing. Further, user-informed maps have already become conflict spaces and subject to threat-actors. It is possible that the future of maps doesn't prioritize crowd-sourcing, but instead "network-sourcing". Based on the actual practice of data collaboration in OpenStreetMap and Wikipedia: reputation is foremost in the level of scrutiny any contribution receives. The anonymous crowd is treated with suspicion. Social networks, both in online and real spaces, are useful for assessment of the utility or validity of a contribution to a network-sourced map product. This requires the development of tools that offer algorithms or affordances to users to assess and assign the reputation needed for certain actions or visualizations to be accessible.

Case study for Future Maps

We now consider the potential impacts of a future of maps which includes these priorities and findings through the use of a narrative use-case based on a scenario offered by the United Kingdom's Defence and Security Accelerator (DASA) "Map the Gap" competition [157,158].

In the "Map the Gap" competition, teams were tasked with surmounting realistic in-field challenges. The context is as follows: when expeditionary forces navigate within enemy territory, it is critical to mission success that physical boundaries be overcome, not just in the short term by advance units (e.g. reconnaissance and special forces which operate at the operational reach of the field army), but also in the long term by units which have trouble navigating physical boundaries such as mechanized support and logistics units [159,160]. In the case of logistics and support units, these physical boundaries cannot just be overcome once, but must be reliably overcome many times with efficiency and robustness [161]. Some of the most notably difficult terrain features to overcome are known as "wet gaps", such as streams, rivers, and bogs [157].

Rivers in particular offer a great number of unique challenges to expeditionary forces. From an engineering perspective, rapid construction of bridges requires knowing a number of difficult to ascertain variables which include but are not limited to, the profile, depth, and other characteristics of the river bed and riparian banks, the ground bearing capacity on both the near and far bank, the gradients and material compositions of the banks, and the logistics of material and equipment access. From a military perspective, bridge building requires allocation of equipment which immediately alerts the enemy to intent and location of potential river crossings. In addition, all current methods of bridge construction in the field place reconnaissance engineers and their equipment in vulnerable positions and take a large amount of time with a high probability of having to abandon the site. At the intersection of military, engineering, and joint operations contexts is the inclusion of numerous stakeholders and domain experts: reconnaissance engineers to identify and choose potential sites, expeditionary and joint operations command staff who select sites based on current unit positions as well as intent and threats after crossing, logistics staff who are involved in this process helping to define requirements, and field intelligence who inform stakeholders with intelligence products such as briefs and maps.

In a reimagining of maps informed by BOLTS data specifications, allowances for fuzzy data, user/role-centric and mission aware maps, and IRTs, this procedure could be greatly expedited and far less dangerous. When the obstacle is identified (e.g. a "wet gap needs to get mapped"), two discrete calls might be made. The first call would go out to a number of individuals from the relevant organizations who have the appropriate clearance and domain expertise to form an Instantaneous Remote Team (IRT) with the purpose of choosing a bridge site, given what is known from remote sensing data and eyes on the ground. The second call goes out to create a digital workspace which can integrate data and coordinate work between the individuals and liaisons of units which are involved in the choosing the site. This workspace includes a variety of geospatial data-sets which offer the ability to project uncertainty over the structures and details they intend to represent.

When field intelligence liaisons access the project-specific workspace, they select a role-based view which offers them data-sets, interactive dashboards, and situation reports from various reconnaissance teams and unmanned aerial vehicles in the area of operations. Local video and satellite reconnaissance data are blended with public source data to provide catalogs to users of the workspace to generate two and three-dimensional renderings of the terrain and relevant objects in the area of operations. Situation reports and intelligence data are processed to present interactive views that create high-sensitivity and high-specificity warnings regarding the potential for enemy activity. Reconnaissance engineers accessing the workspace see none of the detection alerts, situation reports, or positions of unmanned vehicles, but they do see warnings reflecting the potential for enemy activity and probability of detection. If involved engineers want to understand further, and have the clearance to obtain this information, they may change their role and see additional information. Otherwise, engineers weigh the warnings while making decisions regarding where to order the deployment of a variety of semi-autonomous, amphibious vehicles which carry combinations of sensors and sampling tools for the mapping of the variables associated with grading locations for site selection. Remote vehicle operators accessing the space, only see deployment orders, the positions of other remote vehicles, and warnings regarding enemy activity. When operators spot suspicious activity, they can submit situation reports which will be seen by field intelligence, their command, and other operators.

Throughout this process support, communications, logistics, and command elements are in the loop watching for distress calls and requests. Cartographers, graphic designers, and domain experts work in concert to respond to requests for information and develop models and visualizations that are not available via extant generators. They document and enact their process and procedure for developing these artifacts in versioned repositories where new after-action IRTs can be formed with software developers and domain experts around creating generators for them in future operations. The workspace is an extension of a Knowledge Management and Command and Control System (C2) which allows for the integration of data-streams from other related operations and creates special work views for liaisons who need to be aware of the overlap between operations, preventing friendly fire and other silo-related errors. Command and staff elements, related and unrelated to the operation can watch over the area of operations and take the view of any user or role to see what they see in order to intervene or redirect effectively.

While this example is from the military domain, the approach applies as well to similar use in domains of city planning, where joint operations command, field intelligence, and military engineers are replaced by their civilian counterparts, such as local governing bodies, community planners, concerned citizens, and civil engineers. Both domains are often caught in a protracted process fraught with non-productive cycles of arguments exacerbated by hardened interests and conflicting goals. In the city planning domain, there may be a large amount of existing and acquirable data, such as traffic studies, service and infrastructure impact studies, zoning regulations, and legal processes to synthesize and evaluate for accuracy and relevance, but the planning process itself is necessarily speculative. An IRT model that incorporates city officials, developers, residents, and land owners in a role-based workspace design that allows them to iteratively comment on, evaluate, and develop compromises regarding the possible cityscape increases the likelihood of results that are consistently beneficial to all stakeholders.

Each role has overlap with every other, no two maps are the same as each map is curating the information required for sensemaking within each role's information niche. Engineers hot-swap generators for projecting different sets of data over the map, allowing them to dial in to specific factors at different times without the need to request laborious production of multiple maps. Given a clear separation between datasets and map generators, information can be shared in a compartmentalized and secure fashion with trusted and untrusted actors on the ground. Joint operations command and city planners alike could have full access to add experimental generators for projections built from agent-based models and recommendation engines. Maps intended for human understanding should be personalized and tailored towards role-specific reduction of uncertainty. Map generation can be iterated—if the maps presented are not useful, the generators can adapt and adjust to that feedback either automatically or with human preferences in the loop. Maps intended for use by autonomous vehicles are action-oriented reduced representations of local or regional conditions and would be customized to run on minimal hardware or in offline settings. Running through the entirety of these systems are some of the pillars of the future of maps: advanced analytical capacity, action-orientation, flexibility, modularity, accessibility, and interoperability.

Conclusion

In this paper we have surveyed the current state of cartography, with consideration for the pressures applied by COVID-19 as well as the changes in cartographic affordances for areas such as movement data, and addressed recent advances in technology are rapidly shaping the landscape of maps. We then reviewed a variety of fields adjacent to cartography where "maps" play a key role, such as mathematics, ecology, project management, and complex adaptive systems. Across fields and through history, maps and mappers are beset by similar challenges such as: integration of multimodal data, representation of uncertainty, user customization, and designing for action rather than archiving. We synthesized insights and practices from disparate areas in order to provide direction for research to realize a reimagining of maps and offered a use-case related to bridge construction in adversarial settings to convey what that reimagining might look like.

Funding and Acknowledgements

Daniel A. Friedman is funded by the NSF program Postdoctoral Research Fellowships in Biology (NSF 20-077), under award ID #2010290.

Richard J. Cordes is supported in research efforts through a Nonresident Fellowship with the Atlantic Council on appointment to the GeoTech Center.

The paper was written as a result of participation in an incubator named "Reimagining Maps", hosted by the National Geospatial-Intelligence Agency on the DARPA research acceleration platform Polyplexus.

CHAPTER VI

The Innovator's Catechism

Richard J. Cordes, Daniel A. Friedman,
& Steven E. Phelan

ABSTRACT

Innovation teams formed in incubators, research accelerators, hackathon weekends, and within organizations need to quickly align on narrative, workflow, and objectives in order to achieve success. Many of these teams disintegrate or fail to perform due to lack of alignment. Operations orders, such as those in use by the military, have demonstrable impact on organizational efficacy and success. This paper summarizes the history, development, and impact of military operations orders, discusses the history and development of their business counterparts, and presents the "The Innovator's Catechism", a catechism-styled operations order for use by early-stage innovation teams. This operations order is built from the "Facilitator's Catechism", an operations order for rapidly formed research teams, with acknowledgment for the special information requirements present for emergent and early-stage teams that are market-facing.

Introduction

An invention is something that is new and potentially useful. An innovation, on the other hand, is an invention where the benefits, financial or otherwise, exceed the costs of developing and executing the idea. A patent is one measure of invention. Around 400,000 patents are granted each year in the United States for ideas that are new, useful, and non-obvious. Sadly, however, 95% of these patents will never be licensed, indicating a systemic failure to create value [1].

Traditionally, invention and innovation have been seen as branches of creativity and therefore resistant to formalization, relying instead on sparks of genius or Eureka moments [2]. Despite this, leaders and entrepreneurs would dearly love to find ways to lower the cost of innovation and prioritize ideas that create the highest value. Innovation management is the study of techniques to bring order to this chaos.

This paper begins with the observation that high reliability organizations (HROs) tend to have the highest level of formalization or structure in terms of carrying out successful projects. HROs include air traffic control, emergency services, space travel, and operating rooms where failure is not an option. The military also has a very structured operational approach that maximizes coordination between subordinate units and minimizes casualties. This approach is known as an operational order or OPORD. The paper starts by considering whether the structure of an OPORD (or similar device) can be used to increase the reliability of innovation management.

A catechism is a set of formal questions set as a test, most commonly, of religious doctrine. In the mid-1970s, DARPA, the Defense Advanced Research Projects Agency, famous for inventions like the internet and GPS, was struggling to bring more structure to its innovation process. The agency introduced a set of questions, known colloquially as the Heilmeier Catechism, to help evaluate and compare research proposals [3].

Cordes and Friedman (2020) have extended the DARPA catechism by overlaying an OPORD structure, which they termed the Facilitator's Catechism [4]. It was always envisaged that the Facilitator's Catechism could be modified for various use cases including innovation management. This paper combines the Facilitator's Catechism approach with Blank's recent discussion on an innovation pipeline to produce a family of innovator catechisms. The result is a series of structured questions that innovators can ask at each stage of the innovation pipeline to improve the reliability and effectiveness of innovation teams.

Operations Orders

Organization in the cooperative pursuit of common aims and objectives is not uniquely human, but the outcomes of the collaborative pursuits of our species certainly are. The successes of human cooperation are due, in part, to the purposeful, iterative refinement of the frameworks, processes, tools, and techniques used to increase the reliability and performance of teams. Productive novelty in problem solving, or innovation, is required to deal with the modern global landscape of challenges. In addition to the digital and internet revolutions, the modern workforce is seeing changes in the fluidity of team membership and the vertical and horizontal scale of team composition, such as increases in bureaucracy, layers of leadership, the number of individuals occupying the same teams or roles, and the number of remote and temporary workers. In these settings, there is an increased emphasis on inter-organization roles, strategies for managing workflow, team communication, and organizational culture. Organizations use evolutionary pressures and continued study and refinement in order to maintain reliable performance [4,5]. Informing this refinement in modern times, is research on industrial and organizational psychology (IO psychology), sensemaking, active inference, narrative construction, entrepreneurship, and high reliability organizations (HROs), each providing their own perspectives to reduce the enigmatic nature of team performance.

The overlapping domains within IO psychology emphasize the psychological and psychometric study of individuals in context with their relationship to their roles and the climate and culture of the organization in order to discover patterns and indicators associated with individual-, team-, and organization-level performance [6,7]. Studies in sensemaking and active inference offer useful insights and frameworks for understanding how teams and their members communicate, parse, and integrate information to update prior models of the world and negotiate meaning to facilitate action [5,8–10]. The various domains that explore the nature and process of narrative construction, such as study of mythology and theology, narrative identity theory, psychoanalysis, and memetics reveal the more difficult to quantify, emotional and intuition driven aspects of team performance, such as esprit de corps [5,11–14]. While IO psychology, sensemaking, and active inference provide nuanced lenses and frameworks for understanding team performance, the study of entrepreneurship and HROs provides meta-analysis of practical case studies to facilitate the identification of the key factors, best practices, and emergent strategies of both individuals and organizations that lead to peak performance and catastrophe [15].

One such emergent strategy, independently discovered by HROs in varied domains, is the development of use-case specific "Operations Orders" (OPORDs) [4]. OPORDs are documents, with specified format, that clearly inform a team or organization of specific intended outcomes to be achieved and the information deemed necessary for the team to achieve these outcomes [16–18]. Use-case specific OPORDs are used in project management and business contexts, however, these OPORDs are subject to the same evolutionary pressure placed on all strategies used in high reliability environments [4]. The modern innovation and entrepreneurship environment, both pre- and post-COVID-19, have new affordances and challenges that require new tools and adaptation of old ones. The experimental OPORD format, "The Facilitator's Catechism", is an OPORD variation introduced during the COVID-19 pandemic to help emergent, remote teams maintain reliable performance in the absence of clear leadership, physical meetings, or formal organization [4]. However, this OPORD may be poorly fit to teams such as early-stage start-ups, fully remote innovation teams, and emergent hackathon teams, which have these traits but also the added pressure of communicating information and goals that are market-related. Startup teams (and their stakeholders) are also involved in a collaborative mission that can be viewed as presenting the optimal product to the market, so organizational catechism-style OPORDs for startups need to have additional flexibility to adjust approach and have reduced need to plan for deep intra-team adversarial relationships.

Below, the history and development of OPORDs are summarized and the perspectives offered from studies within the domains of IO psychology, sensemaking, active inference, and narrative construction will be used to discuss the basis for the impact of OPORDs on organizational performance. Then, some aspects of the historical and modern innovation and entrepreneurship environment will be discussed in contexts with the benefits and shortcomings of existing business and project management OPORD-like documents as well as the Facilitator's Catechism. Finally, a new Facilitator's Catechism variant, named the "Innovator's Catechism", will be introduced with affordances and adaptations that have the potential to impact innovation teams.

Military Operations Orders

Operations orders (OPORDs) are, traditionally, standardized documents that are used by national militaries to facilitate action (see Figure 1) [4,16,18]. Using clear format, compartmentalization, and codified ontology, OPORDs convey expectations of execution and allow organizations to rapidly align on common goals, approach, and mission-relevant details prior to engaging in military and non-military work [4].

The Israeli OPORD Format

1. Friendly forces.(a) Intent or aim of the higher.(b) Unit's mission.(c) Adjacent forces missions.(d) Additional forces missions.1) Engineers.2) Artillery. 3) Direct support.4) General support.

2. Terrain.(a) General description.(b) Axis.(c) Main obstacles.(d) Trafficability/deployment areas.(e) Key terrain and vital terrain.(f) Summary of effects of terrain on friendly plan.

3. Enemy.(a) Intentions.(b) Deployment and strength.(c) Most probable course of action.

4. Commander's intention (when, what, and why).

5. Method.(a) Scheme of maneuver and fire support.(b) Time phasing and objectives.

6. Forces and tasks.

7. Combat support (general).

8. Administrative and logistics (general).

9. Control.(a) Location of CP's by stages.(b) Radio procedures.

Figure 1. Israeli OPORD Format as of 1988, adapted from [18]

The earliest historical instances of their usage and refinement are found during the Roman management of an expansive border with frontier territories occupied or bordered by recently conquered and fragmented peoples [4,19,20]. These conditions meant regular and rapidly developing incursions and insurrections, leading the Romans to develop protocol for reallocation of strategic assets and security against material sabotage which came in the form of OPORD variants such as service orders for the delivery of supplies and request of reinforcements and sentry orders for managing access to military camps [4,21,22]. This idea of specialization of OPORD by department or type of mission, will return in a later section on OPORDs in businesses. Where sentry orders facilitated explicit process and auditability for reliable physical security of supplies [4], service orders allowed the Roman Army to maintain operational reach despite notable asymmetry between the size and threats of the frontier and the available resources at the Army's disposal [4,19,21]. Emphasizing the importance of these service orders in the Roman Military, there is substantial evidence that Rome's famed road system was not built or used extensively for commercial purposes [21], but instead for maintaining what is referred to in U.S. Military Doctrine as "Economy of Force", or the effective allocation of military assets and the minimization of the cost of their deployment through well informed logistics [21,23,24].

The next notable developments came in the 19th Century, where the new affordance of inexpensive paper offered European armies the freedom to experiment with new OPORD format and practice while an increased emphasis on standing, professional armies and readiness, military-bureaucracy reforms, and more reliable logistics meant that militaries had the structural changes needed to allow them to mobilize, deploy, and pivot in the field faster, farther, and with less warning than ever before [4,24–31]. The French Armies of the Republic began to develop OPORDs that were many pages long, precisely detailing every action that the unit should perform, however, the mechanical, linear nature of the OPORDs was inconsistent with the nonlinearity of the battlespace, and historical records suggest that these detailed orders were rarely carried out and that the practices surrounding them did not propagate [4,32]. Where the French had long, complicated OPORDs, the Prussians, as a result of their embrace of the philosophy and practice of "Auftragstaktik", or "Mission-Type Tactics", developed by Prussian generals von Clausewitz and Griepenkerl and the chief of staff of the Prussian Army, Helmuth von Moltke, saw the emergence of OPORDs that "no longer optimized for detail or technique, but instead for mission, narrative clarity, and minimum time for issuance" [4,18,26].

These OPORDs acknowledged the famed insights of Clausewitz and von Moltke: "war is the realm of uncertainty" [24] and "no plan of operations survives the first collision with the main body of the enemy" [29], respectively. These OPORDs were reflections of the type of field orders von Moltke issued during his campaigns, clearly preferring general directives with guidance rather than strict orders, which earned him criticism but proved effective in the unexpected situations that required increased flexibility [29]. The Prussians believed that the increased fluidity in combat meant that commanders would have to rely on communication of objectives and trust in their officers to act independently in pursuit of those objectives in the field [4,32,33].

The emergence and impact of these formats, and of the underlying military philosophy from which they were developed, inspired a U.S. Cavalry General, Eben Swift, to establish the first instance of a strongly codified "field order" format for OPORDs in 1897 [4,16,32,34]. Swift, who had previously served in the American West fighting the Sioux, Cheyenne, Barrock, and Ute tribes [35–37], in operations that have elements resembling the aforementioned Roman management of frontier territories [4,19,38,39], developed this OPORD format, now called the "Five Paragraph Order" (5PO), to facilitate the practice of "Auftragstaktik" in the field [4,16,18,32,34]. The 5PO prioritized the provision of the information necessary to "enable the subordinates to carry out the operations [at] hand" [18], and clear communication of the commander's "intimation of the end" [18]—what it was that the commander wanted to accomplish, rather than how they wanted it accomplished [4,18,32].

The 5PO was just one of many significant contributions made by Swift. In the domain of military pedagogy, Swift introduced the "applicatory method" of instruction at the Army Staff College at Fort Leavenworth, which included "tactical decision games" (TDGs) [40] and regular in-the-field exercises [34,37]. In the domain of operations planning, Swift created the "Military Decision Making Process" (MDMP, see Figure 2) [40,41] which was a novel checklist and process-oriented approach to decision making which could be rendered on a matrix, placing elements of the OPORD in relationship to the progression of the operation, from planning to execution [40]. All of Swift's notable contributions fit a common theme: adapting the U.S. Military's Officer Corps to a changing environment, one which favored guerilla tactics, flexibility, and adaptation in response to rapidly changing circumstances, rendering traditional expectations of balance of power obsolete [42–44]. Swift would later take the principles and practices that he formulated and taught at Leavenworth and refine them in the field during WWI and in some of the first notable unconventional conflicts and counterinsurgencies of the 20th Century, such as the Punitive Campaign and the Moro Rebellion [34,35]. The environment that Swift was preparing the U.S. Military for became the norm in the coming decades [44–46]. The 5PO was adopted and adapted by other national governments [4] and use-case specific variants of the OPORD emerged, such as WWI trench-to-trench attack orders [47], or WWII attack, defend, and development orders [18,48].

A tracking of the history of changes to OPORDs indicates that mechanisms, sections, and priorities of their format change in response to new affordances, change in the structural complexity of the organization and its environment, and increases to the fluidity of the battlespace [4,16,26]. Changes to affordances available to militaries may include available infrastructure or equipment such as roads [21] or communications systems [50] but also changes to the mediums available for the issuing and writing OPORDs themselves, such as the availability of "tessera" tablets to the Roman Army [22], the availability of paper for the 19th century armies [4], or digital affordances in modern joint operations [51–53], all of which resulted in new emerging practices related to OPORD format and culture [4]. Changes to OPORD structural complexity include expanding layers of bureaucracy [45] and introduction of doctrine [54] such as the 19th century Prussian and French military reforms influenced by Carl von Clausewitz and Henri Antoine Jomini [30], joint operations [55,56] such as those between American Expeditionary Forces (AEF), the French Army, and the British Army during World War I [4,45,47,57], and adaptations to physical changes to the battlespace itself such as the introduction of trench and jungle warfare [4,47,58]. Changes to affordances and structural complexity certainly catalyzed OPORD experimentation, however, changes to structural complexity often cause changes to the fluidity of the battlespace, or the freedom with which Centers of Gravity (COGs), the "strategic centers of friendly and adversary strength, power, and resistance" [56,59], in the battlespace may shift, and increased fluidity of Centers of Gravity have provided the evolutionary pressure necessary to encourage the usage and development of new affordances [4].

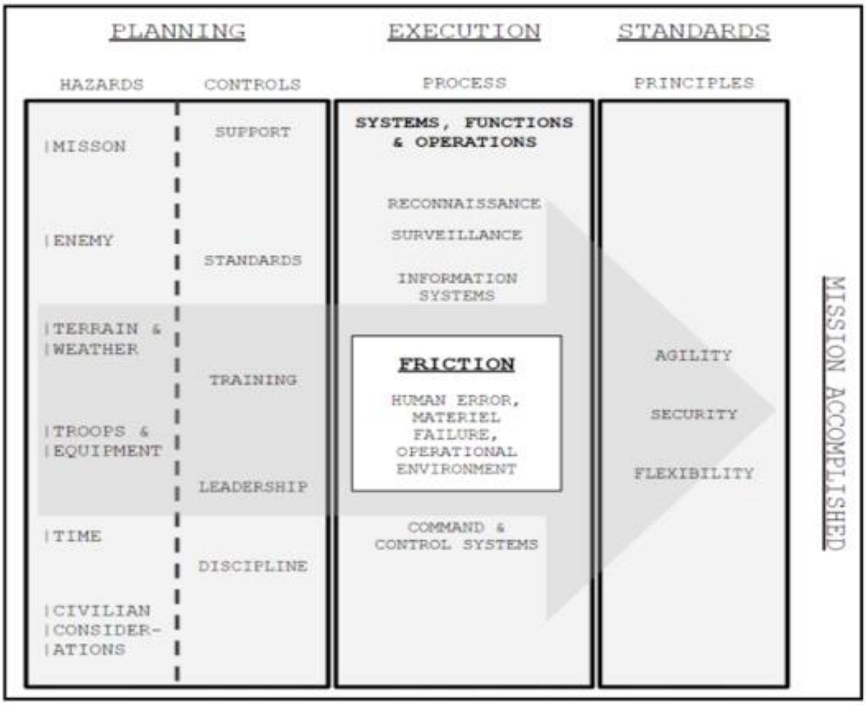


Figure 2. Military Decision Making Process (MDMP) Matrix, adapted from [49]

However, for all the experimentation and the changes that were made to OPORDs in the 20th Century, all "adhered closely" to Swift's original format (see Figure 3) [16]. Further, virtually all military OPORDs identified by meta-analyses from Fort Leavenworth during the Cold War appear to cohere to the requirement that the following items be addressed:

1. The commander's intent.
2. What limiting or controlling factors must be observed.
3. What resources and support have been allotted. [4,16,18]

		Traditional Field Order	Roman Sentry Order	Swift's 1897 OPORD	US WWI OPORD	US 1940 OPORD	US BN. Attack OPORD	US BN. Defend OPORD	US Adapted Vietnam OPORD	IDF OPORD	1988 Soviet OPORD	US Modern SPO	Heilmeier Catechism	Facilitator's Catechism
Items Included in Format	**Mission (0-5)**													
	Mission (Desired Outcome)	3	0	3	3	4	4	0	5	5	4	5	5	5
	Milestones for Gauging Success	0	0	0	0	0	0	0	0	0	0	0	5	5
	Purpose of Mission (Impact of Outcome)	0	0	0	0	0	0	0	0	5	0	4	5	5
	Exit Strategy	0	0	0	2	3	1	0	5	1	1	1	0	3
	Affordances (0-5)													
	Situation Details	1	0	4	4	4	4	4	4	4	4	4	5	5
	Logistics Details	0	0	2	5	4	4	4	3	3	3	4	4	2
	Available Operations Support Details	0	0	1	5	3	4	4	2	4	4	4	0	3
	Administrative and Command Details	0	0	4	5	4	4	4	3	4	4	4	0	4
	Communication Instruction (Signal)	1	5	2	5	4	4	4	3	4	3	4	0	4
	Delegation (0-5)													
	Dictates Execution and Method	4	5	2	5	4	4	4	1	2	4	4	5	2
Attributes of Format	**Attributes (0-3)**													
	Lends Itself to Post-Operation Review	0	3	1	1	1	1	1	1	1	1	2	1	3
	Formalized via Doctrine or Publication	1	2	3	3	3	3	3	0	3	3	3	0	3
	Assumes Organizational Alignment at Issuance	3	3	3	3	3	3	3	3	3	3	3	3	0
	Versioning Compatible	0	0	0	0	0	0	0	0	0	0	2	0	3
	Assumes Team Composition at Issuance	3	2	3	3	3	3	3	3	3	3	3	2	0
REF	Citation	[3]	[9,11]	[3,23]	[3,34]	[4]	[3]	[3]	[3]	[3]	[3]	[1,43]	[98]	n/a
	Appendix section	n/a	n/a	A	C	D	E	F	H	J	I	G	K	L

Comparisons of OPORDs

Items Included in Format

0	not included
1	not generally included, not included as part of doctrine
2	generally included but as subcompartment or unemphasized
3	generally included
4	strictly included
5	strictly included and emphasized

Attributes of Format

0	Format does not have attribute
1	Format does not lend itself to gaining attribute
2	Format has attribute to some degree
3	Clear indication attribute was desired during design

Figure 3. Comparisons of OPORDs

Impact on Organizations

Here we consider the functional features of OPORDs (high reliability, fault tolerance, goal-seeking) in terms of how they are deployed in High Reliability Organizations (HROs) and other complex systems in nature that consist of a massive number of interacting subunits. HROs such as militaries, are organizations that are characterized by their interactions with Complex Threat Surfaces, or threat surfaces which produce non-linear impact if exploited and require non-linear or adaptive defenses [44]. HROs earn their name from maintaining reliable performance and resilience in environments where small errors can create cascading effects and catastrophe [15,60–65]. Given the nature of the environments HROs operate in, there is pressure on these organizations to adapt and develop best practices for handling the myriad of external and internal threats to reliable performance, consequently, they are frequently used as the subject of case studies done in the interest of making these best practices accessible to other organizations [15,60–68]. HROs often converge on the same best practices independently when adapting to environments with similar threats and pressures [15,44], thus it is not coincidence that modern OPORDs appear to cohere to similar standards.

All reflexive systems, at the scale of both organisms and organizations, require ongoing recalibration to survive and thrive. HROs must make these recalibrations consciously [15] and at a rapid pace with limited information in order to update processes and technology to maintain reliable performance [5]. In this cybernetic framing, OPORDs help HROs navigate several interconnected key areas of tradeoff, common to all reflexive systems, to facilitate successful action amidst uncertainty.

EXPLORE-EXPLOIT

"Explore-Exploit" [69,70] refers to the axis of strategic variation related to the adventurousness of the system. Exploratory behavior, or global search, is a broad search through functional and non-functional regimes. Exploitative behavior, or local optimization, is a more narrow search mode based upon the incremental improvement afforded by considering system states close to the current solution. The statistical regularities of the ecosystem and niche are what dictate the success, literally the fitness of a given optimization process [71]. At the scale of the individual, this tradeoff can be anecdotally described as: "sticking with an old favorite ensures a good meal, but if you are willing to explore you might discover something better" [72]. At the scale of the organization, failing to allow experimentation and ingenuity in order to optimize exploitation based on current understanding of system state will leave operations fragile and stagnant in changing environments [15] whereas allowing too much freedom to explore may result in "misadventure" [4]. Approaches such as cybernetics & active inference seek to finesse the explore-exploit tradeoff space through informed action and experimentation [70,73]. As the dimensionality and ruggedness of the performance landscape increases, deep or generative methods become increasingly important [74]. OPORDs help organizations balance this tradeoff by allowing for rapid alignment on clear goals and situational details, which expedites sensemaking and provides a constraint on exploitation (objective) that acts as a constraint on exploration (situation and approach) [4].

LEARN-PERFORM

Information-processing systems must be able to learn and rapidly adapt their models of the world in response to real time observations, and then reliably perform work and act based on these models. Pedagogical literature informing IO psychologists and educators defines learning as the changes to cognitive structure [75,76], and performance as the measurable outputs of behavior relevant to the system of interest [75,77]. Optimization of the learning processes do not necessarily increase in performance metrics and significant changes in performance do not necessarily create learning outcomes [75], creating a learn-perform trade-off for systems to manage. OPORDs provide constraints for learning in the same fashion that they do for exploration, by providing performance requirements as a constraint on operations, but they also provide opportunities to bridge the gap between learning and performance by providing a tool for post-mortem analysis [4]. If the OPORD clearly defines the goals and performance outcomes, then it can be used in post-operation analysis to inform learning that is tied directly to performance.

TOP DOWN-BOTTOM UP

Topologically, distributed systems can have a centralized “hub-and-spoke” structure, a small world architecture with both local and global connections, a sparse or dense local connective structure, or other types of patterns. Multiple kinds of descriptors for static and temporal graphs exist, capturing different aspects of their structure such as the connectedness distribution, PageRank, and semantic similarity [78,79]. Commonly described in graphical settings is a system’s patterns of “top-down” vs. “bottom-up” information processing and decision-making. “Top-down” can refer to information and directives that descend through a managerial hierarchy, or from more abstract areas of cognition into more concrete realizations. “Bottom-up” can refer to systemic changes that are driven by inputs and adjustments from the smallest or most numerous sub-components of a system, for example ant nestmates in the colony or cells in the brain. Collective behavior refers to the properties of interacting system subunits, accounting for the networks of influences that shape group outcomes [80,81]. Collective behavioral systems need to integrate top-down and bottom-up information streams in order to succeed (e.g. not rely too heavily on sensory input nor on preconceptions about the world).

Historically, OPORDs in the military have not provided bottom-up flexibility due to the limited ability to communicate rapidly [4,82]. With the advent of remote and asynchronous communication, OPORDs have emerged in the gray-zone between military and civilian domains that provide some freedom from strict hierarchical control, such as the Heilmeier Catechism—where the parent organization (Defense Advanced Research Projects Agency, DARPA) gives general guidance on a problem and some situational details and the sub-organization (the research team) writes the OPORD and sends it back to the parent organization for approval [4].

The active inference framework deals with how multiscale systems simultaneously enact policy while also updating their internal model of how policy decisions are related to future outcomes [5,83]. Thus active inference reframes and re-navigates some of the tradeoffs mentioned above, such as explore-exploit [73], learn-perform [74,84], and top-down vs. bottom-up [85]. For example, by seeking to experiment in ways that optimally inform the organism, complex long-term policies can be implemented by agents with deep generative models of the world [74]. Active inference emphasizes the role of in-the-loop informative experimentation by system, as guided by their deep generative model. Under active inference, systems act not to maximize their estimated reward at current or future timepoints, but rather engage in sensemaking and policy selection in order to optimally reduce surprising observations in the future—systems that fail to do this (e.g. systems that are continually surprised about key predictions) will soon cease to exist.

As information-innovation ecosystems worldwide become exponentially more complicated and technical, forming teams require well-designed interventions and scaffoldings. Operation Orders (OPORDs) are one such intervention. This modern increase in operational complexity for startups and other small teams is enabled by access to online and remote collaborators, an affordance that military and non-market-facing organizations have been optimizing for decades. Such organizations use OPORDs to communicate about proposed or mandated projects. Changes in technology are associated with changes in the norms and formats of OPORDs in military contexts [4], and arguably the same relationship between technological advances and logistical innovations exists in the business domain. To highlight domains of function interface between market-facing and non-market-facing operations orders, below we trace the history, educational systems, and uses of business-related OPORD-like frameworks and documents.

Business Operations Orders

Like any organization, a business needs to coordinate the activities of its various departments to ensure it reaches its desired goals. Most commonly the overarching goal of a commercial enterprise is to maximize shareholder value [86] but business organizations must also consider other aims as well (e.g. as a public-good corporation, hackathon, etc.). One of the earliest examples of detailed orders to a commercial enterprise is the instructions to the Virginia Colony from the Court of King James in 1606 [87]. The instructions accompanied the official charter that established the colony, which was more concerned with the size of the land grant and rights of the stockholders, including issues of governance and inheritance. The instructions themselves included several practical details, such as selecting a site, dealing with inhabitants, and how to explore the country. For instance:

> *"When you have discovered as far up the river as you mean to plant yourselves, and landed your victuals and munitions; to the end that every man may know his charge, you shall do well to divide your six score men into three parts; whereof one party of them you may appoint to fortifie*

> *and build, of which your first work must be your storehouse for victuals; the other you may imploy in preparing your ground and sowing your corn and roots; the other ten of these forty you must leave as centinel at the haven's mouth. The other forty you may imploy for two months in discovery of the river above you, and on the country about you" (para 6)*

Unlike later military OPORDS, these instructions were not structured into a standard set of paragraphs. The business world would have to wait until the early 20th century to see some formalization start to arise in its approach to operational instructions.

The first undergraduate degree in business was established at Wharton in 1881, followed later by the MBA program at Harvard in 1908 [88]. The advent of the railroad and telegraph had greatly expanded the size and scope of enterprises leading to the establishment of a managerial class to coordinate operations [89]. Business degrees were created to educate this new elite [90]. By 1920, Harvard had established a required course in business policy in the second year of its MBA program focused on the problems faced by top managers [88]. Senior managers brought examples of problems they were facing to class, with students preparing recommendations, and the managers critiquing the proposals. Students were expected to generalize a set of approaches (or policies) from the examples presented. By 1951, the curriculum had morphed into a set of cases that focused on sizing up a situation, planning a program of action, organizing personnel and putting plans into action, and control/re-appraisal [88,91]. Scholars have attributed this development, in part, to exposure to military planning techniques during the Second World War [90] and there are clear parallels between the textbook process and military OPORDS, as well as between these developments and the development of the OPORD itself.

The 1960s represented a golden age for the strategy industry. Business schools started teaching SWOT analysis, several seminal books on corporate strategy were published, a majority of corporations established strategic planning departments, strategy consulting firms were founded, and computer models were developed to optimize profits [90]. Corporations routinely forecasted financial outcomes up to twenty years into the future. The flaws of this approach were exposed during the oil crises of the early 1970s when oil prices soared along with inflation. Carefully crafted forecasts were thrown into disarray leading to a call to embrace uncertain futures through tools such as scenario planning [92]. Learning and adaptation became more important than predicting the future or creating inflexible plans [93]. Some even advocated eliminating uncertainty by actively seeking to shape the environment [94].

Mintzberg [93] has argued that strategic plans are a form of strategic programming that coordinate the various functions of the organization once a creative strategy (or vision or direction) has been selected. In his view, a staff of planners are structurally incapable of creating novel strategies as they are typically removed from the realities of the day-to-day business. "Formal procedures will never be able to forecast discontinuities, inform detached managers, or create novel strategies" (p. 111). However, once given a strategic direction, the planner-as-programmer can develop the operational implications of the approach for the organization.

Mintzberg [93] goes on to divide strategic programming into three components, codification, elaboration, and conversion:

> **Codification** means converting a broad vision into operational terms. For instance, a strategy to offer more online offerings lacks specificity for operational managers. Planners can break this down into specific objectives for various units such as growing online sales by 5% per annum or to 30% of total sales within 5 years.
>
> **Elaboration** means breaking down these objectives into the specific tasks and actions that must be undertaken to realize the objectives. For instance, warehouse space might need to grow to house online inventory. Some parts of the organization must be tasked with growing warehouse capacity

and planners can outline the timing and resources required to do so. Elaboration is the task of providing action plans to organizational units and is most analogous to military OPORDS.

Conversion means updating the organization's policies and procedures to reflect the new strategic direction. For instance, an online strategy has implications for payment, shipping, and return policies that might be quite different from the policies in place for brick-and-mortar operations. Part of making a strategy 'stick' is to remove the frictions created by outdated or missing policies for a new situation.

PLANNING FOR STARTUPS

Startups, like other kinds of teams, can be formally planned or emerge informally in response to factors such as common threats, interests, and opportunities [5,14,44]. Forming startups are not just learning about a sector or skillset, they are also learning about each other as teammates, and about the team as a collective entity. Ontologies, Narratives, Formal documents, and Tools (ONFT, [5]) can be used as a basis for interventions and as a framework to model the process of team "forming, storming, norming, and performing" [95]. Successful startups are able to blend learning and performing (e.g. during a pivot, sprint, or hackathon/collabothon), suggesting that a valuable domain of research would be in understanding the interwoven dynamics of team development (learning) and productivity (performance).

The startup community has not been immune to the fashions and fads of planning in the corporate environment. The Small Business Administration (SBA) was created in 1953 with the ability to issue or guarantee loans for small businesses. It is not clear when the SBA first required a business plan to be submitted with a loan application but it seems the practice was widespread by the 1960s [96]. As such, the requirement for a business plan mirrors the growth of formal planning techniques during the 1950s and 1960s. The current Code of Federal Regulations (13 CFR § 120.191) still requires applicants to provide a business plan for an SBA loan (see Appendix A for a business plan outline).

Perhaps in response to this institutional pressure from the SBA, it became fashionable to require a business plan in other startup settings. Venture capitalists emerged in Silicon Valley in the 1960s and started requiring business plans [96]. As entrepreneurship courses started to gain in popularity in the 1980s, the business plan became a central feature of the program with 78% of business schools requiring a business plan as part of their entrepreneurship major by 2004 [97]. Textbooks also emphasized business plans, specialized business plan writing software emerged, and business plan competitions became popular.

Unfortunately, there is very little evidence that having a (good) business plan improves the performance of a startup [97]. Although there is some evidence that a business plan assists in raising external funds, there is virtually no correlation between the quality/quantity of a plan and performance [98]. In fact, entrepreneurs report they rarely review or update their plans once they have been written and the majority of founders on the Inc 500 list of fastest growing companies report spending more time on informal than formal plans [99]. This aligns well with Mintzberg's [93] insight that formal planning may, in fact, hinder strategy making and creativity rather than enhance it.

The growing disenchantment with business plans led to a new movement in the startup community focused around business models rather than business plans. Every military strategist is familiar with von Moltke's famous dictum that "no plan of operations extends with any certainty beyond the first contact with the main hostile force". Steve Blank [100,101] paraphrased the statement for the startup community as "No business plan survives first contact with the customer".

Blank first started teaching customer development at UC Berkeley in Fall 2004, arguing that startups needed to "get out of the building" and test hypotheses about their assumptions with real customers. Blank's work was amplified by developments in design thinking that encouraged entrepreneurs and innovators to empathize with customers through observation and interaction and then ideate on a range of possible solutions which could then be tested [102].

Eric Ries, a student of Blank, later released The Lean Startup, which further popularized the approach by combining customer discovery with agile development principles [103,104]. The lean startup approach encouraged entrepreneurs to create a minimum viable product (MVP) that could generate revenue as fast as possible and then introduce new features over time (rather than the traditional approach of developing a fully-fledged product before launch). Entrepreneurs were encouraged to fail fast and 'pivot' away from approaches that were unpopular with customers before they ran out of cash (or 'runway').

Around the same time, the first business model canvas was published [105]. A business model canvas replaces a 25-page business plan document with a single page that summarizes the overall plan in a series of categories placed in boxes on the page. The original Business Model Canvas (BMC) divided the page in nine categories: revenue streams, cost structure, value proposition, customer segments, customer relationships, channels, key activities, key partners, and key resources (see Appendix B). Since 2010, a number of other canvases have been proposed including Maurya's [106] Lean Canvas (see Appendix C). The Lean Canvas adds problem, solution, and unfair advantage to the mix by removing key partners, activities, and resources. In doing so, it challenges the entrepreneur to acknowledge existing solutions and how the startup intends to be better than the competition.

Entrepreneurs are now encouraged by leading entrepreneurship educators to combine a business model canvas with the hypothesis testing approach of Blank [100] and Ries [103] to confirm assumptions in the business model. For instance, an entrepreneur might assume that customers are willing to pay $10 a month for a streaming subscription service. However, after demonstrating a prototype to a group of target customers, the feedback might suggest that $5 per month is a more realistic number. Drawing an analogy to science, the entrepreneur's assumptions are like hypotheses that are tested through carefully-designed experiments and analysis. In science, as in entrepreneurship, experiments should be designed to be informative and actionable, whether the results conform to or challenge prior expectations. Entrepreneurs test the biggest assumptions first then alter the BMC in response to customer (and other stakeholder) feedback. The iterative approach ensures that entrepreneurs build products that people want and do not waste time building features and products that will flop once they hit the market. As such, Blank [101] describes a startup as "a temporary organization designed to search for a repeatable and scalable business model". Scaling a company should only occur after a sustainable business model has been validated.

Osterwalder and Blank have also extended the BMC to organizations that do not have revenue, such as government agencies in the defense and intelligence spaces [107]. In this case, revenue is replaced with mission achievement (or impact). Four other tweaks were also made: customer segments are changed to beneficiaries, cost structure is changed to mission cost/budget, channel is changed to deployment, and customer relationships are changed to buy-in/support. The resulting framework was christened the Mission Model Canvas (see Appendix D). The Mission Model Canvas is an example of the productive and bi-directional flow of organizational practices between market-facing and non-market sectors.

The business model canvas enables an entrepreneur to communicate the general thrust of a new venture to a group of stakeholders in a consistent and parsimonious manner. Investors do not have to wade through pages and pages of prose that is often based on very little hard evidence. This frees up time to discuss the general viability of the offering and the assumptions underlying its success. As data is collected and assumptions are updated then the canvas can also be easily modified in real time. Using the canvas to test a set of assumptions also makes everyone in the organization clear on the roadmap from launch to success (or failure).

OPORDS are primarily about coordination. Innovation coordination is more important in a large organization than a startup (which might only comprise one team). However, even in a startup environment, there is still a need to coordinate actions with other stakeholders, particularly investors. The Business Canvas model is not usually prepared for external consumption. Additionally, there can be a tendency to use the Canvas a vision board or incoherent bricolage, rather than a strategic springboard.

RECENT THINKING ON INNOVATION MODELS

Current perspectives on entrepreneurship include several new topics that will be discussed here. Many of these changes to startup logic and practices have arisen due to technological advancement and changes in the innovation/market ecosystem. Fundamentally these approaches are all approaching startups with a lens of increased early integration and coherence. This need for an "Innovation Stack" was well-justified in a recent work by McKelvey: "The problem with solving one problem is that it usually creates a new problem that requires a new solution with its own new problems. This problem-solution-problem chain continues until eventually one of two things happens: either you fail to solve a problem and die, or you succeed in solving all the problems with a collection of both interlocking and independent innovation. This successful collection is what I call an Innovation Stack" [108].

Recently Blank has promulgated an "Innovation Doctrine", emphasizing clarity on areas such as context, leadership, innovation pipeline, ambidexterity [109]. Blank's development from the Business Canvas to the Innovation Doctrine can be seen as a movement upstream in the startup's causal chain – a movement from scaffolding the semantic content and graphical layout of a 2D artifact, to augmenting the kind of doctrine or policy that a startup might adopt, regardless of their use of a canvas or other tooling.

One integrative project in the space is the DLS Methodology (DLS being derived from combining Design thinking, Lean startup, and Scrum) [110]. Another more holistic modern approach to the startup process is the NABC (Needs, Approach, Benefits relative to cost, and Competition) model [111].

Gray Zone Operations Orders

Today, Instantaneous Remote Teams find themselves in the gray zone between market facing and non-market facing domains. Recent developments to OPORD-like documents have occurred in the gray zone between market-facing and non-market-facing domains. George Heilmeier, while serving as the director of the Defense Advanced Research Projects Agency (DARPA) in the 1970's, introduced a "catechism" that has acted as a novel form of OPORD for research teams [4]. Catechisms are, traditionally, a set of questions with predefined answers that act as a basis to solidify religious narratives. Heilmeier's innovation on the catechism was to allow teams to define their own answers to a set of questions related to the research they intended to pursue to generate an OPORD-like document that also acted as a "pre-flight safety checklist" prior to funding. The Heilmeier Catechism format allowed for established teams to distill their mission, situation, and approach in a standardized fashion and then present it to DARPA for approval. Additionally, this format changed the nature of OPORDs by allowing for bidirectional (bottom-up and top-down) informational propagation, by virtue of the call-and-response structure.

The recently introduced Facilitator's Catechism [4] builds on the Heilmeier Catechism in several key dimensions, taking advantage of modern affordances and recognizing contemporary challenges inherent to today's informational ecosystem. Unlike the Heilmeier, the Facilitator's Catechism does not assume fixed team composition or approach at the outset of the project. This flexibility is important for all-online teams, teams with rapidly changing composition, and teams with AI actors. The Facilitator's Catechism introduces the idea of versioning from computer code (e.g. GitHub), which allows the document repository to be a living single source of truth for the project and team. The Facilitator's Catechism can also act as a call for collaborators. The Facilitator's Catechism was written with research- or deliverable-based teams in mind, working in areas that are indirectly market-facing (e.g. grant-funded research). The Heilmeier Catechism introduced a new informational affordance by improving the interface between project funders and proposed research projects. The Facilitator's Catechism builds on this catechism-mediated interfacing of people, projects, and funding with an eye towards unconventional and rapidly formed teams (e.g. during emergencies or hackathons).

The Future of Business OPORDs – What is still needed:

As noted, development in Business OPORDs is oriented towards increasing clarity and success in uncertain or changing contexts. There are several areas, listed here, where current business OPORDs might be made more effective or flexible, drawing from emerging and best practices in HROs, global innovation, and instantaneous online teams.

Notably, there are complementary sets of insights into OPORD design that come from market-facing (business) and non-market-facing (e.g. military) perspective. Across situations and sectors, teams must assess their situation and find successful policies of experimentation, so a variety of practices have converged on asking about the essential features of a team's situation. Figure 4 shows the interfacing of a market-facing OPORD-like document (left side, Lean Canvas) and non-market-facing OPORD (right side, Facilitator's Catechism) via shared areas of focus (center column). This alignability across OPORD formats will return later in the advanced rendering capacities of the Innovator's Catechism.

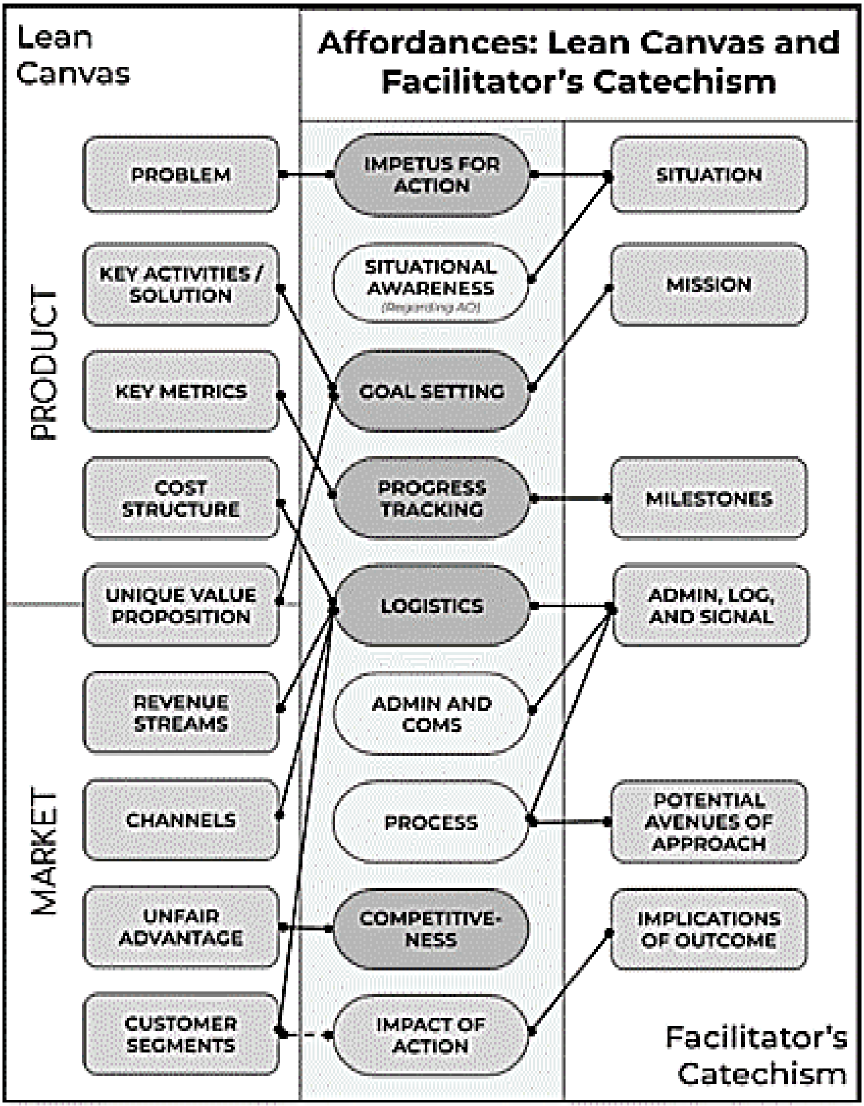


Figure 4. Affordances of the Lean Canvas and Facilitator's Catechism

Currently, organizations are looking across dimensions and sectors to find emerging and successful practices related to innovation, especially in the global and online settings. Small organizations (such as hackathon teams, or startups) are finding value in using computational tools of the kind that larger organizations use as well (e.g. GitHub, CRMs, Cloud services), which facilitates scaling and onboarding. Large organizations of all kinds are looking to small, creative teams within and outside of their ranks (e.g. freelancing, citizen science, working groups) to produce innovation. In the modern entrepreneurship ecosystem, as described above, the trend has been towards increased early-stage systematization, integration across domains and through time, and emphasis on clarity of mission. With all these recent advances in mind, and an eye towards the subsequent introduction of the Innovator's Catechism, we list several areas in which business OPORDs could be further improved:

1. There is no reason that Agile techniques can't be applied to the design and testing phases (not just the build phase). Sprint plans are OPORDS. They are also examples of a time pacing strategy [112]. The pacing and rhythm of business OPORDs is similar to operational tempo in military settings.
2. Versioning systems, usually used to share and annotate code, could help emergent teams build documentation from the beginning of their collaboration,
3. Advanced rendering capacities for reconfigurable visualization could reduce "work about work" by facilitating the rapid preparation of pitch documents, slides, and canvas models.
4. Different renderings (e.g. slides, canvas) of formal documents could be useful to build Rules of Engagement (pre-authorized actions) on hiring, spending etc., maintain values and mission documents.

5. When OPORD frameworks are ill-defined or contain spurious/abstract questions, teams can spend too much time on informal preparation/polishing, and not enough time on the project/development itself.
6. Complexity motivates novel approaches to entrepreneurship [113–115]. emergent startup and the landscape of affordances of different kinds.
7. While "get good feedback & do the most informative experiment" is often given as qualitative advice, this principle is not formally integrated into Business OPORD or presentation formats. This notion of optimal experimentation could be developed using active inference, a multiscale Bayesian framework for action, learning, and development [5,116].

The Innovator's Catechism

Here we present the "Innovator's Catechism" (IC). The conception of the IC began with the question: "What would need to be adapted within or added to the Facilitator's Catechism to make it more useful to early-stage teams in hackathons, working groups, short-term committees, citizen science incubators, and similar groups?" The IC was then constructed by considering both the value offered by the Catechism-styled OPORD, "The Facilitator's Catechism" [4], to organizations while expanding and improving upon previous approaches to systematic improvement of start-up processes and organizational performance in general to acknowledge the unique requirements and limitations of the early-stage innovation and entrepreneurship teams, allowing for its use to reduce "work-about-work" [117] and increase likelihood of success, especially where:

- The team will need to rapidly render information about their objectives and approach to a variety of formats to communicate to external or parent organizations prior to work or in order to secure resources or provide situational awareness at various stages of their development.

- The information requirements and limitations at different stages of progress vary greatly, creating situations where no single, traditional OPORD would be appropriate at every stage.
- Team and project success are market-facing (as opposed to the non-market-facing team settings considered by the initial version of the Facilitator's Catechism).

The IC has affinity on several dimensions with OPORDs in the military and high-reliability space, as well as direct mappings to the state-of-the-art practices in entrepreneurship, and uses the same sections as the Facilitator's Catechism: (a) Header, (b) Situation, (c) Mission, (d) Potential Avenues of Approach, (e) Milestones, (f) Administration, Logistics and Signal, and (g) Footer with one exception, as Implications of Outcome has been replaced with Cost and Benefit. However, the IC is unique among OPORDs in that its questions and format are dependent on the team's position in an innovation pipeline, creating what could be considered a "family" of catechisms in which new questions are added and old ones are updated or expanded upon as the team progresses through each stage. At each stage, the questions asked of the team are only the ones that provide the key pieces of information necessary to ensure success and communicate status given the nature of the current objectives and best practices (see Figure 5). For example, at the Ideation stage, a team should not prioritize considering a revenue model, but at the Pitch stage, a team that has not yet considered a revenue model should not be pitching. The information points produced by the questions also serve to align the team, provide constraints to prevent failure, and can be rendered to numerous formats. Below, the Innovator's Catechism is detailed by stage, with Header and Footer discussed separately, as they remain unchanged throughout.

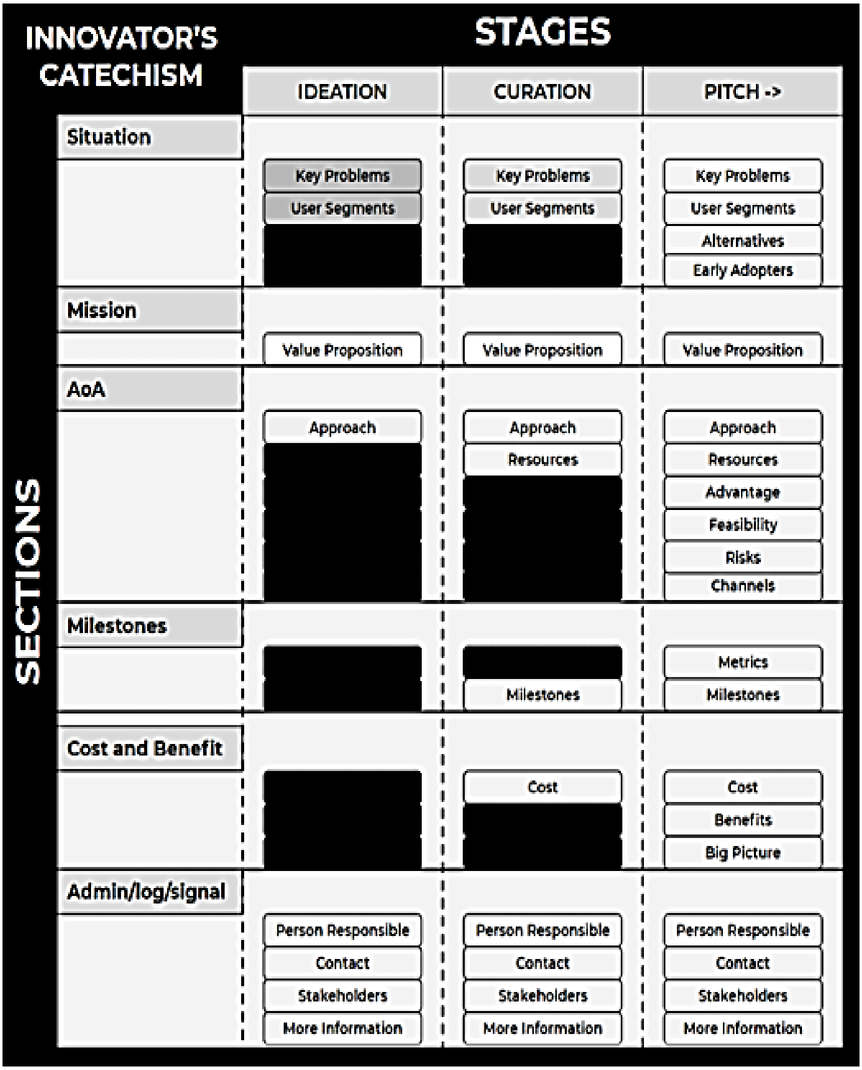


Figure 5. Information Requirements by Stage

The Header section of the IC is included at the very top of the document, providing a section for key details about the project that should be immediately available to any interested party (Project Name, Team Name, Person(s) Responsible, Contact Information, Start Date, etc.). The Header section of the IC includes key elements from the Facilitator's Catechism but rejects others. For example, due to the nature of an entrepreneurial team and the expectations of continuity, "Date of Completion" and "Call for Collaboration End Date" are removed, as is the recommended "Project Callsign". A Team Name might be the company name, but even if the team is emergent, creating a team name separate from the task at hand provides an anchor for development of organizational culture and "esprit de corps" [5,12,118–120]. The "Date of Announcement", which is a more useful wording for the kinds of research projects for which the Facilitator's Catechism was created for, is rephrased as a more general "Start Date" to provide an initial start date for the current stage as well as give context for expectations of current progress.

The Footer is included at the bottom of each page and it is recommended that it provide the current version of the IC format in use, preferably with a hyperlink to the repository where the version specification is held. In addition, if the document is going to be shared outside the context of a framework that provides versioning details, such as GitHub, it is recommended that the footer also contain a note regarding the current version of the team's IC with an embedded hyperlink to where other versions are held.

Stages

In the context of the Innovation pipeline [121], we can partition the startup's journey as occurring through a sequence of stages:

1. Ideation
2. Curation
3. Pitch
4. Exploration
5. Incubation
6. Integration

The pipeline is the representation of the ideal journey from the early-stage recognition of a problem, to the integration of a solution to that problem into the market—or, in the case of non-entrepreneurial innovation teams, integration into the organization. Each stage is represented by its own clear mission, best practices, and information requirements, all of which are meant to lead to outcomes that carry the team to the next stage (see Figure 6).

IDEATION STAGE

At the Ideation Stage, a group has formed around the acknowledgement of a common problem. Regardless of context, the mission is simple: generate a potential innovative solution to this problem. In order to do this successfully, they must clearly define the problem and who it affects, as well as choose an approach with constraints in order to increase the likelihood of success. Approaches revolve around deep questioning related to the problem through methods such as empathizing and narration, placing the team in the shoes of the users, as well as mind and flow mapping, allowing the team to make the problem observable. The IC at this stage asks few questions, only what is necessary to begin Ideation and inform potentially interested parties as to what is being pursued, who is responsible for the project, who the stakeholders are, and how to contact the team (see Figure 7).

	IDEATION	CURATION	PITCH	EXPLORATION	INCUBATION	INTEGRATION
MISSION	Create an innovative solution to a problem	Demonstrate novelty and need	Raise Seed Funds, Acquire a budget	Test Assumptions	Create product for use	Place product into production
BEST PRACTICE	Empathizing, Narration, Paper Prototyping, Mind Mapping	Market survey, Competitor Analysis	Canvas, Slide Deck, NABC, Heilmeier Catechism	Hypothesis Testing, Iterative Development of MVP	SRS, Project Plan	AGILE, SCRUM, Licensing, Alliance, Acquisition
OUTCOME	Promising Idea(s)	Compelling use-case(s)	Communication of need and potential for ROI, Acquire Resources	Validated business model or model of potential impact	Clear plan to place product into production	Production

Figure 6. Innovation Pipeline Matrix

SITUATION	1	What are the key problems the group has been formed to address?	→ Key Problems
	2	Who is affected by these problems?	→ User Segments
	3	What alternative solutions already exist? Why are they inadequate?	→ Alternatives
	4	Who is actively looking for a competitive edge in handling these problems, most affected by the inadequacies of the available alternatives, and flexible in adopting new solutions?	→ Early Adopters
MISSION	5	Given the situation, in clear terms with no jargon, what is your objective? What value do you aim to provide?	→ Value Proposition
POTENTIAL AVENUES OF APPROACH	6	Given the situation and mission, what are the potential avenues of approach?	→ Approach
	7	What resources are required? Which do you need? Which do you already have?	→ Resources
	8	What unique advantage is offered?	→ Advantage
	9	What are the risks?	→ Risks
	10	Given the advantages offered and the risks present, what is the feasibility? Why is this project likely to succeed?	→ Feasibility
	11	What channels will be used to introduce users to the value you intend to provide?	→ Channels
MILESTONES	12	What metrics can be used to track success and measure impact?	→ Metrics
	13	What are the milestones that best indicate progression toward success? When are they expected to be completed by?	→ Milestones
COST & BENEFITS	14	What are the costs associated with providing the intended value?	→ Costs
	15	What are the benefits of providing the intended value?	→ Benefits
	16	If successful, what else is possible?	→ Big Picture
ADMIN, LOG, & SIGNAL	17	Who is responsible for the project?	→ Person Responsible
	18	How should someone contact you?	→ Contact
	19	Who are the current stakeholders in the groups success? Is there a parent organization? Are there sponsors or investors?	→ Stakeholders
	20	Are there any documents, webpages, or repositories that provide more information about the project?	→ More Information

Figure 7. All Questions of The Innovator's Catechism

CURATION STAGE

The team enters the Curation Stage after it has successfully defined a problem, identified the groups of people it affects, and converged on a potential innovative solution. The mission is now to demonstrate the novelty of and need for this solution. At this stage, best practices include approaches like market research and surveys, competitor analysis, and use-case development, consequently, this stage has more information requirements than ideation. Prior to engaging in work, it's important that the team understand the potential costs for the approaches they choose, such as purchasing research tools or commercial intelligence products, and decide on clear milestones to prevent mission or scope creep. The Catechism now adds additional questions and asks for updates to those previously answered, as during this process the definition of the problem or the groups it may affect may have changed. Given that the approaches now become more complex and may take longer periods of time to achieve, the IC now asks for the key milestones that best indicate progress. For these same reasons and the potential for approaches that require a budget, the IC also asks for what resources may be necessary to commit to this work and the expected costs.

PITCH STAGE

At the Pitch stage, the team is now mature enough to define the mission that will carry it through the remaining stages: providing the value of the solution they developed during the Ideation stage and demonstrated the novelty and need for in the Curation stage, consequently, its primary objective is now to communicate this mission and acquire the resources necessary to pursue it. The team now needs to prepare to present its intents to external parties, in a collaborative setting (e.g. hackathon, incubator, or startup-weekend) the team may need to present their potential project to judges or the community, innovation teams within organizations will need to get support and a budget to continue, and start-ups have to acquire funding. This is a stage that any team may need to return to again and again on their journey toward successful integration.

The information requirements at this stage grow rapidly, and the IC now includes all questions (see Figure 7). In addition to all of the questions the IC asks in prior stages, the team must use what it has learned from the Curation stage to define the alternative solutions available, as well as the potential early adopters and the channels over which they will be reached. The team must also define the approach to their evolved mission, the provision of the solution they envisioned, rather than the approach to acquiring funding—to this end, they are asked to define the advantages and risks offered by the approach and the feasibility of success. In addition to milestones, they are now also asked for the metrics that would help measure impact of their solution and the success of the mission. The team now needs to update costs to include the costs associated with the provision of the solution (e.g. cost per user) and add the benefits the provision of the solution might provide (e.g. revenue, cost reduction). Finally, they are now also asked to provide the big picture, if the team were successful and the solution impactful, what would this mean? (e.g. an Airbnb for events, a YouTube specifically for cooking, this privacy solution for Government employees could also be useful in civilian markets).

The IC has the potential to offer a great deal of value to teams at this stage, contributing to informal and formal pitches in several ways. First, the IC can be rapidly rendered to the large variety of formats (e.g. canvas variants, Heilmeier Catechism, NABC) asked for by different organizations and the team may need to present to a large variety of organizations (see Figures 8 and 9, and Appendices E and F). Second, it allows the team to maintain fully-documented traces of their development as ICs' are versioned at different stages and filled out entering new stages, allowing the team to inform any presentations they create with a story. Third, it can act as a presentation document itself, as a stand-alone brief. Fourth, building on these other value-adds, it can be used to quickly create slide decks that include any of the helpful formats or use the questions as the narrative structure for their slides (see Appendix G). Lastly, it can be used to generate a straight-forward elevator pitch, brief, or abstract that communicates a straightforward narrative:

"These **problems** *are being experienced by these* **users**, *and these* **alternatives** *aren't adequately addressing their needs. Our* **mission** *is to provide this* **value** *to these* **users** *using this* **approach** *that (we have this* **advantage** *in providing)/(provides this* **advantage**). *It is* **feasible** *that we will succeed using this* **approach** *for these reasons, despite these* **costs**, *and these* **risks**. *Necessary to pursuing this mission are these* **resources**, *of which we still require: [needed* **resources**]. *Using this* **approach** *this group would likely be* **early adopters** *and we'd introduce them to the value we're providing using these* **channels**. *These* **metrics** *would be used to monitor the impact and these* **milestones** *would best indicate progress. These are the* **stakeholders**. *This is the* **person responsible** *for the project. This is how you* **contact** *the team.* **More information** *is available here."*

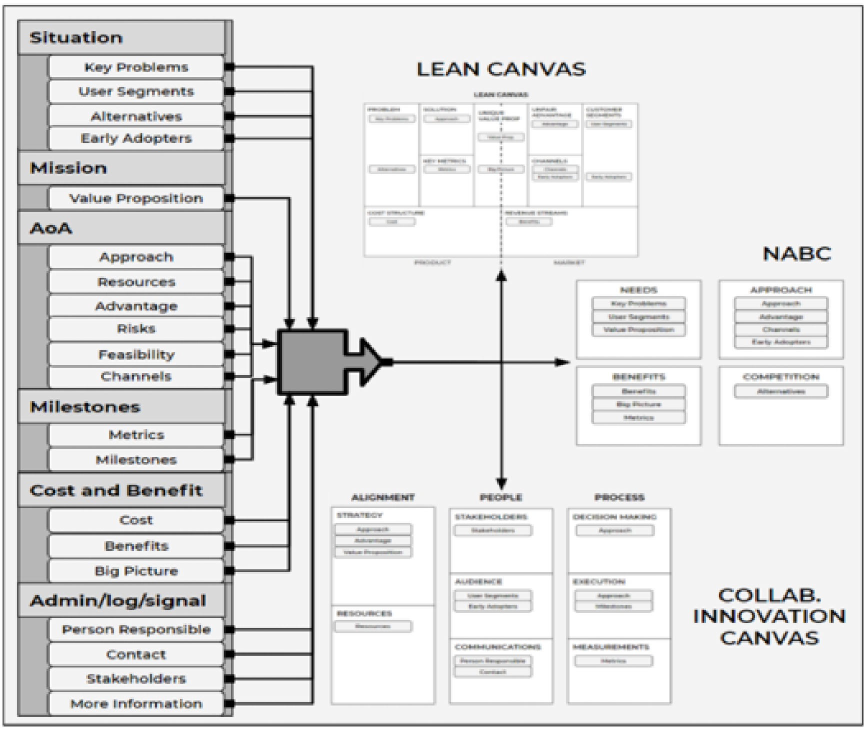


Figure 8. IC Rendering to Various Formats

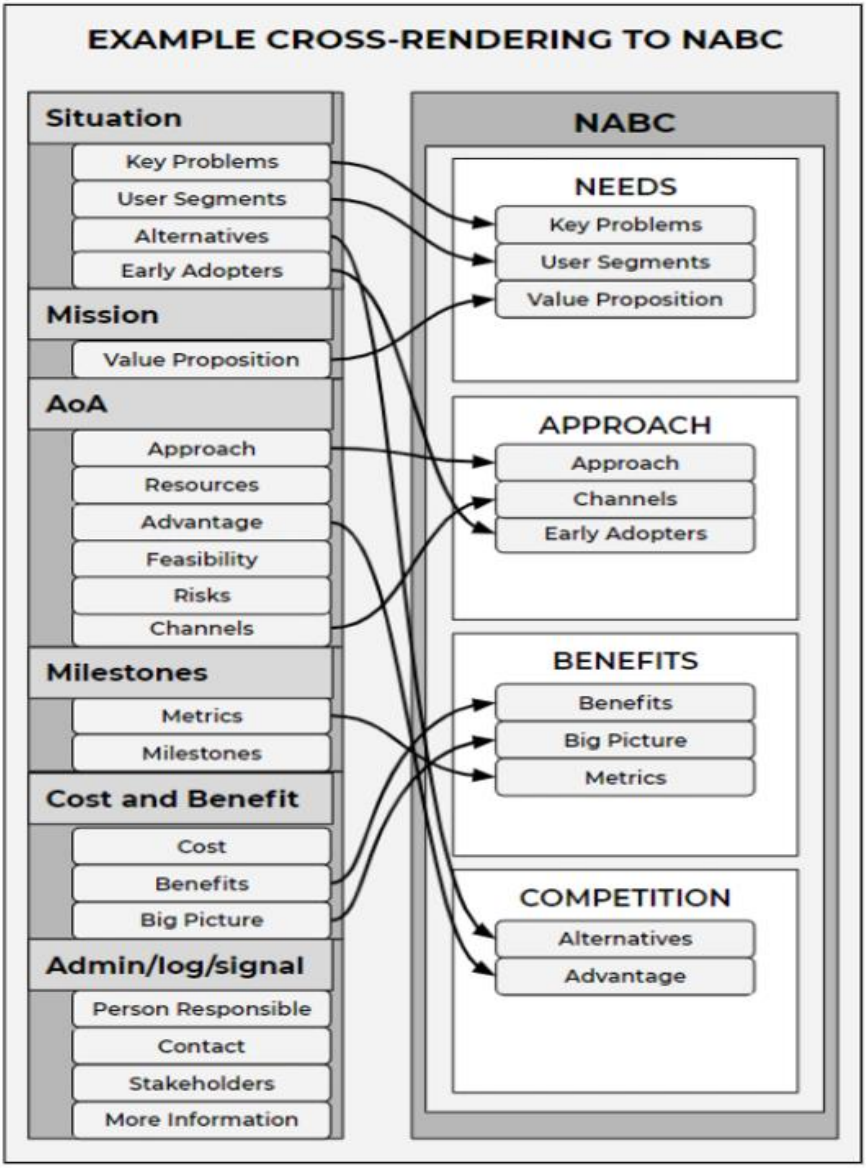


Figure 9. Innovator's Catechism Example Rendering to NABC

AFTER THE PITCH: EXPLORATION, INCUBATION, & INTEGRATION

The IC beyond the pitch adds no new questions or changes to format. Teams that have succeeded in progressing beyond the pitch will likely have to return it often and are now mature enough to exercise maximum freedom of choice. The "missions" of each stage beyond the pitch can now be reflected in the IC as milestones in pursuit of their larger mission. The team can now optimize function and update the IC accordingly so that when the next opportunity or requirement to return to the Pitch stage arises, they can rapidly communicate their current position, track record, and all other relevant information in the format required while reducing work-about-work—allowing them to focus on the mission itself.

Discussion

In this paper, we have reviewed the history, development, and impact of Operations Orders (ORORDs) in the context of state militaries, high-reliability organizations, and entrepreneurship and presented a modified Facilitators Catechism [4] that is specialized for early-stage innovation teams: The Innovator's Catechism (IC).

The IC has several characteristics that distinguish it from alternative approaches for facilitating development in early-stage startups:

> **Catechism Format.** Without clarity of mission, approach, and needs, an early startup may bear an unneeded risk of failure. The document ensures that the team has a clear single source of truth to align on and the questions lend themselves to prompting group discussion that has clear deliverables. The Question-and-Answer format of the Catechism also reduces the need for the supplementary material to ensure that it is being filled out correctly.

Narrative Development. The structure of the family of Innovator's Catechisms (see Figure 7) allows the team and external parties to consider the relevant dimensions of a business approach in the context of a developing narrative. In addition, stage-formalization with clear information requirements for progression clearly marks progress, giving the team a compressible and easily communicated history.

Versioning. Versioning helps the team have a history and identity. It can help when later assigning ownership, assessing reproducibility, and performing statistical analysis of team performance across settings. Versioning with a common format allows evaluation of team performance and development through time.

Modularity. The digital and structured input IC also allows for fluid reformatting into multiple formats (see Figures 8 and 9). This fluid reformatting allows for the rapid production of customizable presentations in a variety of formats such as canvases and slide decks (see Appendices E, F, and G) as well as to the Heilmeier and Facilitator's Catechism formats. This modular format also enables clear comparability between teams using the IC and between the team's expectations and later performance—offering clarity in post-mortem analysis.

These features of the IC, among others, have the potential to increase the efficacy of early-stage innovation teams by allowing the team to quickly communicate its ideas both internally and externally and focus on performance and process. The IC acts as the "pre-flight safety checklist" that Heilmeier prescribed, increasing the likelihood of success while also increasing the speed at which teams that are unlikely to succeed disintegrate by forcing them to reckon with the information requirements commensurate with their current stage of development [4]. The IC specification presented (Appendices H, I, and J) will be hosted using a GitHub repository [1] to allow for new variants to be tracked and versioned under a flexible license. It is recommended that the IC be used in hackathons, research accelerators, incubators, and other innovation related events and initiatives to greatly increase the observability, comparability, and likelihood of success of the work being performed. The design space of approaches for catalyzing healthy, productive, innovative online teams is vast, and the Innovator's Catechism is a first attempt at a catechism-styled OPORD specific to use-cases in this area.

[1] github.com/COGSEC/InnovatorsCatechism

Works Cited

Chapter I
Works Cited

1. Haberfeld MR, Hassell A, editors. A New Understanding of Terrorism: Case Studies, Trajectories and Lessons Learned. Springer, New York, NY; 2009.
2. PTI. Lashkar-E-Taiba Planned To Portray 26/11 Attack "Hindu terror": Ex-Mumbai Top Cop. In: https://www.outlookindia.com/ [Internet]. 18 Feb 2020 [cited 13 May 2020]. Available: https://www.outlookindia.com/website/story/india-news-lashkar-e-taiba-planned-to-make-2611-attack-look-like-hindu-terror-ex-mumbai-top-cop/347506
3. United Nations. The World's Cities in 2018. Statistical Papers - United Nations (Ser. A), Population and Vital Statistics Report. 2018. doi:10.18356/c93f4dc6-en
4. Marwaha N. 26 / 11 Mumbai Attacks: The Night India Won 't Forget - A Timeline. NDTV; 2017. Available: https://www.ndtv.com/mumbai-news/26-11-mumbai-attacks-anniversary-the-night-india-wont-forget-a-timeline-1779897
5. Kilcullen DJ. The City as a System: Future Conflict and Urban Resilience. Fletcher Forum World Aff. 2012;36: 19–39.
6. Rizvi S, Kelly JL. The continued relevance of the November, 2008 Mumbai terrorist attack: Countering new attacks with old lessons. Homeland Security Affairs. 2015;11. Available:

http://www.academia.edu/download/38271312/The_Continued_Relevance_of_the_November_2008_Mumbai_Terrorist_Attack_Countering_New_Attacks_With_Old_Lessons.pdf

7. Ministry of External Affairs India. Ministry of External Affairs India, Mumbai Dossier. Ministry of External Affairs India; 2009.

8. Burton F, West B. From the New York Landmarks Plot to the Mumbai Attack. Stratfor; 2008. Available: https://worldview.stratfor.com/article/new-york-landmarks-plot-mumbai-attack

9. Glanz J, Rotella S, Sanger DE. In 2008 Mumbai attacks, piles of spy data, but an uncompleted puzzle. In: New York Times [Internet]. 2014. Available: http://www.nytimes.com/2014/12/22/world/asia/in-2008-mumbai-attacks-piles-of-spy-data-but-an-uncompleted-puzzle.html

10. Rizvi S, Kelly J. The Continued Relevance Of The November 2008 Mumbai Terrorist Attack: Countering The Next Attack. Homeland Security Affairs. 2015;11. Available: https://www.hsaj.org/articles/4541

11. Spindlove JR, Simonsen CE. Terrorism Today: The Past, The Players, The Future. 4th ed. Prentice-Hall; 2010.

12. Tankel S. Storming the World Stage: The Story of Lashkar-e-Taiba. Oxford University Press; 2013.

13. Wirsing R. India, Pakistan, and the Kashmir dispute: On regional conflict and its resolution. Macmillan; 1998.

14. Fair CC. Lashkar-e-Tayiba and the Pakistani State. Survival . 2011;53: 29–52.

15. Kambere G, Goh PH, Kumar P, Msafir F. The Financing of Lashkar-e-Taiba. Combating Terrorism Exchange. 2011;1: 18.

16. Rotella S. Captured Militant Reaffirms Role of Pakistan in Mumbai Attacks. In: PBS Frontline [Internet]. PBS Frontline; 2012. Available: https://www.pbs.org/wgbh/frontline/article/captured-militant-reaffirms-role-of-pakistan-in-mumbai-attacks/

17. Dill E. Lashkar-e-Taiba: A Global Threat Today, a Threat to Pakistan Tomorrow. 2012 [cited 14 May 2020]. Available: https://apps.dtic.mil/sti/citations/ADA600455

18. Sen S. Heroin Trafficking in the Golden Crescent. The Police Journal: Theory, Practice and Principles. 1992;65: 251–256.

19. Haq I. Pak-Afghan Drug Trade in Historical Perspective. Asian Surv. 1996;36: 945–963.

20. Goodman M. The Business Of Illegal Data. Strata Summit 2011; 2011. Available: https://www.youtube.com/watch?v=6ueKilyThQg

21. Haberfield MR, Hassell A von. A New Understanding of Terrorism. Springer Science & Business Media; 2009.

22. LaRaia W, Walker MC. The Siege in Mumbai: A Conventional Terrorist Attack Aided by Modern Technology. In: Haberfeld MR, Hassell A, editors. A New Understanding of Terrorism: Case Studies, Trajectories and Lessons Learned. New York, NY: Springer US; 2009. pp. 309–340.

23. Kronstadt KA. Terrorist attacks in Mumbai, India, and implications for US interests. Library of Congress Washington DC Congressional Research Service; 2008. Available: https://apps.dtic.mil/docs/citations/ADA492902

24. Arreguín-Toft I. How the weak win wars: A theory of asymmetric conflict. Int Secur. 2001;26: 93–128.

25. Berglund C, Souleimanov EA. What is (not) asymmetric conflict? From conceptual stretching to conceptual structuring. Dynamics of Asymmetric Conflict: Pathways toward Terrorism and Genocide. 2020;13: 87–98.

26. Roser M, Nagdy M. Military Spending. Our World in Data. 2013. Available: https://ourworldindata.org/military-spending

27. Treverton GF, Posen BR. Inadvertent Escalation: Conventional War and Nuclear Risks. Foreign Affairs. 1992. p. 170. doi:10.2307/20045251

28. Rauchhaus R. Evaluating the Nuclear Peace Hypothesis: A Quantitative Approach. J Conflict Resolut. 2009;53: 258–277.

29. Pinker S. The Better Angels of Our Nature: Why Violence Has Declined. Penguin Books; 2012.

30. Peace Research Institute Oslo. UCDP/PRIO Armed Conflict Dataset. In: Peace Research Institute Oslo (PRIO) [Internet]. 13 May 2020 [cited 13 May 2020]. Available: https://www.prio.org/Data/Armed-Conflict/UCDP-PRIO/

31. Troeder EG. A Whole of Government Approach to Gray Zone Warfare. Strategic Studies Institute; 2019. Available: https://ssi.armywarcollege.edu/pubs/display.cfm?pubID=1411

32. McCarthy MC, Moyer MA, Venable BH. Deterring Russia in the Gray Zone. Strategic Studies Institute; 2019. Available: https://ssi.armywarcollege.edu/pubs/display.cfm?pubID=1407

33. Votel JL, Cleveland CT, Connett CT, Irwin W. Unconventional Warfare in the Gray Zone. Joint Force Quarterly. 2016 [cited 13 May 2020]. Available:

https://ndupress.ndu.edu/JFQ/Joint-Force-Quarterly-80/Article/643108/unconventional-warfare-in-the-gray-zone/

34. NATO. The North Atlantic Treaty. In: NATO [Internet]. 1949 [cited 15 May 2020]. Available: http://www.nato.int/cps/en/natohq/official_texts_17120.htm

35. United Nations. Repertory of Practice of United Nations Organs — Codification Division Publications. In: legal.un.org/ [Internet]. 1945 [cited 13 May 2020]. Available: https://legal.un.org/repertory/art51.shtml

36. Acharya A, Marwah S. Nizam, la Tanzim (System, not Organization): Do Organizations Matter in Terrorism Today? A Study of the November 2008 Mumbai Attacks. Stud Conflict Terrorism. 2010;34: 1–16.

37. Naftali T. Blind Spot: The Secret History of American Counterterrorism. Basic Books; 2009.

38. Dale E. Lichtblau, Brian A. Haugh, Gregory N. Larson, Terry Mayfield. Analyzing Adversaries as Complex Adaptive Systems. Institute for Defense Analysis. 2006. doi:IDA Paper P-3868

39. Dolnik A. Understanding Terrorist Innovation: Technology, Tactics and Global Trends. Routledge; 2007.

40. Bhunia S, Tehranipoor M. Introduction to Hardware Security. ScienceDirect; 2011. Available: https://www.sciencedirect.com/topics/computer-science/attack-surface

41. Torkura KA, Sukmana MIH, Kayem AVDM, Cheng F, Meinel C. A cyber risk based moving target defense mechanism for microservice architectures. Proceedings - 16th IEEE International Symposium on Parallel and Distributed Processing with Applications, 17th IEEE International Conference on Ubiquitous Computing and Communications, 8th IEEE International Conference on Big Data and Cloud Computing, 11t. 2019; 932–939.

42. LeRoy BD. Fourth Generation Warfare: The Need for a Comprehensive Approach. School of Advanced Military Studies, US Army Command and General Staff College. 2008. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a484763.pdf

43. McEntire DA. Disaster Response and Recovery: Strategies and Tactics for Resilience. Wiley; 2014. p. 368.

44. Salmeron J, Wood K, Baldick R. Analysis of electric grid security under terrorist threat. IEEE Trans Power Syst. 2004;19: 905–912.

45. Lee R, Assante M, Conway T. Analysis of the Cyber Attack on the Ukrainian Power Grid. Electricity Information Sharing and Analysis Center (E-ISAC). 2016; 1–26.

46. Sims A. The Rising Drone Threat from Terrorists. Georgetown Journal of International Affairs. 2018;19: 97–107.

47. Gershenson C. The Implications of Interactions for Science and Philosophy. Found Sci. 2013;18: 781–790.

48. Gordon DM. The ecology of collective behavior. PLoS Biol. 2014;12: e1001805.

49. Lawson ST. Nonlinear Science and Warfare: Chaos, complexity and the U.S. military in the information age. Routledge; 2013.

50. Mantri P, Thomas J. Nature's Design's: The Biology of Survival. MATEC Web of Conferences. 2019. Available: https://www.matec-conferences.org/articles/matecconf/abs/2019/50/matecconf_icad2019_00023/matecconf_icad2019_00023.html

51. Massari GF. Teams as complex adaptive systems: Collective Intelligence and Adaptive Behaviors. Demelio GP, editor. MECHANICAL AND MANAGEMENT ENGINEERING, Politecnico di Bari. 2019. Available: https://www.dmmm.poliba.it/dottorati/pluginfile.php/261/mod_folder/content/0/PhDThesisMassariGiovanniF.pdf

52. Mitchell M. Complexity: A Guided Tour. Oxford University Press; 2009.

53. Maxfield RR. Complexity and Organization Management. Symposium on Complexity, Global Politics and National Security. 1996. Available: http://www.dodccrp.org/html4/bibliography/comch08.html

54. Dittmer J. Geopolitical assemblages and complexity. Prog Hum Geogr. 2014;38: 385–401.

55. Rosenberg M. Strategy and Geopolitics: Understanding Global Complexity in a Turbulent World. Emerald Group Publishing; 2017.

56. Williamson SC. From fourth generation warfare to hybrid war. ARMY WAR COLL CARLISLE BARRACKS PA; 2009. Available: https://apps.dtic.mil/docs/citations/ADA498391

57. Miralles Canals JJ. Fourth-generation warfare: Jihadist networks and percolation. Math Comput Model. 2009;50: 896–909.

58. Ford MC. Finding the target, fixing the method: methodological tensions in insurgent identification. Stud Conflict Terrorism. 2012;35: 113–134.

59. Ilachinski A. Modelling insurgent and terrorist networks as self-organised complex adaptive systems. Int J Parallel Emergent Distrib Syst. 2012;27: 45–77.

60. Ellis P. Implications of the Complex Adaptive Systems Paradigm. International Safety Research; 2017. Report No.: 6070-01-02. Available: https://cradpdf.drdc-rddc.gc.ca/PDFS/unc266/p805157_A1b.pdf

61. Murphy EM. Complex Adaptive Systems and the Development of Force Structures for the United States Air Force. 2014. Available: https://media.defense.gov/2017/Nov/21/2001847257/-1/-1/0/DP_0018_MURPHY_COMPLEX_ADAPTIVE_SYSTEMS.PDF

62. Bar-Yam Y. Complexity of Military Conflict: Multiscale Complex Systems Analysis of Littoral Warfare. New England Complex Systems Institute; 2003. Report No.: F30602-02-C-0158. Available: https://static1.squarespace.com/static/5b68a4e4a2772c2a206180a1/t/5c09552e352f53aaa5645aa1/1544115504973/SSG_NECSI_3_Litt.pdf

63. Chai S-K. An Organizational Economics Theory of Antigovernment Violence. Comp Polit. 1993;26: 99.

64. Weyrich A, Lenz D, Fickel J. Environmental Change-Dependent Inherited Epigenetic Response. Genes . 2018;10. doi:10.3390/genes10010004

65. Frisch E. Insurgencies are Organizations Too: Organizational Structure and the Effectiveness of Insurgent Strategy. The Peace and Conflict Review. 2011;6: 1–23.

66. Maleszka R. Epigenetic code and insect behavioural plasticity. Curr Opin Insect Sci. 2016;15: 45–52.

67. Grisogono A-M, Ryan A. Designing complex adaptive systems for defence. Systems engineering test and evaluation conference, Canberra. 2003. Available: http://militaryepistemology.com/wp-content/uploads/2003/10/2003-Ryan-Grisogono_Designing-CAS-for-Defence_SETE.pdf

68. Gordon DM. The Evolution of the Algorithms for Collective Behavior. Cell Syst. 2016;3: 514–520.

69. Friedman DA, Johnson BR, Linksvayer TA. Distributed physiology and the molecular basis of social life in eusocial insects. Horm Behav. 2020; 104757.

70. Vodák R, Bíl M, Křivánková Z. A modified ant colony optimization algorithm to increase the speed of the road network recovery process after disasters. International Journal of Disaster Risk Reduction. 2018;31: 1092–1106.

71. Wood G. What ISIS Really Wants. The Atlantic. 15 Feb 2015. Available: http://www.theatlantic.com/features/archive/2015/02/what-isis-really-wants/384980/. Accessed 14 May 2020.

72. Shiwakoti N, Sarvi M, Rose G, Burd M. Animal dynamics based approach for modeling pedestrian crowd egress under panic conditions. Procedia - Social and Behavioral Sciences. 2011;17: 438–461.

73. Dorigo M, Stützle T. Ant Colony Optimization: Overview and Recent Advances. In: Gendreau M, Potvin J-Y, editors. Handbook of Metaheuristics. Cham: Springer International Publishing; 2019. pp. 311–351.

74. Allen M, Friston KJ. From cognitivism to autopoiesis: towards a computational framework for the embodied mind. Synthese. 2018;195: 2459–2482.

75. Dos Santos WD. Carrying pieces of information in organocatalytic bytes: Semiopoiesis-A new theory of life and its origins. Biosystems. 2018;164: 167–176.

76. Nessel RA. WHY FAILING TERRORIST GROUPS PERSIST: THE CASE OF AL-QAEDA IN THE ISLAMIC MAGHREB. Naval Postgraduate School. 2012. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a563498.pdf

77. Abdallah R. ISIL is not dead, it just moved to Africa. In: Al Jazeera [Internet]. 2019 [cited 14 May 2020]. Available: https://www.aljazeera.com/indepth/opinion/isil-dead-moved-africa-191126152156781.html

78. Stanner WEH. On the Interpretation of Cargo Cults. Oceania. 1958;29: 1–25.

79. Eliade M. Mephistopheles and the Androgyne: Studies in Religion Myth and Symbol. Sheed and Ward; 1965.

80. Lyons DE, Young AG, Keil FC. The hidden structure of overimitation. Proc Natl Acad Sci U S A. 2007;104: 19751–19756.

81. Newkirk RW, Bender JB, Hedberg CW. The potential capability of social media as a component of food safety and food terrorism surveillance systems. Foodborne Pathog Dis. 2012;9: 120–124.

82. Sofea Azrina Azizan, Izzatdin Abdul Aziz, Bandar Seri Iskandar. Terrorism Detection Based on Sentiment Analysis Using Machine Learning. Journal of Engineering and Applied Sciences. 2017;12: 961–698.

83. Saperstein AM. Complexity, Chaos, and National Security Policy: Metaphors or Tools? Symposium on Complexity, Global Politics, and National Security; 1996; National Defense University. Available: http://www.dodccrp.org/html4/bibliography/comch05.html

84. Porte TL, Consolini P. Theoretical and operational challenges of "high-reliability organizations": air-traffic control and aircraft carriers. International Journal of Public Administration. 1998;21: 847–852.

85. Weick KE, Sutcliffe KM. Managing the Unexpected. 3rd ed. Wiley; 2015.

86. Christianson MK, Sutcliffe KM, Miller MA, Iwashyna TJ. Becoming a high reliability organization. Crit Care. 2011;15: 314.

87. McKeon LM, Oswaks JD, Cunningham PD. Safeguarding patients: complexity science, high reliability organizations, and implications for team training in healthcare. Clin Nurse Spec. 2006;20: 298–304; quiz 305–6.

88. Szumilas A, Swerhun B, Lye J. Watts at Stake?: Protecting North America's energy infrastructure from cascading failure and terrorist threats. Dalhousie Journal of Interdisciplinary Management. 2011;7. doi:10.5931/djim.v7i2.66

89. De Bruijne M, Van Eeten M. Systems that should have failed: critical infrastructure protection in an institutionally fragmented environment. Journal of contingencies and crisis management. 2007;15: 18–29.

90. See KC, Phua J, Mukhopadhyay A, Lim TK. Characteristics of distractions in the intensive care unit: How serious are they and who are at risk? Singapore Med J. 2014;55: 358–362.

91. Mamouni Limnios EA, Mazzarol T, Ghadouani A, Schilizzi SGM. The Resilience Architecture Framework: Four organizational archetypes. European Management Journal. 2014;32: 104–116.

92. Smith J, Jenks C. Qualitative Complexity: Ecology, Cognitive Processes and the Re-Emergence of Structures in Post-Humanist Social Theory. Routledge; 2006.

93. Flaherty E. Conclusion: A Complexity-Informed Approach to the Study of Social-Ecological Systems. In: Flaherty E, editor. Complexity and Resilience in the Social and Ecological Sciences. London: Palgrave Macmillan UK; 2019. pp. 213–230.

94. Brooker P. Introducing Unmanned Aircraft Systems into a High Reliability ATC System. J Navig. 2013;66: 719–735.

95. Dalamagkidis K, Valavanis KP, Piegl LA. On Integrating Unmanned Aircraft Systems into the National Airspace System: Issues, Challenges, Operational Restrictions, Certification, and Recommendations. Springer Science & Business Media; 2011.

96. Grabowski M, Roberts KH. Reliability seeking virtual organizations: Challenges for high reliability organizations and resilience engineering. Saf Sci. 2019;117: 512–522.

97. Rigaud E, Hollnagel E. Proceedings of the Second Resilience Engineering Symposium: 8-10 November, 2006, Antibes-Juan-les-Pins, France. Presses des MINES; 2006.

98. Royal Canadian Navy. Canada in a New Maritime World. 2016. Available: http://www.navy-marine.forces.gc.ca/assets/NAVY_Internet/docs/en/rcn_leadmark-2050.pdf

99. Hill BP. Maritime terrorism and the small boat attack threat to the United States : a proposed response. Monterey, California. Naval Postgraduate School. 2009. Available: https://calhoun.nps.edu/handle/10945/4929

100. Shaul DS. The threat of Houthi unmanned explosives-laden boats. In: ICT.org [Internet]. 2 Oct 2019 [cited 14 May 2020]. Available: https://www.ict.org.il/Article/2456/The_threat_of_Houthi_unmanned_explosives-laden_boats

101. LaGrone S. Navy : Saudi Frigate Attacked by Unmanned Bomb Boat , Likely Iranian. USNI News; 2017. Available: https://news.usni.org/2017/02/20/navy-saudi-frigate-attacked-unmanned-bomb-boat-likely-iranian

102. Mun J. Flexible Ship Options. 2018. Report No.: NPS-AM-18-235. Available: https://nps.edu/documents/105938399/112603206/NPS-AM-18-235.pdf/6669f6e7-eb71-4ba1-9b9e-d43c2c095693?version=1.0

103. Hack K. The Malayan Emergency as Counter-Insurgency Paradigm. Journal of Strategic Studies. 2009;32: 383–414.

104. Robinson W. Eradicating Organized Criminal Gangs in Jamaica: Can Lessons be Learnt From A Successful Counterinsurgency? 2008. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a491587.pdf

105. Komer RW. The Malayan Emergency in Retrospect: Organization of A Successful Counterinsurgency Effort. Advanced Research Projects Agency; 1972. Report No.: R-957-ARPA. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/748988.pdf

106. Ricks TE. Fiasco: The American Military Adventure in Iraq, 2003 to 2005. Penguin; 2006.

107. McChrystal GS, Collins T, Silverman D, Fussell C. Team of Teams: New Rules of Engagement for a Complex World. Penguin; 2015.

108. Green D. Counterinsurgency Diplomacy: Political Advisors at the Operational and Tactical Levels. Mil Rev. 2007;87: 24.

109. Dahl EJ. Preventing a Day of Terror: Lessons Learned from an Unsuccessful Terrorist Attack. CTX. 2014;4: 71–77.

110. Brafman O, Beckstrom RA. The spider and the starfish: The unstoppable power of leaderless organizations. New York: Portfolio; 2006

Chapter II
Works Cited

1. Wikipedia contributors. Coronavirus disease 2019. In: Wikipedia, The Free Encyclopedia [Internet]. 1 Jul 2020 [cited 1 Jul 2020]. Available: https://en.wikipedia.org/w/index.php?title=Coronavirus_disease_2019&oldid=965478652

2. Shereen MA, Khan S, Kazmi A, Bashir N, Siddique R. COVID-19 infection: Origin, transmission, and characteristics of human coronaviruses. J Advert Res. 2020;24: 91–98.

3. Lake MA. What we know so far: COVID-19 current clinical knowledge and research. Clin Med . 2020;20: 124–127.

4. Korber B, Fischer WM, Gnanakaran S, Yoon H, Theiler J, Abfalterer W, et al. Spike mutation pipeline reveals the emergence of a more transmissible form of SARS-CoV-2. bioRxiv. 2020. p. 2020.04.29.069054. doi:10.1101/2020.04.29.069054

5. Daniloski Z, Guo X, Sanjana NE. The D614G mutation in SARS-CoV-2 Spike increases transduction of multiple human cell types. bioRxiv. 2020. p. 2020.06.14.151357. doi:10.1101/2020.06.14.151357

6. MacLean OA, Orton RJ, Singer JB, Robertson DL. No evidence for distinct types in the evolution of SARS-CoV-2. Virus Evol. 2020;6. doi:10.1093/ve/veaa034

7. van Dorp L, Richard D, Tan CCS, Shaw LP, Acman M, Balloux F. No evidence for increased transmissibility from recurrent mutations in SARS-CoV-2. bioRxiv. 2020. p. 2020.05.21.108506. doi:10.1101/2020.05.21.108506

8. Simkó M, Mattsson M-O. 5G Wireless Communication and Health Effects-A Pragmatic Review Based on Available Studies Regarding 6 to 100 GHz. Int J Environ Res Public Health. 2019;16. doi:10.3390/ijerph16183406

9. Ahmed W, Vidal-Alaball J, Downing J, López Seguí F. COVID-19 and the 5G Conspiracy Theory: Social Network Analysis of Twitter Data. J Med Internet Res. 2020;22: e19458.

10. Cz S. Targeted Bioweapon Covid - 5G - Chemtrails - Corona discharge - Electricity and 5G - Stop 5G v ČR. In: Stop 5G v ČR [Internet]. 21 Jun 2020 [cited 29 Jun 2020]. Available: https://stop5g.cz/us/targeted-bioweapon-covid-5g-chemtrails-corona-discharge-electricity-and-5g/

11. Fact F. Patent application 060606 does not mention inserting microchips into the body. In: Full Fact [Internet]. 28 May 2020 [cited 29 Jun 2020]. Available: https://fullfact.org/online/bill-gates-patent-microchips/

12. Fact F. A patent for the coronavirus spreading in Wuhan was not applied for in 2015. In: Full Fact [Internet]. 27 Jan 2020 [cited 29 Jun 2020]. Available: https://fullfact.org/online/wuhan-virus-patent-gates/

13. Wikipedia contributors. Misinformation related to the COVID-19 pandemic. In: Wikipedia, The Free Encyclopedia [Internet]. 28 Jun 2020 [cited 29 Jun 2020]. Available: https://en.wikipedia.org/w/index.php?title=Misinformation_related_to_the_COVID-19_pandemic&oldid=964994940

14. Brainard J. Scientists are drowning in COVID-19 papers. Can new tools keep them afloat? In: ScienceMag [Internet]. 2020 [cited 5 Aug 2020]. doi:10.1126/science.abc7839

15. Henrich J, Boyd R, Richerson PJ. Five Misunderstandings About Cultural Evolution. Hum Nat. 2008;19: 119–137.

16. Chapeau PA. Ingress: The Niantic Project Files, Volume 1. Niantic Labs;

17. Serrano AR, Rodríguez Serrano A, Martín-Núñez M, Gil-Soldevila S. Ludologic design and augmented reality. The game experience in Pokémon Go! (Niantic, 2016). 2017. doi:10.4185/rlcs-2017-1185en

18. McLuhan M. The Gutenberg Galaxy. University of Toronto Press; 2017.

19. McEwan SR. " THIS MEME IS WHAT WE CALL PROGRESS": HISTORY-AS-MEME, MEME-AS-HISTORY ON 4CHAN. AoIR Selected

Papers of Internet Research. 2018. Available: https://www.spir.aoir.org/ojs/index.php/spir/article/view/10494

20. Benjamin AS. Memory is More than just Remembering: Strategic Control of Encoding, Accessing Memory, and Making Decisions. Elsevier Masson SAS; 2007. pp. 175–223.

21. Hofstadter DR. Gödel, Escher, Bach. Anniversary Edition: An Eternal Golden Braid. 20 Anv edition. Basic Books; 1999.

22. Browne R. Twitter puts fact-checking label on tweets linking 5G with coronavirus. In: CNBC [Internet]. CNBC; 8 Jun 2020 [cited 29 Jun 2020]. Available: https://www.cnbc.com/2020/06/08/twitter-5g-coronavirus.html

23. Ahmed A. Twitter Decided To Tone Down Its Criteria To Flag Tweets Related To Covid-19 And 5G, As It Was Taking Down The Genuine Tweets That Had Nothing To Do With Fake Information. 29 Jun 2020 [cited 29 Jun 2020]. Available: https://www.digitalinformationworld.com/2020/06/twitter-decided-to-tone-down-its-criteria-to-flag-tweets-related-to-covid-19-and-5g.html

24. Caliskan A, Bryson JJ, Narayanan A. Semantics derived automatically from language corpora contain human-like biases. Science. 2017;356: 183–186.

25. Słowik A, Gupta A, Hamilton WL, Jamnik M, Holden SB, Pal C. Exploring Structural Inductive Biases in Emergent Communication. arXiv [cs.CL]. 2020. Available: http://arxiv.org/abs/2002.01335

26. Goel V, Dolan RJ. Social regulation of affective experience of humor. J Cogn Neurosci. 2007;19: 1574–1580.

27. Badcock PB, Friston KJ, Ramstead MJD, Ploeger A, Hohwy J. The hierarchically mechanistic mind: an evolutionary systems theory of the human brain, cognition, and behavior. Cogn Affect Behav Neurosci. 2019;19: 1319–1351.

28. Mitchell M. Complexity: A Guided Tour. Oxford University Press; 2009.

29. Gershenson C, Fernández N. Complexity and information: Measuring emergence, self-organization, and homeostasis at multiple scales. Complexity. 2012. Available: https://onlinelibrary.wiley.com/doi/abs/10.1002/cplx.21424

30. Mantri P, Thomas J. Nature's Design's: The Biology of Survival. MATEC Web of Conferences. 2019. Available: https://www.matec-conferences.org/articles/matecconf/abs/2019/50/matecconf_icad2019_00023/matecconf_icad2019_00023.html

31. Murtagh F. The new science of complex systems through ultrametric analysis: Application to search and discovery, to narrative and to thinking. P-Adic Numbers Ultrametric Anal Appl. 2013;5: 326–337.

32. Stepney S. Complex Systems for Narrative Theorists. Narrating Complexity. 2018. pp. 27–36. doi:10.1007/978-3-319-64714-2_3

33. Cordes RJ, Friedman DA. Emergent Teams for Complex Threats. 2020. Available: https://www.remotorconsulting.com/uploads/4/8/4/2/48428829/emergent_teams_for_complex_threats__1_.pdf

34. Lewin K. Frontiers in Group Dynamics: II. Channels of Group Life; Social Planning and Action Research. Hum Relat. 1947;1: 143–153.

35. Wallach MA, Kogan N, Bem DJ. Group influence on individual risk taking. J Abnorm Soc Psychol. 1962;65: 75–86.

36. Robbins B. Microscope: A Fractal Role-playing Game of Epic Histories. Lame Mage Publications; 2011.

37. Dille F, Platten JZ. The Ultimate Guide to Video Game Writing and Design. Potter/TenSpeed/Harmony; 2010.

38. Toynbee AJ. A Study of History, Vol 4: Breakdowns in Civilizations. Somervell DC, editor. Oxford University Press; 1934.

39. Toynbee AJ. A Study of History, Vol 5: Disintegration of Civilization. Somervell DC, editor. Oxford University Press; 1934.

40. Dannecker A, Richter S, Lechner U, Dressner N, Fabisch S, Ilsemann A. Towards World of Warcraft as an experiment platform for teams. AMCIS 2008 Proceedings. 2008; 138.

41. Suzuki S. Cultural Transmission in International OrganizationsImpact of Interpersonal Communication Patterns in Intergroup Contexts. Hum Commun Res. 1997;24: 147–180.

42. Jørgensen K. Audio and gameplay: An analysis of PvP battlegrounds in World of Warcraft. Game Studies. 2008;8: 1–19.

43. Nardi BA, Ly S, Harris J. Learning Conversations in World of Warcraft. 2007 40th Annual Hawaii International Conference on System Sciences (HICSS'07). 2007. pp. 79–79.

44. Thomas J, Mantri P. Axiomatic Cloud Computing Architectural Design. MATEC Web of Conferences. 2019;301: 00024.

45. Campbell J. The Hero with a Thousand Faces. New World Library; 2008.

46. Campbell J, Brown SL. The Hero's Journey: Joseph Campbell on His Life and Work (The Collected Works of Joseph Campbell). Third edition. Cousineau P, editor. New World Library; 2014.

47. Luhmann N. The autopoiesis of social systems. Sociocybernetic paradoxes. 1986.

48. Zeleny M. SELF-ORGANIZATION OF LIVING SYSTEMS: A FORMAL MODEL OF AUTOPOIESIS. Int J Gen Syst. 1977;4: 13–28.

49. Maula M. The senses and memory of a firm–implications of autopoiesis theory for knowledge management. Journal of Knowledge Management. 2000. Available: https://www.emerald.com/insight/content/doi/10.1108/13673270010372288/full/html

50. Sinek S. The Infinite Game. Portfolio; 2019.

51. Conley R. Simon Sinek's 5 Steps for Mastering the "Infinite" Game of Leadership. In: Blanchard LeaderChat [Internet]. 27 Oct 2017 [cited 29 Jun 2020]. Available: https://leaderchat.org/2017/10/27/simon-sineks-5-steps-for-mastering-the-infinite-game-of-leadership/

52. de Vladar HP, Santos M, Szathmáry E. Grand Views of Evolution. Trends Ecol Evol. 2017;0. doi:10.1016/j.tree.2017.01.008

53. Wolfe CT. Vital anti-mathematicism and the ontology of the emerging life sciences: from Mandeville to Diderot. Synthese. 2017; 1–22.

54. Packard N, Bedau MA, Channon A, Ikegami T, Rasmussen S, Stanley K, et al. Open-Ended Evolution and Open-Endedness: Editorial Introduction to the Open-Ended Evolution I Special Issue. Artificial Life. 2019. pp. 1–3. doi:10.1162/artl_e_00282

55. Pryor CA. Spreadsheets-in-Space: A Quantitative Exploration of Movement, Currency Creation, and Conflict within EVE Online. University of Arkansas, Fayetteville. 2019. Available: https://scholarworks.uark.edu/etd/3236/

56. Anania EC, Keebler JR, Anglin KM, Kring JP. Using the Cooperative Board Game Pandemic to Study Teamwork. Proc Hum Fact Ergon Soc Annu Meet. 2016;60: 1770–1774.

57. Crichton MT, Flin R, Rattray WAR. Training Decision Makers – Tactical Decision Games. Journal of Contingencies and Crisis Management. 2000;8: 208–217.

58. Hadley K, Reid K. Work in Progress: A Delphi Study to Investigate the Value of Board Games to Teach Teamwork Skills. 2017 ASEE Annual Conference & Exposition Proceedings. ASEE Conferences; 2017. doi:10.18260/1-2--29140

59. Wolfe J, Box TM. Team Cohesion Effects on Business Game Performance. Simul Games. 1988;19: 82–98.

60. Fogel S. "EVE Online" is crowdsourcing the search for real exoplanets. In: Engadget [Internet]. 22 Feb 2017 [cited 1 Jul 2020]. Available: https://www.engadget.com/2017-02-22-eve-online-project-discovery-exoplanets.html

61. Thomas J, Zaytseva A. Mapping complexity/Human knowledge as a complex adaptive system. Complexity. 2016;21: 207–234.

62. Mikhailova A, Friedman DA. Partner Pen Play in Parallel (PPPiP): A New PPPiParadigm for Relationship Improvement. Arts Health. 2018;7: 39.

63. Lefebvre A, Delorme R, Delanoë C, Amsellem F, Beggiato A, Germanaud D, et al. Alpha Waves as a Neuromarker of Autism Spectrum Disorder: The Challenge of Reproducibility and Heterogeneity. Front Neurosci. 2018;12: 662.

64. Kanjo E, Younis EMG, Ang CS. Deep learning analysis of mobile physiological, environmental and location sensor data for emotion detection. Inf Fusion. 2019;49: 46–56.

65. Risi S, Preuss M. From Chess and Atari to StarCraft and Beyond: How Game AI is Driving the World of AI. KI-Künstliche Intelligenz. 2020;34: 7–17.

66. Van Creveld M. Technology and War: From 2000 B.C. to the Present. Revised & Expan edition. Touchstone; 1991.

67. Beckett IFW. The Amateur Military Tradition, 1558-1945. Manchester University Press; 1991.

68. Montola M. The invisible rules of role-playing: the social framework of role-playing process. International journal of role-playing. 2009. Available: https://pdfs.semanticscholar.org/afee/e239d8922c8eeb2d3dc2e22ac600a3fc495c.pdf

69. Bowman SL, Standiford A. Educational larp in the middle school classroom: A mixed method case study. International Journal of Role-playing. 2015. Available: http://ijrp.subcultures.nl/wp-content/uploads/2015/03/IJRP5_BowmanStandiford.pdf

70. Kineman JJ. A causal framework for integrating contemporary and Vedic holism. Prog Biophys Mol Biol. 2017;131: 402–423.

71. Fang Z, Zhou X, Song A. Architectural Models Enabled Dynamic Optimization for System-of-Systems Evolution. Complexity. 2020;2020. doi:10.1155/2020/7534819

72. Studer J, Major SAF, MacCuish DA. … THERE FIVE RINGS OR A LOOP IN FOURTH GENERATION WARFARE? A STUDY ON THE APPLICATION OF WARDEN'S OR BOYD'S THEORIES IN 4GW. , AL: Air Command and Staff College …. 2005. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.114.591&rep=rep1&type=pdf

73. Hammes TX. Information operations in 4GW. Global Insurgency and the Future of Armed Conflict. 2010.

74. Nieto-Gomez R. Stigmergy at the edge: Adversarial stigmergy in the war on drugs. Cogn Syst Res. 2016;38: 31–40.

75. Andrade RO, Yoo SG. Cognitive security: A comprehensive study of cognitive science in cybersecurity. Journal of Information Security and Applications. 2019;48: 102352.

76. Junio TJ. Military History and Fourth Generation Warfare. Journal of Strategic Studies. 2009;32: 243–269.

Chapter III
Works Cited

1. Bouizegarene N, Ramstead M, Constant A, Friston K, Kirmayer L. Narrative as active inference. 2020. doi:10.31234/osf.io/47ub6

2. Ramstead MJD, Friston KJ, Hipólito I. Is the Free-Energy Principle a Formal Theory of Semantics? From Variational Density Dynamics to Neural and Phenotypic Representations. arXiv [q-bio.NC]. 2020. p. 889. doi:10.3390/e22080889

3. Badcock PB, Friston KJ, Ramstead MJD, Ploeger A, Hohwy J. The hierarchically mechanistic mind: an evolutionary systems theory of the human brain, cognition, and behavior. Cogn Affect Behav Neurosci. 2019;19: 1319–1351. doi:10.3758/s13415-019-00721-3

4. Veissière SPL, Constant A, Ramstead MJD, Friston KJ, Kirmayer LJ. Thinking Through Other Minds: A Variational Approach to Cognition and Culture. Behav Brain Sci. 2019; 1–97. doi:10.1017/S0140525X19001213

5. Hofstadter DR. Gödel, Escher, Bach. Anniversary Edition: An Eternal Golden Braid. 20 Anv edition. Basic Books; 1999. Available: https://play.google.com/store/books/details?id=izy9Tg6rmb8C

6. Reznikova Z. Studying Animal Languages Without Translation: An Insight from Ants. Springer, Cham; 2017. doi:10.1007/978-3-319-44918-0

7. Friedman DA, Johnson BR, Linksvayer TA. Distributed physiology and the molecular basis of social life in eusocial insects. Horm Behav. 2020; 104757. doi:10.1016/j.yhbeh.2020.104757

8. Johnson BR, Linksvayer TA. Deconstructing the superorganism: social physiology, groundplans, and sociogenomics. Q Rev Biol. 2010;85: 57–79. Available: https://www.ncbi.nlm.nih.gov/pubmed/20337260

9. Ricci A, Omicini A, Viroli M, Gardelli L, Oliva E. Cognitive Stigmergy: Towards a Framework Based on Agents and Artifacts. Environments for Multi-Agent Systems III. Springer Berlin Heidelberg; 2007. pp. 124–140. doi:10.1007/978-3-540-71103-2_7

10. Theraulaz G. Embracing the Creativity of Stigmergy in Social Insects. Archit Design. 2014;84: 54–59. doi:10.1002/ad.1808

11. Gurrapadi N, Taw L, Macedo M, Oliveira M, Pinheiro D, Bastos-Filho C, et al. Modelling the Social Interactions in Ant Colony Optimization. Intelligent Data Engineering and Automated Learning – IDEAL 2019. Springer International Publishing; 2019. pp. 216–224. doi:10.1007/978-3-030-33617-2_23

12. Gordon DM. From division of labor to the collective behavior of social insects. Behav Ecol Sociobiol. 2016;70: 1101–1108. doi:10.1007/s00265-015-2045-3

13. Ketcham R. Task Allocation and the Logic of Research Questions: How Ants Challenge Human Sociobiology. Biol Theory. 2019;14: 52–68. doi:10.1007/s13752-018-0308-8

14. Wilson EO, Hölldobler B. Dense heterarchies and mass communication as the basis of organization in ant colonies. Trends Ecol Evol. 1988;3: 65–68. doi:10.1016/0169-5347(88)90018-3

15. Stark D. Ambiguous assets for uncertain environments: Heterarchy in postsocialist firms. Электронный журнал www ecsoc msses ru Том 1, № 2, 2000. 2000;1: 7. Available: https://ecsoc.hse.ru/data/2011/12/08/1208204950/ecsoc_t1_n2.pdf#page=7

16. Aime F, Humphrey S, DeRue DS, Paul JB. The Riddle of Heterarchy: Power Transitions in Cross-Functional Teams. AMJ. 2014;57: 327–352. doi:10.5465/amj.2011.0756

17. Reznikova Z. Experimental paradigms for studying cognition and communication in ants (Hymeno- ptera: Formicidae). Myrmecol News. 2008;11: 201–214. Available: http://www.cajal.csic.es/actividades/cognition-and-comunication-in-ants.pdf

18. Friedman DA, Søvik E. The ant colony as a test for scientific theories of consciousness. Synthese. 2019; 1–24. doi:10.1007/s11229-019-02130-y

19. Pang C, Szafron D. Single Source of Truth (SSOT) for Service Oriented Architecture (SOA). Service-Oriented Computing. Springer Berlin Heidelberg; 2014. pp. 575–589. doi:10.1007/978-3-662-45391-9_50

20. Kruse B, Blackburn M. Collaborating with OpenMBEE as an Authoritative Source of Truth Environment. Procedia Comput Sci. 2019;153: 277–284. doi:10.1016/j.procs.2019.05.080

21. Gray PH. The effects of knowledge management systems on emergent teams: towards a research model. The Journal of Strategic Information Systems. 2000;9: 175–191. doi:10.1016/S0963-8687(00)00040-8

22. Malhotra Y. Why Knowledge Management Systems Fail: Enablers and Constraints of Knowledge Management in Human Enterprises. In: Holsapple CW, editor. Handbook on Knowledge Management 1: Knowledge Matters. Berlin, Heidelberg: Springer Berlin Heidelberg; 2004. pp. 577–599. doi:10.1007/978-3-540-24746-3_30

23. Hirsh JB, Mar RA, Peterson JB. Personal narratives as the highest level of cognitive integration. The Behavioral and brain sciences. 2013. pp. 216–217. doi:10.1017/S0140525X12002269

24. O'Duinn J. Distributed Teams: The Art and Practice of Working Together While Physically Apart. Release Mechanix, LLC; 2018. Available: https://www.amazon.com/Distributed-Teams-Practice-Together-Physically/dp/1732254907

25. Cordes RJ, Friedman DA. Emergent Teams for Complex Threats. 2020. Available: https://www.remotorconsulting.com/uploads/4/8/4/2/48428829/emergent_teams_for_complex_threats__1_.pdf

26. Sheth B. Chat bots are the new HR managers. Strategic HR Review. 2018;17: 162–163. doi:10.1108/SHR-03-2018-0024

27. Matthies C, Dobrigkeit F, Hesse G. An Additional Set of (Automated) Eyes: Chatbots for Agile Retrospectives. 2019 IEEE/ACM 1st International Workshop on Bots in Software Engineering (BotSE). 2019. pp. 34–37. doi:10.1109/BotSE.2019.00017

28. Kowatsch T, Nißen M, Shih C-HI, Rüegger D, Volland D, Filler A, et al. Text-based Healthcare Chatbots Supporting Patient and Health Professional Teams: Preliminary Results of a Randomized Controlled Trial on Childhood Obesity. 2017. Available: https://www.alexandria.unisg.ch/id/eprint/252944

29. Brooker P. Introducing Unmanned Aircraft Systems into a High Reliability ATC System. J Navig. 2013;66: 719–735. doi:10.1017/S0373463313000337

30. Wax A, DeChurch LA, Contractor NS. Self-Organizing Into Winning Teams: Understanding the Mechanisms That Drive Successful Collaborations. Small Group Research. 2017;48: 665–718. doi:10.1177/1046496417724209

31. Friedman D, Cordes RJ. Infinite Games for Infinite Teams. DARPA; 2020 Jul.

32. Fischer U, Mosier K, Orasanu J, Fischer U, Morrow D, Miller C, et al. Exploring Communication in Remote Teams: Issues and Methods. Proc Hum Fact Ergon Soc Annu Meet. 2013;57: 309–313. doi:10.1177/1541931213571068

33. Atkeson CG, Benzun PWB, Banerjee N, Berenson D, Bove CP, Cui X, et al. Achieving Reliable Humanoid Robot Operations in the DARPA Robotics Challenge: Team WPI-CMU's Approach. In: Spenko M, Buerger S, Iagnemma K, editors. The DARPA Robotics Challenge Finals: Humanoid Robots To The Rescue. Cham: Springer International Publishing; 2018. pp. 271–307. doi:10.1007/978-3-319-74666-1_8

34. Grabowski M, Roberts KH. Reliability seeking virtual organizations: Challenges for high reliability organizations and resilience engineering. Saf Sci. 2019;117: 512–522. doi:10.1016/j.ssci.2016.02.016

35. McEntire DA. Disaster Response and Recovery: Strategies and Tactics for Resilience. Wiley; 2014. p. 368.

36. Rigaud E, Hollnagel E. Proceedings of the Second Resilience Engineering Symposium: 8-10 November, 2006, Antibes-Juan-les-Pins, France. Presses des MINES; 2006. Available: https://play.google.com/store/books/details?id=0TGovvHYlckC

37. Weick KE, Sutcliffe KM. Managing the Unexpected. 3rd ed. Wiley; 2015.

38. Avey AE. Function and Forms of Thought. Henry Holt and Company; 1927.

39. Sloman S, Fernbach P. The Knowledge Illusion: Why We Never Think Alone. Penguin; 2018. Available: https://play.google.com/store/books/details?id=Sf9MDwAAQBAJ

40. Tett G. The Silo Effect: The Peril of Expertise and the Promise of Breaking Down Barriers. Simon and Schuster; 2015. Available: https://play.google.com/store/books/details?id=ga7_BgAAQBAJ

41. Ellis P. Implications of the Complex Adaptive Systems Paradigm. International Safety Research; 2017. Report No.: 6070-01-02. Available: https://cradpdf.drdc-rddc.gc.ca/PDFS/unc266/p805157_A1b.pdf

42. Royal Canadian Navy. Canada in a New Maritime World. 2016. Available: http://www.navy-marine.forces.gc.ca/assets/NAVY_Internet/docs/en/rcn_leadmark-2050.pdf

43. Littoral Combat Ship: Still relevant? In: naval technology [Internet]. Naval Technology; 2020 [cited 3 Sep 2020]. Available: https://www.naval-technology.com/features/featurelittoral-combat-ship-still-relevant-4531801/

44. Weick KE. The Collapse of Sensemaking in Organizations: The Mann Gulch Disaster. Adm Sci Q. 1993;38: 628–652. doi:10.2307/2393339

45. MacLeod M. What makes interdisciplinarity difficult? Some consequences of domain specificity in interdisciplinary practice. Synthese. 2018;195: 697–720. doi:10.1007/s11229-016-1236-4

46. Jørgensen K. Audio and gameplay: An analysis of PvP battlegrounds in World of Warcraft. Game Studies. 2008;8: 1–19. Available: http://www.gamestudies.org/0802/articles/jorgensen

47. Olsson G. Abysmal: A Critique of Cartographic Reason. University of Chicago Press; 2010. Available: https://play.google.com/store/books/details?id=vU69nFrs3TcC

48. LaRaia W, Walker MC. The Siege in Mumbai: A Conventional Terrorist Attack Aided by Modern Technology. In: Haberfeld MR, Hassell A, editors. A New Understanding of Terrorism: Case Studies, Trajectories and Lessons Learned. New York, NY: Springer US; 2009. pp. 309–340. doi:10.1007/978-1-4419-0115-6_17

49. Haberfeld MR, Hassell A, editors. A New Understanding of Terrorism: Case Studies, Trajectories and Lessons Learned. Springer, New York, NY; 2009. doi:10.1007/978-1-4419-0115-6

50. Housley W. Story, Narrative and Team Work. Sociol Rev. 2000;48: 425–443. doi:10.1111/1467-954X.00224

51. Weick KE, Roberts KH. Collective Mind in Organizations: Heedful Interrelating on Flight Decks. Adm Sci Q. 1993;38: 357–381. doi:10.2307/2393372

52. Enya A, Dempsey S, Pillay M. High Reliability Organisation (HRO) Principles of Collective Mindfulness: An Opportunity to Improve Construction Safety Management. Advances in Safety Management and Human Factors. Springer International Publishing; 2019. pp. 3–13. doi:10.1007/978-3-319-94589-7_1

53. SHRM. Understanding and Developing Organizational Culture. In: SHRM [Internet]. 29 Jul 2020 [cited 3 Sep 2020]. Available: https://www.shrm.org/resourcesandtools/tools-and-

samples/toolkits/pages/understandinganddevelopingorganizationalculture.asp x

54. U.S. Joint Chiefs of Staff. Joint Publication 5-0: Joint Operation Planning. Washington, DC: Government Printing Office; 2017.

55. U.S. Joint Chiefs of Staff. The National Military Strategy of the United States of America 2015. 2015. Available: https://www.jcs.mil/Portals/36/Documents/Publications/National_Military_Strategy_2015.pdf

56. Crider C, McCrary L, Calfee R, Stephens W. Tradecraft for the Church on Mission. Upstream Collective; 2017.

57. Mean WWWIT. Mission: a problem of definition. Themelios. 2008;33: 46–59. Available: https://www.movements.net/s/Mission-a-Problem-of-Definition-Ferdinando-s22s.pdf

58. Swales JM, Rogers PS. Discourse and the Projection of Corporate Culture: The Mission Statement. Discourse & Society. 1995;6: 223–242. doi:10.1177/0957926595006002005

59. Stallworth Williams L. The Mission Statement: A Corporate Reporting Tool With a Past, Present, and Future. The Journal of Business Communication (1973). 2008;45: 94–119. doi:10.1177/0021943607313989

60. Peterson JB. Personality and Its Transformations: Selected Readings. P.S. Presse; 1998. Available: https://play.google.com/store/books/details?id=Cl2mNwAACAAJ

61. Tudge JRH, Winterhoff PA. Vygotsky, Piaget, and Bandura: Perspectives on the Relations between the Social World and Cognitive Development. Hum Dev. 1993;36: 61–81. doi:10.1159/000277297

62. Allen NJ, Pickering WSF, Watts Miller W. On Durkheim's Elementary Forms of Religious Life. Routledge; 2012. Available: https://play.google.com/store/books/details?id=UL9mAgAAQBAJ

63. Hobsbawm E, Ranger T. The Invention of Tradition. Cambridge University Press; 2012. Available: https://play.google.com/store/books/details?id=IckLAQAAQBAJ

64. Turner JH, Maryanski A, Petersen AK, Geertz AW. The Emergence and Evolution of Religion: By Means of Natural Selection (Evolutionary Analysis in the Social Sciences). 1 edition. Routledge; 2017. Available: https://www.amazon.com/Emergence-Evolution-Religion-Selection-Evolutionary-dp-113808090X/dp/113808090X/ref=mt_other?_encoding=UTF8&me=&qid=

65. Peterson JB. Maps of Meaning: The Architecture of Belief. Psychology Press; 1999. Available: https://play.google.com/store/books/details?id=8Siqb_pbg0MC

66. Neumann E. The Origins and History of Consciousness. Princeton University Press; 1954. Available: https://play.google.com/store/books/details?id=mf3RDwAAQBAJ

67. Jackson P. Maps of Meaning: An Introduction to Cultural Geography. Psychology Press; 1994. Available: https://play.google.com/store/books/details?id=3Er4BAmRLLMC

68. Stanish C. The Evolution of Human Co-operation: Ritual and Social Complexity in Stateless Societies. Cambridge University Press; 2017. p. 351. Available: https://docs.google.com/document/d/1qcZmz_Q5tnLk5vt0TeTSdIMUfBGM4tNT3dVni3F0Sdw/edit

69. Johnson DR, Feldman SC, Lubin H, Southwick SM. The therapeutic use of ritual and ceremony in the treatment of post-traumatic stress disorder. J Trauma Stress. 1995;8: 283–298. doi:10.1007/BF02109565

70. Sherwin D, Sherwin M. Turning people into teams : rituals and routines that redesign how we work. 2018. p. 153.

71. Linn BM. The Echo of Battle. Harvard University Press; 2009. Available: https://play.google.com/store/books/details?id=clKtd4O3MOgC

72. Olson HF. Dynamical analogies. Van Nostrand Princeton, NJ; 1958. Available: https://ugeb.pw/dynamical-analogies.pdf

73. Hutter M. Universal Artificial Intelligence: Sequential Decisions Based on Algorithmic Probability. Springer Science & Business Media; 2004. Available: https://play.google.com/store/books/details?id=ziLLYu7oIkQC

74. Dawkins R. The Selfish Gene. Oxford University Press; 2016. Available: https://play.google.com/store/books/details?id=ekonDAAAQBAJ

75. Heylighen F. Selection criteria for the evolution of knowledge. Proc 13th Int Congress on Cybernetics. Association Internat. de Cybernétique; 1993. pp. 524–528. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.32.2294&rep=rep1&type=pdf

76. Weick KE, Sutcliffe KM, Obstfeld D. Organizing and the Process of Sensemaking. Organization Science. 2005;16: 409–421. doi:10.1287/orsc.1050.0133

77. Weick KE. Sensemaking in Organizations. SAGE; 1995. Available: https://play.google.com/store/books/details?id=nz1RT-xskeoC

78. Renzl B. Trust in management and knowledge sharing: The mediating effects of fear and knowledge documentation. Omega. 2008;36: 206–220. doi:10.1016/j.omega.2006.06.005

79. Reynaud B. Forms of trust and conditions for their stability. Cambridge J Econ. 2017;41: 127–145. doi:10.1093/cje/bew001

80. Mach M, Dolan S, Tzafrir S. The differential effect of team members' trust on team performance: The mediation role of team cohesion. J Occup Organ Psychol. 2010;83: 771–794. doi:10.1348/096317909X473903

81. Cooley D, Parks-Yancy R. The Effect of Social Media on Perceived Information Credibility and Decision Making. Journal of Internet Commerce. 2019;18: 249–269. doi:10.1080/15332861.2019.1595362

82. Handy C. Trust and the Virtual Organization. Harvard Business Review. 1 May 1995. Available: https://hbr.org/1995/05/trust-and-the-virtual-organization. Accessed 30 Mar 2020.

83. Lester PB, Vogelgesang GR. Swift Trust in Ad Hoc Military Organizations. Oxford Handbooks Online. 2012. doi:10.1093/oxfordhb/9780195399325.013.0067

84. Stewart NK. South Atlantic Conflict of 1982: A Case Study in Military Cohesion. U.S. Army Research Institute for the Behavioral and Social Sciences; 1988. Available: https://play.google.com/store/books/details?id=vHfRzV6jm68C

85. McKeon LM, Oswaks JD, Cunningham PD. Safeguarding patients: complexity science, high reliability organizations, and implications for team training in healthcare. Clin Nurse Spec. 2006;20: 298–304; quiz 305–6. doi:10.1097/00002800-200611000-00011

86. Porte TL, Consolini P. Theoretical and operational challenges of "high-reliability organizations": air-traffic control and aircraft carriers. International Journal of Public Administration. 1998;21: 847–852. doi:10.1080/01900699808525320

87. Christianson MK, Sutcliffe KM, Miller MA, Iwashyna TJ. Becoming a high reliability organization. Crit Care. 2011;15: 314. doi:10.1186/cc10360

88. Bierly PE, Spender J-C. Culture and high reliability organizations: The case of the nuclear submarine. J Manage. 1995;21: 639–656. doi:10.1016/0149-2063(95)90003-9

89. McRaven WH. Spec Ops: Case Studies in Special Operations Warfare: Theory and Practice. Random House Publishing Group; 2009. Available: https://play.google.com/store/books/details?id=0MTdIQHcDGQC

90. Marshall-Pescini S, Schwarz JFL, Kostelnik I, Virányi Z, Range F. Importance of a species' socioecology: Wolves outperform dogs in a conspecific cooperation task. Proc Natl Acad Sci U S A. 2017;114: 11793–11798. doi:10.1073/pnas.1709027114

91. Dahl EJ. Preventing a Day of Terror: Lessons Learned from an Unsuccessful Terrorist Attack. CTX. 2014;4: 71–77. Available: https://globalecco.org/preventing-a-day-of-terror-lessons-learned-from-an-unsuccessful-terrorist-attack

92. Robinson W. Eradicating Organized Criminal Gangs in Jamaica: Can Lessons be Learnt From A Successful Counterinsurgency? 2008. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a491587.pdf

93. Lebeuf C, Storey M-A, Zagalsky A. How Software Developers Mitigate Collaboration Friction with Chatbots. arXiv [cs.HC]. 2017. Available: http://arxiv.org/abs/1702.07011

94. SEBoK. [cited 1 Sep 2020]. Available: https://www.sebokwiki.org/wiki/Guide_to_the_Systems_Engineering_Body_of_Knowledge_(SEBoK)

95. Levenchuk A. Towards a Systems Engineering Essence. arXiv [cs.SE]. 2015. Available: http://arxiv.org/abs/1502.00121

96. Levenchuk AI. Sistemnoye myshleniye [System thinking]. Moscow: Izdatelskiye resheniya. 2018.

97. Constant A, Ramstead MJD, Veissière SPL, Friston K. Regimes of Expectations: An Active Inference Model of Social Conformity and Human Decision Making. Front Psychol. 2019;10: 679. doi:10.3389/fpsyg.2019.00679

98. Goertzel B. The Hidden Pattern: A Patternist Philosophy of Mind. Universal-Publishers; 2006. Available: https://play.google.com/store/books/details?id=juj30GyFzOUC

99. European Commission. Artificial Intelligence for Europe. European Commission; 2018. Available: https://ec.europa.eu/transparency/regdoc/rep/1/2018/EN/COM-2018-237-F1-EN-MAIN-PART-1.PDF

100. About the Essence Specification Version 1.2. [cited 6 Sep 2020]. Available: https://www.omg.org/spec/Essence/

101. Harrald J, Jefferson T. Shared Situational Awareness in Emergency Management Mitigation and Response. 2007 40th Annual Hawaii International Conference on System Sciences (HICSS'07). 2007. pp. 23–23. doi:10.1109/HICSS.2007.481

102. Sandved Smith L, Hesp C, Lutz A, Mattout J, Friston K, Ramstead M. Towards a formal neurophenomenology of metacognition: modelling meta-awareness, mental action, and attentional control with deep active inference. 2020. doi:10.31234/osf.io/5jh3c

103. Инженер и муравей — Блог ШСМ. [cited 8 Sep 2020]. Available: https://blog.system-school.ru/2020/06/11/engineer-and-ant/

104. Friston K, Da Costa L, Hafner D, Hesp C, Parr T. Sophisticated Inference. arXiv [q-bio.NC]. 2020. Available: http://arxiv.org/abs/2006.04120

105. Friston KJ, Parr T, Yufik Y, Sajid N, Price CJ, Holmes E. Generative models, linguistic communication and active inference. Neurosci Biobehav Rev. 2020. doi:10.1016/j.neubiorev.2020.07.005

106. Sajid N, Ball PJ, Friston KJ. Active inference: demystified and compared. arXiv [cs.AI]. 2019. Available: http://arxiv.org/abs/1909.10863

107. Ralph P. Software engineering process theory: A multi-method comparison of Sensemaking–Coevolution–Implementation Theory and Function–Behavior–Structure Theory. Information and Software Technology. 2016;70: 232–250. doi:10.1016/j.infsof.2015.06.010

108. Wikipedia contributors. Process theory. In: Wikipedia, The Free Encyclopedia [Internet]. 27 Jun 2020 [cited 21 Jul 2020]. Available: https://en.wikipedia.org/w/index.php?title=Process_theory&oldid=964740866

109. Friston K, Fortier M, Friedman DA. Of woodlice and men. ALIUS Bulletin. 2018;2: 17. Available: https://www.aliusresearch.org/uploads/9/1/6/0/91600416/alius_bulletin_n%C2%B02__2018_.pdf#page=27

110. Constant A, Ramstead MJD, Veissière SPL, Campbell JO, Friston KJ. A variational approach to niche construction. J R Soc Interface. 2018;15. doi:10.1098/rsif.2017.0685

111. Mirza MB, Adams RA, Friston K, Parr T. Introducing a Bayesian model of selective attention based on active inference. Sci Rep. 2019;9: 13915. doi:10.1038/s41598-019-50138-8

112. Friston KJ, Rosch R, Parr T, Price C, Bowman H. Deep temporal models and active inference. Neurosci Biobehav Rev. 2018;90: 486–501. doi:10.1016/j.neubiorev.2018.04.004

113. Parr T, Corcoran AW, Friston KJ, Hohwy J. Perceptual awareness and active inference. Neurosci Conscious. 2019;2019: niz012. doi:10.1093/nc/niz012

114. Boonstra EA, Slagter HA. The Dialectics of Free Energy Minimization. Front Syst Neurosci. 2019;13: 42. doi:10.3389/fnsys.2019.00042

115. Vasil J, Badcock PB, Constant A, Friston K, Ramstead MJD. A World Unto Itself: Human Communication as Active Inference. Front Psychol. 2020;11: 417. doi:10.3389/fpsyg.2020.00417

116. Hutto DD. The cost of over-intellectualizing the free-energy principle. Behav Brain Sci. 2020;43: e105. doi:10.1017/S0140525X19002851

117. Carney J. Hard Truths and Comforting Fictions: Does Narrative Actually Construct Identity? Evolutionary Studies in Imaginative Culture. 2019;3: 37–40. Available: http://www.jstor.org/stable/10.26613/esic.3.1.115

118. Gallagher S, Daly A. Dynamical Relations in the Self-Pattern. Front Psychol. 2018;9: 664. doi:10.3389/fpsyg.2018.00664

119. Demekas D, Parr T, Friston KJ. An Investigation of the Free Energy Principle for Emotion Recognition. Front Comput Neurosci. 2020;14: 30. doi:10.3389/fncom.2020.00030

120. Friston KJ, Parr T, de Vries B. The graphical brain: Belief propagation and active inference. Netw Neurosci. 2017;1: 381–414. doi:10.1162/NETN_a_00018

121. Parr T, Markovic D, Kiebel SJ, Friston KJ. Neuronal message passing using Mean-field, Bethe, and Marginal approximations. Sci Rep. 2019;9: 1889. doi:10.1038/s41598-018-38246-3

122. Friston KJ, Frith CD. Active inference, communication and hermeneutics. Cortex. 2015;68: 129–143. doi:10.1016/j.cortex.2015.03.025

123. Ramstead MJD, Veissière SPL, Kirmayer LJ. Cultural Affordances: Scaffolding Local Worlds Through Shared Intentionality and Regimes of Attention. Front Psychol. 2016;7: 1090. doi:10.3389/fpsyg.2016.01090

124. Vygotsky L. S.(1981). The genesis of higher mental functions. The Concept of Activity in Soviet Psychology, Sharpe. 1931.

125. Bolis D, Schilbach L. "Through others we become ourselves": The dialectics of predictive coding and active inference. 2019. doi:10.31234/osf.io/6uwyn

126. Kirchhoff M, Parr T, Palacios E, Friston K, Kiverstein J. The Markov blankets of life: autonomy, active inference and the free energy principle. J R Soc Interface. 2018;15: 20170792. doi:10.1098/rsif.2017.0792

127. Palacios ER, Razi A, Parr T, Kirchhoff M, Friston K. On Markov blankets and hierarchical self-organisation. J Theor Biol. 2019; 110089. doi:10.1016/j.jtbi.2019.110089

128. Friston K. A free energy principle for a particular physics. arXiv [q-bio.NC]. 2019. Available: http://arxiv.org/abs/1906.10184

129. Ramstead MJD, Badcock PB, Friston KJ. Answering Schrödinger's question: A free-energy formulation. Phys Life Rev. 2018;24: 1–16. doi:10.1016/j.plrev.2017.09.001

130. Katsevman M. Exploring the exocortex: an approach to optimizing human productivity. online from logarchy org. 2008.

131. Bonaci T, Herron J, Matlack C, Chizeck HJ. Securing the exocortex: A twenty-first century cybernetics challenge. 2014 IEEE Conference on Norbert Wiener in the 21st Century (21CW). 2014. pp. 1–8. doi:10.1109/NORBERT.2014.6893912

132. The unexpected: narrative temporality and the philosophy of surprise. Choice Reviews Online. 2013;50: 50–6589–50–6589. doi:10.5860/CHOICE.50-6589

133. Andrade RO, Yoo SG. Cognitive security: A comprehensive study of cognitive science in cybersecurity. Journal of Information Security and Applications. 2019;48: 102352. doi:10.1016/j.jisa.2019.06.008

134. Thomas J, Mantri P. Axiomatic Cloud Computing Architectural Design. MATEC Web of Conferences. 2019;301: 00024. doi:10.1051/matecconf/201930100024

135. Fuller RB. Synergetics: Explorations in the geometry of thinking. 1982. Available: https://books.google.com/books?hl=en&lr=&id=AKDgDQAAQBAJ&oi=fnd&pg=PA701&dq=synergetics+fuller&ots=SV4RrGAXbU&sig=d2cWIVKRMkEy0Cb5rjoZxViBfTs

136. SISO. Guide for Coalition Battle Management Language (C-BML) Phase 1. 2017. Report No.: SISO-GUIDE-004. Available: https://www.sisostds.org/DesktopModules/Bring2mind/DMX/API/Entries/Download?Command=Core_Download&EntryId=45913&PortalId=0&TabId=105

137. Schade U, Hieb MR. Battle management language: A grammar for specifying orders. IEEE Spring Simulation. IEEE; 2007. Available:

https://pdfs.semanticscholar.org/480e/f3fbd15932c2b46f1c21cffef2aaaec57a88.pdf

138. de Reus NM, de Krom PPJ, Mevassvik OM, Alstad A, Sletten G. BML-enabling national C2 systems for coupling to Simulation. 2008 Spring Simulation Interoperability Workshop (SIW), April 14-18, 2008, Providence, Rhode Island, USA, 628-638. repository.tudelft.nl; 2008. Available: https://repository.tudelft.nl/view/tno/uuid:56267b48-4378-4967-a947-b3d9f28a549f

139. Dunbar RIM. Neocortex size as a constraint on group size in primates. J Hum Evol. 1992;22: 469–493. Available: http://etherplan.com/neocortex-size-as-a-constraint-on-group-size-in-primates.pdf

140. Dunbar RIM. Grooming, Gossip, and the Evolution of Language. Harvard University Press; 1998. Available: https://play.google.com/store/books/details?id=nN5DFNT-6ToC

141. Kim T-W, Jung J-R, Kim S-W. Implications of the Dunbar Number in Collective Intelligence based on Social Network Services. International Journal of Contents. 2012;8: 1–6. doi:10.5392/IJoC.2012.8.3.001

142. Siebold GL. Military group cohesion. Military life: The psychology of serving in peace and combat. 2006;1: 185–201. Available: https://books.google.com/books?hl=en&lr=&id=MNaym4QmPy8C&oi=fnd&pg=PA185&dq=siebold+military+group+cohesion+psychology+of+serving&ots=O_whJZF5nc&sig=k20Yf-cnqM0OU6UUJqOxUafSlKg

143. Britt TW, Oliver KK. Morale and cohesion as contributors to resilience. In: Sinclair RR, editor. Building psychological resilience in military personnel: Theory and practice , (pp. Washington, DC, US: American Psychological Association, xi; 2013. pp. 47–65. doi:10.1037/14190-003

144. Craib R, Bradway G, Dunn X, Krug J. Numeraire: A cryptographic token for coordinating machine intelligence and preventing overfitting. Retrieved. 2017. Available: https://www.gwkjbc.com/Uploads/2018-10-29/5bd66a7b27ba5.pdf

145. Litvak V, Mattout J, Kiebel S, Phillips C, Henson R, Kilner J, et al. EEG and MEG data analysis in SPM8. Comput Intell Neurosci. 2011;2011: 852961. doi:10.1155/2011/852961

146. Friston KJ, Diedrichsen J, Holmes E, Zeidman P. Variational representational similarity analysis. Neuroimage. 2019; 115986. doi:10.1016/j.neuroimage.2019.06.064

147. Hafner D, Ortega PA, Ba J, Parr T, Friston K, Heess N. Action and Perception as Divergence Minimization. arXiv [cs.AI]. 2020. Available: http://arxiv.org/abs/2009.01791

148. Wim. matterbridge. Github; Available: https://github.com/42wim/matterbridge

149. Proust J, Fortier M. Metacognitive Diversity: An Interdisciplinary Approach. Oxford University Press; 2018. Available: https://play.google.com/store/books/details?id=oBFQDwAAQBAJ

150. cadCAD – A Python package for designing, testing and validating complex systems through simulation. [cited 26 Mar 2020]. Available: https://cadcad.org/

151. Yang L, Cormican K, Yu M. Ontology-based systems engineering: A state-of-the-art review. Comput Ind. 2019;111: 148–171. doi:10.1016/j.compind.2019.05.003

152. Parr T, Friston KJ. Generalised free energy and active inference. Biol Cybern. 2019;113: 495–513. doi:10.1007/s00422-019-00805-w

153. Engineered System (glossary). [cited 7 Sep 2020]. Available: https://www.sebokwiki.org/wiki/Engineered_System_(glossary)

154. ISO/IEC/IEEE 15288:2015. 2020 [cited 6 Sep 2020]. Available: https://www.iso.org/standard/63711.html

Chapter IV
Works Cited

1. U.S. Joint Chiefs of Staff. Joint Publication 5-0: Joint Operation Planning. Washington, DC: Government Printing Office; 2017.
2. Richardson J, James A, Mittrick M, Hanratty T, Heilman E. Methodology for using the operations order to filter intelligence reports. International Society for Optics and Photonics; 2018. p. 1065304.
3. Smith ML. The Five Paragraph Field Order: Can a Better Format Be Found to Transmit Combat Information to Small Tactical Units? School of Advanced Military Studies, US Army Command and General Staff College of Fort Leavenworth Kansas; 1988. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a210966.pdf
4. Filiberti EJ. The Standard Operations Order Format: Is Its Current Form and Content Sufficient for Command and Control? ARMY COMMAND AND GENERAL STAFF COLL FORT LEAVENWORTH KS SCHOOL OF ADVANCED …; 1987. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a191781.pdf
5. Welch K. Caesar and his officers in the Gallic War commentaries. Julius Caesar as Artful Reporter: The War Commentaries as Political Instruments. 1998; 85–110.
6. Caesar J. Commentaries on the Gallic War. Crocker and Brewster; 1865.

7. Carl Von Clausewitz, Howard M, Paret P, Howard M, Brodie B. On War. Howard M, Paret P, editors. Princeton University Press; 1989.

8. Harbottle TB. Dictionary of Battles from the Earliest Date to the Present Time. S. Sonnenschein & Company, Limited; 1904.

9. Best EE. The Literate Roman Soldier. Class J. 1966;62: 122–127.

10. Livy. The History of Rome, Books 1-5. Hackett Publishing; 2006.

11. Polybius. The Histories of Polybius (Complete). Library of Alexandria; 1889.

12. Tacitus. Tacitus Complete Works. Random House; 1964.

13. Birtle AJ. The Origins of the Legion of the United States. J Mil Hist. 2003;67: 1249–1261.

14. de Blois L, Demougin ACS, Olivier Hekster G de KL de L, Lo Cascio E, Rich MPJ, Witschel C. Impact of Empire. Brill; 2007.

15. Pliny (the Elder). The Complete Works of Pliny the Elder. Delphi Classics; 2015.

16. Adamson G. Letter from a Soldier in Pannonia. Bull Am Soc Papyrol. 2012;49: 79–94.

17. Millender EG. Spartan Literacy Revisited. Class Antiq. 2001;20: 121–164.

18. Dickey E. Education, Research, and Government in the Ancient Greek World. 2014. Available: https://www.youtube.com/watch?v=H0z9sJyTv2w

19. Gleason JP. Roman roads in Gaul: how lines of communication and basing support operational reach. ARMY COMMAND AND GENERAL STAFF COLLEGE FORT LEAVENWORTH KS SCHOOL OF …; 2013. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a606035.pdf

20. US Department of the Army. ADP 3-0: Unified Land Operations. 2011.

21. Gat A. A History of Military Thought: From the Enlightenment to the Cold War. Oxford University Press; 2001.

22. Linn BM. The Echo of Battle. Harvard University Press; 2009.

23. Swift E. Field Orders, Messages and Reports. Journal of the United States Cavalry Association. 1897;10: 221–233.

24. Constant A, Ramstead MJD, Veissière SPL, Friston K. Regimes of Expectations: An Active Inference Model of Social Conformity and Human Decision Making. Front Psychol. 2019;10: 679.

25. Weick KE. The Collapse of Sensemaking in Organizations: The Mann Gulch Disaster. Adm Sci Q. 1993;38: 628–652.

26. Lyons DE, Young AG, Keil FC. The hidden structure of overimitation. Proc Natl Acad Sci U S A. 2007;104: 19751–19756.

27. Weick KE, Sutcliffe KM. Managing the Unexpected. 3rd ed. Wiley; 2015.

28. Sonnenberger M. Art of War Papers: Initiative within the Philosophy of Auftragstaktik Determining Factors of the Understanding of Initiative in the German Army 1806-1955. US Army Combined Arms Center, Fort Leavenworth Kansas; 2013. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a599111.pdf

29. Cordes RJ, Friedman D. Emergent Teams for Complex Threats. 2020. doi:10.5281/zenodo.3986085

30. Reeves JH. Cavalry Raids. Journal of the United States Cavalry Association. 1897;10: 232–247.

31. Smith H. Field Orders. Journal of the Military Service Institute of the United States. 1914; 26.

32. US War Department. Field Service Regulations United States Army. 1918. Available: https://play.google.com/store/books/details?id=sP8sAAAAIAAJ

33. US War Department. Instructions for the offensive combat of small units. 1918. Report No.: 802. Available: http://hdl.handle.net/2027/uiug.30112068991873

34. US War Department. Tactical Order for Small Units in Trench Warfare. 1918. Report No.: 798.

35. Corlett CH. Evolution of field orders. Coast artillery journal. 1925.

36. Keegan J. The Face Of Battle: A Study of Agincourt, Waterloo and the Somme. Random House; 2011.

37. During F, Guenther GB, editors. Review of Military Literature. Fort Leavenworth Command and General Staff College; 1935.

38. US Department of the Army. FM 7-5 Infantry Field Manual Organization and Tactics of Infantry The Rifle Battalion. United States Government Printing Office; 1940.

39. Hart BHL. Strategy. Praeger; 1967.

40. Lawson ST. Nonlinear Science and Warfare: Chaos, complexity and the U.S. military in the information age. Routledge; 2013.

41. Gore J. Chaos, complexity, and the military. National Defense University; 1996. Available: https://apps.dtic.mil/sti/citations/ADA441996

42. Current ML. Chaos, complexity, and ethnic conflict: A study in the application of the principles of chaos and complexity theory to the analysis of ethnic conflict. ARMY COMMAND AND GENERAL STAFF COLL FORT LEAVENWORTH KS; 2000. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a384437.pdf

43. US Department of the Army. Staff Organization and Procedure. 1960. Report No.: FM 101-5.

44. US Department of the Army. The Operations Process. 2010. Report No.: FM 5-0.

45. Rottman GL. Viet Cong and NVA Tunnels and Fortifications of the Vietnam War. Bloomsbury Publishing; 2012.

46. Herrington S. Stalking the Vietcong: Inside Operation Phoenix: A Personal Account. Random House Publishing Group; 2012.

47. Wiest A, McNab C. The Vietnam War. Cavendish Square Publishing, LLC; 2016.

48. Wiest A, editor. Rolling Thunder in a Gentle Land. Osprey Publishing Ltd.; 2006.

49. Johansson A. "Life is Chaos Now" : Water, Modernity and Changing Landscapes in the Mekong Delta, Vietnam. 2019. Available: https://www.diva-portal.org/smash/record.jsf?pid=diva2:1326750

50. Dieu NT, Nguyen TD. The Mekong River and the Struggle for Indochina: Water, War, and Peace. Greenwood Publishing Group; 1999.

51. Studer J, Major SAF, MacCuish DA. … THERE FIVE RINGS OR A LOOP IN FOURTH GENERATION WARFARE? A STUDY ON THE APPLICATION OF WARDEN'S OR BOYD'S THEORIES IN 4GW. , AL: Air Command and Staff College …. 2005. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.114.591&rep=rep1&type=pdf

52. Junio TJ. Military History and Fourth Generation Warfare. Journal of Strategic Studies. 2009;32: 243–269.

53. Robinson L. Masters of Chaos: The Secret History of the Special Forces. PublicAffairs; 2004.

54. Ives CK. US Special Forces and Counterinsurgency in Vietnam. 2007. doi:10.4324/9780203964941

55. Rosenau W. Special Operations Forces and Elusive Enemy Ground Targets: Lessons from Vietnam and the Persian Gulf War. Rand Corporation; 2001.

56. Tzu S. Sun Tzu Art of War. Vij Books India Pvt Ltd; 2012.

57. Jones S. Scouting for Soldiers: Reconnaissance and the British Cavalry, 1899—1914. War Hist. 2011;18: 495–513.

58. Garber WB Jr. The Art of Command and Control in Mechanized Task Force Offensive Operations. ARMY WAR COLL CARLISLE BARRACKS PA; 1986. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a170451.pdf

59. Van Creveld M. Command in War. Harvard University Press; 1985.

60. Vyatkin A, Metelkin I, Mikhailova A, Cordes RJ, Friedman DA. Active Inference & Behavior Engineering for Teams. 2020. doi:10.5281/zenodo.4021163

61. Vandergriff DE. How the Germans Defined Auftragstaktik: What Mission Command IS -AND- is Not. Small Wars Journal. 2018.

62. Oberkommando GH. On the German Art of War: Truppenführung. Lynne Rienner Publishers; 2001.

63. Citino RM. The German Way of War. From the Thirty Years' War to the Third Reich, Lawrence, KS. 2005. Available: https://brill.com/downloadpdf/book/edcoll/9789004310032/B9789004310032_015.pdf

64. Kallmes K. Auftragstaktik: Decentralization in Military Command. In: realcleardefense.com [Internet]. 2017 [cited 15 Sep 2020]. Available: https://www.realcleardefense.com/articles/2017/04/28/auftragstaktik_decentralization_in_military_command_111267.html

65. Siebold GL. Military group cohesion. Military life: The psychology of serving in peace and combat. 2006;1: 185–201.

66. Lester PB, Vogelgesang GR. Swift Trust in Ad Hoc Military Organizations. Oxford Handbooks Online. 2012. doi:10.1093/oxfordhb/9780195399325.013.0067

67. Dunbar RIM. Neocortex size as a constraint on group size in primates. J Hum Evol. 1992;22: 469–493.

68. Dunbar RIM. Grooming, Gossip, and the Evolution of Language. Harvard University Press; 1998.

69. Arlington Cemetery - Eben Swift. In: http://www.arlingtoncemetery.net/ [Internet]. 2006 [cited 16 Sep 2020]. Available: http://www.arlingtoncemetery.net/eben-swift.htm

70. U.S. Joint Chiefs of Staff. Joint Publication 3-0: Joint Operations. Washington, DC: Government Printing Office; 2017. Report No.: 3-0.

71. Gray PH. The effects of knowledge management systems on emergent teams: towards a research model. The Journal of Strategic Information Systems. 2000;9: 175–191.

72. Malhotra Y. Why Knowledge Management Systems Fail: Enablers and Constraints of Knowledge Management in Human Enterprises. In: Holsapple CW, editor. Handbook on Knowledge Management 1: Knowledge Matters. Berlin, Heidelberg: Springer Berlin Heidelberg; 2004. pp. 577–599.

73. Gawrych GW. The 1973 Arab-Israeli War: The Albatross Of Decisive Victory [Illustrated Edition]. Pickle Partners Publishing; 2015.

74. Paret P, Howard M, Hunter R. Israel and the Arab World: The Crisis of 1967. Mil Aff. 1967;31: 196.

75. US Department of the Army. ADP 4-0: Sustainment. Washington, DC: Government Printing Office; 2019.

76. Shaw R. Strange Attractors, Chaotic Behavior, and Information Flow. Zeitschrift für Naturforschung A. 1980;36: 80–112.

77. Eckmann J-P, Ruelle D. Ergodic theory of chaos and strange attractors. The theory of chaotic attractors. Springer; 1985. pp. 273–312.

78. US Army. A Leader's Guide to After-Action Reviews - Training Circular. 1993. Report No.: TC 25-20.

79. NATO. STANAG 2014 - Formats for orders and designation of timings, locations, and boundaries. 2014. Report No.: MAS(ARMY)0307-TOP/2014. Available: https://www.trngcmd.marines.mil/Portals/207/Docs/TBS/STANAG%202014%20Edition%2009-%20FORMATS%20FOR%20ORDERS%20(OPORD).pdf

80. U.S. Joint Chiefs of Staff. Joint Publication 5-0: Joint Planning. Washington, DC: Government Printing Office; 2017.

81. U.S. Joint Chiefs of Staff. Joint Publication 4-0: Joint Logistics. 2013.

82. U.S. Dept. of the Army. ADP 1-02: Operational Terms and Military Symbols. Washington, DC: Government Printing Office; 2018.

83. Blais C, Turnitsa C, Gustavsson P. A strategy for ontology research for the coalition battle management language (C-BML) product development group. Proceedings of the Fall Simulation Interoperability Workshop. 2006. pp. 11–22.

84. Schade U, Hieb MR. Battle management language: A grammar for specifying reports. IEEE Spring Simulation Interoperability Workshop. pdfs.semanticscholar.org; 2007. Available: https://pdfs.semanticscholar.org/480e/f3fbd15932c2b46f1c21cffef2aaaec57a88.pdf

85. SISO. Guide for Coalition Battle Management Language (C-BML) Phase 1. 2017. Report No.: SISO-GUIDE-004. Available: https://www.sisostds.org/DesktopModules/Bring2mind/DMX/API/Entries/Download?Command=Core_Download&EntryId=45913&PortalId=0&TabId=105

86. de Reus NM, de Krom PPJ, Mevassvik OM, Alstad A, Sletten G. BML-enabling national C2 systems for coupling to Simulation. 2008 Spring Simulation Interoperability Workshop (SIW), April 14-18, 2008, Providence, Rhode Island, USA, 628-638. repository.tudelft.nl; 2008. Available: https://repository.tudelft.nl/view/tno/uuid:56267b48-4378-4967-a947-b3d9f28a549f

87. Schade U, Hieb MR. Battle management language: A grammar for specifying orders. IEEE Spring Simulation. IEEE; 2007. Available: https://pdfs.semanticscholar.org/480e/f3fbd15932c2b46f1c21cffef2aaaec57a88.pdf

88. Blais C, Abbott J, Diallo S, Levine S, Gustavsson PM, Nero E, et al. Coalition Battle Management Language (C-BML) phase 1 specification development: an update to the M&S community. Fall Simulation Interoperability Workshop. 2009. pp. 1–9.

89. Socom US. UInited States Special Operations Command History 1987-2007. 2007.

90. Meacham JA. Wisdom and the Context of Knowledge: Knowing that One Doesn't Know. 1983. pp. 111–134.

91. Szubin HZ, Porten B. An Aramaic Joint Venture Agreement: A New Interpretation of the Bauer-Meissner Papyrus. Bull Am Schools Orient Res. 1992;288: 67–84.

92. Wirth N. On multiprogramming, machine coding, and computer organization. Commun ACM. 1969;12: 489–498.

93. Charrel P-J, Galarreta D. Project Management and Risk Management in Complex Projects: Studies in Organizational Semiotics. Springer Science & Business Media; 2007.

94. Banfield R, Todd Lombardo C, Wax T. Design Sprint: A Practical Guidebook for Building Great Digital Products. "O'Reilly Media, Inc."; 2015.

95. Davidson Frame J. The New Project Management: Tools for an Age of Rapid Change, Complexity, and Other Business Realities. John Wiley & Sons; 2002.

96. Chen X-P, Yao X, Kotha S. Entrepreneur Passion And Preparedness In Business Plan Presentations: A Persuasion Analysis Of Venture Capitalists' Funding Decisions. AMJ. 2009;52: 199–214.

97. Mason C, Stark M. What do Investors Look for in a Business Plan?: A Comparison of the Investment Criteria of Bankers, Venture Capitalists and Business Angels. Int Small Bus J. 2004;22: 227–248.

98. Bonvillian WB, Van Atta R, Windham P. The DARPA Model for Transformative Technologies: Perspectives on the US Defense Advanced Research Projects Agency. Open Book Publishers; 2019.

99. Fuchs ERH. Cloning DARPA Successfully. Issues Sci Technol. 2009;26: 65–70.

100. Cheung N, Howell J. Tribute to George Heilmeier, inventor of liquid crystal display, former DARPA director, and industry technology leader. IEEE Commun Mag. 2014;52: 12–13.

101. Shapiro J. George H. Heilmeier. IEEE Spectrum. 1994;31: 56–59.

102. Roland A, of History Alex Roland, Shiman P, Aspray W. Strategic Computing: DARPA and the Quest for Machine Intelligence, 1983-1993. MIT Press; 2002.

103. Boyd JR. The Westminster Shorter Catechism: With Analysis, Scriptural Proofs, Explanatory and Practical Inferences, and Illustrative Anecdotes. M.W. Dodd; 1856.

104. Porte TL, Consolini P. Theoretical and operational challenges of "high-reliability organizations": air-traffic control and aircraft carriers. International Journal of Public Administration. 1998;21: 847–852.

105. Lekka C. High reliability organisations: A review of the literature. Health and Safety Laboratory; 2011.

106. Weick KE, Roberts KH. Collective Mind in Organizations: Heedful Interrelating on Flight Decks. Adm Sci Q. 1993;38: 357–381.

107. Haimes YY. Risk Modeling of Interdependent Complex Systems of Systems: Theory and Practice. Risk Anal. 2018;38: 84–98.

108. Muñoz-Carrillo JL, Castro-García FP, Chávez-Rubalcaba F, Chávez-Rubalcaba I, Martínez-Rodríguez JL, Hernández-Ruiz ME. Immune system disorders: Hypersensitivity and autoimmunity. Immunoregulatory Aspects of Immunotherapy London: InTechOpen. 2018; 1–30.

109. Dozmorov IM, Dresser D. Immune System as a Sensory System. Int J Biomed Sci. 2010;6: 167–175.

110. Bolders AC, Tops M, Band GPH, Stallen PJM. Perceptual Sensitivity and Response to Strong Stimuli Are Related. Front Psychol. 2017;8: 1642.

111. Acevedo B, Aron E, Pospos S, Jessen D. The functional highly sensitive brain: a review of the brain circuits underlying sensory processing sensitivity and seemingly related disorders. Philos Trans R Soc Lond B Biol Sci. 2018;373. doi:10.1098/rstb.2017.0161

112. Gell-Mann M. The Quark and the Jaguar: Adventures in the Simple and the Complex. Macmillan; 1995.

113. Mesjasz C. Complexity and Social Systems. Proceedings of the 4th Polish Symposium on Econo- and Sociophysics. 2009;117: 706–715.

114. Roberts KH. Some Characteristics of One Type of High Reliability Organization. Organization Science. 1990;1: 160–176.

115. Isermann R. Fault-Diagnosis Systems: An Introduction from Fault Detection to Fault Tolerance. Springer Science & Business Media; 2006.

116. Grabowski M, Roberts KH. Reliability seeking virtual organizations: Challenges for high reliability organizations and resilience engineering. Saf Sci. 2019;117: 512–522.

117. Norman D. The Design of Everyday Things: Revised and Expanded Edition. Basic Books; 2013.

118. Weick KE. Sensemaking in Organizations. SAGE; 1995.

119. Vogus TJ, Welbourne TM. Structuring for high reliability: HR practices and mindful processes in reliability-seeking organizations. Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior. 2003;24: 877–903.

120. Eisenhardt KM. High reliability organizations meet high velocity environments: Common dilemmas in nuclear power plants, aircraft carriers, and microcomputer firms. New challenges to understanding organizations. 1993.

121. Christianson MK, Sutcliffe KM, Miller MA, Iwashyna TJ. Becoming a high reliability organization. Crit Care. 2011;15: 314.

122. Heylighen F, Joslyn C. Cybernetics and Second-Order Cybernetics. In: Meyers RA, editor. Encyclopedia of Physical Science and Technology (Third Edition). New York: Academic Press; 2003. pp. 155–169.

123. Constant A, Ramstead MJD, Veissière SPL, Campbell JO, Friston KJ. A variational approach to niche construction. J R Soc Interface. 2018;15: 20170685.

124. Parr T, Friston KJ. Generalised free energy and active inference. Biol Cybern. 2019;113: 495–513.

125. Hafner D, Ortega PA, Ba J, Parr T, Friston K, Heess N. Action and Perception as Divergence Minimization. arXiv [cs.AI]. 2020. Available: http://arxiv.org/abs/2009.01791

126. Ramstead MJD, Constant A, Badcock PB, Friston KJ. Variational ecology and the physics of sentient systems. Phys Life Rev. 2019. doi:10.1016/j.plrev.2018.12.002

127. Bisong E. Optimization for Machine Learning: Gradient Descent. Building Machine Learning and Deep Learning Models on Google Cloud Platform. 2019. pp. 203–207. doi:10.1007/978-1-4842-4470-8_16

128. Seth AK, Friston KJ. Active interoceptive inference and the emotional brain. Philos Trans R Soc Lond B Biol Sci. 2016;371: 20160007.

129. Friston KJ, Parr T, de Vries B. The graphical brain: Belief propagation and active inference. Netw Neurosci. 2017;1: 381–414.

130. Colyvan M, Ginzburg LR. Analogical thinking in ecology: looking beyond disciplinary boundaries. Q Rev Biol. 2010;85: 171–182.

131. Olson HF. Dynamical analogies. Van Nostrand Princeton, NJ; 1958.

132. Olson HF. Solutions of engineering problems by dynamical analogies. Van Nostrand; 1966.

133. Hills TT. Animal foraging and the evolution of goal-directed cognition. Cogn Sci. 2006;30: 3–41.

134. Hills TT, Todd PM, Lazer D, Redish AD, Couzin ID, Cognitive Search Research Group. Exploration versus exploitation in space, mind, and society. Trends Cogn Sci. 2015;19: 46–54.

135. DeYoung CG, Quilty LC, Peterson JB, Gray JR. Openness to experience, intellect, and cognitive ability. J Pers Assess. 2014;96: 46–52.

136. Ashton MC, Lee K, Vernon PA, Jang KL. Fluid Intelligence, Crystallized Intelligence, and the Openness/Intellect Factor. J Res Pers. 2000;34: 198–207.

137. Ziegler M, Cengia A, Mussel P, Gerstorf D. Openness as a buffer against cognitive decline: The Openness-Fluid-Crystallized-Intelligence (OFCI) model applied to late adulthood. Psychol Aging. 2015;30: 573–588.

138. Hogan MJ, Staff RT, Bunting BP, Deary IJ, Whalley LJ. Openness to experience and activity engagement facilitate the maintenance of verbal ability in older adults. Psychol Aging. 2012;27: 849–854.

139. Cota W, Ferreira SC, Pastor-Satorras R, Starnini M. Quantifying echo chamber effects in information spreading over political communication networks. EPJ Data Science. 2019;8: 35.

140. Heylighen F. Selection criteria for the evolution of knowledge. Proc 13th Int Congress on Cybernetics. Association Internat. de Cybernétique; 1993. pp. 524–528.

141. Ledesma RD, Sánchez R, Díaz-Lázaro CM. Adjective checklist to assess the big five personality factors in the Argentine population. J Pers Assess. 2011;93: 46–55.

142. Kent S. Strategic Intelligence for American World Policy. Princeton University Press; 1949.

143. Salas E, Sims DE, Burke CS. Is there a "Big Five" in Teamwork? Small Group Research. 2005;36: 555–599.

144. Runsten P. Team Intelligence: The Foundations of Intelligent Organizations - A Literature Review. 2017 [cited 31 Aug 2020]. Available: http://dx.doi.org/

145. Hutter M. Universal Artificial Intelligence: Sequential Decisions Based on Algorithmic Probability. Springer Science & Business Media; 2004.

146. Bandura A, Freeman WH, Lightsey R. Self-efficacy: The exercise of control. Worth Publishers; 1997.

147. Weiner IB, Craighead WE, editors. Self-Efficacy. The Corsini Encyclopedia of Psychology. Hoboken, NJ, USA: John Wiley & Sons, Inc.; 2010. p. 69.

148. Schippers MC, Scheepers AWA, Peterson JB. A scalable goal-setting intervention closes both the gender and ethnic minority achievement gap. Palgrave Communications. 2015;1: 15014.

149. Latham GP, Locke EA. Self-regulation through goal setting. Organ Behav Hum Decis Process. 1991;50: 212–247.

150. Tudge JRH, Winterhoff PA. Vygotsky, Piaget, and Bandura: Perspectives on the Relations between the Social World and Cognitive Development. Hum Dev. 1993;36: 61–81.

151. Bruineberg J, Rietveld E. Self-organization, free energy minimization, and optimal grip on a field of affordances. Front Hum Neurosci. 2014;8: 599.

152. Campbell J. The Hero with a Thousand Faces. New World Library; 2008.

153. Neumann E. The Origins and History of Consciousness. Princeton University Press; 1954.

154. Peterson JB. Maps of Meaning: The Architecture of Belief. Psychology Press; 1999.

155. Jung CG. Symbols of Transformation (Collected Works of C.G. Jung Vol.5). 2nd ed. edition. Princeton University Press; 1977.

156. Hobsbawm E, Ranger T. The Invention of Tradition. Cambridge University Press; 2012.

157. Ben-Shalom U, Klar Y, Benbenisty Y. Characteristics of Sense-Making in Combat. In: Nathan PE, editor. Oxford Handbook of Military Psychology. OUP USA; 2012. pp. 218–231.

158. Al-Ali AG, Phaal R. Design Sprints for Roadmapping an Agile Digital Transformation. 2019 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC). 2019. pp. 1–6.

159. Friston K, Schwartenbeck P, Fitzgerald T, Moutoussis M, Behrens T, Dolan RJ. The anatomy of choice: active inference and agency. Front Hum Neurosci. 2013;7: 598.

160. Chen AG, Benrimoh D, Parr T, Friston KJ. A Bayesian Account of Generalist and Specialist Formation Under the Active Inference Framework. Frontiers Artificial Intelligence Appl. 2020;3: 69.

161. Hunt ER, Franks NR, Baddeley RJ. The Bayesian superorganism: externalized memories facilitate distributed sampling. J R Soc Interface. 2020;17: 20190848.

162. Noneman M. A Glossary of Scrum Terms. 2017 [cited 23 Sep 2020]. Available: https://www.madisonhenry.com/blog/a-glossary-of-scrum-terms

163. Cordes RJ. Making sense of sensemaking: What it is and what it means for pandemic research - Atlantic Council. In: atlanticcouncil.org [Internet]. 18 Aug 2020 [cited 20 Aug 2020]. Available: https://www.atlanticcouncil.org/blogs/geotech-cues/making-sense-of-sensemaking-what-it-is-and-what-it-means-for-pandemic-research/

164. Yufik YM, Friston K. Life and Understanding: The Origins of “Understanding” in Self-Organizing Nervous Systems. Front Syst Neurosci. 2016;10: 98.

165. Friston KJ, Lin M, Frith CD, Pezzulo G, Hobson JA, Ondobaka S. Active Inference, Curiosity and Insight. Neural Comput. 2017;29: 2633–2683.

166. Enya A, Dempsey S, Pillay M. High Reliability Organisation (HRO) Principles of Collective Mindfulness: An Opportunity to Improve Construction Safety

Management. Advances in Safety Management and Human Factors. Springer International Publishing; 2019. pp. 3–13.

167. Drucker PF. Management: Tasks, practices, responsibilities. New York. 1974.

168. Haberfield MR, Hassell A von. A New Understanding of Terrorism. Springer Science & Business Media; 2009.

169. Huber GP, Daft RL. The information environments of organizations. In: Jablin FM, editor. Handbook of organizational communication: An interdisciplinary perspective , (pp. 1987. pp. 130–164.

170. Pang C, Szafron D. Single Source of Truth (SSOT) for Service Oriented Architecture (SOA). Service-Oriented Computing. Springer Berlin Heidelberg; 2014. pp. 575–589.

171. Chown B. Applying a single source of truth approach to the information needed for Functional Safety. 2018 IEEE/AIAA 37th Digital Avionics Systems Conference (DASC). 2018. pp. 1–5.

172. United States Joint Chiefs of Staff. DOD Dictionary of Military and Associated Terms. Department of Defense; 2019. Available: https://www.jcs.mil

173. Ramstead MJD, Veissière SPL, Kirmayer LJ. Cultural Affordances: Scaffolding Local Worlds Through Shared Intentionality and Regimes of Attention. Front Psychol. 2016;7: 1090.

174. Smith J. Heilmeier Catechism: Nine Questions To Develop A Meaningful Data Science Project. In: datascientistinsights.com [Internet]. 11 Jun 2013 [cited 28 Sep 2020]. Available: https://datascientistinsights.com/2013/06/11/heilmeier-catechism-nine-questions-to-develop-a-meaningful-data-science-project/

175. Popoola OMJ. Selecting an Impactful Research Topic/Title. ICAN-Malaysia District Society Workshop; 2017. Available: https://dosen.perbanas.id/wp-content/uploads/2017/08/Selecting-an-impactful-research-topic-or-title-Aug2017.pdf

176. Ioannidis JPA. Why Most Clinical Research Is Not Useful. PLoS Med. 2016;13: e1002049.

177. Friedman D, Cordes RJ. Infinite Games for Infinite Teams. DARPA; 2020 Jul.

178. Praderio C. Watch a group of people flip over a car to save the driver trapped inside. In: insider.com/ [Internet]. 20 Jul 2016 [cited 24 Sep 2020]. Available: https://www.insider.com/people-lift-up-flipped-car-and-save-driver-2016-7

179. Tribune Media Wire. Group of Strangers Flip Car, Save Man Trapped Inside Crushed Convertible. In: WNEP [Internet]. 20 Jul 2016 [cited 24 Sep 2020]. Available: https://www.wnep.com/article/news/local/group-of-strangers-flip-

car-save-man-trapped-inside-crushed-convertible/523-9da76b31-285d-410b-bc09-f42f87947fe0

180. Vargas V. Good Samaritans Flip Car, Help Save Victims of Crash in Santa Ana. In: NBC Southern California [Internet]. 14 May 2019 [cited 24 Sep 2020]. Available: https://www.nbclosangeles.com/news/good-samaritans-help-crash-victims-in-santa-ana/136050/

181. Hochstein B, Rangarajan D, Mehta N, Kocher D. An Industry/Academic Perspective on Customer Success Management. J Serv Res. 2020;23: 3–7.

182. Bass JM. Scrum master activities: process tailoring in large enterprise projects. Commun ACM. 2010;53: 126–130.

183. Palantir - Solutions. In: Palantir.com [Internet]. [cited 23 Sep 2020]. Available: https://www.palantir.com/solutions/

184. Palantir. BrightNetwork - Deployment Strategist Overview. In: BrightNetwork.co.uk [Internet]. [cited 21 Sep 2020]. Available: https://www.brightnetwork.co.uk/graduate-jobs/palantir/deployment-strategist

185. Palantir. Deployment Strategists. In: palantir.com [Internet]. [cited 21 Sep 2020]. Available: https://www.palantir.com/careers/teams/deployment-strategists

186. Wischner J. How Employees at Palantir Technologies Use Data to Tackle Real Problems. In: talentspace.io [Internet]. [cited 21 Sep 2020]. Available: https://talentspace.io/advice/deployment-strategist-palantir-technologies

187. Hayne SC. The facilitators perspective on meetings and implications for group support systems design. SIGMIS Database. 1999;30: 72–91.

188. Keltner J (sam). Facilitation: Catalyst for Group Problem Solving. Manage Commun Q. 1989;3: 8–32.

189. Kelly GG, Bostrom RP. A Facilitator's General Model for Managing Socioemotional Issues in Group Support Systems Meeting Environments. Journal of Management Information Systems. 1997;14: 23–44.

190. Anson R, Fellers J, Kelly GG, Bostrom RP. Facilitating Research with Group Support Systems. Small Group Research. 1996. pp. 179–214. doi:10.1177/1046496496272001

191. Proceedings of the 1975 IEEE-USSR Joint Workshop on Information Theory, Moscow, USSR. IEEE; 1975.

192. Problems in Quantum Communication and Information Theory. Proceedings of the 1975 Institute of Electrical and Electronics Engineers IEEE-USSR Joint Workshop on Information Theory. IEEE; 1975. pp. 15–19.

193. Lee BG, Kansky J, Goyal AK, Pflügl C, Diehl L, Belkin MA, et al. Beam combining of quantum cascade laser arrays. Opt Express. 2009;17: 16216–16224.

194. Stewart NK. South Atlantic Conflict of 1982: A Case Study in Military Cohesion. U.S. Army Research Institute for the Behavioral and Social Sciences; 1988.

195. Brainard J. Scientists are drowning in COVID-19 papers. Can new tools keep them afloat? In: ScienceMag [Internet]. 2020 [cited 5 Aug 2020]. doi:10.1126/science.abc7839

196. Quezada RL, Talbot C, Quezada-Parker KB. From bricks and mortar to remote teaching: a teacher education programme's response to COVID-19. null. 2020; 1–12.

197. Brynjolfsson E, Horton JJ, Ozimek A, Rock D, Sharma G, TuYe H-Y. COVID-19 and Remote Work: An Early Look at US Data. National Bureau of Economic Research; 2020. doi:10.3386/w27344

198. Omary MB, Eswaraka J, Kimball SD, Moghe PV, Panettieri RA Jr, Scotto KW. The COVID-19 pandemic and research shutdown: staying safe and productive. J Clin Invest. 2020;130: 2745–2748.

199. Mihelic MF. Development of a New US Currency for the Post-Pandemic Remote Culture. UTHSC Faculty Publications. 2020 [cited 13 Jun 2020]. Available: https://dc.uthsc.edu/gsmk_facpubs/17/

200. Martin T, Hofman JM, Sharma A, Anderson A, Watts DJ. Exploring Limits to Prediction in Complex Social Systems. Proceedings of the 25th International Conference on World Wide Web - WWW '16. 2016. doi:10.1145/2872427.2883001

201. Wolfram S. A new kind of science. Wolfram media Champaign, IL; 2002.

202. Ioannidis JPA. Why most discovered true associations are inflated. Epidemiology. 2008;19: 640–648.

203. CreativeCommons.org. Creative Commons — Attribution-ShareAlike 4.0 International — CC BY-SA 4.0. [cited 29 Sep 2020]. Available: https://creativecommons.org/licenses/by-sa/4.0/legalcode

204. Biege S, Lay G, Zanker C, Schmall T. Challenges of measuring service productivity in innovative, knowledge-intensive business services. null. 2013;33: 378–391.

205. Elias GS, Garfield R, Robert Gutschera K. Characteristics of Games. MIT Press; 2012.

206. Hadley K, Reid K. Work in Progress: A Delphi Study to Investigate the Value of Board Games to Teach Teamwork Skills. 2017 ASEE Annual Conference & Exposition Proceedings. ASEE Conferences; 2017. doi:10.18260/1-2--29140

207. Bowers C, Salas E, Prince C, Brannick M. Games teams play: A method for investigating team coordination and performance. Behav Res Methods Instrum. Comput. 1992;24: 503–506.

208. Wolfe J, Box TM. Team Cohesion Effects on Business Game Performance. Simul Games. 1988;19: 82–98.

209. Crichton MT, Flin R, Rattray WAR. Training Decision Makers – Tactical Decision Games. Journal of Contingencies and Crisis Management. 2000;8: 208–217.

210. Hadley KR. Teaching Teamwork Skills through Alignment of Features within a Commercial Board Game. International Journal of Engineering Education. 2014;30: 1376–1394.

211. Wax A, DeChurch LA, Contractor NS. Self-Organizing Into Winning Teams: Understanding the Mechanisms That Drive Successful Collaborations. Small Group Research. 2017;48: 665–718.

Chapter V
Works Cited

1. Olsson G. Abysmal: A Critique of Cartographic Reason. University of Chicago Press; 2010.
2. maps4news.com. Maps4News. In: maps4news.com [Internet]. 30 Jan 2019 [cited 15 Oct 2020]. Available: https://maps4news.com/blog/cartography-change-technology/
3. North J. The Norton history of astronomy and cosmology. 1995.
4. Aveni A, Romano G. Orientation and Etruscan ritual. Antiquity. 1994;68: 545–563.
5. Brown LA. The Story of Maps. Courier Corporation; 1979.
6. Casson L. Travel in the Ancient World. JHU Press; 1994.
7. Bagrow L. History of Cartography. Transaction Publishers; 2010.
8. Woodward D, Harley JB, Others. The History of Cartography, Volume 1: Cartography in Prehistoric, Ancient, and Medieval Europe and the Mediterranean. Wiley Online Library; 1987.
9. Winther RG. When Maps Become the World. University of Chicago Press; 2020.
10. Whitewater Baldy Fire 2012. [cited 30 Oct 2020]. Available: https://www.flickr.com/photos/66435184@N02/7287321294

11. COVID-19 Map - Johns Hopkins Coronavirus Resource Center. [cited 30 Oct 2020]. Available: https://coronavirus.jhu.edu/map.html

12. White TD, Ong T, Ferretti F, Block BA, McCauley DJ, Micheli F, et al. Tracking the response of industrial fishing fleets to large marine protected areas in the Pacific Ocean. Conserv Biol. 2020. doi:10.1111/cobi.13584

13. George Floyd Protests - George Floyd Protests. [cited 30 Oct 2020]. Available: https://risk-analytics.io/pages/george_floyd_protests.html

14. Kovarik V, Talhofer V. General procedure of thematic map production using GIS technology. International Conference on Military Technologies Proceeding, ICMT. 2013. pp. 1401–1408.

15. Rowson R. Brits more comfortable sharing data with pharma since COVID-19 – survey. Pharmaphorum; 28 Jul 2020 [cited 30 Oct 2020]. Available: https://pharmaphorum.com/views-and-analysis/brits-data-sharing-pharma-covid-19-survey/

16. Ghafur S, Van Dael J, Leis M, Darzi A, Sheikh A. Public perceptions on data sharing: key insights from the UK and the USA. Lancet Digit Health. 2020;2: e444–e446.

17. Gerdon F, Nissenbaum H, Bach RL, Kreuter F. Individual Acceptance of Using Health Data for Private and Public Benefit: Changes During the COVID-19 Pandemic. Harvard Data Science Review. 2020. Available: https://hdsr.mitpress.mit.edu/pub/3uc0p5dq

18. Gramigna J. Institutional trust, mental distress increase in New Zealand following COVID-19 lockdown. In: healio.com [Internet]. Jun 2020 [cited 30 Oct 2020]. Available: https://www.healio.com/news/psychiatry/20200610/institutional-trust-mental-distress-increase-in-new-zealand-following-covid19-lockdown

19. Cordes RJ. Transfer of EU user data to the United States halted - Atlantic Council. In: atlanticcouncil.org [Internet]. 25 Sep 2020 [cited 30 Oct 2020]. Available: https://www.atlanticcouncil.org/blogs/geotech-cues/transfer-of-eu-user-data-to-the-united-states-halted/

20. Anyaso H. Americans' trust in institutions to handle COVID-19 is fading. In: northwestern.edu [Internet]. 8 Jun 2020 [cited 30 Oct 2020]. Available: https://news.northwestern.edu/stories/2020/06/americans-trust-in-institutions-to-handle-covid-19-is-fading/

21. Drees J. How the COVID-19 pandemic has shifted patients' support for health data sharing: Pew survey. In: beckershospitalreview.com/ [Internet]. 16 Sep 2020 [cited 30 Oct 2020]. Available: https://www.beckershospitalreview.com/healthcare-information-

technology/how-the-covid-19-pandemic-has-shifted-patients-support-for-health-data-sharing-pew-survey.html

22. lstomsl. Do I need to know how to code to be a GIS professional? 15 May 2017 [cited 6 Oct 2020]. Available: http://millermountain.com/geospatialblog/2017/05/15/coding-for-gis-professionals/

23. Mapbox. Vector Tiles Documentation. In: Mapbox.com [Internet]. [cited 19 Oct 2020]. Available: https://docs.mapbox.com/vector-tiles/reference/

24. Sloman S, Fernbach P. The Knowledge Illusion: Why We Never Think Alone. Penguin; 2018.

25. Tett G. The Silo Effect: The Peril of Expertise and the Promise of Breaking Down Barriers. Simon and Schuster; 2015.

26. Hanauer SB. A poor view from specialty silos. Nat Rev Gastroenterol Hepatol. 2010;7: 1–2.

27. Kelly YP, Goodwin D, Wichmann L, Mendu ML. Breaking Down Health Care Silos. Harvard Business Review. 1 Jul 2019. Available: https://hbr.org/2019/07/breaking-down-health-care-silos. Accessed 25 Aug 2020.

28. Morse D, Moyer JW. A teenager was drowning. 911 sent help to the wrong place. The Washington Post. 21 Aug 2020. Available: https://www.washingtonpost.com/dc-md-va/2020/08/21/drowning-death-911-response/. Accessed 6 Oct 2020.

29. Gayle D. Australian police warn Apple maps "could kill": Users looking for city directed to barren outback more than 40 miles away. In: dailymail.co.uk [Internet]. Dec 2012 [cited 8 Oct 2020]. Available: https://www.dailymail.co.uk/sciencetech/article-2245773/Drivers-stranded-Aussie-desert-Apple-glitch-Australian-police-warn-Apple-maps-kill.html

30. Merchant B. This Is the Remote Desert Where Apple Maps Is Stranding Australian Drivers. In: vice.com [Internet]. Dec 2012 [cited 8 Oct 2020]. Available: https://www.vice.com/en/article/qkkvzv/this-is-the-hellhole-that-apple-maps-is-sending-australians-into

31. Van Staaveren J. Gradual Failure: The Air War Over North Vietnam, 1965-1966. Lulu.com; 2011.

32. Nielsen Norman Group. Are Users Stupid? In: https://www.nngroup.com/ [Internet]. 2001 [cited 20 Oct 2020]. Available: https://www.nngroup.com/articles/are-users-stupid/

33. Olleros FX. Learning to Trust the Crowd: Some Lessons from Wikipedia. 2008 International MCETECH Conference on e-Technologies (mcetech 2008). 2008. pp. 212–216.

34. Cordes RJ, Friedman DA. Emergent Teams for Complex Threats. 2020. Available: https://www.remotorconsulting.com/uploads/4/8/4/2/48428829/emergent_teams_for_complex_threats__1_.pdf

35. Nelson J. How to Visualize Uncertainty With Know-It-All Vector Data. 2 Apr 2020 [cited 6 Oct 2020]. Available: https://www.esri.com/arcgis-blog/products/arcgis-pro/mapping/how-to-visualize-uncertainty-with-know-it-all-vector-data/

36. Cairo A, Schlossberg T. Those Hurricane Maps Don't Mean What You Think They Mean. The New York Times. 29 Aug 2019. Available: https://www.nytimes.com/interactive/2019/08/29/opinion/hurricane-dorian-forecast-map.html. Accessed 6 Oct 2020.

37. Tullis P. GPS Is Easy to Hack, and the U.S. Has No Backup. Scientific American. doi:10.1038/scientificamerican1219-38

38. Williams A. Microsoft Flight Simulator's Data Insanity Spawns Enormous Buildings And Anomalies From OpenStreetMap. 21 Aug 2020 [cited 6 Oct 2020]. Available: https://hackaday.com/2020/08/21/microsoft-flight-simultors-data-insanity-spawn-enourmous-buildings-an-anomalies-from-openstreetmap/

39. Reddit Handle u/Spanholz. r/TheSilphRoad - About OpenStreetMap and Pokemon Go. In: reddit.com [Internet]. 24 Jan 2017 [cited 29 Oct 2020]. Available: https://www.reddit.com/r/TheSilphRoad/comments/5pvkkn/about_openstreetmap_and_pokemon_go/

40. Hsu J. The Strava heat map and the end of secrets. WIRED, Jan. 2018 [cited 7 Oct 2020]. Available: https://www.wired.com/story/strava-heat-map-military-bases-fitness-trackers-privacy/

41. Viewer. [cited 6 Oct 2020]. Available: https://eerscmap.usgs.gov/uswtdb/viewer/#3/37.25/-96.25

42. Turf.js [cited 23 Oct 2020]. Available: http://turfjs.org/

43. Turf. Github; Available: https://github.com/Turfjs/turf

44. Keith DR, Houston S, Naumov S. Vehicle fleet turnover and the future of fuel economy. Environ Res Lett. 2019;14: 021001.

45. Big Data Program. [cited 6 Oct 2020]. Available: https://www.noaa.gov/organization/information-technology/big-data-program

46. Dempsey C. What is a GeoTIFF? 13 Dec 2019 [cited 8 Oct 2020]. Available: https://www.gislounge.com/what-is-a-geotiff/

47. White TD, Carlisle AB, Kroodsma DA, Block BA, Casagrandi R, De Leo GA, et al. Assessing the effectiveness of a large marine protected area for reef shark conservation. Biol Conserv. 2017;207: 64–71.

48. White TD, Ferretti F, Kroodsma DA, Hazen EL, Carlisle AB, Scales KL, et al. Predicted hotspots of overlap between highly migratory fishes and industrial fishing fleets in the northeast Pacific. Sci Adv. 2019;5: eaau3761.

49. Låg S, Knutsen KE, Vartdal BJ. Ship Connectivity. 2015 [cited 25 Oct 2020]. doi:10.13140/RG.2.1.4429.2961

50. Cloud Optimized GeoTIFF. [cited 6 Oct 2020]. Available: https://www.cogeo.org/

51. SpatioTemporal Asset Catalog. [cited 6 Oct 2020]. Available: https://stacspec.org/

52. Daily Satellite Imagery and Insights. 16 Oct 2020 [cited 23 Oct 2020]. Available: https://www.planet.com/

53. CARTO. Improving Healthcare Access with BigQuery Tiler — CARTO Blog. [cited 6 Oct 2020]. Available: https://carto.com/blog/improving-healthcare-access-bigquery-tiler/

54. Anwar S. ML Enabler — completing the Machine Learning pipeline for mapping. In: Development Seed [Internet]. 11 Jul 2019 [cited 6 Oct 2020]. Available: https://medium.com/devseed/ml-enabler-completing-the-machine-learning-pipeline-for-mapping-3aae94fa9e94

55. Pixel8.earth. [cited 6 Oct 2020]. Available: https://www.pixel8.earth/

56. Vision. [cited 6 Oct 2020]. Available: https://www.mapbox.com/vision/

57. Emerging Technology from the arXiv. Given a satellite image, machine learning creates the view on the ground. MIT Technology Review. Available: https://www.technologyreview.com/2018/07/05/141591/given-a-satellite-image-machine-learning-creates-the-view-on-the-ground/. Accessed 6 Oct 2020.

58. Tucker P. The Newest AI-Enabled Weapon: "Deep-Faking" Photos of the Earth. 31 Mar 2019 [cited 6 Oct 2020]. Available:

https://www.defenseone.com/technology/2019/03/next-phase-ai-deep-faking-whole-world-and-china-ahead/155944/

59. Recreating historical streetscapes using deep learning and crowdsourcing. [cited 6 Oct 2020]. Available: https://opensource.googleblog.com/2020/09/recreating-historical-streetscapes.html

60. Population Density Maps. [cited 6 Oct 2020]. Available: https://dataforgood.fb.com/tools/population-density-maps/

61. Mapping roads through deep learning and weakly supervised training. [cited 6 Oct 2020]. Available: https://ai.facebook.com/blog/mapping-roads-through-deep-learning-and-weakly-supervised-training/

62. Biazzo S. Process mapping techniques and organisational analysis: Lessons from sociotechnical system theory. Business Process Management Journal. 2002;8: 42–52.

63. Coulson-Thomas CJ. Business process re-engineering: the development requirements and implications. Executive Development. 1995;8: 3–6.

64. Harrington. Business Process Improvement. McGraw-Hill Education (India) Pvt Limited; 2005.

65. Kettinger WJ, James T. C. Teng, Guha S. Business Process Change: A Study of Methodologies, Techniques, and Tools. Miss Q. 1997;21: 55–80.

66. Povey B. The development of a best practice business process improvement methodology. Benchmarking for Quality Management & Technology. 1998;5: 27–44.

67. Cordes RJ, Friedman DA. The Facilitator's Catechism. 2020. doi:10.5281/zenodo.4062541

68. Filiberti EJ. The Standard Operations Order Format: Is Its Current Form and Content Sufficient for Command and Control? ARMY COMMAND AND GENERAL STAFF COLL FORT LEAVENWORTH KS 1987. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a191781.pdf

69. Smith ML. The Five Paragraph Field Order: Can a Better Format Be Found to Transmit Combat Information to Small Tactical Units? School of Advanced Military Studies, US Army Command and General Staff College of Fort Leavenworth Kansas; 1988. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a210966.pdf

70. Deelman E, Blythe J, Gil Y, Kesselman C, Mehta G, Vahi K, et al. Mapping Abstract Complex Workflows onto Grid Environments. Int J Grid Util Comput. 2003;1: 25–39.

71. Sakellariou R, Zhao H, Deelman E. Mapping Workflows on Grid Resources: Experiments with the Montage Workflow. Grids, P2P and Services Computing. 2010. pp. 119–132. doi:10.1007/978-1-4419-6794-7_10

72. Daniel Hunt V. Process Mapping: How to Reengineer Your Business Processes. John Wiley & Sons; 1996.

73. Johansson HJ. Business process reengineering: Breakpoint strategies for market dominance. John Wiley & Sons; 1993.

74. Manganelli RL, Klein MK. The reengineering handbook: a step-by-step guide to business transformation. 1994. Available: http://agris.fao.org/agris-search/search.do?recordID=XL2012000177

75. Melan EH. Process Management: Methods for Improving Products and Service. McGraw-Hill; 1993.

76. Morris DC, Brandon J. Re-engineering your business. McGraw-Hill Companies; 1993.

77. Kim B, McCullough MB, Simmons MM, Bolton RE, Hyde J, Drainoni M-L, et al. A novel application of process mapping in a criminal justice setting to examine implementation of peer support for veterans leaving incarceration. Health Justice. 2019;7: 3.

78. Braglia M, Frosolini M, Zammori F. Uncertainty in value stream mapping analysis. Int J Logist Res Appl. 2009;12: 435–453.

79. Wang M, Wang H. From process logic to business logic—A cognitive approach to business process management. Information & Management. 2006;43: 179–193.

80. Koch N, Kraus A. The expressive power of uml-based web engineering. Second International Workshop on Web-oriented Software Technology (IWWOST02). CYTED; 2002. pp. 105–119.

81. Bass JM. Scrum master activities: process tailoring in large enterprise projects. Commun ACM. 2010;53: 126–130.

82. Al-Ali AG, Phaal R. Design Sprints for Roadmapping an Agile Digital Transformation. 2019 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC). 2019. pp. 1–6.

83. Church A. Limitations of UML? In: softwareengineering.stackexchange.com [Internet]. 2014 [cited 24 Aug 2020]. Available: https://softwareengineering.stackexchange.com/questions/145949/limitations-of-uml/227763

84. Kumar A, Zhao JL. Dynamic Routing and Operational Controls in Workflow Management Systems. Manage Sci. 1999;45: 253–272.

85. Kang I, Park Y, Kim Y. A framework for designing a workflow-based knowledge map. Business Process Management Journal. 2003;9: 281–294.

86. Booch G, Jacobson I, Rumbaugh J. OMG unified modeling language specification. Object Management Group ed: Object Management Group. 2000;1034.

87. Walter L. Hürsch CVL. Separation of Concerns. 1995 [cited 24 Aug 2020]. Available: http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.29.5223

88. cadCAD. cadCAD – A Python package for designing, testing and validating complex systems through simulation. In: https://cadcad.org/ [Internet]. [cited 22 Oct 2020]. Available: https://cadcad.org/

89. Latour B. Reassembling the social. An introduction to actor-network-theory. Am J Econ Sociol. 2013;14: 73–87.

90. Cohen PR. The Big Mechanism Program and the Future of Scholarship. DARPA Biological Technologies Office Symposium; 2015 Feb 11. Available: https://www.youtube.com/watch?v=GCaXSyY_C9Y

91. Cohen PR. DARPA's Big Mechanism program. Phys Biol. 2015;12. doi:10.1088/1478-3975/12/4/045008

92. Cohen PR. Acquiring Big Mechanisms by Reading Primary Literature Seminar. John Hopkins Whiting School of Engineering; 2015. Available: https://www.clsp.jhu.edu/events/acquiring-big-mechanisms-by-reading-primary-literature-paul-cohen-information-innovation-office-darpa-and-the-university-of-arizona/#.XL0nLehKiUk

93. Dunne C, Shneiderman B, Gove R, Klavans J, Dorr B. Rapid understanding of scientific paper collections: Integrating statistics, text analytics, and visualization. Journal of the American Society for Information Science and Technology. 2012;63: 2351–2369.

94. Davis PK, O'Mahony A, Pfautz J. Social-Behavioral Modeling for Complex Systems. John Wiley & Sons; 2019.

95. Friston KJ, Parr T, de Vries B. The graphical brain: Belief propagation and active inference. Netw Neurosci. 2017;1: 381–414.

96. Parr T, Markovic D, Kiebel SJ, Friston KJ. Neuronal message passing using Mean-field, Bethe, and Marginal approximations. Sci Rep. 2019;9: 1889.

97. Zeleny M. SELF-ORGANIZATION OF LIVING SYSTEMS: A FORMAL MODEL OF AUTOPOIESIS. Int J Gen Syst. 1977;4: 13–28.

98. Luhmann N. The autopoiesis of social systems. Sociocybernetic paradoxes. 1986.

99. cadCAD – A Python package for designing, testing and validating complex systems through simulation. [cited 26 Mar 2020]. Available: https://cadcad.org/

100. Vyatkin A, Metelkin I, Mikhailova A, Cordes RJ, Friedman DA. Active Inference & Behavior Engineering for Teams. 2020. doi:10.5281/zenodo.4021163

101. Fang Z, Zhou X, Song A. Architectural Models Enabled Dynamic Optimization for System-of-Systems Evolution. Complexity. 2020;2020. doi:10.1155/2020/7534819

102. VSAT - TecOffshore. In: tecoffshore.com [Internet]. [cited 25 Oct 2020]. Available: http://www.tecoffshore.com/communications/vsat/

103. Inga E, Cespedes S, Hincapie R, Cardenas CA. Scalable Route Map for Advanced Metering Infrastructure Based on Optimal Routing of Wireless Heterogeneous Networks. IEEE Wirel Commun. 2017;24: 26–33.

104. Friedman D, Cordes RJ. Infinite Games for Infinite Teams. DARPA; 2020 Jul.

105. Ebener S, Khan A, Shademani R, Compernolle L, Beltran M, Lansang M, et al. Knowledge mapping as a technique to support knowledge translation. Bull World Health Organ. 2006;84: 636–642.

106. Vail EF. Knowledge Mapping: Getting Started with Knowledge Management. Information Systems Management. 1999;16: 16–23.

107. Wexler MN. The who, what and why of knowledge mapping. Journal of Knowledge Management. 2001. pp. 249–264. doi:10.1108/eum0000000005868

108. Edwards S, Cooper N. Mind mapping as a teaching resource. Clin Teach. 2010;7: 236–239.

109. Mento AJ, Martinelli P, Jones RM. Mind mapping in executive education: applications and outcomes. Int J Manage Enterp Dev. 1999;18: 390–416.

110. Wischner J. How Employees at Palantir Technologies Use Data to Tackle Real Problems. In: talentspace.io [Internet]. [cited 21 Sep 2020]. Available: https://talentspace.io/advice/deployment-strategist-palantir-technologies

111. IntelTechniques.com. [cited 23 Oct 2020]. Available: https://inteltechniques.com/

112. Dedijer S. Ragusa Intelligence and Security (1301-1806): A Model for the Twenty-First Century? Int J Intell CounterIntelligence. 2002;15: 101–114.

113. Hribar G, Podbregar I, Ivanuša T. OSINT: A “Grey Zone”? Int J Intell CounterIntelligence. 2014;27: 529–549.

114. Kim T-W, Jung J-R, Kim S-W. Implications of the Dunbar Number in Collective Intelligence based on Social Network Services. International Journal of Contents. 2012;8: 1–6.

115. Avey AE. Function and Forms of Thought. Henry Holt and Company; 1927.

116. Advanced Distributed Learning. xAPI-Spec. 2017. Available: https://github.com/adlnet/xAPI-Spec

117. Betts B. The Learning Technology Manager’s Guide to xAPI. HT2 Labs; 2018. Available: https://www.ht2labs.com/xapi-guide-download/#.WgHZmhNSzBI

118. SCORM. SCORM Explained: In Depth Review of the SCORM eLearning Standard. 2004. Available: https://scorm.com/scorm-explained/?utm_source=google&utm_medium=natural_search

119. IEEE. IEEE 1484.12.1-2002 - IEEE Standard for Learning Object Metadata. 2002. Available: https://standards.ieee.org/standard/1484_12_1-2002.html

120. Cordes RJ, Murphy S. Education and Heuristic Discovery Market Analysis. COGSEC; 2019 May.

121. Mikhailova A, Friedman DA. Partner Pen Play in Parallel (PPPiP): A New PPPiParadigm for Relationship Improvement. Arts Health. 2018;7: 39.

122. Cordes RJ. DARPA Initiatives in Focus: Heuristic Data and Third Wave AI. COGSEC; 2019 Apr. Report No.: COGSEC-DIF-10.19 / TASK 002. Available: https://cordes-rj.github.io/pubs/COGSEC_DIF_1_19.pdf

123. Cordes RJ. Problems Unsolved: Incomplete Military and USG Research Initiatives on Education, Heuristic Discovery, and NextGen AI. COGSEC; 2019 Apr. Report No.: COGSEC-PU.EHDAI-3.4 / Task 002.

124. Wiens JJ, Donoghue MJ. Historical biogeography, ecology and species richness. Trends Ecol Evol. 2004;19: 639–644.

125. Martínez-Harms MJ, Quijas S, Merenlender AM, Balvanera P. Enhancing ecosystem services maps combining field and environmental data. Ecosystem Services. 2016;22: 32–40.

126. Westneat DF. Behavioral ecology: 40 years of fusion with ecology. Behav Ecol. 2011;22: 234–235.

127. Gordon DM. The ecology of collective behavior. PLoS Biol. 2014;12: e1001805.

128. Simon D. Biogeography-Based Optimization. IEEE Trans Evol Comput. 2008;12: 702–713.

129. Larkin AA, Martiny AC. Microdiversity shapes the traits, niche space, and biogeography of microbial taxa. Environ Microbiol Rep. 2017;9: 55–70.

130. Hajima T, Kawamiya M, Watanabe M, Kato E, Tachiiri K, Sugiyama M, et al. Modeling in Earth system science up to and beyond IPCC AR5. Progress in Earth and Planetary Science. 2014;1: 29.

131. Benton TG, Solan M, Travis JMJ, Sait SM. Microcosm experiments can inform global ecological problems. Trends Ecol Evol. 2007;22: 516–521.

132. Tang W, Davidson JD, Zhang G, Conen KE, Fang J, Serluca F, et al. Genetic Control of Collective Behavior in Zebrafish. iScience. 2020;23: 100942.

133. Friedman DA, Johnson BR, Linksvayer TA. Distributed physiology and the molecular basis of social life in eusocial insects. Horm Behav. 2020; 104757.

134. Baedke J. The epigenetic landscape in the course of time: Conrad Hal Waddington's methodological impact on the life sciences. Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences. 2013;44: 756–773.

135. Pigliucci M. Genotype-phenotype mapping and the end of the "genes as blueprint" metaphor. Philos Trans R Soc Lond B Biol Sci. 2010;365: 557–566.

136. Orgogozo V, Morizot B, Martin A. The differential view of genotype-phenotype relationships. Front Genet. 2015;6: 179.

137. Erwin DH. The topology of evolutionary novelty and innovation in macroevolution. Philos Trans R Soc Lond B Biol Sci. 2017;372: 20160422.

138. Hwang S, Park S-C, Krug J. Genotypic Complexity of Fisher's Geometric Model. Genetics. 2017;206: 1049–1079.

139. Fraïsse C, Gunnarsson PA, Roze D, Bierne N, Welch JJ. The genetics of speciation: Insights from Fisher's geometric model. Evolution. 2016;70: 1450–1464.

140. Longino HE. Studying Human Behavior. In: University of Chicago Press [Internet]. pu3430623_3430810; Jan 2013 [cited 11 Dec 2017]. Available: http://www.press.uchicago.edu/ucp/books/book/chicago/S/bo13025491.html

141. Winther RG. Mapping the Deep Blue Oceans. In: Tambassi T, editor. The Philosophy of GIS. Cham: Springer International Publishing; 2019. pp. 99–123.

142. Weisstein EW. Map. In: mathworld.wolfram.com [Internet]. Wolfram Research, Inc.; [cited 26 Oct 2020]. Available: https://mathworld.wolfram.com/Map.html

143. Arfken GB, Weber HJ, Harris FE. Mathematical Methods for Physicists, 7th edition. Academic Press; 2013.

144. Rampasek L, Goldenberg A. TensorFlow: Biology's Gateway to Deep Learning? Cell Syst. 2016;2: 12–14.

145. Latorre M, Montáns FJ. Stress and strain mapping tensors and general work-conjugacy in large strain continuum mechanics. Appl Math Model. 2016;40: 3938–3950.

146. Leike J. What is AIXI? In: jan.leike.name [Internet]. 2015 [cited 26 Oct 2020]. Available: https://jan.leike.name/AIXI.html

147. Hutter M. Universal Artificial Intelligence: Sequential Decisions Based on Algorithmic Probability. Springer Science & Business Media; 2004.

148. Rouse M. Definition of Cryptology. In: searchsecurity.techtarget.com [Internet]. TechTarget; 21 Sep 2005 [cited 26 Oct 2020]. Available: https://searchsecurity.techtarget.com/definition/cryptology

149. Vaudenay S. A Classical Introduction to Cryptography: Applications for Communications Security. Springer Science & Business Media; 2005.

150. Muter EM, Maher CA. Recognizing isomorphism and building proof: Revisiting earlier ideas. Proceedings of the twentieth annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education. 1998. pp. 461–467.

151. Maher CA, Powell AB, Uptegrove EB. Combinatorics and Reasoning: Representing, Justifying and Building Isomorphisms. Springer Science & Business Media; 2010.

152. Goerss PG, Jardine JF. Simplicial functors and homotopy coherence. Simplicial Homotopy Theory. 2009; 431–462.

153. Goerss PG, Jardine JF. Simplicial Homotopy Theory. Birkhäuser; 2012.

154. Ramzy I, Arora A. Using Zero Knowledge to Share a Little Knowledge: Bootstrapping Trust in Device Networks. Stabilization, Safety, and Security of Distributed Systems. Springer Berlin Heidelberg; 2011. pp. 371–385.

155. Bowe S, Gabizon A, Green MD. A Multi-party Protocol for Constructing the Public Parameters of the Pinocchio zk-SNARK. Financial Cryptography and Data Security. Springer Berlin Heidelberg; 2019. pp. 64–77.

156. Barta O, Ishai Y, Ostrovsky R, Wu DJ. On Succinct Arguments and Witness Encryption from Groups. Advances in Cryptology – CRYPTO 2020. Springer International Publishing; 2020. pp. 776–806.

157. Defence and Security Accelerator. Competition document: Map the Gap: autonomous gap survey crossing. In: gov.uk [Internet]. Mar 2020 [cited 27 Oct 2020]. Available: https://www.gov.uk/government/publications/competition-map-the-gap-autonomous-gap-crossing-survey/competition-document-map-the-gap-autonomous-gap-survey-crossing

158. Jacobs co. Jacobs Helps Devise Semi-Autonomous Scouting System for British Army to "Map the Gap." In: Jacobs.com [Internet]. 24 Aug 2020 [cited 25 Sep 2020]. Available: https://www.jacobs.com/newsroom/news/jacobs-helps-devise-semi-autonomous-scouting-system-british-army-map-gap

159. US Department of the Army. ADP 3-0: Unified Land Operations. 2011.

160. US Department of the Army. ADP 4-0: Sustainment. Washington, DC: Government Printing Office; 2019.

161. U.S. Joint Chiefs of Staff. Joint Publication 3-0: Joint Operations. Washington, DC: Government Printing Office; 2017. Report No.: 3-0

Chapter VI
Works Cited

1. Walker J. The Real Patent Crisis Is Stifling Innovation. Forbes Magazine. 2014 [cited 16 Dec 2020]. Available: https://www.forbes.com/sites/danielfisher/2014/06/18/13633/?sh=236331e16f1c

2. Root-Bernstein R, Root-Bernstein M. Sparks of Genius: The 13 Thinking Tools of the World's Most Creative People. HMH; 2013.

3. Brantley C. The Heilmeier Catechism. IEEE-USA Today's Engineer. 2012.

4. Cordes RJ, Friedman DA. The Facilitator's Catechism. 2020. doi:10.5281/zenodo.4062541

5. Vyatkin A, Metelkin I, Mikhailova A, Cordes RJ, Friedman DA. Active Inference & Behavior Engineering for Teams. 2020. doi:10.5281/zenodo.4021163

6. Barbera KM. The Oxford Handbook of Organizational Climate and Culture. Oxford University Press; 2014.

7. Jex SM, Britt TW. Organizational Psychology: A Scientist-Practitioner Approach. John Wiley & Sons; 2014.

8. Friston K. The free-energy principle: a unified brain theory? Nat Rev Neurosci. 2010;11: 127–138.

9. Weick KE, Sutcliffe KM, Obstfeld D. Organizing and the Process of Sensemaking. Organization Science. 2005;16: 409–421.

10. Weick KE. Sensemaking in Organizations. SAGE; 1995.

11. Neumann E. The Origins and History of Consciousness. Princeton University Press; 1954.

12. Peterson JB. Maps of Meaning: The Architecture of Belief. Psychology Press; 1999.

13. Jung CG. Symbols of Transformation (Collected Works of C.G. Jung Vol.5). 2nd ed. edition. Princeton University Press; 1977.

14. Friedman D, Cordes RJ. Infinite Games for Infinite Teams. DARPA; 2020 Jul.

15. Weick KE, Sutcliffe KM. Managing the Unexpected. 3rd ed. Wiley; 2015.

16. Filiberti EJ. The Standard Operations Order Format: Is Its Current Form and Content Sufficient for Command and Control? ARMY COMMAND AND GENERAL STAFF COLL FORT LEAVENWORTH KS SCHOOL OF ADVANCED …; 1987. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a191781.pdf

17. Smith H. Field Orders. Journal of the Military Service Institute of the United States. 1914; 26.

18. Smith ML. The Five Paragraph Field Order: Can a Better Format Be Found to Transmit Combat Information to Small Tactical Units? School of Advanced Military Studies, US Army Command and General Staff College of Fort Leavenworth Kansas; 1988. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a210966.pdf

19. Caesar J. Commentaries on the Gallic War. Crocker and Brewster; 1865.

20. Goffart W. Rome's Final Conquest: The Barbarians. History Compass. 2008;6: 855–883.

21. Gleason JP. Roman roads in Gaul: how lines of communication and basing support operational reach. ARMY COMMAND AND GENERAL STAFF COLLEGE FORT LEAVENWORTH KS SCHOOL OF …; 2013. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a606035.pdf

22. Best EE. The Literate Roman Soldier. Class J. 1966;62: 122–127.

23. U.S. Department of the Army. Field Manual 1-02: Operational Terms and Graphics. 2004.

24. Carl Von Clausewitz, Howard M, Paret P, Howard M, Brodie B. On War. Howard M, Paret P, editors. Princeton University Press; 1989.

25. Van Creveld M. Command in War. Harvard University Press; 1985.

26. Sonnenberger M. Art of War Papers: Initiative within the Philosophy of Auftragstaktik Determining Factors of the Understanding of Initiative in the German Army 1806-1955. US Army Combined Arms Center, Fort Leavenworth Kansas; 2013. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/a599111.pdf

27. Beyerchen AD. Clausewitz, Nonlinearity, and the Importance of Imagery. Symposium on Complexity, Global Politics, and National Security; 1996; National Defense University. Available: http://www.dodccrp.org/html4/bibliography/comch07.html

28. Corum JS. The Roots of Blitzkrieg: Hans von Seeckt and German Military Reform. 1st ed. University Press of Kansas; 1992.

29. von Moltke H, Hughes DJ. Moltke on the Art of War: Selected Writings. Ballantine Books; 1993.

30. Prebilič V. Theoretical aspects of military logistics. Defense & Security Analysis. 2006;22: 159–177.

31. Brubaker R. Ethnicity Without Groups. Harvard University Press; 2004.

32. Swift E. Field Orders, Messages and Reports. Journal of the United States Cavalry Association. 1897;10: 221–233.

33. Vandergriff DE. How the Germans Defined Auftragstaktik: What Mission Command IS -AND- is Not. Small Wars Journal. 2018.

34. Hanes CL. Operational Art: The Framework for Successful Transitions in the US Army and Its Importance in Officer Education. US Army School for Advanced Military Studies Fort Leavenworth United States; 2018. Available: https://apps.dtic.mil/dtic/tr/fulltext/u2/1071813.pdf

35. Texas State Historical Association. Eben Swift. In: TSHAonline.org [Internet]. [cited 6 Dec 2020]. Available: https://www.tshaonline.org/handbook/entries/swift-eben

36. Heitman FB. Historical register and dictionary of the United States Army, from its organization, September 29, 1789, to March 2, 1903. Washington: Gov't. Print. Off.; 1903.

37. Matheny MR. Carrying the War to the Enemy: American Operational Art to 1945. University of Oklahoma Press; 2012.

38. Rickey D. Forty Miles a Day on Beans and Hay: The Enlisted Soldier Fighting the Indian Wars. University of Oklahoma Press; 2012.

39. Chun CKS. US Army in the Plains Indian Wars 1865–1891. Bloomsbury Publishing; 2013.

40. Vandergriff DE. From Swift to Swiss: Tactical decision games and their place in military education and performance improvement. Perform Improv Advis. 2006;45: 30–39.

41. Vandergriff DE. Adopting Mission Command: Developing Leaders for a Superior Command Culture. Naval Institute Press; 2019.

42. Arreguín-Toft I. How the weak win wars: A theory of asymmetric conflict. Int Secur. 2001;26: 93–128.

43. Berglund C, Souleimanov EA. What is (not) asymmetric conflict? From conceptual stretching to conceptual structuring. Dynamics of Asymmetric Conflict: Pathways toward Terrorism and Genocide. 2020;13: 87–98.

44. Cordes RJ, Friedman DA. Emergent Teams for Complex Threats. 2020. doi:10.5281/zenodo.3986085

45. Linn BM. The Echo of Battle. Harvard University Press; 2009.

46. Sweeney WC. Military Intelligence, a New Weapon in War. Frederick A. Stokes Company; 1924.

47. US War Department. Tactical Order for Small Units in Trench Warfare. 1918. Report No.: 798.

48. US Department of the Army. FM 7-5 Infantry Field Manual Organization and Tactics of Infantry The Rifle Battalion. United States Government Printing Office; 1940.

49. TRADOC. Risk Management for Brigades and Battalions: Task Force XXI Update. Report No.: 99-5. Available: https://www.globalsecurity.org/military/library/report/call/call_99-5_toc.htm

50. Reeves JH. Cavalry Raids. Journal of the United States Cavalry Association. 1897;10: 232–247.

51. Schade U, Hieb MR. Battle management language: A grammar for specifying orders. IEEE Spring Simulation. IEEE; 2007. Available: https://pdfs.semanticscholar.org/480e/f3fbd15932c2b46f1c21cffef2aaaec57a88.pdf

52. Blais C, Turnitsa C, Gustavsson P. A strategy for ontology research for the coalition battle management language (C-BML) product development group. Proceedings of the Fall Simulation Interoperability Workshop. 2006. pp. 11–22.

53. de Reus NM, de Krom PPJ, Mevassvik OM, Alstad A, Sletten G. BML-enabling national C2 systems for coupling to Simulation. 2008 Spring Simulation Interoperability Workshop (SIW), April 14-18, 2008, Providence, Rhode Island,

USA, 628-638. repository.tudelft.nl; 2008. Available: https://repository.tudelft.nl/view/tno/uuid:56267b48-4378-4967-a947-b3d9f28a549f

54. U.S. Joint Chiefs of Staff. Joint Publication 6-0 Joint Communication Systems. Independently Published; 2020.
55. McChrystal GS, Collins T, Silverman D, Fussell C. Team of Teams: New Rules of Engagement for a Complex World. Penguin; 2015.
56. U.S. Joint Chiefs of Staff. Joint Publication 5-0: Joint Operation Planning. Washington, DC: Government Printing Office; 2017.
57. Keegan J. The Face Of Battle: A Study of Agincourt, Waterloo and the Somme. Random House; 2011.
58. U.S. War Department. Instructions for the offensive combat of small units. 1918. Report No.: 802. Available: http://hdl.handle.net/2027/uiug.30112068991873
59. Eikmeier DC. Center of gravity analysis. Mil Rev. 2004;84: 2–5.
60. Weick KE, Roberts KH. Collective Mind in Organizations: Heedful Interrelating on Flight Decks. Adm Sci Q. 1993;38: 357–381.
61. Weick KE. The Collapse of Sensemaking in Organizations: The Mann Gulch Disaster. Adm Sci Q. 1993;38: 628–652.
62. Porte TL, Consolini P. Theoretical and operational challenges of "high-reliability organizations": air-traffic control and aircraft carriers. International Journal of Public Administration. 1998;21: 847–852.
63. Christianson MK, Sutcliffe KM, Miller MA, Iwashyna TJ. Becoming a high reliability organization. Crit Care. 2011;15: 314.
64. McKeon LM, Oswaks JD, Cunningham PD. Safeguarding patients: complexity science, high reliability organizations, and implications for team training in healthcare. Clin Nurse Spec. 2006;20: 298–304; quiz 305–6.
65. Vogus TJ, Welbourne TM. Structuring for high reliability: HR practices and mindful processes in reliability-seeking organizations. Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior. 2003;24: 877–903.
66. Bierly PE, Spender J-C. Culture and high reliability organizations: The case of the nuclear submarine. J Manage. 1995;21: 639–656.
67. Szumilas A, Swerhun B, Lye J. Watts at Stake?: Protecting North America's energy infrastructure from cascading failure and terrorist threats. Dalhousie Journal of Interdisciplinary Management. 2011;7. doi:10.5931/djim.v7i2.66

68. Enya A, Dempsey S, Pillay M. High Reliability Organisation (HRO) Principles of Collective Mindfulness: An Opportunity to Improve Construction Safety Management. Advances in Safety Management and Human Factors. Springer International Publishing; 2019. pp. 3–13.

69. Hills TT, Todd PM, Lazer D, Redish AD, Couzin ID, Cognitive Search Research Group. Exploration versus exploitation in space, mind, and society. Trends Cogn Sci. 2015;19: 46–54.

70. Smith R, Schwartenbeck P, Stewart JL, Kuplicki R, Ekhtiari H, Paulus MP. Imprecise action selection in substance use disorder: Evidence for active learning impairments when solving the explore-exploit dilemma. Drug Alcohol Depend. 2020;215: 108208.

71. Gordon DM. The ecology of collective behavior. PLoS Biol. 2014;12: e1001805.

72. Wilson RC, Geana A, White JM, Ludvig EA, Cohen JD. Humans use directed and random exploration to solve the explore–exploit dilemma. J Exp Psychol Gen. 2014;143: 2074–2081.

73. Linson A, Parr T, Friston KJ. Active inference, stressors, and psychological trauma: A neuroethological model of (mal)adaptive explore-exploit dynamics in ecological context. Behav Brain Res. 2020;380: 112421.

74. Tschantz A, Baltieri M, Seth AK, Buckley CL. Scaling active inference. arXiv [cs.LG]. 2019. Available: http://arxiv.org/abs/1911.10601

75. Soderstrom NC, Bjork RA. Learning versus performance: an integrative review. Perspect Psychol Sci. 2015;10: 176–199.

76. Benjamin AS. Memory is More than just Remembering: Strategic Control of Encoding, Accessing Memory, and Making Decisions. Benjamin AS, Ross BH, editors. Psychol Learn Motiv. 2007;48: 175–223.

77. Giberson TR. Industrial–Organizational Psychology and the Practice of Performance Improvement. Performance Improvement Quarterly. 2015;28: 7–26.

78. Hamilton W, Ying Z, Leskovec J. Inductive representation learning on large graphs. Adv Neural Inf Process Syst. 2017. Available: http://papers.nips.cc/paper/6703-inductive-representation-learning-on-large-graphs

79. Broniatowski DA, Moses J. Measuring Flexibility, Descriptive Complexity, and Rework Potential in Generic System Architectures: METRICS FOR GENERIC SYSTEM ARCHITECTURES. Syst Eng Electr. 2016;19: 207–221.

80. Sheldon DR, Dietterich T. Collective Graphical Models. In: Shawe-Taylor J, Zemel R, Bartlett P, Pereira F, Weinberger KQ, editors. Advances in Neural Information Processing Systems. Curran Associates, Inc.; 2011. pp. 1161–1169.

81. Latour B, Centre de Sociologie de l'Innovation Bruno LaTour. Reassembling the Social: An Introduction to Actor-Network-Theory. OUP Oxford; 2005.

82. Hutchison L. Solving the OPORD Dilemma: How to Speak Doctrinally Without Putting Soldiers to Sleep. In: medium.com [Internet]. 20 Feb 2017 [cited 8 Dec 2020]. Available: https://medium.com/leadership-counts/solving-the-opord-dilemma-how-to-speak-doctrinally-without-putting-soldiers-to-sleep-123e1136fd6

83. Friston KJ, Rosch R, Parr T, Price C, Bowman H. Deep temporal models and active inference. Neurosci Biobehav Rev. 2017;77: 388–402.

84. FitzGerald THB, Dolan RJ, Friston K. Dopamine, reward learning, and active inference. Front Comput Neurosci. 2015;9: 136.

85. Ramstead MJD, Constant A, Badcock PB, Friston KJ. Variational ecology and the physics of sentient systems. Phys Life Rev. 2019. doi:10.1016/j.plrev.2018.12.002

86. Rappoport A. Creating shareholder value: a guide for managers and investors. Rev and updated ed NY: Free Press. 1998;205: 9.

87. Instructions for the Virginia Colony. 1606 [cited 24 Nov 2020]. Available: http://www.let.rug.nl/usa/documents/1600-1650/instructions-for-the-virginia-colony-1606.php

88. Arben PD. The integrating course in the business school curriculum, or, whatever happened to business policy? Bus Horiz. 1997;40: 65–70.

89. Chandler AD. Strategy and Structure: Chapters in the History of the Industrial Enterprise. MIT Press; 1990.

90. Ghemawat P. Competition and Business Strategy in Historical Perspective. Bus Hist Rev. 2002;76: 37–74.

91. Smith GA. Policy Formulation and Administration: A Casebook of Senior Management Problems in Business. R.D. Irwin; 1951.

92. De Geus AP. Planning as learning. Harvard Business Review. 1988; 70–74.

93. Mintzberg H. The fall and rise of strategic planning. Harv Bus Rev. 1994;72: 107–114.

94. Porter ME. Competitive Strategy: Techniques for Analyzing Industries and Competitors. Free Press; 1980.

95. Gajda R. Utilizing Collaboration Theory to Evaluate Strategic Alliances. American Journal of Evaluation. 2004;25: 65–77.

96. Berry T. A short history of business plans. 2011 [cited 24 Nov 2020]. Available: https://timberry.bplans.com/a-short-history-of-business-plans/

97. Karlsson T, Honig B. Judging a business by its cover: An institutional perspective on new ventures and the business plan. Journal of Business Venturing. 2009. pp. 27–45. doi:10.1016/j.jbusvent.2007.10.003

98. Mollov A, Pearlmutter M, Singh S, Bygrave WD. Pre-start-up formal business plans and post-start-up performance: A study of 116 new ventures AU - Lange, Julian E. Venture Capital. 2007;9: 237–256.

99. Allred A, Addams HL, Chakraborty G. Is Informal Planning the Key to the Success of the Inc. 500? Journal of Small Business Strategy. 2007;18: 95.

100. Blank S. The Four Steps to the Epiphany: The Road Map for Successful Startups. CafePress; 2005.

101. Blank S. Why the lean start-up changes everything. Harv Bus Rev. 2013;91: 63–72.

102. Brown T. Design thinking. Harv Bus Rev. 2008;86: 84–92, 141.

103. Ries E. The Lean Startup: How Constant Innovation Creates Radically Successful Businesses. Kindle Edition. New York, NY: Penguin Books; 2011.

104. Schwaber K, Beedle M. Agile software development with Scrum. Prentice Hall Upper Saddle River; 2002.

105. Osterwalder A, Pigneur Y. Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers. John Wiley & Sons; 2010.

106. Maurya A. Running lean: iterate from plan A to a plan that works. O'Reilly Media, Inc.; 2012.

107. Blank S. Mission Model Canvas: An Adapted Business Model Canvas for Mission Driven Organizations. In: steveblank.com [Internet]. 23 Feb 2016 [cited 28 Nov 2020]. Available: https://steveblank.com/2016/02/23/the-mission-model-canvas-an-adapted-business-model-canvas-for-mission-driven-organizations/

108. McKelvey J. The Innovation Stack: Building an Unbeatable Business One Crazy Idea at a Time. Penguin; 2020.

109. Blank S. The Innovation Doctrine: What Comes After Lean. Wiley; 2021.

110. Ndenge K. Combining Agile, Lean Startup and Design thinking - UX Collective. In: UX Collective [Internet]. 8 Sep 2019 [cited 7 Dec 2020]. Available:

https://uxdesign.cc/dls-bootstrapping-innovating-with-limited-resources-5163b7ab5be3

111. Carlson CR. Innovation for Impact. Harv Bus Rev. 2020.
112. Eisenhardt KM, Brown SL. Time pacing: competing in markets that won't stand still. Harv Bus Rev. 1998;76: 59–69.
113. Boland P, Riggio B, Phelan S. Lean Startup: Opportunity Discovery or Opportunity Creation? Available at SSRN 2534139. 2013. Available: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2534139
114. Phelan S. The complexity of opportunity. Available at SSRN 2398743. 2014. Available: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2398743
115. Phelan SE. Austrian theories of entrepreneurship: Insights from complexity theory. Rev Austrian Econ. 2016;29: 277–297.
116. Friston K, Martin F, Friedman DA. Of woodlice and men. ALIUS Bulletin. 2018;2: 17–43.
117. Spadafora A. Eliminating work about work with team tools. 2 Nov 2018 [cited 15 Dec 2020]. Available: https://www.techradar.com/news/eliminating-work-about-work-with-team-tools
118. Hobsbawm E, Ranger T. The Invention of Tradition. Cambridge University Press; 2012.
119. Stewart NK. South Atlantic Conflict of 1982: A Case Study in Military Cohesion. U.S. Army Research Institute for the Behavioral and Social Sciences; 1988.
120. Lester PB, Vogelgesang GR. Swift Trust in Ad Hoc Military Organizations. Oxford Handbooks Online. 2012. doi:10.1093/oxfordhb/9780195399325.013.0067
121. Blank S, Newell P. What your innovation process should look like. Harv Bus Rev. 2017.
122. sba.gov. How to write a business plan. In: sba.gov [Internet]. [cited 18 Dec 2020]. Available: https://learn.sba.gov/learning-center-plan/learning-center-how-to-write-a-business-plan
123. Strategyzer.com. Business Model Canvas – Download the Official Template. In: strategyzer.com [Internet]. [cited 18 Dec 2020]. Available: https://www.strategyzer.com/canvas/business-model-canvas
124. leanstack.com. 1-Page Business Plan. In: leanstack.com [Internet]. [cited 18 Dec 2020]. Available: https://leanstack.com/leancanvas

125. Osterwalder A. The Mission Model Canvas: An Adapted Business Model Canvas For Mission-Driven Organizations. In: strategyzer.com [Internet]. [cited 18 Dec 2020]. Available: https://www.strategyzer.com/blog/posts/2016/2/24/the-mission-model-canvas-an-adapted-business-model-canvas-for-mission-driven-organizations

126. Woods T. The Collaborative Innovation Canvas: A Visual Strategy. In: hypeinnovation.com [Internet]. 8 Jul 2015 [cited 17 Dec 2020]. Available: https://blog.hypeinnovation.com/the-collaborative-innovation-canvas-a-visual-strategy

127. Kawasaki G. The Only 10 Slides You Need in Your Pitch. In: guykawasaki.com [Internet]. 5 Mar 2015 [cited 18 Dec 2020]. Available: https://guykawasaki.com/the-only-10-slides-you-need-in-your-pitch/

Appendices

Chapter IV
Appendices

Appendix A

Eben Swift's 1897 Format [3,23]

THE BODY OF SWIFT'S FORMAT

1. Information of the enemy and general situation.
-This paragraph included information on the enemy's location and what the higher commander thought the enemy's intentions were.
-In absences of information it was the higher commander's best guess or idea.

2. Your own plans.
-This paragraph contains an intimation of the end in view.
-It gave only so much of the general plan as would enable the subordinates to carry out the operations in hand.

3. Your dispositions.
-This paragraph described the manner in which troops were distributed and assigned tasks to the various fractions of command.
-It established the method of enumerating troops apart from the text, in the left margin, in a column headed "Distribution of Troops."
-Most important distribution of troops is stated first to better impress themselves upon the memory.
-Designates a start point and time.

4. Destination of trains.
-Addresses the need to separate light and heavy baggage.
-Contains all the orders needed for the trains, ammunition columns and sanitary troop.

5. Position of the commander.
-Gives position of commander.
-Gives hour for staff officers to report for orders.

Appendix B

WWI Suggested Trench-to-Trench Attack OPORD [34]

SUGGESTED FORM AND HEADINGS FOR A BATTALION TRENCH-TO-TRENCH ATTACK ORDER.

Title..

Place..

Date and Hour..

Field Order No..........................
(Reference to Map Used).

Paragraph No. 1.—Information of the enemy.
Our supporting troops.
Our flanking troops.
General plan for our forces.

Paragraph No. 2.—Mission of the battalion.
Zero day and hour.
Limit of the zone of operations.
Objectives.

Paragraph No. 3.—(*a*) Artillery support.
Time of its opening.
Rate of advance of barrage.
Where and when barrage will settle.
(*b*) Orders to each company, as to sector or direction of advance, information, objective, distance, and intervals.
(*c*) Cleaning up parties.—Composition, mission of each. Disposition of prisoners. Mission after cleaning up.
(*d*) Machine guns.
Position.
Objectives.
Mission.
(*e*) One-pounder gun or 37 mm. gun or 3" Stokes mortar.
Position in the advance.
Mission.
Objectives.
Position and duties in occupation.
(*f*) Outlining of front.
1. On request of Aeroplanes.
2. Hour each line will signal lights.
(*g*) Liaison.
With the artillery.
Within the battalion.

Cont. Next Page.

Paragraph No. 4.— Plan for occupation of captured ground.
Order to each company as to:
(a) 1. Organization of ground to be held.
2. Reconnaissance.
Contact with the enemy.
Further objectives.
Patrols.
Outposts.
3. Liaison.
Within the battalion.
With neighboring troops.
With colonel.
With artillery.
(b) Machine guns.
Mission.
Sites.
(c) One-pounder guns or 37 mm. guns or 3" Stokes mortar.
Sites.
Objectives.
(d) Service of observation.
Enemy's line.
Observation posts.
(e) Reports.
Munition.
Materiel.
To whom sent and hour.

Paragraph No. 5.—(a) Supply.—Individual equipment and supplies. Additional communication trenches to be dug or connections to be made with trench system of old positions.

Munitions.—Depots to be established in jumping-off trench and by whom.

Designate carrying parties.

Materiels.—Point where depot will be established and the materiels to be assembled.

Carrying parties and command.

Ration and water.—Amounts other than that carried by the individual soldier. For use preceding the advance and to be subsequently carried forward.

Carrying parties.

(b) Circulation.—Designating of communicating trenches for "forward" and "rear" traffic.

For evacuation of wounded.

(c) First aid stations.—Location of.

Paragraph No. 6.—Position of battalion commander and his headquarters during the advance and in the conquered position.

Name and rank of the Battalion Commander.

How and to whom issued.

Appendix C

WWI Battalion OPORD [3]

WWI BATTALION ORDER FORMAT

1. Information of the Enemy.
2. Mission of the Regiment. Attack formations. Phases and objectives. Commander's intent.
3. Limits of the Front.
4. Mission of Each Company.
5. Attack Formation of the Battalion.
6. Formation Prior to the Assault.
7. Cleaning up. Positions. Mission.
8. Advance. How it will take place, the barrages use of signals.
9. Machine gun company. Mission, route of advance, position, the objectives.
10. One-pounder guns/mortars. Positions; route ofadvance and objectives.
11. Divisional Group of Machine Guns.
12. Tanks. Missions.
13. Liaison. with the battalion, neighbors, with artillery.
14. Marking out the Front. Arrangements for indicating the front when halted or on the request of an aviator.
15. Organization of the Captured Ground.
16. Dress, Equipment, Pack of the Men.
17. Supplies. Organization, location of depots, munitions and fire-works. Rations, water, other materiel (tools, barbed wire, sand bags).
18. Medical Services. Locations of first-aid stations.
19. Prisoners. Measures to be taken.

Appendix D

1940 U.S. OPORD [4]

APPENDIX G, 1940 OPERATIONS ORDER FORMAT*

Form 5

GENERAL FORM FOR A COMPLETE WRITTEN
FIELD ORDER [1] [2] [3]

Issuing unit
Place of issue
Date and hour of issue

FO ______
Maps: (Those needed for an understanding of the order.)

1. INFORMATION.--Include appropriate information covering-
   a. *Enemy.*--Composition, disposition, location, movements, strength; identifications; capabilities. Refer to intelligence summary or report when issued.
   b. *Friendly forces.*--Missions or operations, and locations of next higher and adjacent units; same for covering forces or elements of the command in contact; support to be provided by other forces.

2. DECISION OR MISSION.[1]--Decision or mission; details of the plan applicable to the command as a whole and necessary for coordination.

TROOPS

(Composition of tactical components of the command, if appropriate)

3. TACTICAL MISSIONS FOR SUBORDINATE UNITS.[1]--Specific tasks assigned to each element of the command charged with the execution of tactical duties, which are not matters of routine or covered by standing operating procedures. A separate lettered subparagraph for each element to which instructions are given.
   x. Instructions applicable to two or more units or elements or to the entire command, which are necessary for coordination but do not properly belong in another subparagraph.

4. ADMINISTRATIVE MATTERS.--Instructions to tactical units concerning supply, evacuation, and traffic details which are required for the operation (unless covered by standing operating procedure or administrative orders; in the latter case, reference will be made to the administrative order).

5. SIGNAL COMMUNICATION.
   a. *Orders for employment* of means of signal communication not covered in standing operating procedure. Refer to signal annex or signal operation instructions, if issued.
   b. *Command posts and axes of signal communication.*--Initial locations for unit and next subordinate units; time of opening, tentative subsequent locations when appropriate. Other places to which messages may be sent.

Appendix E

U.S. WWII Battalion Attack OPORD [3]

BATTALION ATTACK ORDER

1. (a) Information relative to the enemy.
(b) Situation and missions of friendly troops; adjacent units; supporting artillery, tanks, and aviation; covering troops.

2. Battalion plan of action, objectives, zone of action, line of departure, direction of attack, hour of attack.

3. Tactical missions for subordinate units.
(a) Base of fire: general position area of heavy weapons; target areas or sectors of fire.
(b) Assignment of rifle companies to attacking echelon and reserve; objectives and missions.
(c) Antitank measures; mission of antitank units.

4. Administrative matters.
(a) Supply: disposition of company carriers and unit trains; establishment of initial ammunition point; method of distribution of ammunition and other combat supplies.
(b) Initial location of aid station; distribution of medical section.

5. Communications; initial command and observation posts and message center; telephone and radio; light wire local systems; panel stations and dropping grounds; signal light conventions.
ps291/21A

Appendix F

U.S. WWII Battalion Defend OPORD [3]

BATTALION DEFEND ORDER

1. Information relative to the enemy and friendly troops including the mission of the regiment, units on the flanks of the battalion, covering forces, artillery, antitank and aviation support.

2. General plan of defense; boundaries of battalion defense area; exact course of the main line of resistance; distribution of rifle units to combat echelon, reserve and where necessary, the combat outpost; any attachments to rifle companies.

3. Defensive areas (boundaries) of rifle companies of the combat echelon; mission and location of reserve; departure positions for counterattack; positions for flank defense.

4. Missions and distribution of heavy machine guns; emplacements and target areas of battalion mortars; emplacements and sectors of fire of antitank weapons.

5. Security elements; location and mission of combat outposts and advance detachments.

6. Supply: location of battalion ammunition point; aid station; arrangements for ammunition distribution, including amount to be dumped on the position if required; disposition of carriers and unit trains.

7. Communications: location of battalion command and observation posts and message center; telephone and radio, light wire local systems, panel stations and dropping grounds, signal light connections.

Appendix G

U.S. Modern Five Paragraph Order Scan [43], in 4 parts:

Operation Order ______________________________
(Type and serial number) (Note 1)

Reference: List any map, chart, or other document required to understand the order. Reference to a map will include the country or geographical area and/or map series number, edition (if required), scale, and map sheet name or number.

Time zone: (The zone applicable to the operation; if not required for clarity, omit).

Task Organization: Where the organization for combat of the command is long or complicated, list here the task subdivisions or tactical components comprising the command with the names and ranks of the commanders if appropriate. This listing constitutes attachment unless qualified by such terms as "SPT" or "DS" indicating a support or direct support role for the unit commander.
When the task organization is not shown, this information is included in paragraph 3 or in an annex.

1. SITUATION. Information of the overall situation essential to understand the current situation. This paragraph is divided into three subparagraphs as follows.
   a. Enemy Forces. Factual information concerning the enemy. Often a reference to a published intelligence document, overlay, or annex will be sufficient. (Note 2.)
   b. Friendly Forces. Information concerning higher, adjacent, supporting, or reinforcing units. Information should be limited to that which the subordinate commanders need to know to accomplish their assigned missions.
   c. Attachments and Detachments. List the units attached to or detached from the headquarters issuing the order together with the effective time. If these units are indicated in the task organization, an appropriate reference is entered. In the case of a unit which has been attached for some period of time, the term "remains attached" may be used.

G1.

2. MISSION. A clear concise statement of the task to be accomplished by the command and its purpose. This normally requires the inclusion of the WHO, WHAT, WHEN, and WHY of the commander's decision. The WHERE of the decision may be included if needed for clarity. The HOW (unit(s) making the main attack, and other amplifications), more properly belong in paragraph 3a, "Concept of operation." The mission is stated in full, even if shown on the operation overlay. There are no subparagraphs in paragraph 2.

3. EXECUTION.

a. In the first subparagraph give the concept of operation. This is a statement of the commander's visualization of the conduct of the overall operation. The concept clarifies the purpose of the operation and is stated in sufficient detail to ensure appropriate action by subordinates in the absence of additional specific instructions. The concept usually includes the development and phasing of the operation, use of nuclear fires, unit making the main attack (in those operations where appropriate), the formation to be employed (the HOW), whether or not a preparation is to be fired, and the duration prior to H-hour.

b. In subsequent separate lettered subparagraphs give the specific tasks to be accomplished by each element of the command charged with the execution of tactical missions. These elements are listed in the order:

(1) Combined arms commands in numerical or alphabetical order.

(2) Infantry elements.

(3) Armor elements.

(4) Artillery.

G2.

(5) Combat support elements (e.g. armored carrier units, engineer units, as applicable).

(6) Reserves.

c. If a task organization is not used, the organization for combat is shown under those units to and from which attachments and detachments are made. Units attached for operational control may also be indicated.

d. Combat arms units are listed in numerical sequence by parent regimental (or div) number.

e. The artillery subparagraph is divided into two numbered subparagraphs; the first covers field artillery, the second air defense artillery. As a minimum the artillery subparagraph indicates the artillery organization for combat (when not already indicated in a task organization).

f. Tactical support elements are listed in alphabetical sequence by branch. Normal service missions are not included. It is not necessary to list all the units in the command nor is it required to give instructions for the total employment of a particular unit. For example, instructions to an engineer unit concern only the tactical support portion of the unit's mission.

g. Instructions to the reserve appear in the next to the last subparagraph of paragraph 3 entitled "Reserve." In the case of a unit totally in reserve at the time the order becomes effective, this is the only subparagraph where such a unit will appear. Units not in reserve at the time of the order but designated as reserve at some future time are listed with a qualifying phrase as to when or under what conditions the unit will be in reserve. The listing of two or more units in this subparagraph does not in itself indicate an attachment.

G3.

h. The last subparagraph of paragraph 3 is entitled "Coordinating instructions," and contains details of coordination and control applicable to two or more elements of the command. Troop safety measures appropriate to the nuclear battlefield may be shown here. Restrictions on use of nuclear weapons may be included. If instructions relative to a preparation are not included in the concept of operation they are shown here.

4. ADMINISTRATION AND LOGISTICS. A statement of pertinent administrative instructions and the way administrative support is to be provided for the operation to include the allocation of critical supply of items such as nuclear weapons. If an administrative order is in effect, or is being issued separately, or if an administrative annex is being issued make reference thereto. Paragraph 4 contains such subparagraphs as are required and follows the sequence of the administrative order.

5. COMMAND AND SIGNAL. Instructions relative to command and the operation of signal communications. This paragraph may have as many subparagraphs as are required. Normally three subheadings are listed: Signal, Command, and Axis of Command Post displacement. (Normally the main echelon of the headquarters unless otherwise specified.) Signal Instructions may refer to an annex, but as a minimum, should list the index and issue number of the signal operations instructions (SOI) which is in effect. Command instructions include command post location of subordinate and higher units. Designation of alternate command post and succession of command will be entered in this subparagraph if not adequately covered in SOP or annex. The axis of CP displacement consists of one or more future locations.

Acknowledgement instructions. These are a part of the ending and must be included here. Normally the single word "acknowledge" is sufficient. This indicates that the receiver will, by use of the message reference number in the heading, acknowledge that he has received and understands the order.

____

(Commander) (Note 3)

Part 4. Final.

Appendix H

U.S. Vietnam War Three Paragraph Order [3]

* The unit mission and the concept of operation complete in all available detail.
* Additional essential information to include enemy, support available, terrain, and command ana communication details.
* Essential supply and evacuation details.

Appendix I

Soviet OPORD as of 1988 [3]

<u>THE CURRENT SOVIET FORMAT</u>

1. Assessing the enemy.
   -to his front.
   -to adjacent unit's front.
   -information varies with mission assigned.

2. Unit's mission assigned by senior commander.

3. Senior commander's employment of weapons within units zone.

4. Unit commander concept of operation.
   -which enemy to rout and in what sequence.
   -main effort sector.
   -enemy targets to destroy by weapons.
   -combat formation anu nature of maneuver.

5. Task to subordinate units.
   -varies offense/defense.
   -the "I order" paragraph listing tasks for subordinate units.

6. Readiness time for action.

7. Command posts.
   -place and time for deployment of CP's.

8. Chain of command.
   -names deputy commander.
   -who assumes control in event the commander is put out of action.

Appendix J

Israeli OPORD as of 1988 [3]

THE CURRENT ISRAELI FORMAT

1. Friendly forces.
   (a) Intent or aim of the higher.
   (b) Unit's mission.
   (c) Adjacent forces missions.
   (d) Additional forces missions.
      1) Engineers.
      2) Artillery.
      3) Direct support.
      4) General support.

2. Terrain.
   (a) General description.
   (b) Axis.
   (c) Main obstacles.
   (d) Trafficability/deployment areas.
   (e) Key terrain and vital terrain.
   (f) Summary of effects of terrain on friendly plan.

3. Enemy.
   (a) Intentions.
   (b) Deployment and strength.
   (c) Most probable course of action.

4. Commander's intention (when, what, and why).

5. Method.
   (a) Scheme of maneuver and fire support.
   (b) Time phasing and objectives.

6. Forces and tasks.

7. Combat support (general).

8. Administrative and logistics (general).

9. Control.
   (a) Location of CP's by stages.
   (b) Radio procedures.

Appendix K

Heilmeier Catechism [98]

- What are you trying to do? Articulate your objectives using absolutely no jargon.
- How is it done today, and what are the limits of current practice?
- What's new in your approach and why do you think it will be successful?
- Who cares?
- If you're successful, what difference will it make?
- What are the risks and the payoffs?
- How much will it cost?
- How long will it take?
- What are the midterm and final "exams" to check for success?

Appendix L

The Facilitator's Catechism

Full Title of Project

Project Callsign:
Team Name:
Facilitator:
Contact Information:
Date of Announcement:
Call for Collaboration Ends:
Intended Date of Completion:

SITUATION

What is the nature of the situation or problem the team is being formed to address? If there are traditional methods which would normally be used to address the situation or problem, what are their limitations and why are they inadequate? What makes the problem novel? What will happen if this situation is not resolved or addressed?

MISSION

Given the situation, what are the team's explicit objectives?

POTENTIAL AVENUES OF APPROACH

Given the situation and mission, what are the potential avenues of approach? For each potential approach: What tools, techniques, or expertise, alone or in combination, may provide opportunities for an approach to the situation? What are the risks? What are the potential limitations?

MILESTONES

Given the situation, mission, and the avenues of approach, what are the milestones that would best indicate the mission's progress?

IMPLICATIONS OF OUTCOME

If all or some milestones were achieved what does the success mean to stakeholders, the situation, and to team members? What else might be affected? What work will come next?

ADMINISTRATION, LOGISTICS, AND COMMUNICATIONS

Who is the facilitator responsible for the project's completion? Who, if anyone, is the team accountable to? What resources and support elements are required? What resources are already available and how can they be accessed? What are the requirements for participation? How will the group communicate? Where and how will the work be done? Under what circumstances will the project close and the group disintegrate?

Appendix M

Comparisons of OPORDS

Section	Item	Traditional Field Order	Roman Sentry Order	Swift's 1897 OPORD	US WWI OPORD	US 1940 OPORD	US BN Attack OPORD	US BN Defend OPORD	US Adapted Vietnam OPORD	1988 Soviet OPORD	IDF OPORD	US Modern SPO	Heilmeier Catechism	Facilitator's Catechism
Items Included in Format	**Mission (0-5)**													
	Mission (Desired Outcome)	3	0	3	3	4	4	0	5	5	4	5	5	5
	Milestones for Gauging Success	0	0	0	0	0	0	0	0	0	0	0	5	5
	Purpose of Mission (Impact of Outcome)	0	0	0	0	0	0	0	0	5	0	4	5	5
	Exit Strategy	0	0	0	2	3	1	0	5	1	1	1	0	3
	Affordances (0-5)													
	Situation Details	1	0	4	4	4	4	4	4	4	4	4	5	5
	Logistics Details	0	0	2	5	4	4	4	3	3	3	4	4	2
	Available Operations Support Details	0	0	1	5	3	4	4	2	4	4	4	0	3
	Administrative and Command Details	0	0	4	5	4	4	4	3	4	4	4	0	4
	Communication Instruction (Signal)	1	5	2	5	4	4	4	3	4	3	4	0	4
	Delegation (0-5)													
	Dictates Execution and Method	4	5	2	5	4	4	4	1	2	4	4	5	2
Attributes of Format	**Attributes (0-3)**													
	Lends Itself to Post-Operation Review	0	3	1	1	1	1	1	1	1	1	2	1	3
	Formalized via Doctrine or Publication	1	2	3	3	3	3	3	0	3	3	3	0	3
	Assumes Organizational Alignment at Issuance	3	3	3	3	3	3	3	3	3	3	3	3	0
	Versioning Compatible	0	0	0	0	0	0	0	0	0	0	2	0	3
	Assumes Team Composition at Issuance	3	2	3	3	3	3	3	3	3	3	3	2	0
REF	Citation	[3]	[9,11]	[3,23]	[3,34]	[4]	[3]	[3]	[3]	[3]	[3]	[1,43]	[98]	n/a
	Appendix section	n/a	n/a	A	C	D	E	F	H	J	I	G	K	L

Comparisons of OPORDs

Items Included in Format	
0	not included
1	not generally included, not included as part of doctrine
2	generally included but as subcompartment or unemphasized
3	generally included
4	strictly included
5	strictly included and emphasized

Attributes of Format	
0	format does not have attribute
1	format does not lend itself to gaining attribute
2	format has attribute to some degree
3	clear indication attribute was desired during design

Chapter VI
Appendices

Appendix A

Business Plan Outline [122]

Executive Summary

Business Description & Vision

Definition of the Market

Description of Products and Services

Organization & Management

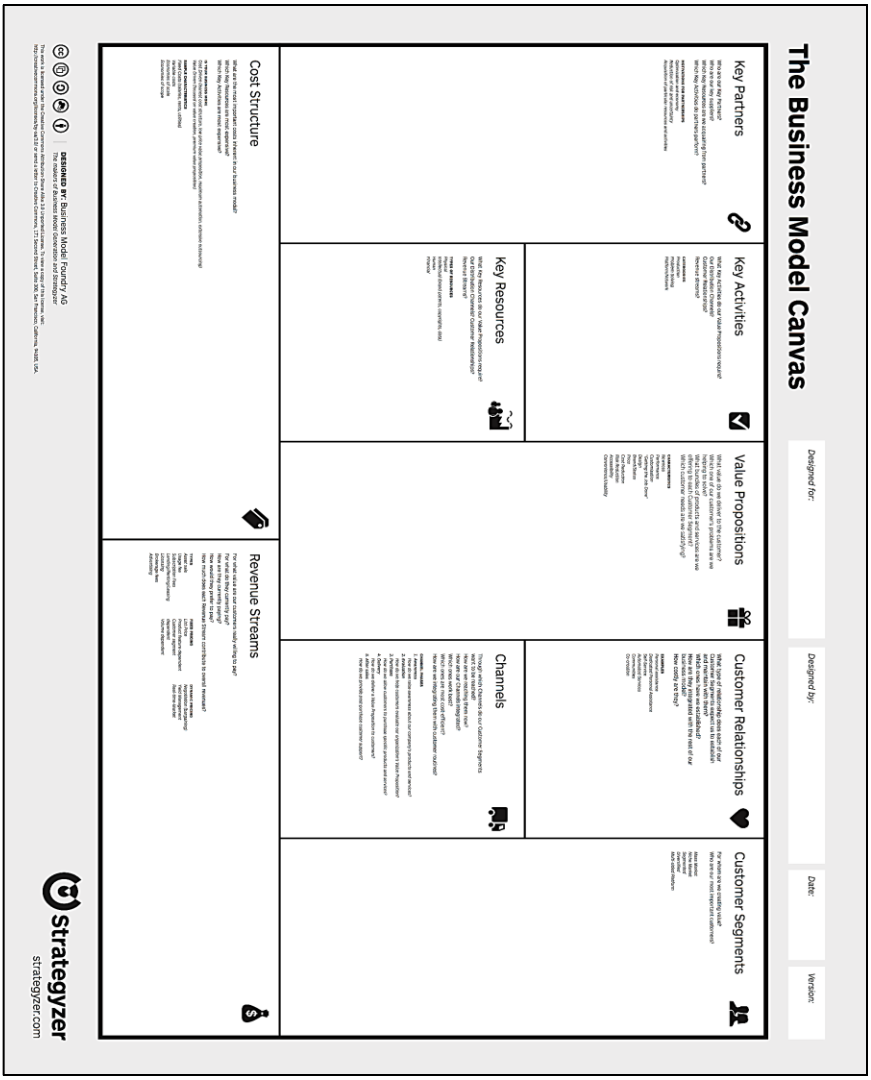
Marketing and Sales Strategy

Financial Management

Appendix B

Business Model Canvas [123]

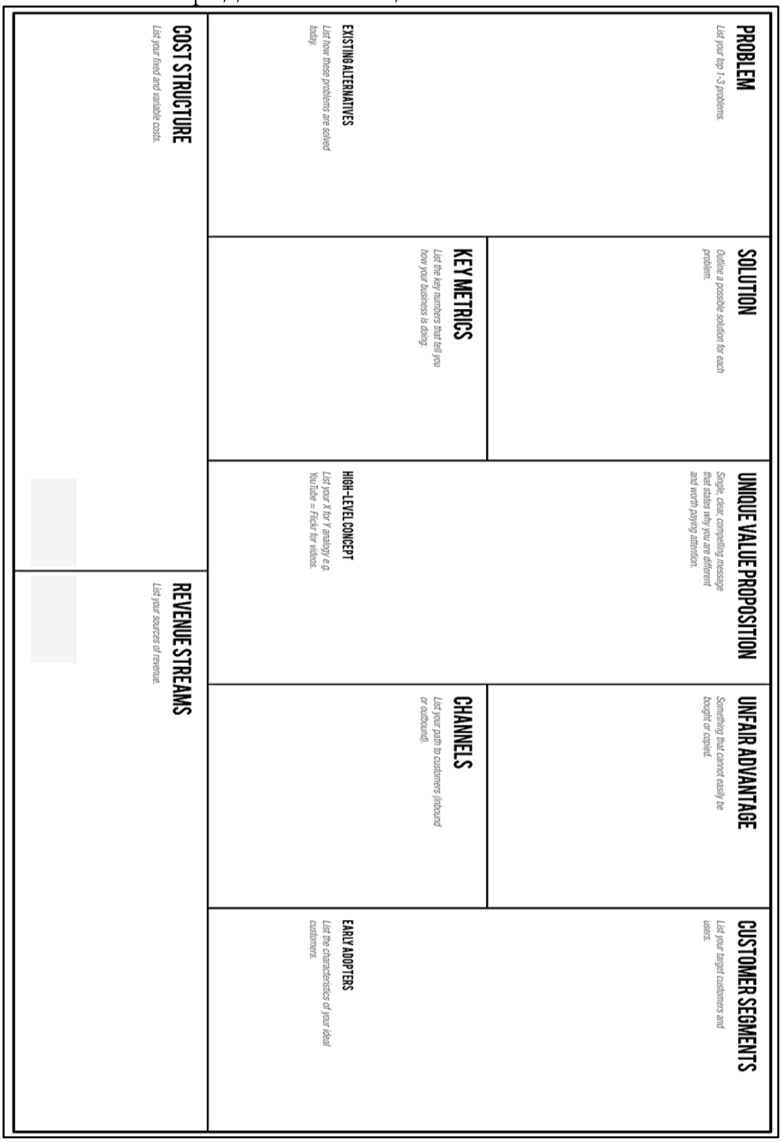
File available at https://www.strategyzer.com/canvas/business-model-canvas



Appendix C

Lean Canvas [124]

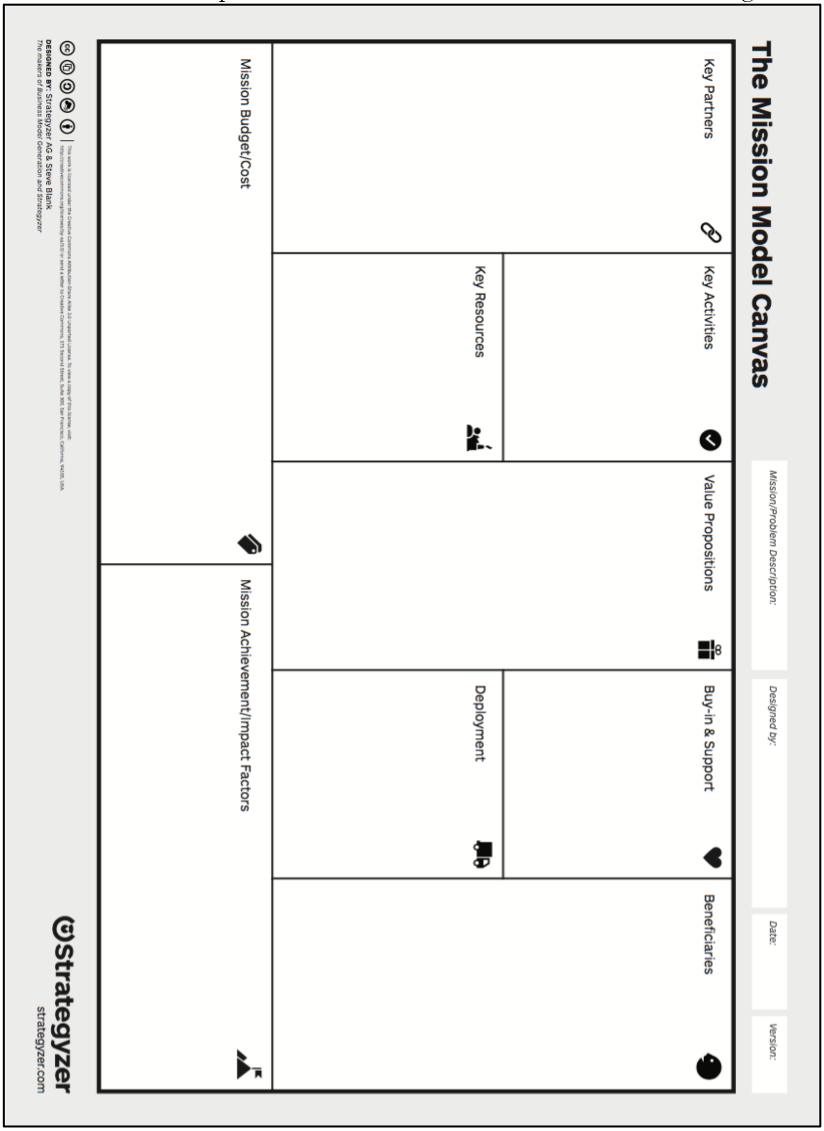
File available at https://leanstack.com/leancanvas



Appendix D

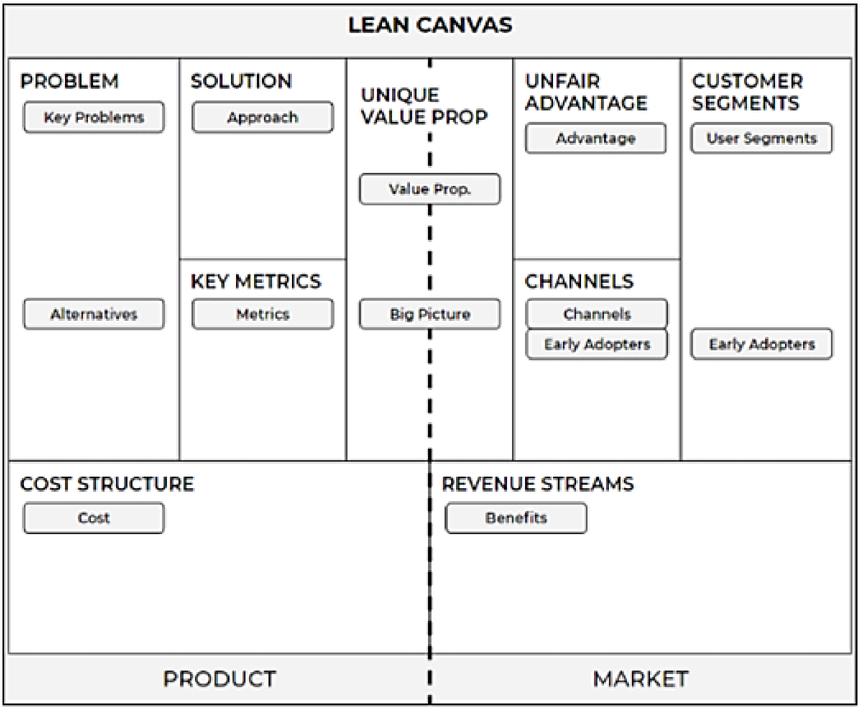
Mission Model Canvas [125]

File available at https://www.strategyzer.com/blog/posts/2016/2/24/the-mission-model-canvas-an-adapted-business-model-canvas-for-mission-driven-organizations



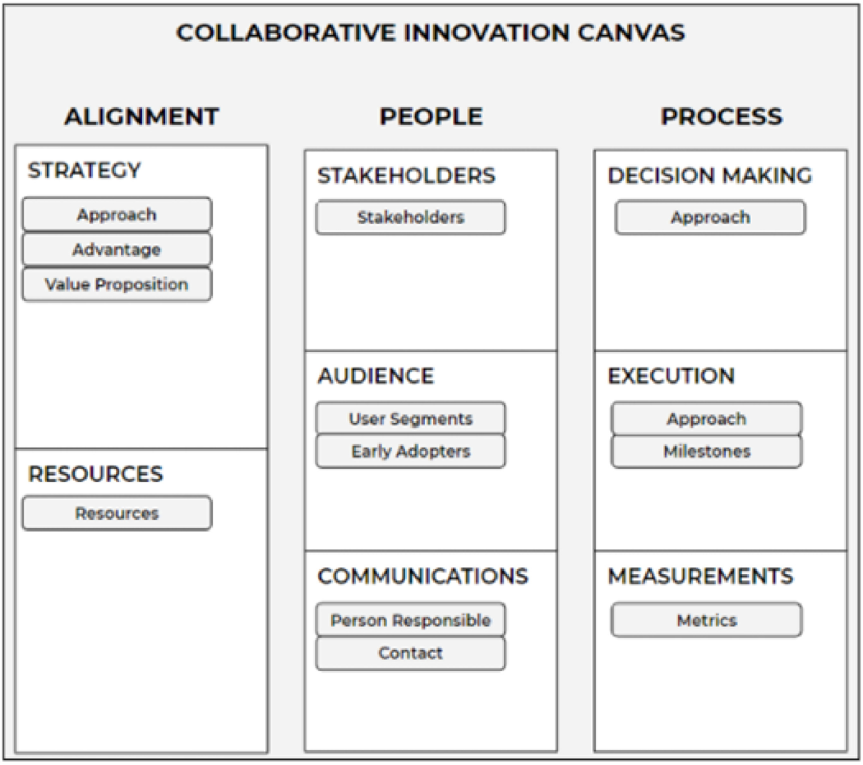
Appendix E

IC to Lean Canvas Rendering adapted from [124]



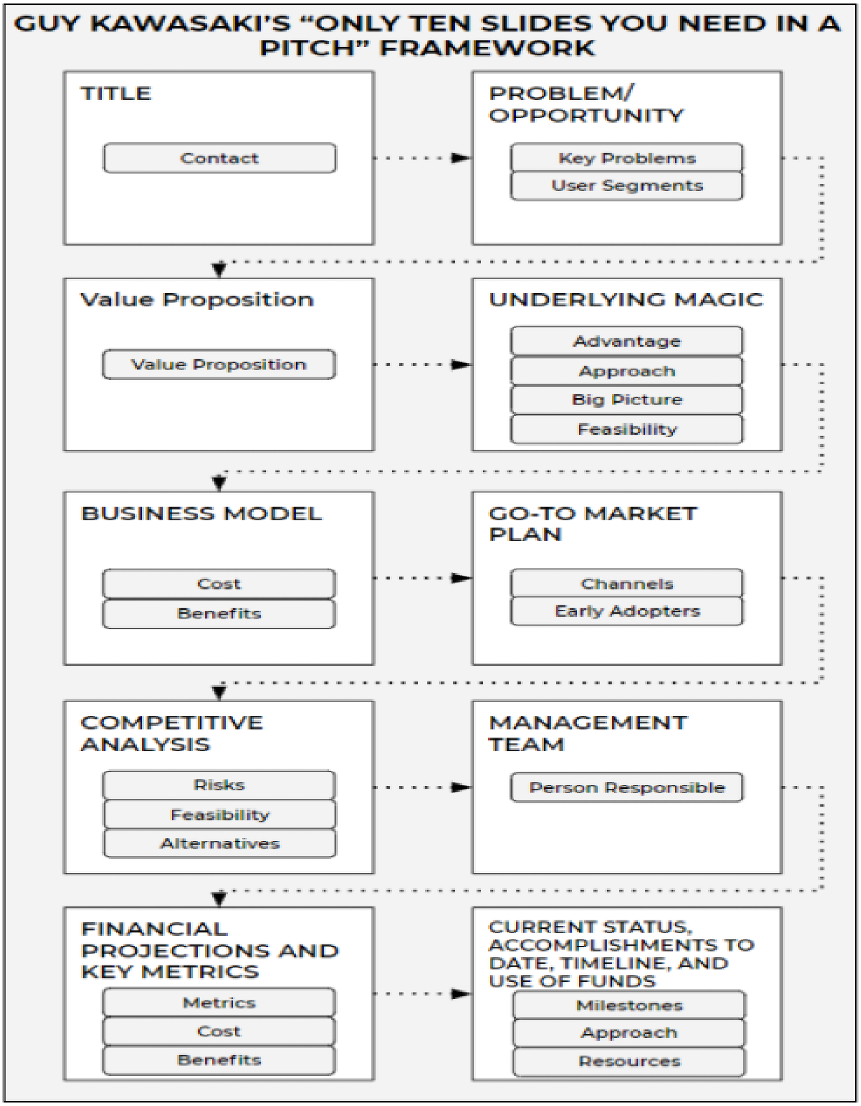
Appendix F

IC to Collaborative Innovation Canvas Rendering adapted from [126]



Appendix G

IC to Kawasaki's "Only Ten Slides" Framework adapted from [127]



Appendix H

Innovator's Catechism – Ideation

File available at https://github.com/COGSEC/InnovatorsCatechism

Full Title of Project

Team Name:
Person Responsible:
Contact Information:
Start Date:

SITUATION

Key Problems. *What are the key problems the group has been formed to address?*
User Segments. *Who is affected by these problems?*

MISSION

Value Proposition: *Given the situation, in clear terms, with no jargon, what is your objective? What value do you aim to provide?*
To create an innovative solution to a problem.

POTENTIAL AVENUES OF APPROACH

Approach. *Given the situation and mission, what are the potential avenues of approach?*

ADMIN, LOGISTICS, AND COMS

Person Responsible. *Who is responsible for the project?*
Contact Information. *How should someone contact you?*
Stakeholders. *Who are the current stakeholders in the group's success? Is there a parent organization? Are there sponsors or investors?*
More Information. *Are there any documents, webpages, or repositories that provide more information about the project?*

Appendix I

Innovator's Catechism – Curation

File available at https://github.com/COGSEC/InnovatorsCatechism

Full Title of Project

Team Name:
Person Responsible:
Contact Information:
Start Date:

SITUATION

Key Problems. *What are the key problems the group has been formed to address?*
User Segments. *Who is affected by these problems?*

MISSION

Value Proposition: *Given the situation, in clear terms, with no jargon, what is your objective? What value do you aim to provide?*
Demonstrate novelty and need of solution.

POTENTIAL AVENUES OF APPROACH

Approach. *Given the situation and mission, what are the potential avenues of approach?*
Resources. *What resources are required? Which do you need? Which do you already have?*

MILESTONES

Milestones. *What are the milestones that best indicate progression toward success? When are they expected to be completed by?*

COST AND BENEFIT

Cost. *What are the costs associated with providing the intended value?*

ADMIN, LOGISTICS, AND COMS

Person Responsible. *Who is responsible for the project?*
Contact Information. *How should someone contact you?*
Stakeholders. *Who are the current stakeholders in the group's success? Is there a parent organization? Are there sponsors or investors?*
More Information. *Are there any documents, webpages, or repositories that provide more information about the project?*

Appendix J

Innovator's Catechism – Pitch

File available at https://github.com/COGSEC/InnovatorsCatechism

Full Title of Project

Team Name:
Person Responsible:
Contact Information:
Start Date:

SITUATION

Key Problems. *What are the key problems the group has been formed to address?*
User Segments. *Who is affected by these problems?*
Alternatives. *What alternative solutions already exist? Why are they inadequate?*
Early Adopters. *Who is actively looking for a competitive edge in handling these problems, most affected by the inadequacies of the available alternatives, and flexible in adopting new solutions?*

MISSION

Value Proposition: *Given the situation, in clear terms, with no jargon, what is your objective? What value do you aim to provide?*

POTENTIAL AVENUES OF APPROACH

Approach. *Given the situation and mission, what are the potential avenues of approach?*
Resources. *What resources are required? Which do you need? Which do you already have?*
Advantage. *What unique advantage is offered?*
Risks. What are the risks?
Feasibility. *Given the advantages offered and the risks present, what is the feasibility? Why is this project likely to succeed?*
Channels. *What channels will be used to introduce users to the value you intend to provide?*

MILESTONES

Metrics. *What metrics can be used to track success and measure impact?*
Milestones. *What are the milestones that best indicate progression toward success? When are they expected to be completed by?*

COST AND BENEFIT

Cost. *What are the costs associated with providing the intended value?*
Benefits. *What are the benefits of providing the intended value?*

Big Picture. *If successful, what else is possible?*

ADMIN, LOGISTICS, AND COMS

Person Responsible. *Who is responsible for the project?*
Contact Information. *How should someone contact you?*
Stakeholders. *Who are the current stakeholders in the group's success? Is there a parent organization? Are there sponsors or investors?*
More Information. *Are there any documents, webpages, or repositories that provide more information about the project?*