NORTH ATLANTIC TREATY ORGANIZATION

SCIENCE AND TECHNOLOGY ORGANIZATION

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STO TECHNICAL REPORT **TR-SAS-139**

NATO Analytical War Gaming – Innovative Approaches for Data Capture, Analysis and Exploitation

(Jeux de guerre analytiques de l'OTAN – Démarches innovantes d'acquisition, analyse et exploitation des données)

This report documents the findings of the Task Group SAS-139 (System Analysis and Studies Panel) regarding best practices and innovative approaches for NATO Analytical Wargaming.

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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

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NATO Analytical War Gaming – Innovative Approaches for Data Capture, Analysis and Exploitation

(STO-TR-SAS-139)

Executive Summary

Efforts to synchronize military operations research, analysis and planning are needed to improve NATO member nations' warfighting forces readiness and effectiveness. Analytical wargaming, a well-established method for assessing concepts, exploring analytical questions, and rehearsing decisions about warfighting strategy, courses of action, operational plans, and tactics, is a critical component of these efforts.

The objective of the NATO SAS-139 Research Task Group (RTG) was to advance NATO wargaming methodology through improving analytical war gaming capabilities in order to better support NATO military decision-making processes. The RTG was established in May 2018 and ran until May 2021. Over three years, SAS-139 defined analytical wargaming as a distinct research method and identified innovation challenges. They examined complementary research methods and advances in tools and technologies that could be applied to advance analytical wargaming practice.

SAS-139 also established a NATO wargaming community of interest and associated collaboration hub. Members expressed interest in continuing the community beyond the end of the RTG. Serendipitously, in 2021 NATO committed to develop an "audacious" wargaming capability that will build on and extend the team's efforts and complement the well-established series of Connections Wargaming conferences.

This report provides guidelines for ensuring analytical rigor and meaningful data capture in analytical wargame methods, identifies other analytical methods that complement wargaming, and investigates practical tools and innovative applications. The team's principal findings include the following, which are discussed in more detail in the report:

1) Professional analytical wargamers use a disciplined process and Standard Operating Procedures (SOPs) to specify wargame research questions, design, develop, and execute a wargame, and capture and data generated in wargame play.
2) There are opportunities for innovation in each stage of the analytical wargaming process. There is a need to develop a science of wargaming that can incorporate a broader range of analytical methods. Deliberations generated two lenses through which to view ideas about innovation in analytical wargaming: One should ask if innovation ideas will add value to developing better military plans and decisions, and if innovation will contribute to improving the validity and reliability of analytical wargaming findings.
3) Wargamers have been experimenting with forms of distributed gaming for a number of years, however, distributed processes pose a number of control and player experience challenges for analytical wargaming. The team's investigation indicated that while it is tempting to assume that distributed wargaming is less expensive and more effective than in-person wargaming, there is little empirical evidence to support this assumption. Considerable innovation and investment is required to develop a methodology for designing and executing rigorous, distributed military wargames at tactical, operational, and strategic warfare levels.

Jeux de guerre analytiques de l'OTAN – Démarches innovantes d'acquisition, analyse et exploitation des données

(STO-TR-SAS-139)

Synthèse

L'amélioration de l'état de préparation et de l'efficacité des forces de combat de l'OTAN nécessite des efforts de synchronisation de la recherche, de l'analyse et de la planification des opérations militaires. Les jeux de guerre analytiques, méthode bien établie pour évaluer les concepts, étudier les questions d'analyse et répéter des décisions sur la stratégie de combat, les modes d'action, les plans opérationnels et la tactique, sont un élément essentiel de ces efforts.

L'objectif du groupe de recherche (RTG) SAS-139 était de faire progresser la méthodologie des jeux de guerre de l'OTAN en améliorant les capacités des jeux de guerre analytiques afin de mieux soutenir les processus décisionnels militaires de l'OTAN. Le RTG a été créé en mai 2018 et s'est poursuivi jusqu'en mai 2021. En trois ans, le SAS-139 a défini les jeux de guerre analytiques comme une méthode de recherche distincte et identifié les défis d'innovation. Il a examiné des méthodes de recherche complémentaires et les progrès des outils et technologies pouvant être appliqués pour faire progresser la pratique des jeux de guerre analytiques.

Le SAS-139 a également établi une communauté d'intérêts des jeux de guerre de l'OTAN et une plateforme de collaboration correspondante. Les membres ont exprimé leur intérêt à poursuivre la communauté après la fin du RTG. De manière inattendue, en 2021, l'OTAN s'est engagée à mettre au point une capacité de jeux de guerre « audacieuse » qui s'appuierait sur les travaux de l'équipe et les prolongerait et à compléter la série bien établie des Connections Wargaming Conferences.

Le présent rapport fournit des directives servant à garantir la rigueur analytique et l'acquisition sensée de données dans les méthodes de jeux de guerre analytiques, identifie d'autres méthodes d'analyse qui complètent les jeux de guerre et étudie des outils pratiques et des applications innovantes. Les découvertes principales de l'équipe, discutées plus en détail dans le rapport, sont les suivantes :

1) Les joueurs professionnels des jeux de guerre appliquent un processus rigoureux et des procédures opérationnelles standard (POS) pour établir les questions de recherche du jeu de guerre, concevoir, développer et exécuter un jeu de guerre et acquérir les données produites au cours d'une partie.
2) Il existe des occasions d'innovation à chaque étape du processus des jeux de guerre analytiques. Il est nécessaire de mettre au point une science des jeux de guerre, pouvant intégrer une large gamme de méthodes d'analyse. Les débats ont fourni deux prismes par lesquels examiner les idées sur l'innovation dans les jeux de guerre analytiques : il faut se demander si les idées innovantes ajouteront de la valeur au développement de plans militaires et aux décisions et si l'innovation contribuera à améliorer la validité et la fiabilité des découvertes liées aux jeux de rôle analytiques.
3) Les joueurs ont expérimenté plusieurs formes de jeu réparti pendant plusieurs années ; cependant les processus répartis présentent un certain nombre de problèmes de contrôle et d'expérience des joueurs dans le jeu de guerre analytique. Les investigations de l'équipe indiquent que même s'il est tentant de supposer que le jeu de guerre réparti est moins coûteux et plus efficace que le jeu

de guerre en personne, peu de preuves empiriques confirment cette hypothèse. Le développement d'une méthodologie de conception et d'exécution de jeux de guerre militaires répartis et rigoureux sur les plans tactique, opérationnel et de la guerre stratégique nécessite une innovation et un investissement considérables.

Chapter 1 – INTRODUCTION

Efforts to synchronize military operations analysis, research, and planning are needed to improve NATO member nations' warfighting forces readiness and effectiveness. Analytical wargaming, which is a well-established method for assessing and rehearsing decisions about warfighting strategy, concepts of operations, operational plans, and tactics, is a critical component of these efforts.

This Chapter describes the SAS-139 Research Task Group's (RTG's) approach to researching innovation in analytical wargaming, the team's research activities, COVID-19 mitigation efforts, and how this report is organized.

1.1 BACKGROUND

The NATO Systems Analysis and Studies Panel identified a need to reinvigorate aspects of wargaming capabilities in the NATO community. Whilst NATO Organizations and some Nations were executing wargames, the practice of wargaming in NATO was ad hoc with no overarching program of work. Recognizing that staff in Nations and organizations had a lot of individual experience, the panel identified the need to share best practices, lessons learnt and potential improvements in capability. SAS-ET-DN was organized and co-led by NATO Allied Command Transformation (ACT) and the United States in 2017 and developed the technical proposal for the work described in this report. The ET focused on innovation in analytical wargaming to address a wide range of NATO military planning requirements. The team aimed to investigate advances in data capture and analytical practices that could be fruitfully applied to improve NATO analytical wargaming practices. The NATO Science and Technology Organization Board approved the proposed three-year research task group activity entitled NATO SAS RTG-139 NATO Analytical War Gaming – Innovative Approaches for Data Capture, Analysis and Exploitation (RTG) in November 2017. The RTG commenced in May 2018 with a calling message for participation from NATO members. Nine member nations, three NATO organizations, and Australia agreed to sponsor representatives. The RTG ended in May 2021.

1.2 SAS RTG-139 SCIENTIFIC OBJECTIVES AND ACHIEVEMENTS

The objective of NATO SAS-139 research activities was to advance NATO wargaming methodology through improving analytical war gaming capabilities in order to better support NATO military decision-making processes. The RTG aimed to provide guidelines for ensuring analytical rigor and meaningful data capture in analytical wargame methods, identify and share analytical methods for wargaming, and investigate practical tools and applications.

Year one focused on specifying research questions and organizing research teams. The RTG surveyed analytical war gaming capabilities in order to identify areas of best practice and gaps, shortfalls, and challenges in data capture and analysis. RTG members initially met in Paris May 2018 at the NATO Collaborative Science Office to organize the research project and tasks and agreed continue their work through in-person meetings convened twice per year – once in Europe and once in the U.S. – and virtually on a quarterly basis. In a meeting in October 2018 hosted by the U.S. Air Force at the Basic Research Innovation and Collaboration Center in Arlington, Virginia, the team developed a framework to describe the analytical Wargaming process and began surveying capabilities in order to identify areas of best practice, gaps, and challenges in wargame data capture and analysis.

In year two, the RTG conducted research on opportunities to advance analytical wargaming approaches and tools, seeking to identify innovative approaches and solutions, and observe demonstrations of those solutions. The team met in March 2019 at the Centre for Maritime Research and Experimentation (CMRE)

in La Spezia, Italy, and in December 2019 at a meeting hosted by the U.S. Air force Research Laboratory at the Wright Brothers Institute in Dayton, Ohio in the U.S. Over the course of the year, the team identified analytical advances and approaches to improving wargame data capture and analysis, took briefings on topics that could inform innovation in analytical wargaming, and observed demonstrations of relevant tools and technologies. The CMRE meeting was held jointly with NATO IST-141 Exploratory Visual Analytics to exchange information and identify synergies and opportunities for collaborative research. In addition, an interactive demonstration of tools and technologies for wargaming was organized by a member of SAS-139 and held at the Connections UK Wargaming conference in London, UK in September 2019.

The RTG's focus in year three was extracting findings and developing a final technical report aimed at professional wargame and other operations analysts, military practitioners, and decision makers. The Netherlands organization for applied scientific research (TNO) and the U.S. Naval War College offered to host meetings in 2020, however the team's work was interrupted by the onset of the COVID-19 pandemic in early 2020. The RTG successfully pivoted to entirely virtual meetings and used an internal peer review process to discuss and review work products. Pre-COVID in-person meetings provided the opportunity to build the relationships needed to function effectively as a virtual research team. COVID-19 affected SAS-139's efforts to demonstrate additional Wargaming technology, but it also provided a unique opportunity to research distributed wargaming, a practice that was almost unheard of before 2020 in NATO but became rapidly familiar to wargame practitioners as in-person wargames shifted to virtual wargames almost overnight. Finally, SAS-139 set up a 'NATO Wargaming' collaboration site to reach a broader community of wargamers across NATO.

Towards the end of SAS-139 activities, the NATO Audacious Wargaming initiative was established to further wargaming capability and capacity within NATO, and to coordinate efforts across NATO commands. The SAS-139 wargaming community of interest will continue to live on through this endeavor.

The team's principal findings include the following, which are discussed in more detail in the report.

Professional analytical wargamers use a disciplined process and Standard Operating Procedures (SOPs) to specify wargame research questions, design, develop, and execute a wargame, and capture and data generated in wargame play [1], [2]. As Figure 1-1 shows, this process includes preliminary analysis, clarifying tasking, specifying a problem, purpose, objectives, and research hypotheses or questions, designing, and developing the wargame to address the research specifications, and managing and controlling execution to achieve research specifications. The team identified opportunities for innovation in each stage of the analytical wargaming process, which are described in more detail in Part I.

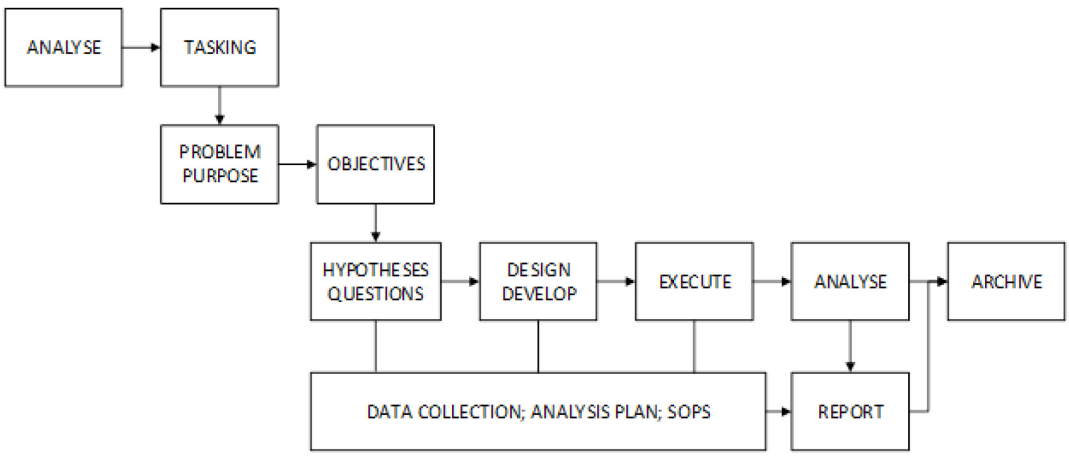

Figure 1-1: Analytical Wargaming Process.

Many analytical wargamers treat operational plans and concepts as theories about decision making and design games to investigate the feasibility and suitability of these theories. Analytical wargames are quasi experiments in decision making that help us understand why people make the choices they make, what constraints they face in particular contexts, and what opportunities they see to create new approaches to a particular problem set [3]. However, SAS RTG-139 found a dearth of literature on the science of wargaming. Most of the wargaming literature treats wargaming as a practical art rather than a scientific research method integrated with other military research and situated in contemporary decision or complexity science disciplines. Whilst the existing literature provides useful advice and frameworks for how to design, develop, and execute a wargame, it does not provide a rigorous foundation for innovation to reinvigorate NATO analytical wargaming. Hence, the team's second finding is that NATO needs to invest in developing the science of wargaming, and identified two lenses through which to view ideas about innovation:

1) One should ask if innovation ideas will add value to developing better military plans and decisions; and
2) One should ask if innovation will contribute to improving the validity and reliability of analytical wargaming findings.

Other methodological opportunities that the SAS-139 team did not have time to explore include using policy analysis tools such as the Institutional Analysis and Development (IAD) framework as a guide in specifying war game design [4].[1] Similarly, tools and methods from the computational and data sciences could be employed in wargaming, such as artificially intelligent analytics that can crawl through "big data", network analyses, multi-dimensional visualization tools, and data simulation methods [5][2]. For example, wargamers may find data mining and network analysis tools useful for analyzing war game data; Monte Carlo and graph theory could be useful for diagnostic problems; cellular automata and agent-based models could be employed in modeling data; and genetic algorithms and particle swarm optimization may be useful for synthesis.

Finally, the SAS-139 team found that some wargamers have been experimenting with forms of distributed gaming for a number of years. The COVID pandemic generated new interest in ways to wargame without meeting in person. The primary characteristic of distributed wargaming is that participants are not co-located and they rely on virtual communication channels. Players and game controllers can be geographically isolated or clustered, and they can play at the same time (synchronously) or at intervals (asynchronously). Distributed processes pose a number of control and player experience challenges for analytical wargaming. The team's investigation indicated that while it is tempting to assume that distributed wargaming is less expensive and more effective than in-person wargaming, the objectives of commercial and military wargaming are quite different. Commercial producers aim to make a profit; they seek ways to make their games entertaining and addictive. They count on players trying to game the game and once hooked, returning to buy new versions. By contrast, analytical wargaming producers aim to educate, provide essential experience in decision making and command, and build knowledge about complex warfighting issues. Moreover, while the cost structures of in-person and distributed wargaming differ, there is insufficient research on these differences to support assumptions about relative costs and benefits.

That said, academic success using online games to gather empirical evidence to support theories about strategic behavior such as Charles Holt's Veconlab show promise for creating distributed analytical wargaming.[3] However, considerable innovation and investment is required to develop a methodology for designing and executing rigorous, distributed military wargames at tactical, operational, and strategic warfare levels.

[1] For background on the IAD framework see Ref. [4].

[2] For a primer on data science see Ref. [5].

[3] The University of Virginia hosts Veconlab, provides the opportunity for researchers to conduct distributed, online experiments to investigate economic and other strategic theories, and for educators to demonstrate decision making. See, for example http://veconlab.econ.virginia.edu/games.php. For information about the founder, Professor Charles Holt see https://economics.virginia.edu/people/profile/cah2k. Note that Dr Holt does all the programming required to support this site on a volunteer rather than paid basis.

1.3 SCIENTIFIC TOPICS COVERED

The RTG initially pursued nine overlapping research topics, organizing into sub-groups to pursue each topic. The research topics were:

1) Defining analytical war gaming as a distinct practice, identifying innovative approaches and tools for analyzing games, and collecting and documenting relevant definitions and terms.
2) Mapping analytic tasks to the wargaming process.
3) Researching developments in automation and artificial intelligence that can support analytic wargaming.
4) Compiling best practices for analytical wargaming.
5) Identifying and observing demonstrations of state-of-the-art tools and techniques to support analytical wargaming.
6) Mapping stakeholders and developing a sustainable community of practice.
7) Developing guidelines for fitting techniques with analytical wargaming processes and practical evaluation criteria for rigor.
8) Identifying sources of bias and mitigation strategies.
9) Investigating decision science aspects of analytical wargaming.

Over the course of the effort, the RTG identified issues, challenges, and redundancies across their research topic areas, and consolidated their work to focus on gaps, shortfalls, and challenges in war game analysis and game play; exploiting wargame results to inform decision making; analytical methods and techniques that can be used in wargaming; ensuring analytical rigor in wargames; and collaboration opportunities and best practices amongst NATO member states to advance the state-of-the-art in analytical war gaming and provide a capability to the Alliance.

1.4 SYNERGIES AND COMPLEMENTARITIES

The aim of the NATO SAS-139 RTG was to improve NATO's analytical wargaming capability by providing guidelines for ensuring analytical rigor and meaningful data capture in wargames. In the course of its work, the RTG discovered synergies and complementarities with the SAS-130 RTG "Course of Action Analysis in the 21st Century," NATO IST-141 "Exploratory Visual Analytics," and SAS-170 "Distributed Wargaming."

SAS-139 RTG work provides an overarching framework that complements and can incorporate SAS-130 work on course of action analyses. Our findings inform best practices in analytical wargaming course of action analyses, and identify opportunities for innovation and investment in training, processes, tools, facilities, and products.

The SAS-139 RTG discovered synergies with NATO IST-141, which aims to research, develop, and apply exploratory visual analytics to exploit and make sense of large and complex data to help make tacit knowledge explicit; and provide acute situation awareness and support to decision making in cyber, maritime, and social media domains. The objective of the joint meeting was to discuss how advances in visualization and visual analytics could be applied to improve analytical wargaming. Participants identified a need for continuous development of tools to improve perception, comprehension, and communication of relevant information before, during and after wargame execution. The two Task Groups also identified interactive visualizations and visual analytics as potentially useful approaches for extracting knowledge from data and to support analytical wargames.

SAS-139 did some initial research into distributed wargaming and this has been shared with SAS-170, whose aim is to create a best practice guide on this subject.

1.5 EXPLOITATION AND IMPACT

SAS-139 RTG work advances strategic and operational decision making and synchronization in NATO by creating a NATO analytical wargaming community of interest, developing analytical wargaming capabilities in many NATO Organizations and Nations, sharing best practices, and identifying and encouraging the use of innovative methods for data capture and analysis.

SAS-139 work has already been presented at the Connections wargaming conferences and the NATO Operations Research and Analysis conference. There is opportunity in the future to present specific chapters at conferences or adapt them to journal articles.

As the SAS-139 RTG was winding down, the NATO Audacious Wargaming Capability was being set up. NATO Audacious Wargaming will continue SAS-139's efforts to maintain an active analytical wargaming community, and it's members will continue to meet and expand based on the network of relationships developed in this research task group, and through Connections wargaming conferences. NATO Audacious Wargaming will establish wargaming in NATO as a professional discipline by building wargaming capacity and capability, education, and training.

1.6 REPORT STRUCTURE

This report is organized into four parts, eleven chapters, and two annexes. Part I lays the foundation for subsequent parts and chapters. The chapters discuss the use of analytical wargaming in military planning, and the challenges associated with achieving rigor. Taken together, the chapters in this part provide two lenses through which to view ideas about innovation in analytical wargaming – the extent to which proposals improve military planning and decision making, and the extent to which proposals improve the validity and reliability of wargaming findings. Part II focuses on applying advances in Artificial Intelligence (AI) and automation to analytical wargaming. The chapters in Part III discuss a range of analytical methods that complement analytical wargaming, and the two chapters in Part IV reflect on the issues and challenges associated with distributed analytical wargaming. Findings from the team's survey of tools and techniques are discussed in the introductory sections and chapters. Annex A contains a guide to continuing development as an analytical wargame practitioner: the Wargaming Professional Guide NATO edition. Annex B provides a list of additional background references used by this Research Task Group.

Whilst this report is lengthy, each chapter can be read as a stand-alone document, so readers are free to skip ahead to areas that most interest them.

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Part I – ANALYTICAL WARGAMING

I.1 ANALYTICAL WARGAMING

Wargamers often quip that there are as many definitions of "wargame" and "analytical wargame" as there are wargamers. Building on more than 80 years of wargaming experience at the U.S. Naval War College from the vantage point of 1966, Francis McHugh defined wargaming as "a simulation, in accordance with predetermined rules, data, and procedures, of selected aspects of a conflict situation." He characterized a wargame as a "practice field" for acquiring skill and experience in decision making and an "experimental trial ground" for testing concepts and plans [1]. Similarly, in his paper in Chapter 2 of this report, Lantto defines wargaming as "a structured, analytical method for deriving insights to support decision making." The official NATO definition is "a simulation of a military operation, by whatever means, using specific rules, data, methods and procedures", and the more recent UK definition is "A scenario-based warfare model in which the outcome and sequence of events affect, and are affected by, the decisions made by the players" [2].

While recognizing that all wargames have experiential and educational aspects, the SAS-139 team defined an **analytical** wargame as a game designed and conducted in such a way to maximize its contribution to a larger analytic effort. Whereas educational wargames are designed to primarily support teaching objectives, and experiential wargames are designed to provide a decision-making experience for players and perhaps build collaborative networks, analytical wargames are designed to rigorously address specific research questions. As Collins and Bastings point out in their paper in Chapter 3, analytical wargaming is a research method that has long been used to explore difficult problems and a wide range of dilemmas directly and indirectly related to military strategy, operations, and tactics. For example, focusing on specific military research questions, the Australian Department of Defence and the U.S. Pacific Fleet Command develop comprehensive research programs that use analytical wargaming to complement exercises, experiments, and modelling and simulation efforts.

Professional analytical wargamers use a disciplined process and Standard Operating Procedures (SOPs) to specify wargame research questions, design, develop, and execute a wargame, and capture and data generated in wargame play. As Figure I-1 shows, this process includes preliminary analysis, clarifying tasking, specifying a problem, purpose, objectives, and research hypotheses or questions, designing, and developing the wargame to address the research specifications, and managing and controlling execution to achieve research specifications.

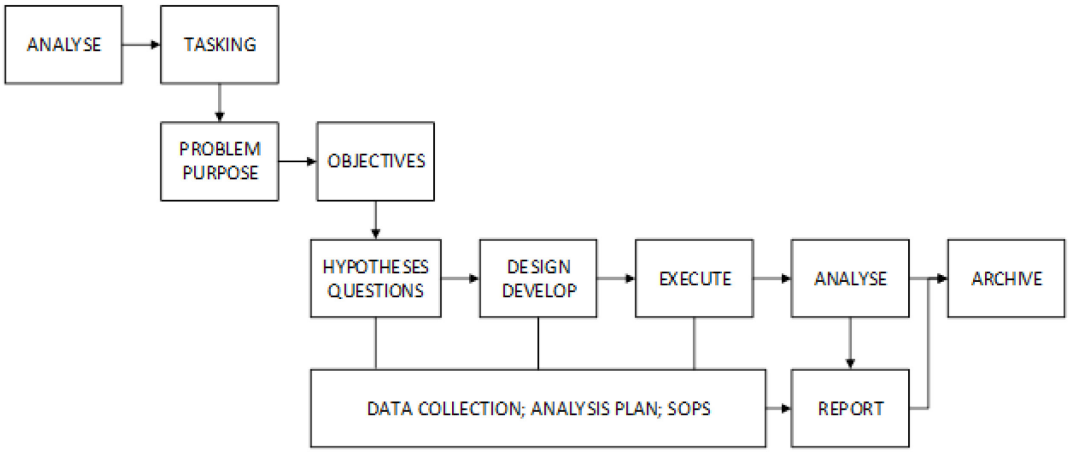

Figure I-1: Analytical Wargaming Process.

Wargame design and development involve specifying a decision context and environment for player interaction based on preliminary research about the problem, determining the size, scale, and operating area of the game, identifying the decision-making tasks involved in addressing the research questions, and developing decision-making rules for playing the game and adjudicating interactions. Activities include creating products for game play such as a road to crisis, scenarios or injects, references, orders of battle and capabilities, a common operating picture, game pieces, move templates, player instructions, and decision aids. The decision environment may be instantiated using a physical map, a game board, computers, or simulators. Other activities include determining required player qualifications, recruiting, and registering players, developing data collection and analysis plans, obtaining and organizing facilities for play, and recruiting and training facilitators and data collectors. Data capture may include manual methods such as note-taking, as well as automated methods using computers and other recording devices. Analytic approaches include inductive and deductive strategies, and qualitative and quantitative methods. During execution, wargamers collect and analyze data generated in play to maintain rigor and identify preliminary research findings. Following execution, wargamers analyze all the wargame data, and report and disseminate their findings in ways that can be used by decision makers interested in refining policies, strategies, concepts, and plans, or investing in forces and capabilities.

The SAS-139 team determined that each element of the wargaming process poses opportunities and challenges for developing new knowledge, processes, and tools that improve rigor, efficiency, and effectiveness in data capture and analysis. Challenges in initial analysis, tasking, and specification include searching, visualizing, and assessing prior research to discover relevant findings, estimating the rigor of findings, and identifying knowledge gaps, as well as organizing, structuring, summarizing, and archiving relevant research for easy retrieval and review. Similarly, innovation in data search and visualization can improve design, development, execution, data collection, analysis, and reporting activities.

Innovation opportunities and challenges related to design, development, and execution include providing low cost, easy to use common operating pictures for wargame play that can be updated at different time intervals, and decision aids for players and adjudicators. New tools and approaches are needed to control for bias, crawl through contextual data to write scenarios, create situation updates, survey players, and respond to player information requests as wargame play evolves. Increasingly, warfighting involves humans, and sentient, autonomous machines. RTG members observed that deploying these advanced capabilities in NATO forces will require learning to wargame with and against machines.

Analytical wargame data collection, analysis, and reporting is ripe for innovation that can support the following activities in small- and large-scale games:

- Automating collection, organization, and management of wargame data, which includes structured and unstructured text, images, behavior, adjudication decisions, and discussion generated in the course of wargame play, which may involve joint/combined military operations in multiple domains and theaters at strategic, operational, or tactical levels of analysis.
- Visualizing player and adjudicator decisions, decision making processes, and outcomes (including changes in the operating picture) related to command and control, intelligence, fires (kinetic and non-kinetic), protection, maneuver, and logistics/sustainment (including humanitarian assistance and disaster recovery).
- Identifying data that address research questions or support research hypotheses.
- Estimating bias, validity, and reliability.
- Surveying players perceptions and insights.
- Communicating findings and the evidence that supports findings.
- Efficiently archiving data so that it is easily grasped, accessible for future reference, and can be shared with other researchers.

Wargaming is one of the oldest methods for researching military operations. Many analytical wargamers treat operational plans and concepts as theories about decision making and design games to investigate the feasibility and suitability of these theories. For example, Polski provides a framework for examining the nature of war fighting as a research challenge in the context of professional research standards [3].

However, SAS RTG-139 found a dearth of literature on the science of wargaming. Most of the wargaming literature treats wargaming as a practical art rather than a scientific research method integrated with other military research and situated in contemporary decision science disciplines. Whilst the existing literature provides useful advice and frameworks for how to design, develop, and execute a wargame, it does not provide a rigorous foundation for innovation to reinvigorate NATO analytical wargaming. Hence, one of the team's initial concerns was to orient analytical wargaming in military and scientific research traditions.

The papers in this part lay a foundation for developing the military decision making and scientific research aspects of innovation in analytical wargaming. Lantto's paper in Chapter Two orients analytical wargaming in military planning traditions. He provides a primer on the use of analytical wargaming in military planning and decision making and articulates commanders' and planning staff requirements for innovation to develop cost-effective and timely simulations, tools that support relative combat power analysis, and methods that produce findings that can support decisions to improve readiness. Collins and Bastings paper in Chapter Three orients analytical wargaming in scientific research traditions. Scientific research methods involve collecting data to objectively test theoretical statements or hypotheses about social or natural phenomena. Analysts who employ scientific research methods are primarily concerned with designing research that produces valid, unbiased findings that consumers can use to make informed choices. Collins and Bastings focus on challenges associated with addressing bias and validity in analytical wargaming. Their discussion underscores the need to integrate experimental design principles and research on judgement and decision making in order to consistently generate rigorous findings.

Taken together, the papers in this part provide two lenses through which to view the ideas espoused in the papers in subsequent parts of this report – or other venues. Using Lantto's paper as a lens, one should ask if innovation ideas will add value to developing better military plans and decisions. Using Collins and Bastings paper as a lens, one should ask if ideas will contribute to improving the validity and reliability of analytical wargaming findings.

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Chapter 2 – ANALYTICAL WARGAMING AND MILITARY PLANNING

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2.1 INTRODUCTION

Wargaming can be used in military planning for four main purposes. At the beginning of the planning when evaluating the situation/task received, at the stage of preparation of courses of actions, at the stage of preparations of the plan and at the stage of evaluation of the plan. Operational analytical methods can also be used to evaluate the situation and to complement the wargaming methods.

In this chapter, the Comprehensive Operations Planning Directive (COPD), Military Decision-Making Process (MDMP), and The Canadian Forces Operational Planning Process (OPP) have been used as examples to illustrate how wargaming can be inserted into military planning for conventional operations [1], [2].

In Phase 3 of the COPD process (Operational Orientation), in Phase 2 of the MDMP process (Mission Analysis), and in Phase 2 of the OPP process (Orientation), a wargame can be played where the main goal is deeper understanding of the higher HeadQuarter (HQ) Concept of Operations (CONOPS).

In Phase 4a of the COPD process (Operational CONOPS Development), in Phase 4 of the MDMP process (Course of Action Analysis), and in Phase 3 of the OPP process (Course of Action), the main goals of a wargame could be to illustrate Courses of Action (COA) for analysis.

In Phase 4b of the COPD process (Operational Assessment / OPLAN Review), in Phase 7 of the MDMP process (Order Production), and Phase 4/5 of the OPP process (Plan Development / Plan Review), a wargame can be played to test and evaluate the plan against an intelligent thinking adversary.

It often takes a long time to design and organize an analytical wargame, and in military planning, time is usually the most valuable resource, especially in rapid response planning, which is why wargames are often overlooked. Analytical wargaming must be able to support both a rapid response planning and long-term preparatory planning in order to be most effective. Therefore, rapid methods for arranging wargaming are required if they are to be fully integrated into planning. This can be achieved by developing wargaming procedures and models in advance, along with an in-house wargaming capability, requiring only small tailoring or adaptation to the current situation to be fit for purpose.

Different types and levels of battle outcome predictive models have been developed to analyze wargaming combat situations. For example, Quantified Judgement Method of Analysis (QJMA), Tactical Numerical Deterministic Model (TNDM), Stephen Biddle's formal model of capability, Soviet/Russian models to calculate combat outcomes and Situational Force Scoring (SFS) from RAND [2], [3], [4], [5], and [6].

Simple models can quickly provide support for resolving the outcome of battles at the strategic level. More detailed data-driven models can help resolving combat outcomes on a tactical level relatively quickly, if set up in advance.

2.2 WARGAMING A HIGHER-LEVEL HEADQUARTERS CONOPS

The concept of operations, or CONOPS developed by a higher HQ can be tested against the most likely (and/or most dangerous) adversary course of action through simple wargaming methods. The CONOPS can be demonstrated and analyzed through the wargame, illustrating to the commander and the planners the role, task, and significance of their own force in support of the operating idea of the higher HQ.

In this example, a simple wargame can be implemented using maps and tokens. The map describes the entire area of operations of the higher HQ CONOPS. The tokens describe the higher HQ forces and the adversary forces (taking care to show the same level of detail and accuracy on both sides). Using this set-up in a seminar wargame style can be suitable for simple conversational style wargaming.

The higher HQ operation is represented in the wargame by discussing the strategy and making moves, illustrated with tokens on the maps. Movement is time-bounded, and the actions of own side are pitted against the most likely actions and responses on the adversary side. In this example, the participants are not actually wargaming by making their own independent decisions, but rather focusing to understand, illustrate and analyze the higher HQ operation.

The adversary's actions provide insights into the likely goals, objectives, and desired end states of the adversary operation. Observations are also obtained about the forces and capabilities used by the adversary and how they might be used. In addition, observations are obtained about the forces and capabilities of the higher HQ, as well as the positions and significance of your own forces in the higher HQ CONOPS. It also identifies lines and areas that are important for military activities, as well as planned movement routes.

The wargame should utilize battle models that are both accurate and fast-working (during the game itself) to keep the time spent in the wargame as short as possible – recognizing that time will be a valuable resource.

Participants are ideally the commanders and staff planners, so that they can make their own observations. The most important thing in this type of wargaming is to fully understand the CONOPS, their place in it. It can also be used to understand potential risks and vulnerabilities, and to refine the planning if necessary. Sometimes tactical or operational-level players can participate in the higher HQ course of action wargames, which will look at the same operation from a different perspective. The wargames can also be used to discuss different CONOPS options, or different ways a situation could develop and therefore different ways to respond.

2.3 RELATIVE COMBAT POWER ANALYSIS

In connection with the evaluation of possibilities resulting from different options and actions, a relative combat power analysis is prepared, which identifies possible ways of operating from own and adversary perspectives. This relative combat power analysis also supports the wargaming of the course of action and the Operational PLAN (OPLAN).

The relative combat power analysis compares your own available forces and capabilities with those of the adversary. The adversary's forces are analyzed on the basis of the adversary's action options estimated by the higher HQ. The relative combat power analysis can be used to identify own and an adversary's weaknesses, missing capabilities, and critical capabilities.

A number of things affect the relative combat power analysis, and therefore planners must be involved (or perform themselves) the analysis to ensure all factors are accounted for. Examples of factors include:

Rough relative combat power analysis is a quick analysis made by estimating the number of fighting forces per battalion/company/ship/airplane/etc. in relation to the adversary's fighting forces. The result is an indicative estimate of the number of forces on the battlefield.

Relative combat power analysis is a more detailed analysis and considers the relationship between own and adversary forces, equipment, and capabilities, assessing both numbers of fighting forces but also their capabilities against each other. This analysis can be strengthened and made more accurate using operational analytical methods, such as QJMA or TNDM. Whatever method is used, the data and methods must be validated to assess the accuracy of the result.

The calculation in all cases must be made in a time-bound way in order to identify the challenges and opportunities that will arise as the military power develops in battlefield during the game.

2.4 WARGAMING COURSES OF ACTION

A wargame can be designed to illustrate a Course of Action (COA) and the related activities. In this case, the detail should cover the actions of subordinate forces, the necessary support and movement areas to be used, as well as the timing of movement, actions, and events. The adequacy of capabilities and forces is examined down to the precision of any subordinate forces. The COA wargaming can assess whether or not the actions described in the COA will fulfill the goals of the higher HQ.

Wargaming COAs can test how the course of action might develop, and how the course of action could work against the adversary's actions. It can be useful to evaluate how the course of action responds to the overall mission, and also obtain information about the necessary preparations required.

Observations are also obtained on where and how potentially military engagements (battles) might occur and to explore the options, for example how the engagement might be better supported. The comparison of course of actions must also provide insights into the strengths and weaknesses of the course of action, as well as its advantages and disadvantages.

COA wargaming can be used to explore the possibilities of moving troops and platforms, including the time factors involved. It can also be used to assess the combat power relations of possible battles. Having said that, the most important consideration of COA wargaming is to assess the feasibility of the course of action and the risks involved.

The choice of method of wargaming is influenced by the accuracy and time required to evaluate and review the course of actions. Commonly used methods of COA wargaming are either single move wargaming or rough wargaming. Single movement wargaming is an extremely simple method of wargaming that is suitable for rough consideration of opposing plans or courses of action. A wargaming group (one or more persons) are given both side's plans or courses of action, and they can play out a wargame based this single input alone, assuming they are familiar with the scenario and environment from their planning work. Rough wargaming usually looks at the activities of a number of key subordinates in a few stages of the operation (2 – 3 wargame turns). The wargame turns consists of a starting position, operation of the active player (usually the attacker), the other sides' response to the active side and counter action of the active side. The starting situation for the next turn of wargaming depends on the on the chosen wargaming review method (level, progression, area, or phase review) and the wargame turn is executed on the same principle when the active side in the round start (which does not have to be the same as the previous round).

In either case, the wargaming team presents the course of wargame and its main events. The team must be experienced planners, and also ideally experienced wargamers, in order to be confident in the reliability of the assessment. The team can use previously created relative combat power analysis, historical minima, and norms to aid in its assessment. Based on these inputs, the wargaming team can discuss and resolve significant events during the wargame.

In order to evaluate own courses of action, at least one wargame must be played against the most likely adversary course of action. However, many assumptions must be made in order to forecast what the adversary is most likely to do, so it would be appropriate to conduct several wargames, pitting all own potential courses of action against all possible adversary courses of action.

A COA wargame can be played with fewer precise details and less preparation than the wargame to test and understand the operation plan. The operational plan wargame usually has a different aim; in this case the wargame will be used to further develop the operation plan and ensure the synchronization of its components.

A note of caution; the wargames should include a level of detail that is necessary to understand and play out the situation, but no more; if the designers strive for too much detail, there is a danger of falling in to arguing about things that have not been planned or decided with necessary precision or accuracy.

The purpose of course of action wargaming is to find, for comparison, a course of action that is most likely to achieve the commander's objectives, with the best chance that the forces will be available for a follow-up mission after the operation. An appropriate course of action should also provide as much room for maneuver as possible for subordinates and have a sufficiently large capacity to respond to unexpected developments. In order to achieve these goals through wargaming, the wargame must illustrate related issues such as movement, the outcome of military engagements (battles), and the actions of the opponent.

Observations by the players will lead to understanding of the idea of the course of action, how it may fare against an adversary course of action, and the likely risks and vulnerabilities. Wargame participants should be the commander and staff planners.

2.5 A WARGAME OF THE OPERATION PLAN

The Operation Plan (OPLAN) is tested, synchronized, and familiarized with the OPLAN wargame. The operation plan is tested in its entirety by playing a wargame against the adversary's course of actions. Friendly actions are played in wargame according to the ideas already written down in the operation plan. The adversary's actions are played war-wisely and intelligently, with the starting situation as assessed. The wargame serves as an introduction to the operation plan for the participants and is more detailed than the COA wargame.

In the wargame the critical events are played that are directly related to the execution of a given mission. Critical events include, for example, those that require significant action or decisions. These may include, for example, the use of adversary's reserves.

In the OPLAN wargame, the entire operation plan is played against the adversary's course of actions to identify the necessary decision points, movement management challenges, additional synchronization needs, the functionality of the OPLAN, and emerging points in the OPLAN that require refinement.

The team playing the adversary should not feel obliged to stick to the estimated course of actions if they turn out not to be reasonable. The actions of the adversary must be influenced by the observations it receives about the actions of the opponent. It is better to wargame against a smart adversary when creating a plan than to run into a smart opponent on the battlefield with a plan that has not been properly tested.

Traditional wargame methods or simulations are the most common ways to wargame the OPLAN. Activities are viewed on maps, terrain boxes, computer simulations, or other tools that describe the operating terrain with sufficient accuracy. Wargame situations and solutions are recorded for analysis.

The scope and accuracy of the situations of the wargame being played can vary greatly. From the perspective of own forces, all higher HQ and neighboring forces and capabilities that may have an impact on the conduct

of the operation should be considered. Adversary's forces and operations are prepared on the basis on intelligence estimates of the situation and should be assessed more broadly. In particular, the Air Force and other far-reaching weapon systems must be assessed as a whole rather than individual units.

The wargame is started by actions of the active side, maybe one who has the advantage or is in a position to take the initiative. Wargame events cause Action – Reaction – Counter action chains. The Action is an initiative by one playing team. The Reaction is the other team's response to this initial action. The Counter action is the first team's response to this reaction, and so on. The wargame turns continue until the wargame events are completed.

The likely consequences and outcomes will be assessed and adjudicated after each turn. The wargame storyline develops as each subsequent turn is influenced by the results of the previous turns. For analysis purposes, each specific wargame event is analyzed and evaluated, and tasks that subordinate units must perform are identified. The adequacy of capabilities and forces is examined with the precision of any subordinate forces.

As Helmut von Moltke was classically quoted that "no battle plan ever survives contact with the enemy," however it can be continued that the idea behind the plan must withstand contact. The aim of a wargame is to analyze the course of the battle, how a situation may develop, and the measures needed to carry it out including any countermeasures required. A wargame results in observations of shortfalls in an OPLAN, synchronization needs, risks and opportunities, situations requiring a decision by the commander and his or her critical information requirements, and participants' advanced understanding of the operation, its objectives, operations, and each forces contribution. Hence, wargames can be valuable tools to refine military plans and courses of action.

2.6 REFERENCES

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Chapter 3 – IMPROVING AND ASSESSING ANALYTICAL RIGOR IN WARGAMING

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3.1 INTRODUCTION

Analytical wargames are a useful method in the analyst's toolkit; and have long been used to explore difficult problems or make important decisions. Once considered a niche specialty, in more recent years experienced wargamers have been widely sharing their knowledge through internet blogs, podcasts, and conferences, opening up the specialty to a wider audience. In order to maintain the credibility of the profession of wargaming, wargamers, both novices and experts alike, must strive for excellence in the art and science of wargaming and creating 'valid' wargames is a key aspect of this. This chapter discusses how to improve validity in wargames and avoid bias by using principles of experimentation. It also identifies techniques to assess the validity of a wargame and communicate confidence in wargame results to a sponsor. It is drawn from the authors' experiences as well as established literature.

As with any analytical study, it is important that the analyst team are able to assess the validity of the methods used, so that the results of the wargame are credible and acceptable. Often wargames are used to provide advice or supporting evidence for decisions with significant consequences, they can also produce unexpected or controversial results and receive pressure from sponsors to achieve a pre-determined outcome; in all these cases it is especially important that the analysts can improve validity where possible and demonstrate the validity of the methods used.

3.1.1 Defining Validity

The NATO Code of Best Practice (COBP) for Judgement Based OA [1] assesses validity in the context of judgement-based methods. Wargames are all about judgement, therefore almost all of the same principles apply. The COPB defines validity as having two primary dimensions; *objectivity* and *rigor*. Analysis should be *objective* and is characterized by recorded argumentation and rationale following an agreed and sound process. *Rigor* is achieved by enforcement of logical rules, methods should be applied as proposed, and any deviations justified and documented.

The COBP also defines additional dimensions of validity:

- Repeatability;
- Auditability/transparency;
- Independence and lack of bias;
- Grounding/consistency (in/with standards, and other data and methods);
- Understand-ability;
- Explanatory power;
- Completeness;
- Robustness under uncertainty; and
- Clear separation of data from the method which uses it.

These dimensions are important in the context of wargames. For example, the wargame process should be transparent and free from bias as much as possible, and it should be understandable and explainable to any outside observer. Having said that, most wargames by their nature would not score perfectly on these dimensions of validity, e.g., bias is inherent in all of us (which is discussed later in the paper) and it is well known that wargames cannot predict the future and by their nature are not perfectly repeatable. This is not to say that wargames are not valid! If the analyst team needs a method that will give them a single optimized answer that can be proven 'right' to 100% repeatedly, then it is likely wargaming is the wrong method of choice. If wargaming has been chosen as the right method, then the dimensions of validity can be used as guidelines to strive for improvements throughout the wargame design process.

The book *Successful Professional Wargames: A Practitioner's Handbook* [2] lightly touches on validity in wargames and defines validity as 'fitness for purpose'. Fitness for purpose might mean that a 'quick and dirty' wargame design, designed and conducted in a few hours, is perfectly valid, if the purpose included getting results quickly for a rough-order of magnitude type-decision that cannot wait. Other wargames might take months to plan, and the purpose may include rigorous analysis to support a high-level policy or investment decision. In this case the validity requirements will be different, but no less important. Analysts must always consider the purpose of the wargame when assessing and improving validity.

Assessment of validity in most wargames is usually limited to play-testing before the wargame, and an After-Action Review (AAR) afterwards with the design team and players. This process of play-testing and AAR is of utmost importance; however, this paper goes beyond these and suggests additional considerations for the entire wargaming process (as introduced in this section's introduction) and post-wargame reporting to improve and assess validity.

As mentioned already, by their nature, no wargame will ever be perfect and produce a single optimal right answer. However, using scientific and experiment principles, such as those documented in the GUIDEx [3], such as control groups, hypotheses, and determining cause and effects, can improve the validity of games. The work starts early in the design phase of the wargame and continues throughout execution and post-wargame analysis and reporting.

3.2 VALIDITY IN THE WARGAME DESIGN, EXECUTION AND ANALYSIS

The GUIDEx defines the critical components required to initiate, conduct and exploit Defence experimentation programs. Wargaming can be identified as a specific method for experimentation and therefore much can be learned from the GUIDEx with respect to improving validity throughout the wargame process.

The GUIDEx specifies four logically sequenced requirements for a valid experiment, and these requirements can be applied to wargaming. These four requirements will be explored in the context of wargaming later in the chapter, but first the use of a hypothesis statement will be discussed as a valuable tool to integrate validity into the overall aim of the wargame.

3.3 THE HYPOTHESIS STATEMENT

Most analytical wargame designs will have a clear aim that the wargame is trying to achieve, or a clear question to be answered. This aim is very important, and to further strengthen it, a complementary hypothesis statement can be formulated. A hypothesis is a statement of expectation or prediction that you believe to be true, but you are not 100% sure it is true (because then it would not be a hypothesis, it would be a fact). Hypothesis statements can be added into the wargame design to guide the collection of results.

For example, if the wargame aim is to test out a new defensive strategy in a military combat wargame, the hypothesis might be "the new defensive strategy is effective". This is not a good hypothesis statement though, because what does 'effective' mean in this context? Lower allied casualties? Quicker resolution of

combat? Also, the new defensive strategy is more effective compared to what? The old defensive strategy? Are you assessing the effectiveness in this single scenario, or do you need to assess across a range of scenarios?

Creating a good hypothesis statement is easier said than done but one litmus test of a good hypothesis statement is that it can be confirmed, or rejected, after the wargame execution, ideally by some quantifiable measure[1].

A key element here is 'quantifiable measure.' A hypothesis needs a supporting analysis plan to collect relevant data from the wargame and the analyst team should take care to look for evidence to support the hypothesis. Equally, if not more important, is to look for evidence that may lead to the hypothesis being rejected[2]. Confirmation bias (where we only look for evidence to confirm our beliefs) is a common problem when using hypothesis statements.

Hypothesis statements are written using 'IF A…THEN B' format. IF [the treatment is applied] THEN [the effect will be this]. The treatment and effect are often referred to as the independent variable and the dependent variable. Going back to the example, a better hypothesis statement might read "IF the new defensive strategy is applied (the treatment) THEN there will be a reduction in casualties (the independent variable)." This is something the game designers believe to be true but want to test to see if it is actually true through the wargame process.

Related to the hypothesis, the GUIDEx also defines four requirements of a good, or valid, experiment, and the same four requirements can be applied to wargames. These are:

- Ability to use the capability (or A occurred);
- Ability to detect change (B changed as A changed);
- Ability to isolate the reason for change (A alone caused B); and
- Ability to relate results to actual operations.

The following sections describe considerations for the wargame design team, loosely based around meeting the four requirements. These are all important considerations when designing a game but also are areas for consideration in the AAR and when discussing the validity of the results.

3.4 ABILITY TO USE THE CAPABILITY

3.4.1 Players Need to Use the Capability Under Test

One sure way to wargame failure is if players cannot use the capability you are testing in the game. There may be technical reasons for this – anything relying on computer power might not work due to bugs, glitches, or network issues. There are other reasons why the players cannot use the capability though – it might be too complicated and takes too long to learn, maybe they don't have the right background and skills to truly understand, use and test it. Will the players understand all the acronyms in use or the specialized terminology? How much training do they need? One common mistake is to give the players too much information about the capability and they either don't have time to read it or they reach cognitive overload and get overwhelmed. Less information can often be better, depending on the game.

[1] Technically it is impossible to confirm a hypothesis as true. You can only build up evidence to support it. It is possible to reject it by finding counter-evidence. In statistics an alternative hypothesis is created, and the aim is to reject the alternative hypothesis.

[2] The "Italian Flag" model is a useful construct here – evidence is collected and sorted into three categories, Green for evidence that supports the hypothesis, White for neutral evidence, and Red for evidence which might reject the hypothesis. The strength and balance of evidence across the three categories is then considered [4].

A bad wargame design may lead to players not using the capability under test because they do not get the opportunity to do so. For example, there is no point designing a wargame to test a mountain warfare strategy with a scenario set in sandy desert. Wargamers are often tempted to reuse an existing scenario because it seems easier or to save work hours, but this only works if the scenario is already fit for purpose (e.g., if a game is being repeated). The vignettes or event injects should allow for the capability to be used. It is ok for the players to *choose* not to use the capability; not ok if the players never have the opportunity to use it. This risk is mitigated through using a good scenario writer, well-structured scenario development sessions and play-testing of the game using the scenario.

On the other side of the spectrum, there is also the possibility that players are sometimes 'forced' to use the capability and the considerations for the possible use of alternative existing capabilities (which may be simpler and cheaper) can get ignored. This may occur when sponsor or other senior stakeholders are convinced of the benefits of some new capabilities and not open to objective testing.

3.4.2 Ability of the Wargame Player Teams

The importance of players in wargames is not to be under-estimated. Choosing the right people to play the right roles is part of the wargame design process, and if the wrong people are playing, it may lead to poor results and undermine the output of a wargame. A good player is likely to be one that is willing to play along within the rules and framework of the game[3], has some knowledge of the subject under discussion, and can take decisions at the appropriate level. A Subject Matter Expert (SME) who has great knowledge of the subject may not understand how to play the game well, and this can cause problems. For example, SMEs who have detailed knowledge of a historical event but cannot see how things may have turned out differently, given the same inputs, may struggle to come up with new ideas. A Lance Corporal may be excellent at tactical-level decisions, but when the wargame is run at the strategic level this does not fit the expertise the Lance Corporal brings to the game, and vice-versa for higher ranks.

Equally important is ensuring the right balance of expertise in the game – did the Blue team win because they were employing a better strategy, or did they win because they have more knowledge about the subject or are more experienced gamers and stronger communicators[4]? One way to check for, and mitigate this, in advance, is to create a personal questionnaire before the game, asking about the player's expertise, experience, and (in an international game) their language skills. The results of this questionnaire can help the wargame designer allocate people to teams and consider mitigating strategies. In NATO, those people who are fluent in the language of the game (e.g., English) will often dominate the conversation over people who are working in their second or third language. This is not because they have better ideas, but because they can express themselves more easily. This can be mitigated through a balance of native speakers in each team, and methods allowing everyone a chance to speak or provide input. Some NATO games deliberately placed inexperienced students in teams with experienced military officers to provide fresh insight [5], [6]. However, in these games the facilitators had to work hard to ensure the experienced military did not dismiss ideas from the students, and more than once had to intervene to ensure all voices were heard.

Another important but often over-looked consideration is the amount of cohesiveness within a team. Do people get along well, are they used to working together and have developed a 'team bond' already in previous work (which can be negative as well)? Or are they strangers who meet for the first time in the game room? Teams often go through a staged process of 'forming, storming, norming, and performing,' and it may be best to lead the team through the first 2 – 3 stages BEFORE the wargame starts rather than have them go through the stages in the first few turns, possibly affecting the results. This can be done by playing ice-breaking team events

[3] This may be someone who is experienced in wargaming but may not be. Experienced wargamers are very useful for play-testing, but during conduct of the wargame itself, they may start arguing about the 'proper' way to play.

[4] An interesting example of this is when General Zhukov was in a wargame in December 1940 playing the Germans, and decisively beat the Soviets. Stalin was so angry he fired the Chief of the General Staff and replaced him with Zhukov. The game was re-run with Zhukov as the Soviet Commander and won (and this game result was the one publicized) [7].

(such as 'build a tower out of spaghetti sticks' [8]) to get the team bonding before they play the game, or planning for a dry-run wargame to introduce the team to the process, before the actual game starts.

Most of the advice about selecting players also applies to the wargame design team. Selecting people with the right level of knowledge (enough to understand the conversation, but not so much they do not bring their own biases to the table) and skills is important. In the case of the analyst team, analysts are not merely note-takers, but there to draw conclusions and ask probing questions. Where more than 2 – 3 analysts are employed in the wargame, it is recommended to appoint a lead analyst who can coordinate the overall collection of data and ensure consistency across wargame groups.

3.5 ABILITY TO DETECT CHANGE

3.5.1 Understanding Cause-and-Effect and relating it to Outcomes

Another principle drawn from science is ensuring that the wargame analysts can truly understand the cause and effect, and not erroneously attribute a change in effect to the wrong cause. Using the same example hypothesis statement, "IF the new defensive strategy is applied THEN there will be a reduction in casualties," the analyst must be sure that any reduction in casualties is a result of applying the new strategy (directly or indirectly), and not the result of something else. For example, if two wargames are run, one using an old strategy, and one using a new updated strategy, and an expert player turned up late and could only attend the second wargame, do the analysts really know if the new strategy was better because it produced better results, or that the new expert player had such a large influence that they alone produced better results?

If a good hypothesis statement is written as recommended, it is natural for the analysts to expect that statement to be true and therefore reflect the outcome of the game. If a different outcome than expected occurs, that is a *good thing* because something new is learnt. So, two good outcomes are: a) Confirm the existing hypothesis, to build evidence for it or b) Deny the existing hypothesis, so it can be rejected and replaced by a new theory. A bad outcome is c) Neither confirm nor reject, because no change in outcome was detected. This most certainly happens when the environment (i.e., the scenario, or sometimes the players) does not allow for the new capability to be used to its full extent. For example, a wargame to test new Pre-crisis Deterrence Response Options would not allow the Response Options to be fully tested if the scenario started in all-out crisis for which the Response Options are not designed for.

There is an even worse outcome that is d) A change in outcome is detected, but it is wrongly attributed to the capability under test, when actually the outcome has nothing to do the capability. There are two ways to counter this; mitigate for biases in the original design (e.g., don't set up the wargame so that Blue team wins every time, no matter what), and post-wargame do an in-depth analysis in the after-action review on why something happened. Did the Blue team win because of the new capability they were employing, or were they just superior wargamers to the Red team?

3.5.2 The Importance of a Data Collection and Analysis Plan

The data collection and analysis plan is a crucial document for analytical wargaming. It does not have to be long, but does need certain details such as:

- What are the wargame objectives, and how will the analyst know if they have been achieved or not?
- What evidence will be collected to prove the hypothesis? What evidence to look for to reject it?
- How will results be measured? How do these relate to wargame outcomes?
- What are the data collection tools and methods?

- How will the lead analyst ensure consistency of data collection?
- Is there a plan for analysis of the data after the wargame?
- Does the data collection plan integrate into the game control mechanisms, so is as frictionless as possible?

A common bias in analysis is Maslow's Hammer: "it is tempting, if the only tool you have is a hammer, to treat everything as if it were a nail" [9]. Analysts often employ techniques they are familiar with, without spending enough time thinking about the appropriateness of the methods. An example of this would be if a wargame type was chosen without considering whether or not that type is conducive to collecting the type of data required to solve the original problem.

Another trap is to measure any available data, without considering whether that data is important enough to be measured. This is common in computer and simulation-supported wargames. Measuring the number of kilometers travelled by a unit might be an important outcome in certain games, and completely irrelevant in others. The analyst should link each type of recorded data back to the wargame objectives. It can be useful to think in terms of Measures of Performance (MoPs) and Measures of Effectiveness (MoEs). In a wargame context, MoPs are data that can be directly measured, and MoEs are related to measuring the outcome. As an example, an MoE might be 'campaign success' and related to several MoPs such as 'number of casualties,' 'territory controlled' and 'population support.'

Another consideration is triangulation of results. If it is possible to derive three methods of collecting data to answer each analytical question, the result will be stronger than if just one method is used. For example, if the number of casualties in a wargame is an important measure; count the number of actual casualties, but also take analysis observation notes and supplement it with specific after action review questions.

Changes in the way data are collected during the course of the wargame should be monitored and carefully controlled. If the criteria or measures change over the course of different vignettes, or the analysis methods change, then you can end up in a situation of not comparing 'apples to apples. If there is a suggestion to change the way data is collected during wargame execution, the decision to change must be a conscious decision after considering how it may affect the overall conclusions from the wargame. It is natural for the analysts to start collecting all sorts of data or make different observations; this might be conscious or unconscious. Data collection should be planned for and collected consistently across different analyst teams.

Daily analyst meetings are recommended over the course of a multi-day wargame. At each meeting, progress of data collection towards the objectives should be discussed. If there is enough data and evidence for one objective, efforts can be refocused to collect data against different objectives. Changes in data collection, and the impact these might have on the validity of the game, can also be discussed. If possible, the analysts can also brief the initial results to the players so they can receive feedback and clear up any misunderstandings.

3.5.3 Consideration of Statistical Sample Sizes

Sample sizes can be a real problem in wargames. Due to the high level of effort and resources required to put on a game, games can often be designed as a 'one-shot' operation lasting a day, or a few days, never to be repeated. Repetition is important however, so the wargame designer should carefully consider whether it is better to develop multiple low-resource games that are repeated, than to develop a single, high-resource game. Smaller games that can be repeated will in some cases produce more insightful results, but the designer may have to account for other constraints, such as the availability of players, sufficient numbers of appropriately skilled adjudicators and analysts, sponsor's expectations for a 'big' event, the importance of VIP days etc. Similarly, consideration on how many scenarios or vignettes are necessary to fully test the

capability is important. For example, for a capability designed for an urban operation, does it need to be tested in different sizes of cities, in different locations, with different features and level of development? Or is a single setting enough? The question of what sample size is sufficient to answer the analytical question should be considered as part of the design planning.

3.6 ABILITY TO ISOLATE THE REASON FOR CHANGE

3.6.1 Control Groups and Controlling Factors

When looking for true cause-and-effect, there are different ways to isolate a reason for the change. One is to control all factors except for the treatment (e.g., two identical games, but one with an old strategy, and one with the new strategy) across multiple games. Keep the same players, the same scenario, the same lighting conditions in the room… everything. The problem with this approach is that it is almost impossible to achieve! Something always changes. The trick is to change as few factors as possible, and then note down all the changes that inevitably will occur. The most common factor that changes throughout the game and is almost impossible to keep the same is player learning. Players learn from their mistakes, they learn how to play the game, and they learn the team dynamics in the room. This is something to consider when attributing success (or failure) to another cause. A way to overcome this may be:

- Repeat the game using small groups from a large cohort of similar participants;
- Break down the game into vignettes and randomizing the order in which they occur between runs;
- Run the game in parallel, with one group operating without the capability as a control and compare their performance;
- Run the game twice in parallel, switching who gets the treatment (the new capability) first. Do the players who had the new capability first, improve over the team who didn't? Or do the players playing the game without the capability first, do better when they get it for the second game?
- Use a "disguised scenario" in order to deceive the players that are playing a different game, when in fact it is a repeat of the initial game.

One way of controlling external factors is to use computer simulation modelling. Computers can be set up to replicate things in a way no human can, and there are many examples of how computer simulation has been successfully applied in gaming. Another way of controlling game changes is to employ a 'game controller' who is the only person authorized to make changes to the game design during game play. Any suggested changes must be run through the game controller, who will carefully weigh up the benefits of the change against the impact it might have on the analytical results.

The discussion of what can be controlled for, and what can't, should be part of wargame design. After the wargame is played, any changes that did occur (controlled or not) can be fed into the after-action review and discussed. For example, some of the players stopped playing and went to lunch early…but they weren't contributing anyway so this change was unlikely to affect the outcome. More significant changes can be analyzed to understand their likely effect, and if important, this can be part of the customer briefing.

3.6.2 Controlling for and Recognizing Variability in Analysis

Related to controlled and uncontrolled changes, is recognizing, and controlling for variability in the analysis. When multiple analysts are employed, or multiple games are run, is the data is being collected in the same way by all analysts? Without any direction and guidance apart from 'take notes,' one analyst might look at the overall strategy and big picture, whilst another analyst might record all the tiny details. To combat variability, an analysis plan detailing what data to collect, when, and how is essential. Simply 'taking notes'

is subjective, based on observation, misses anything not directly observed, and are tainted by analyst's background and opinions. Confirmation bias is a big problem in data collection, as discussed later. Introducing a checklist to guide the data collection can be of much help.

Another way to combat variability in the analysis is to set up automatic data collection – whether that be recording each move in the game in a systematic way (perhaps by using video), automatic voice recording or recording of results of voting, or using computer simulation etc. One danger with relying on automatic data collection is that it might be too tempting to record what is easy to measure and ignore data that is hard to record. The latter may be just as, if not more important.

Anecdotal evidence [10] suggests that two groups of analysts, viewing exactly the same game, can often come up with different results. One way to mitigate against this is to use objective measurement criteria as much as possible, that is, criteria that does not require an opinion or human judgement. Measuring the number of casualties is objective, asking the players to judge how successful the campaign was is subjective. Subjectivity is not always bad; having a mix of objective and subjective criteria is ideal to see the overall picture. Using pre-defined criteria with score scales can be used: this helps to objectify multiple measuring points and provides data for the analysis phases, especially when supplemented with arguments on why the criteria has been scored a certain way.

When different teams of analysts collect data from different playing teams (e.g., different analysts assigned to the Blue team and the Green team) a data collection plan is even more important, to ensure consistency of data collection amongst the teams. As mentioned before, a lead analyst should be assigned to ensure the data collection plan is being followed.

3.7 ABILITY TO RELATE THE RESULTS TO OPERATIONS

3.7.1 Games Should NOT Be Real, but They Should Be Realistic

Wargames are a necessary abstraction of reality, if they reflected real life perfectly then they would not be a wargame any longer. They can never be 100% realistic nor strive to be, because this would incur unnecessary expense and other resources. However, the capability being tested should have some resemblance to the real-world capability. It is a regular criticism of wargames that the new super tanker being evaluated can magically deploy at zero days' notice and travel at 1000 miles an hour to reach its destination within minutes, and with no extra logistical support. Or that the autonomous systems being explored are available by the tens of thousands, because suddenly the military budget to buy them is unlimited. A level of realism is important.

Realism also applies to the players and the scenario. The players playing the game should be representative of those who will be the end users of the capability, e.g., OF-4 and above for strategic level decisions, or C2 experts for a new C2 system. This is an area where getting the real operators, or end users, to play will provide valuable insight. Often these players are too busy to take part in the game, so they can sometimes be substituted for other people with relevant experience.

Creating a scenario is quite an art, and can be based on real events, real actors, and geography (but do not have to be). It is a difficult balance between not overwhelming players with too many details but including all the important elements. Wargames are often criticized for leaving out important but 'inconvenient' elements such as a civilian population, 3rd party actors, or logistic supply chains.

What is important is not to get as close to reality as possible, but to understand the level of realism and representativeness, make a judgement as to whether this is appropriate (is it 'fit for purpose'), and to communicate this to the customer as part of the results.

3.8 MITIGATING BIAS TO SUPPORT VALIDITY

As already alluded to, one of the aspects that contributes to achieving validity is addressing the potential bias that may occur: during the entire process of design, execution and post-wargame analysis and reporting, different biases can occur that can negatively influence the outcome and therefore the validity of the wargame.

The NATO Alternative Analysis (AltA) Handbook [11] describes methods that support the deliberate application of independent, critical thought and alternative perspectives to improve decision-making. The AltA Handbook defines bias as "…a distortion of thinking and perceptions that can lead to false assumptions and flawed analysis. A bias is an inclination – either consciously realized or completely unknown to a person – to present or be predisposed towards a particular perspective. This is often accompanied by an intentional or unintentional refusal to reflect upon the possible merits of alternative points of view."

Often the existence and occurrence of bias is linked to different systems of decision making within the human mind. This link is also mentioned by Kahneman [12] and other psychology papers as referred to in the UK's Joint Doctrine Publication, "Understanding and Decision Making (UK-JPD-04) [13]. They all state that the human mind consists of two systems of decision making: System One for intuitive thinking and System Two for analytical thinking. Bias is the result of the application of heuristics in System One thinking: cognitive 'rules of thumb' that allow us to make quick mental calculations that are necessary for quick decisions and responses.

Given these definitions one could argue that heuristics and perhaps even System One thinking (ergo intuitive) should be avoided as much as possible. But both System One and System Two thinking have their value. The UK-JDP-04 gives a comparison between intuitive and analytical thinking (see Table 3-1). Intuitive thinking has been compared with analytical thinking, particularly against reasoning, judgement, and decision-making. Complex problems may involve a combination of both thinking modes and it helps to understand which thinking mode is best suited, both at which time and for which part of the problem. It is the awareness of the existence of both thinking modes within oneself and others that helps recognizing the possibilities of the occurrence of biases.

Table 3-1: Intuitive vs Analytical Thinking.

Intuitive	Analytical
Can be very effective under time pressure and reacting to sudden, unexpected events	Superior when accuracy and evidence are needed, and time and information are available
Expertise is often based on intuitive thinking developed through experience, and can be very accurate	Novices will rely on analytical thinking until they become more expert
More vulnerable to heuristics and biases	Skilled analytical thinking is less influenced by emotion and heuristics
May use valuable situational information that is perceived unconsciously	Can encourage 'stove-piped' thinking
Has been shown to be superior to analytical thinking for some types of complex or unstructured problems	Many tools and techniques have been developed in the tradition of objectivity and determinism and only use conscious means
General (non-expert) intuition can be more effective than analysis for novel, undefined problems	Training in logic can enhance analytical reasoning
Large capacity and concurrent	Limited capacity and therefore consecutive

As already stated above, the primary source of bias can be found in the use of heuristics during intuitive thinking. These heuristics can cause people to overlook, reject, or forget important incoming or missing information that is not in accord with their assumptions and expectations. More senior people may even be more susceptible to these mind-set problems as a result of their expertise and past success in using time-tested mental models. Tetlock [14] refers to them as so called 'hedgehogs': people that interpret the world in line with one or two standout ideas. This way fully committing themselves to confirmation bias, meaning they naturally search for information that reinforces existing beliefs.

One of the benefits of manual wargaming is the ability to challenge the reasons for a decision at the time it is made, and even before the result is known. This can 'force' the participant to engage 'System Two' thinking when they might have been merely reacting with 'System One' thinking. This is a decided advantage over wargames that are dominantly supported by computer simulation. When the participants realize they made a mistake but are not open about this, then all you get at the after-action review is a post hoc rationalization for their action which doesn't really help. Having a forced distinction between the different steps in the wargame helps to also sequentially capture reasoning and from that being able to challenge it.

People are almost always a dominant element in wargaming (whether it being in the design, execution or analysis phase), therefore taking notice of the possibility of bias occurring is of key importance. On the other hand, one could argue that analytical wargaming in itself is a systematic method for analyzing warfighting decisions and therefore mitigating bias is inherent in the process. As Polski and Logel state [15]: "War games are designed to challenge the assumptions …identify critical issues for further analysis" and "Achieving rigor in wargaming includes taking steps to minimize bias….".

Nevertheless, the awareness of the possible occurrence of bias should be present and explicitly explored in either design, execution and post-wargame analysis and reporting. The NATO AltA handbook summarizes the most common perceptual and cognitive biases, based on documentation of the US Center for the Study of Intelligence (see Figure 3-1).

This paper has already mentioned multiple examples of either occurrence or mitigation of biases: e.g. not to focus solely on collecting data that supports the hypothesis but also look for evidence that may lead to it being rejected, paying attention on including the right people in the wargaming teams (either having enough knowledge on the topic and wargaming, but not being prejudiced too much), use of data-collection techniques that support the hypothesis, analysis is reported in a similar way across teams and uses similar data, etc.

These examples show that bias is 'hidden' in various aspects concerning wargaming: it concerns all phases of the game and although always introduced by people, it can also be reflected in the methods and tools that are used during the process. Table 3-2 tries to span the spectrum of possible instances where bias can occur, and the sources of bias. The ways the bias can manifest itself are numerous [16], the most dominant ones in wargaming are:

- Confirmation bias (being dominantly interested in information confirming our existing perceptions), mitigated by the selection of team members as diverse as possible and constructing heterogeneous teams. This not only applies to the teams with wargame players, but also the wargame design team.
- Anchoring bias (being over-reliant about the first piece of information), mitigated by organizing the introduction of new information, for example on new capabilities, in such a way that different groups retrieve information in a different order.
- Ostrich effect (to ignore dangerous or negative information by 'burying' one's head in the sand): mitigated by explicitly addressing both favorable and not-favorable information in the data-collection process.
- Sampling bias (selecting a sample that will favor some outcomes more than others, e.g., setting up the wargame scenarios, vignettes, players, etc. to favor one of the teams)

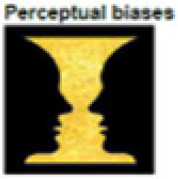
Bias	Description
Perceptual biases 	**Expectations:** You tend to perceive what you expect to perceive. More (unambiguous) information is needed to recognize an unexpected phenomenon. **Resistance:** Perceptions resist change even in the face of new evidence. **Ambiguities:** Initial exposure to ambiguous or blurred stimuli interferes with accurate perception, even after more and better information becomes available.
Biases in estimating probabilities 	**Availability:** Probability estimates are influenced by how easily one can imagine an event or recall similar instances. **Anchoring:** Probability estimates are adjusted only incrementally in response to new information or further analysis. **Overconfidence:** In translating feelings of certainty into a probability estimate, people are often over confident, especially if they have considerable expertise.
Biases in evaluating evidence 	**Consistency:** Conclusions drawn from a small body of consistent data engenders more confidence than one drawn from a larger body of less consistent data. **Missing information:** It is difficult to judge well the potential impact of missing evidence even if the information gap is known. **Discredited evidence:** Even though evidence supporting a perception may be proven wrong, the perception may not quickly change.
Biases in perceiving causality 	**Rationality:** Events are seen as part of an orderly, causal pattern. Randomness, accident, and error tend to be rejected as explanations for observed events. **Attribution:** Behaviour of others is attributed to some fixed nature of the person or country while your own behaviour is attributed to the situation in which you find yourselves.

Figure 3-1: Common Biases.

Table 3-2: Sources and Stages of Bias in Wargaming.

Stage → / Source ↓	Design	Execution	Post-wargame Analysis and reporting
Sponsor			
Adjudicators / facilitator			
Analysts / Data collectors			
Players			
Tools / methods			

It is the task of the wargame lead analyst to be aware of these instances and highlight possible bias when they see it. In addition to the specific mitigation options mentioned above, the installing of a devil's advocate, during the entire wargame process (design, execution, analysis, and reporting) is a generic method to continuously process and content of the wargame.

In an article called "The Three Witches of Wargaming" [17] Stephen Downes-Martin specifically addresses three possible sources of bias that frequently attempt to influence the design of the wargame, but also even during the game itself:

- The chain of command of the wargame lead analyst;
- The senior leaders of player cells, the cell 'leads;' and
- The wargame sponsor.

To Downes-Martin, these three represent classes of senior stakeholders that, given their experience, are not able to return to previous jobs: "It means that if they get their old jobs back as individual contributors they rarely perform as well as they did before they took leadership positions. …This is one reason why the military calls some very senior leaders "general officers" that is, "generalists" which is to say, "not expert specialists anymore". He then identified three risk factors: the perpetrators knew, or thought they knew, what the answer to the problem they were considering would turn out to be if they went to all the trouble of doing the work properly, were under career pressure; or were working in a field where individual experiments are not expected to be precisely reproducible.

Downes-Martin stresses that one must accept the possibility that all three factors characterize the stakeholders of any wargame that addresses important national-security issues and thus that these three classes of stakeholders will have to be prevented from interfering inappropriately with the game's design and thereby be protected from charges of manipulating its results.

He continues with, to him, three personal characteristics that a wargame lead analyst must have in order to pre-empt problems with these stakeholders:

1) A high degree of professional expertise (in wargame design, execution, and analysis);
2) The moral courage, integrity, poise, and charisma to face down inappropriate interference from seniors; and
3) The ability to perform an objectives analysis, applied to the specifics of wargaming.

The first two are required for various professions, one could state that if the latter is performed correctly as well, a solid base is constructed to support a wargame 'fit for purpose.'

3.9 POST-WARGAME ASSESSMENT OF VALIDITY

Up to now this paper has considered how to build validity into the wargame process (design, execution, and analysis). An important part of the wargame process is communicating the results to the customer. Part of the results should include an assessment of the validity of the game – in other words, was it really fit for its intended purpose, and are the results valid?

The world of simulation modelling has long-considered the concept of assessing validity. In this world it is common to refer to two main aspects of validity; internal and external validation, where internal validation examines individual components and checks for errors (was the model built right), and external validation assesses the model's fitness for purpose (did we build the right model). These concepts can be applied to assessing the validity of wargames, where internal validation will check the wargame components and

processes (e.g., the adjudication process, the scenario, resource, and player details, etc.), examines cause-and-effect, and asks the question 'was the wargame designed and executed right.' External validation will assess the wargame's fitness for purpose, examine the ability to relate to the real-world and ask, 'did we design the right wargame?' These concepts, along with a third pillar of philosophical validity, are discussed in the context of wargames by Bowden [18]. Philosophical validity considers accounting for all possible perspectives of the problem or solution.

3.9.1 After-Action Reviews and Surveys

There are different ways to retrieve input about the quality of the wargame after the event has taken place, and like any good method, the right one(s) should be chosen for the situation. One easy and common method is to create a quick survey of all the participants. Did they think the wargame was worthwhile? Are they confident in the results? If the wargame was to be run again, what would they change? These questions can also form part of the After-Action Review (AAR).

There are, however, a couple of things that are worth considering:

- Are the results counter-intuitive (differ from the accepted wisdom before the event)? Are the participants culturally homogeneous? If the results are counter-intuitive but supported by some very knowledgeable SMEs it might turn out that the prevailing wisdom has always been wrong but has remained because of fixed biases of certain senior officers (so there is a danger that there are other areas that might be wrong). If the participants are all the same type of people, their performance may well be distorted by Group Think. A way to overcome this, is by having a diverse set of Adjudicators/Analysts as they are more likely to spot this Group Think, than if they come from the same type of people as the participants.
- Be wary of situations where all the participants agree the wargame was good simply because they had an enjoyable experience or are happy that they got the result they expected or wanted – this does not automatically mean the result is valid and may be an indicator that the game played to their cognitive biases or pre-existing beliefs.

The results of the survey or AAR can be reported as evidence, along with the evidence found as part of the data and analysis. In the following paragraphs, two methods to assess and report the overall validity of a wargame are briefly explained. By using one (or more) of these methods to structure the data from the survey or AAR and assess the validity, also communication to the customer about validity increases in quality.

3.9.2 Dstl's Evidence Framework to Assess Wargames

Dstl's Evidence Framework was developed to assess evidence against fitness for purpose in relation to decision support methods. It has also been applied to quickly assess the validity of simulation models [19], and was further adapted to assess the validity of wargames. Their framework is a two-part assessment process, consisting of the Evidence Profile and the Validation Profile. The wargame design team and other relevant stakeholders (such as the players) rate the wargame from 1 – 4 (where 1 is the best quality evidence possible, and 4 is the little or low quality evidence) following discussion on key criteria, relevant to the original purpose of the game.

Firstly, the Evidence Profile looks at five elements:

- Comprehensiveness
  - The breadth and depth of the wargame
  - Are key aspects and uncertainties covered?

- Relevance
  - Are the assumptions relevant to the application of the wargame?
  - Do changing the assumptions significantly change the findings?
  - Are wargame perspectives informed by credible sources?
- Challenge
  - To what extent have the findings been subject to peer review and independent challenge?
- Quantity
  - Number and variety of methods or lines of enquiry considered or
  - Was this a 'best practice' approach with extensive track record?
- Veracity
  - Is the wargame situated within a broader evidence base or bigger picture?
  - Have alternative explanations been explored, can cause and effect be determined?

Secondly, the Validation Profile considers four additional elements:

- Face
  - Do the reviewers think the wargame is fit for purpose?
  - Are the findings and arguments plausible "on the face of it, do I believe them?"
- Criterion
  - Do the measures reflect the question to be answered?
  - Are the inputs and outputs appropriate to the question being studied?
- Construct
  - Are the key mechanisms of the game appropriate and representative?
- Content
  - Is it possible to bridge the gap from findings to insight?

Under each of the headings above, a statement is generated to describe the wargame, and then rated between 1 (weak statement) to 4 (strong statement).

By turning each of the qualitative statements into a quantitative measure, a figure can be created that can easily be put into the wargame report or customer briefing, such as Figure 3-2, which was presented by Dstl at Connections UK in 2019 [20]. Analysts should take care not to report purely the quantitative result and not the supporting evidence however, because the final number means nothing without the supporting rationale. The key is the discussion that is captured and used to provide an evidence based rule of thumb assessment for determining the validity of the proposition made concerning the wargame.

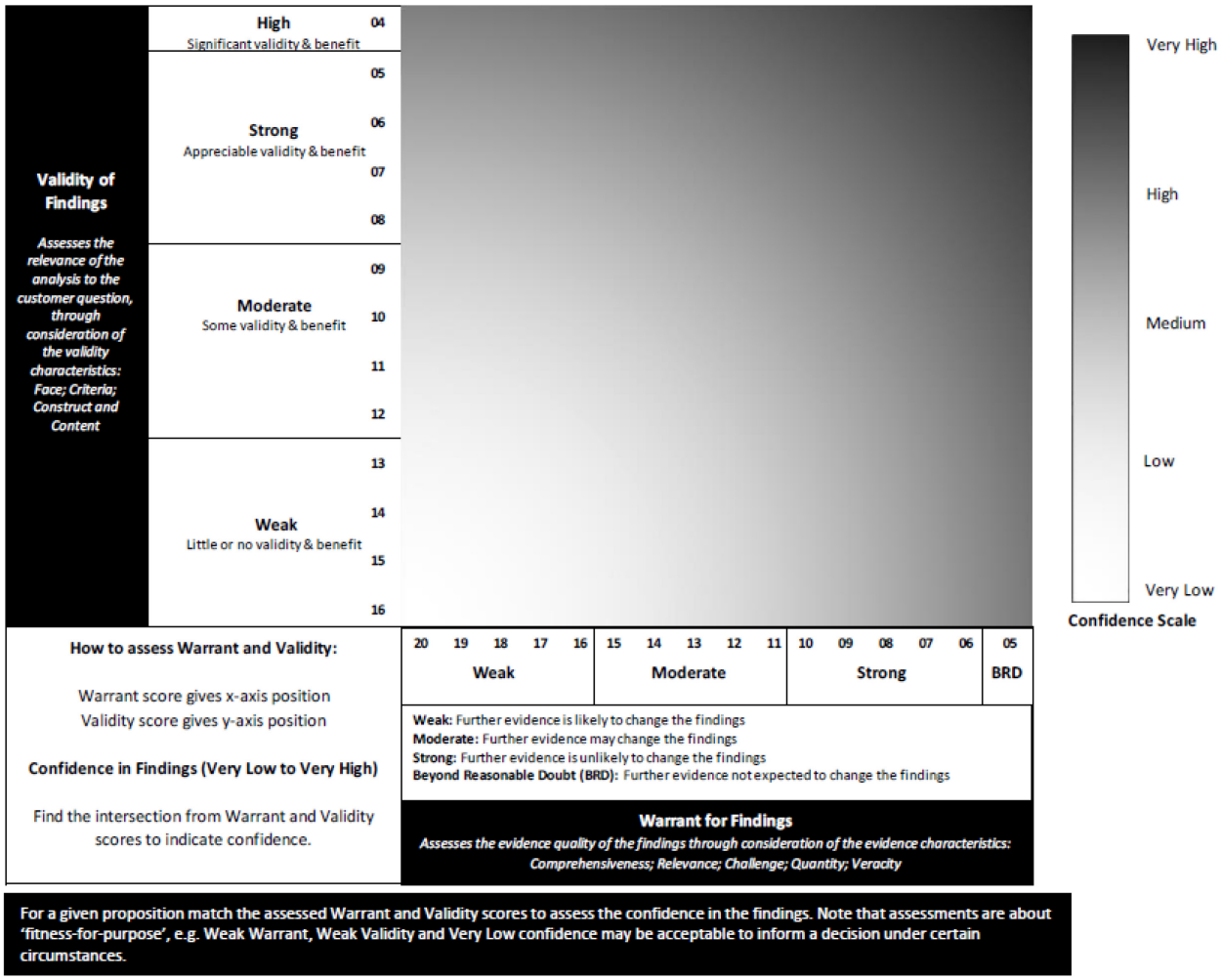


Figure 3-2: Confidence Assessment Table.

3.9.3 DSTO's Model to Assess Confidence

A model developed by Coutts [21] is an alternative to the Dstl Evidence Framework. The first column in Table 3-3 represents the three main areas of uncertainty of Situation (e.g., the decision variables being considered), Alternatives (e.g., different course of action) and Outcomes (e.g., the wargame outputs). These three main areas can be assessed using criteria such as the ability to represent (the situation, the alternatives, the outcomes), the level and quality of information uncovered about these three areas, and the ability to differentiate or assess the differences between the various alternatives and associated outcomes. Each cell in the table can be colored green, amber or red, depending on the level of confidence the design team have in the wargame (high, medium, or low confidence). This is a quick and easy way to show confidence in the wargame design and associated results that can be included in a report or presentation to the customer.

Table 3-3: Framework to Assess Confidence.

	Ability to Represent	Level and Quality of Information	Ability to Differentiate
Situation	The relative number of known factors of the situation able to be represented.	Relative number of input situational variables with a certainty of at least 90%.	N/A
Alternatives	The relative number of known factors representing alternatives able to be represented.	Relative number of input CoA variables with a certainty of at least 90%.	Level of insensitivity to small changes in model parameter values (sensitivity).
Outcomes	The level of model (operational validation) accuracy.	The quality of elicited conditional probability information (elicitation source confidence).	The maximum level of difference in utility between CoA.

3.10 CONCLUSION

Understanding the level of validity and the various ways it can be improved is important in analytical games, not only to increase the confidence in results but also to create stronger evidence for important decision making. Lessons from scientific experiments and validation of simulation models can be applied to wargames in order to improve validity. Validity starts immediately in the wargame design phase through the creation of wargame objectives, hypothesis statements, controlling for factors, looking out for and acknowledging bias, and detailed analysis planning. It continues through execution when any decisions to change the wargame design on the fly must be assessed for any impact on the validity of the game. After the wargame, the analyst should make an assessment of the game's validity, and therefore how confident anyone can be in the results.

This level of confidence should be communicated to the customer or sponsor of the wargame. As with any analysis technique, the analyst and game designer must choose the right method appropriate for the situation; more important decisions might need more careful thought about how to ensure validity. The fundamental measure of wargame validity is that a wargame must be fit for purpose, so common sense should be applied regarding the amount of effort and resources that is applied to ensure validity. An extremely detailed wargame does not automatically equate to a valid wargame, as less detail and more abstraction is sometimes better.

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Part II – ARTIFICIAL INTELLIGENCE AND AUTOMATION

II.1 ARTIFICIAL INTELLIGENCE AND AUTOMATION

Commercial developers have been using advances in Artificial Intelligence (AI) and automation to develop games for entertainment and education for some time. The papers in this part of the report contribute to clarifying the opportunities and challenges associated with applying advances in AI and automation to innovation in analytical wargaming.

SAS-139 RTG members found widespread interest in the advanced tools used by commercial game developers among analytical wargame consumers and producers. Team members reported that the up-tick in online gaming has prompted many senior military leaders to encourage them to apply commercial approaches in analytical wargaming. However, they found an equally widespread gap in knowledge about these technologies, the implications of using them in analytical wargaming decision environments, and practical applications. Given sufficient scale, the team found that while automating data entry, decision aids for players and adjudicators, and analytic procedures may cost effectively improve military planning, decision making, and the rigor of wargaming findings, the benefits of investing in artificial intelligence at this time are less clear.

Concretely, AI can be defined as machine intelligence capable of cognitive skills such as pattern recognition, understanding natural language and images, learning from experience, reasoning, and strategizing. In her paper in Chapter 4, DeRosa draws a distinction between automation and autonomy. Automation focuses on automatically controlling operating processes and has an impressive track record for routine processes, whereas autonomy, which is required for the types of independent machine operations associated with AI, has a less impressive track record despite many years of research and development.

SAS-139 RTG members surveyed a wide range of tools to identify advances that could support innovation in analytical wargaming processes. Some of these tools, such as AFSIM, GameNet, J-Core, JAWT, and SWIFT, are wargaming platforms that allow users to automate many aspects of data capture, analysis, and adjudication. Tools employing virtual and augmented reality such as Tactical Sandbox, Microsoft HoloLens or CMRE's undersea lab for testing algorithms demonstrate the potential to create virtual environments for wargame play. And as Ruestchmann describes in his paper in Chapter 5, other tools that exploit developments in AI, such as tree-based models, Natural Language Processing (NLP), and pattern recognition could be used by players, adjudicators, and wargame analysts to support decision analysis and identifying points of friction in wargames.

De Spiegeleire, Sweijs, and Maas recently surveyed the state-of-the-art in the many approaches and disciplines in AI and machine learning that are associated with making machines intelligent and applying these advances to future force development [1]. Looking at trends in China, Israel, Russia, and the U.S., they identify research and development efforts in machine learning-based visual recognition, voice recognition, human-machine interaction, and high-performance computing. Applied research in these countries includes target recognition, in-flight missile guidance, intelligent unmanned systems including weaponry, failure prediction, simulating complex Joint force battlefield operations, and developing robotic forces for border control.

While generally enthusiastic about the potential for AI in the medium and long term, De Spiegeleire, et al. caution that much work remains to emulate let alone effectively augment human intelligence in complex decision environments like warfighting or analytical wargaming. Success stories in AI and automation tend to focus on applications that involve rapidly digesting text, calculating values, and emulating simple tasks and processes. However, as Serre observes in his survey of artificial vision research, scientists have

encountered critical limitations in creating machines that can effectively emulate or augment human capabilities [2]. One very critical limitation for strategic interaction is that artificial neural networks can be fooled by minute manipulations that are barely visible to a human eye. In her paper in Chapter 4, DeRosa discusses some of the challenges associated with applying AI and automation to complex, adaptive, multi-domain operating processes, and identifies a need for assessment and further research focusing on human factors. In his paper in Chapter 5, Ruestchmann highlights the potential paradox associated with employing AI and automation in wargames specifically designed to analyze player decisions, e.g., if games tools are making decisions for players how shall we account for the validity and reliability of outcomes? Is an AI-augmented wargaming experience relevant for improving military planning and decision making? He also calls attention to the need to understand the logic of how inferences are generated in wargames, and in particular, "sense-think-act" processes in order to control for bias and ensure plausibility.

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Chapter 4 – A PERSPECTIVE ON AUTOMATION AND AUTONOMY FOR ANALYTICAL WARGAMING

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4.1 TOOLS AND TECHNOLOGY IN ANALYTICAL WARGAMES

Wargames are a "warfare model or simulation whose operation does not involve the activities of actual military forces, and whose sequence of events affects and is, in turn, affected by the decisions made by players representing the opposing sides" [1]. This definition highlights three key elements of a wargame, namely the presence of players, the adversarial nature, and the centrality of the decision-making processes.

There are many research initiatives investigating improvements to analytical wargaming design, execution, and exploitation. Automation and Autonomy (A&A) represent capabilities that might provide interesting opportunities and might significantly support analytical wargames, for example in the case of not co-located players (i.e., distributed wargames) or non-playing characters.

Tools and technology are used in analytical wargaming as a means to facilitate, collect, analyze and display relevant aspects of human decision-making processes. An in-depth analysis investigating wargaming for the U.S. Marine Corps, classified the current tools used in support to the development and execution of wargames as [2]:

- **Decision tools:** tools "capable of moving, displaying, synthesizing, and manipulating information so that the anatomy of a decision can be understood and an autopsy of the results can be assessed."
- **Scenario tools:** tools "capable of representing the effects of the decisions and events by evolving to accommodate the consequences and depicting the resultant situation."
- **Adjudication tools:** tools "capable of in-stride resolution of conflict and the management of results."
- **Synthesis tools:** tools "which facilitate visualization and collaboration by allowing inputs from different sources to be merged, displayed, and manipulated."

Moreover, the same study categorizes the software-based tools in Commercial Off-The-Shelf (COTS), program of record (i.e., a program founded through multi-year defence programs), government off-the-shelf and custom-built.

At national level, some interesting examples of wargaming platforms are present. For example, the United States have developed the Standard Wargaming Integration and Facilitation Tools (SWIFT). Australia, instead, has developed the Joint Analytical Wargaming Tool (JAWT). These tools have proven to be useful to support gaming at different levels (i.e., strategic, tactical and operational) and with different objectives. Moreover, they appear to be more useful and adaptable to experimentation requirements than more complicated program of record models and simulations [2].

Modern technologies are providing increased capabilities to analytical wargames at constantly lower costs. However, organizations still resort to manual games or computer supported games regardless of the level of resources available. In fact, these have several advantages that include cost, flexibility, adaptability, adjudication transparency, large libraries of game mechanics and ease of use when dealing with classified topics [2].

While automation and autonomy might provide relevant support in the advancement of analytical wargaming practice, their adoption should be carefully assessed. In some scientific domains, such as human factors and cognitive engineering, the importance of the understanding of their impact beyond the technological component has been stressed and awareness is rising. In fact, introducing automation and autonomy in analytical wargames will intrinsically change the game environment and might impact the way humans (e.g., player) interacts with them.

4.2 AUTOMATION AND AUTONOMY

Often the terms automation and autonomy are used interchangeably. However, they imply substantial technical differences. While the reader is referred to the abundant literature on the topic, here we summarize basic aspects to clarify such concepts:

- **Automation:** "technique[s], methods[s] or system[s] of operating or controlling a process by… automatic means, as by electronic devices, reducing human intervention to a minimum" [3];
- **Autonomy:** the ability of machines (hardware and software) to perform independently under significant uncertain conditions for extended periods without external intervention [4]. Autonomous systems are able to operate with limited or non-existent communication and present the ability to compensate for system failures.

4.2.1 Levels of Automation

Full autonomy has not been achieved and never will be in analytical wargaming, as it requires a human-in-the-loop by definition. One key element concept when discussing automation is known as Level Of Automation (LOA). No unique definition or taxonomy of LOA has been proposed (i.e., Ref. [5]). Some refer to the decision-making cycle steps, the roles within the decision cycle [6], the type of system output (i.e., notification, suggestion or action) [7] or the information processing steps (i.e., sensory processing, perception/working memory, decision making and response selection) [5].

Following this last perspective, LOA can be defined along the dimensions of information acquisition automation, information analysis automation, decision automation and action automation. As shown in Figure 4-1, a generic system can be characterized by different levels of automation along the four dimensions. For example, System A (full line) exhibit high LOA for information acquisition and information analysis, while presents low LOA for decision and action. System B (dotted line), instead, has a low LOA along all the four dimensions. The interesting factor of such a model is the identification of dimensions along which LOA can be expressed. The LOA is not explicitly defined as a combination of levels along these dimensions. In fact, no specific scale of LOA is proposed. The reasons behind this choice are to be found in the difficulty to map each specific technology in a specific level and to clearly define the benefits and limits of each LOA. Nevertheless, they are useful to guide the discussions around specific aspects of automation design [8], [9].

4.2.2 Design and A&A

Often design choices related to the adoption of A&A are merely technology oriented, such as technical feasibility. The human-system integration perspective is often overlooked. However, the design consideration should look at the full spectrum of the impact of A&A introduction, including factors related to the human component (e.g., players, facilitators, and adjudicators) [10]. In fact, several studies underline the correlation of A&A with trade-offs in human performances, workload, and situational awareness (i.e., Ref. [11]).

Issues that have been widely discussed in human factors engineering include out-of-the-loop performance, brittleness, trust, vigilance and complacency [12] Out-of-the-loop performance can be understood as the issues of resuming manual control when needed [13], while brittleness as the difficulty of realizing the malfunctioning of A&A and the reasons for it [14].

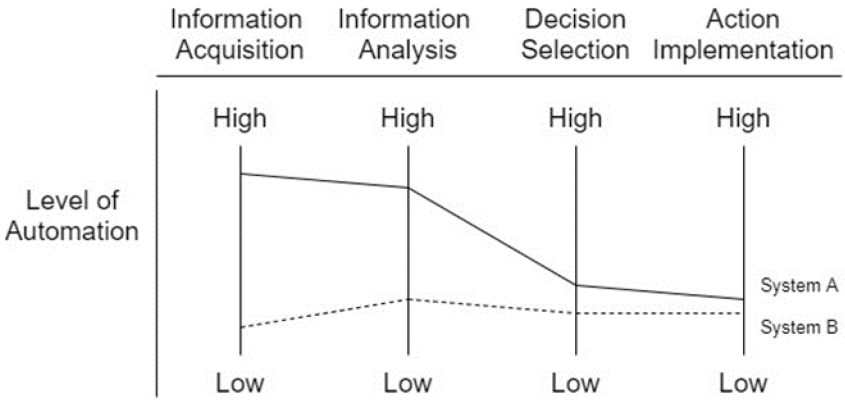

Figure 4-1: Systems with Different Levels of Automation Along the Four Automation Dimensions (Adapted from Ref. [5]).

4.3 A PARADIGM SHIFT: ASSESSING A&A FOR ANALYTICAL WARGAME DESIGN

The use of new technologies and approaches in analytical wargaming should be carefully researched and understood in order to ensure the needed scientific rigor in the use of analytical wargames. In fact, the introduction of A&A might impact the decision-making process under analysis.

Many of the considerations regarding A&A in games are generally related to the game platform, therefore, attain to the wargaming cycle phases that deal with design, execution and data collection. However, the full cycle could benefit from the introduction of A&A in different phases. Figure 4-2 presents the wargaming process defined by the NATO SAS-139 RTG. The actors involved in this process, can be categorized as:

- Player;
- Designer;
- Facilitator;
- Data collector;
- Adjudicator;
- Observer;
- Stakeholder-sponsor-client; and
- Analyst.

The first five actors can be denoted as wargaming ecosystem internal actors, while the remaining ones as the external actors. Internal actors have a direct role in the wargaming process as opposed to external actors, who have an indirect role. For example, analysts might support the designer expressing needs regarding the data to be collected. Similarly, we can identify phases that refer directly to the creation, deployment and use of the ecosystem, namely:

- Hypotheses-Questions;
- Design-Develop;
- Data collection, analytical plan, SOPS; and
- Execute.

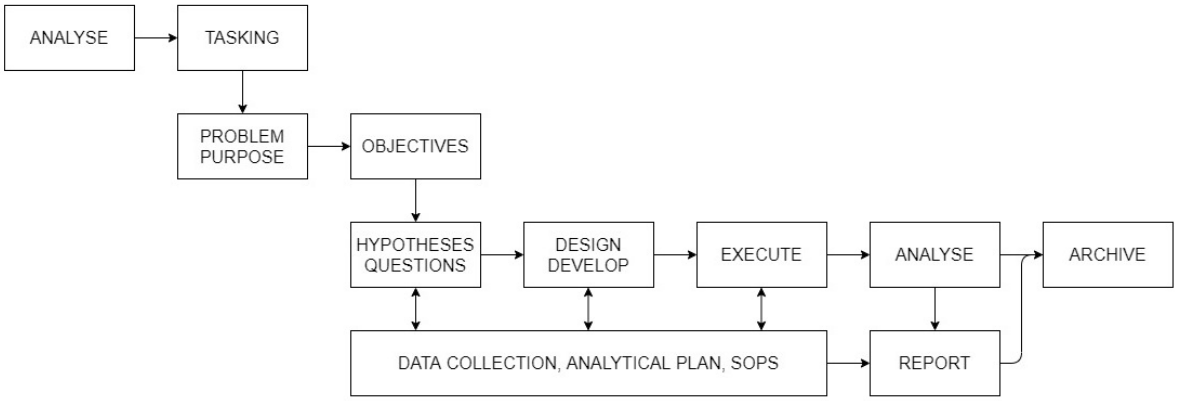

Figure 4-2: Analytical Wargaming Process.

These phases will be denoted as core wargaming ecosystem phases. These phases will involve mainly the internal actors and the observers. All these actors in different phases could be supported by A&A. In general, automation applies to all actors in all phases, while current autonomy capabilities have a reduced applicability. Specifically, they mainly focus on the design, execute and data collection phases, for example supporting scenario generation or acting as non-player character (e.g., troops). However, future advances in the field of artificial intelligence and machine learning, which are enabling capabilities of autonomy, might allow to expand the use of such technologies (see Chapter 5).

When planning for the use of A&A a specific assessment should be performed for a given technology or tool. This assessment should take into consideration the tasks that will be involved and the actors supported.

For example, Table 4-1 shows the potential application of visual analytics, visualization, and interactive visualization to support the actors in different phases. In the interest of brevity, the phases not involved are omitted in this actor-phase matrix.

Table 4-1: Assessment of the Potential Adoption of Visual Analytics (VA), Visualization (Vis) and Interactive Visualization (IVis) in Analytical Wargames.

Actor Supported	Analytical Wargame Process Phases						
	Tasking	Design-Develop	Execute	Data Collection	Analyze	Report	Archive
Designer	-	IVis	-	-	-	-	IVis
Adjudicator	-	-	Vis	-	-	-	-
Facilitation	-	-	Vis	-	-	-	-
Player	-	-	Vis , IVis	-	-	-	-
Analyst	-	IVis	Vis , VA, IVis	-	VA	-	-
Customer and Sponsor	Vis	-	-	-	-	Vis, IVis	-
Observer	-	-	IVis	-	VA	-	-
Data collector	-	-	Vis	Vis	Vis	-	-

When assessing what functions of the core ecosystem phases should involve A&A, an evaluation framework should be applied in the early stage of the design phase, in order to ensure a correct assessment of the potential implications and the impact on the actors involved. In the context of analytical wargaming, we could apply the assessment framework proposed in Ref. [10].

This work presents an A&A adoption assessment framework, based on the work proposed in Ref. [5]. This framework includes a first assessment phase, which aims at defining if A&A should be introduced or not. The fundamental criteria for the first assessment phase are the need for A&A, the feasibility of its adoption and the cost of a potential A&A failure. The assessment should then proceed with the evaluation of the type of A&A on the basis of an actor-activity matrix (e.g., Table 4-1). Finally, a second set of assessment criteria would guide the assessment of the impact on the design (from a designer perspective), the impact on the execution (both from a facilitators, adjudicator, and player perspective) and the impact on data collection. These criteria should consider performance, information presentation, monitoring and vigilance, trust, and engagement.

An analysis on how the different factors identified in human factors engineering might impact the development and deployment of an analytical wargaming is reported in Ref. [10]. Further research is expected to focus on the different factors highlighted in order to characterize the problem with respect to wargaming.

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Chapter 5 – APPLYING AI AND AUTOMATION TO WARGAMING: AN OVERVIEW OF OPPORTUNITIES WITH A FOCUS ON INTELLIGENT COMPONENTS

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5.1 INTRODUCTION

This chapter offers the perspective of a game designer and game facilitator in order to find out where Artificial Intelligence (AI) capabilities may usefully be applied in the wargaming analytical process.

Looking at the gaming industry, a source of constant innovation for obvious business reasons, we can observe that AI is used with the prospect of a better game experience, such as "thinking" opponents in order to limit the game design budget [1].

In the professional wargaming field (vs. entertainment gaming), AI may be inserted into the various phases: designing game components and scenarios, capturing data during a session, providing automated opponents and allies, helping to adjudicate in-game tasks. We will discuss how AI is already used or may be an asset in designing and running manual wargames.

Stuart Russell and Peter Norvig [2] define AI as "the designing and building of intelligent agents that receive percepts from the environment and take actions that affect that environment." From a gaming perspective, this definition encompasses many tasks a player do during a game session: learning, inferring decisions based on partial data, planning, designing, and testing courses of actions, etc.

An innovative milestone, such as the *StarCraft 2* with DeepMind capable of besting 99.8 percent of human players in competition [3], gives us a learning case embracing multiple AI techniques within a complex environment involving intelligent agents.

Another test of integration of AI comes with RAND [4]. It gives us a return of experience regarding how AI and autonomous systems impact a strategic wargame about deterrence and escalation. Policy researcher Yuna Hu Wong used a wargame of a future conflict involving the US, China, Japan, South and North Korea where autonomous systems participle to nation-against-nation conflict. One of the lessons learnt states that "past cases of inadvertent engagement of friendly or civilian targets by autonomous systems may offer insights about the technical accidents or failures involving more-advanced systems." The use of AI can extend insights on the game play for both players and game designers.

We first take an overview of the wargaming process and will further focus on a simplified cycle of decision where intelligent agents could prove efficient.

5.2 OVERVIEW OF THE WARGAMING ANALYTICAL PROCESS AND INTEGRATION OF AI

Considering the process used by the SAS-139 Analytical Wargaming program and reproduced below, we followed a twofold approach to consider integrating AI in the various phases:

- What already available AI techniques would prove useful into the wargaming process (techno-centric approach)?
- What would a designer or a player need if we were able to integrate some kind of autonomous system or to give autonomy to game components?

Those two questions lead to an oscillation between a top-down (business needs first) and a bottom-up (technology first) views of AI applied to wargaming.

Answering the first question above (techno-centric), AI apply mostly to the colored phases in Figure 5-1.

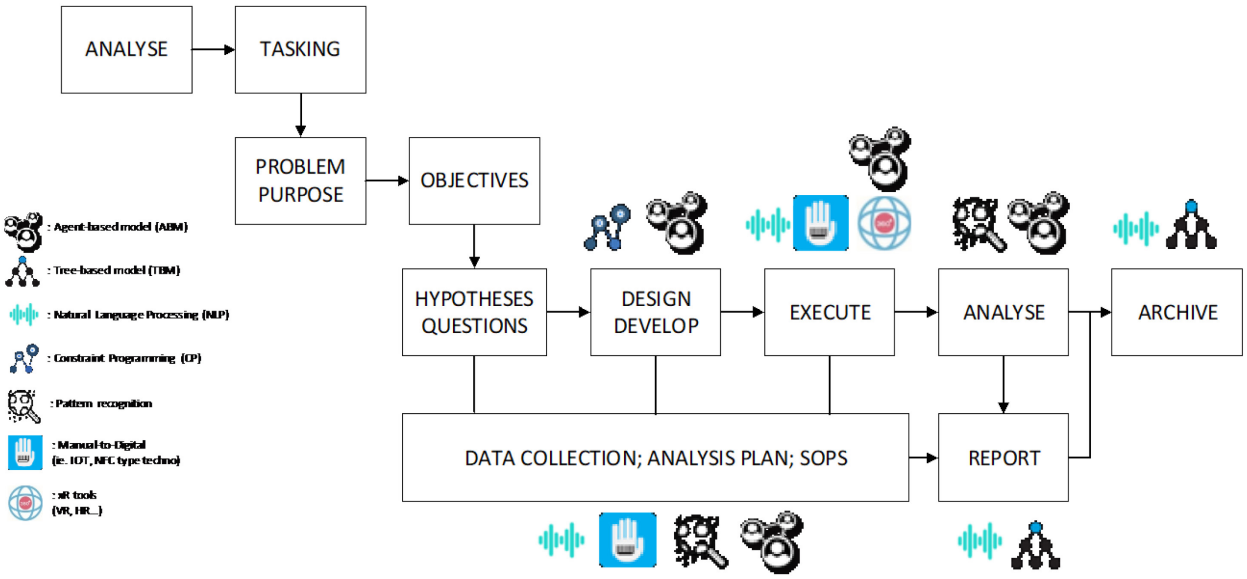

Figure 5-1: Wargame Analytical Process and AI Capabilities.

We chose to arbitrarily regroup AI technologies, each with its own icon, for a quick overview:

- ***Tree-based models***: those models embrace well mastered techniques leading to build decision support tools (tree-based). Those algorithms are used for generic decision by autonomous in-game "unit" (friendly or enemy). They implement plausible behavior for simple-tasked units, encoding a unit behavior via traditional "if/else/then" blocks. Those trees can be improved by designing them from a set of observations coded in previous similar game sessions.
- ***Natural Language Processing (NLP)***: NLP is already widely used in many professions and for the general public. Surprisingly, it is making its way to the wargaming field more recently for two main uses: as a leaning assistant to teach how a game is played ("Say, Alexa, how can I resolve …?"), as a capture tool for post-game processing in the Analyze Phase.
- ***Pattern Recognition***: those technologies include capture of image or video as raw data in order to be processed and be transmitted to agent-based system (see Section 5.3). Capturing movements of players between them (or the factions they represent) leads to portray communication behaviors as the game scenario progresses.
- ***Agent-based models***: they are ostensibly the closest approximation of a real opponent (red team) or "aide de camp" (for a blue team). More a modelling technique that is enabled by AI techniques, Agent-based models appear to be good candidates in most of the phases described in Figure 5-1. Opportunities behind those models are developer further in this article.

Finally, a couple of *AI enablers*, may be considered [5]:

- ***Manual-to-Digital Assistance***, typically with the potential of Internet of Things (IOT), connected objects. There are already some hobby games that take advantage of the connected objects capabilities in order to improve the tracking of in-game objects (a simple mean to record game data) or giving them some sensor abilities to their surroundings. In manual games, a simple counter with a Near-Field Communication (NFC) chip fulfills this goal.
- ***xR tools****:* they include all reality or virtual reality enhancement tools, worn by the players themselves (helmet, gloves etc.) or through a more natural but elaborate gaming environment with touch panels and holograms. For example, Airbus Defense and Space publishes a Tactical Sandbox (Figure 5-2) to view 3D maps of battlefield locations for mission planning or training exercises. Still a quite cumbersome system, French military officers wear head-mounted displays and use gesture to manipulate the maps and objects. Network capabilities allows outside players to participate with a digital presence. This technical environment mimics a well-known natural one that officers are used to in the field. The technology acceptability is improving. Microsoft HoloLens, already in its second generation, is pushing the commercial technology forward into the military world (Nov 2019, $473 M contract with the US Army).
- **Intelligent data consolidation and archiving tool**: in the wargame analytical process (Figure 5-1), the final step is the archiving process. This task is critical in order to be able to gain from the experience of previous sessions and act as a knowledge database for future games. Consolidation of the data for any AAR (After Action Review) is mandatory before the archiving step. Expect AI sorting techniques to do, at least partially, the job of sorting critical observations on the course of actions taken by the players such as modification of orders given to units or other raw data (casualties, elongation of operations, etc.)

Figure 5-2: Airbus Defense and Space Tactical Sandbox.

5.3 THE "SENSE-THINK-ACT" CYCLE

In a decision thinking process, which is basically the core of a game session from the players perspective, the seven-step usual approach is: identify the problem, collect information, identify the alternatives, weigh the evidence, choose from the alternatives, implement the action and evaluate the results.

Actual game sessions tend to compress this process to a simple three-step cycle: Sense, Think, Act. We will use this cycle as an overlay to the Execute phase of the wargaming design-and-run process, as a framework to pinpoint where AI techniques could be used effectively.

The Sense-Think-Act cycle refers to observation of the player's environment, making a decision based on those observations, then acting upon them:

- *Sense*: the player detects, or comes to learn about data within the game environment that may influence his/her behavior (e.g., external events to assess, threatening units to block etc.).
- *Think*: the player makes a decision about what to do in response.
- *Act*: the player selects then performs actions to implement the effects of the previous decision.

Now the game situation has changed and the cycle must repeat itself with new data.

Where AI can help be used in the Execute phase the automation of those 3 steps? The short answer would be that intelligent agents can be successfully integrated into this cycle.

This decision cycle tends to make us reflect on what an advanced decision-making process would be with the aid of AI. The element of surprise or apparent advanced thinking is what the players are looking for when confronted to an autonomous unmanned opponent or ally. An efficient AI answer lies in the state transition method, a sound approach and a comprehensive one notably for the designers in order to examine game results. As any state can legally follow any other state, it renders them implicit.

This decision cycle mainly supports either the "opponent" (rational or semi-ration intelligent being) or "aide de camp" (AI acts as the intelligent filter for information for a human decision maker, asking appropriate questions, identifies things the decision maker may be interested) component of a wargame. The following section develops those approaches.

Transitions between states (i.e., behaviors) are the essence of a doctrine at strategic level or rules of engagement at tactical level. They describe how units are supposed to react within a given context or, at least, infer a behavior based on similar contexts. Again, observations of previous wargames help highlight those states as some cannot be obvious to the players, especially if they are not familiar with the behavior of the actors of the game scenario.

The transition state methodology is particularly well suited to the Sense-Think-Act for it displays its "causality thinking." Players can understand how a game unit (or any abstraction used by the game scenario) proceed for a simple reasoning. Many AI techniques are available to the game designers. Most are well-known and already widely used in the video game industry.

5.4 INTELLIGENT COMPONENTS FOR WARGAMES

Versatile intelligent agents, or distributed AI or agent-based systems, all belong to AI techniques which are a significant upgrade to the in-game components that players expect to behave with some kind of autonomy.

Intelligent agents direct their actions towards achieving goals that may have been assigned by the game designer initially or by themselves during the game session. Their goal-directed behavior gives them a sense of autonomy from the player's perspective.

Typically, a unit, such as an armed force, should act according to a set of patterns that give this "feeling" of autonomy. Feeling is inherently biased but we have to remember that wargames sessions are trying hard to be strong in regards to the plausibility of the model exposed to the players.

5.4.1 Opponent and Aide de Camp

Intelligent agents come in a variety of types, they can be as simple as a reflex machine, a more intuitive goal-or-utility-based agents or learning agents. We focus on the utility-based agents with their appropriate capabilities to function where there are many different actions available with a simple centralized transition rules system. Utility is a measure of how important the action is to the agent regarding both the context it is able to observe and its state (e.g., in a public order scenario, how a population "unit" should react to a repressive action).

Applied to an automated opponent, the typical use case is widely known in the hobby game industry. We refer again to the *Starcraft 2* example which emphasizes the capacities to implement de Sens-Think-Act process to a high level of expertise. All wargame sessions do not need this kind of high level "thinking" for an AI and players can be content with rational opponent-agents. Those agents choose one action to execute based on its relative utility. A scoring system help evaluate the utility of each action along with a certain amount of randomness in order to "surprise" the players. Initially, this is the job of the game or scenario designers to weight the actions, an arbitrary human task.

To support the wargame analytical process, intelligent agents may be encountered as in-game virtual participants and automated assistants to the game designer or facilitator. Some examples of what could be useful – and sometimes already done – are given below:

- ***Acting as in-game autonomous units:*** abstractions of entities such as non-regular organizations, population of refugees, political bodies, communication network, etc. Depending on the level of play, computer algorithms take care of intricate parameters which tend to cloud the player's decisions during a game (e.g., environmental specificities).
- ***Acting as assistants to the players*** (the aide de camp AI): at operational or strategic level, the players choose the overall course of actions that the semi-autonomous units under their command implement based on the utility-system. The implementation can be used to choose a path in order to go from A to B on a map for logistic duties, attack a position with an assortment of units, evaluate the probabilities of success negotiate a position within an international assembly, etc. Another benefit in the execution of the game is to use teaching assistant, learning how to play as the game progresses (e.g., asking how to resolve an action).
- ***Acting as assistants to the designers***: looking to test game mechanisms, AI may be assisting the designers in their design processes before the game is tested with human players. Depending on the game engine and specifications process of the model, designers could also use a Scenario Generator based, for example, on a set of parameters such as: theatre of operation (possibly generating terrain), battle order and duration of scenario. Such a generator is typically an asset for putting up a set of small training scenarios for testing a few aspects of the game, possibly without external adjudication, and learning exercises in order to train key mechanisms.

We may argue that it is somewhat paradoxical to use AI in order to alleviate players, designers and analysts, as a fundamental aspect of wargaming is to provide humans with the opportunity to make decisions and experience the consequences of their decisions. This is why players need to understand how analysis are made by AI in order to limit potential bias that the automated analysis may lead to.

5.4.2 Recording Data to Build Agent-Based System

Similar to archiving issues, capturing data is a matter of format and storage in order to be able to retrieve and feed them to our AI algorithms.

Possibly the main difficulty when running a session is, first, to decide what set of data is most relevant to further processing then finding a way to capture them with confidence in their value (structured data being much simpler to capture). They come in many forms and simultaneously. One simple solution, usually

implemented in medium-large sized sessions, is to have a dedicated team of human observers. But an agent-based system would need to have access to a minimal set of information regarding their environment in order to move from one state to another one. A process of data collection followed by the extraction of main features would lead to a model that can be used by the AI, corrected by the human game designer.

Data capture will not need to be continuous and may be done only for key events during the game such as end of turns (if there are any) or when key achievement arises, which means accepting losing some information along this process. Captures come from human observations, photos, or videos (board, online movements, possibly participants' behaviors) and sounds.

Data are needed for unsupervised learning by association and observations on how the game develops. Most of the wargame sessions are run from a model-based approach, which is created from the game designer's mind.

Supervised learning leads to prediction by imitation, what Georgios N. Yannakakis and Julian Togelius called "*estimated experience*" [6]. Their preferred method insists on leaning only from ordinal relations where there is consistency on the use of the scale by the players.

Model-free approaches are more ambitious to construct. Their foundations are solely built on the data captured (e.g., player state) in order to produce a model, unknown at the start of the process. There may be no clear initial assumptions of what the output model would looks like, although designers have some expectation of what the model is supposed to do because inputs to the model are defined beforehand. As such, the mapping from inputs to outputs could be unknown. The results also help the game designers for further supervised learning of agents. Figure 5-3 shows the overall process.

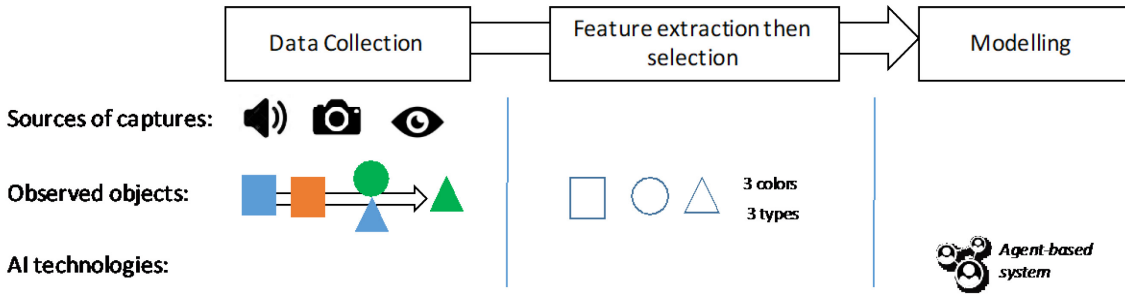

Figure 5-3: From Data Collection to Modelling.

The player state may include non-debatable inputs such as counters on a map or movement of units as well as qualitative – and debatable – inputs well like emotional/behavioral state (voice raised, lots of player's interaction, arguments, pauses etc.).

Behavioral data come from what the player does during the session. It means understanding the inner course of action taken by the players, how they play the game, how strategies are built (e.g., which parameters involved in the decision), how behavioral patterns can be identified. For example, without the aid of any automatic data capture device or AI algorithms, we ran sessions with sociologists acting as silent observers during the game and as part of the debriefing team along with the players. We were looking at behavioral data such as: face (eye movement especially) and body movement, patterns or flows of movements inside the room(s) between the tables (where teams were assigned), volume of speech etc. Cameras have already been used to capture some input from the behavior of players. Capturing a selection of physiological as well as bodily inputs are helpful for a learning agent. For example, cortisol levels may be monitored for stress conditions.

In a game environment where players are divided into factions or teams, movements of those players instruct the observer on the dynamics of the game. Recorded movements of the players between faction spaces

(a simple table, a room etc.) provide data that help to calculate how interactions work within the game model; a calculated output for predictions.

Nevertheless, the reality check shows that, more often than not, data has to be re-formatted before it can be automatically processed. It implies that the data capture and, later on, the archiving process have to be considered in wargaming design.

5.4.3 Feeding Fake Data

We need to record data but we can also use those data to tamper with "adversary" AI. Deception AI is one path that could be explored within a game session itself. Especially regarding intelligence, as in real life, pushing data that has been deliberately tampered with could help show the effects on the decision making of an AI-assisted opponent.

5.5 EMBEDDING AUTONOMOUS SYSTEMS INTO THE GAME DESIGN-AND-RUN PROCESS

Thanks to AI, game sessions involving autonomous systems improve both the designers' and players' experience. AI helps speed up the process of designing scenarios, thus gaining potentially more sessions played. Active autonomous systems within a game broaden the insights gained for playing the game. The players may train with reasonably plausible aides or opponents, being assisted during the game in their decisions as well as in the learning of the game itself. Mixing technologies and manual wargaming ease the insertion and immersion of new players. As an added benefit, these innovative approaches may also attract techno-savvy players or stakeholders who may help promote the wargame practice overall.

Regarding the AI as aide de camp, it is reasonable to design AI assistants that are capable of producing three possible courses of action (COA), presented as different options for the players to choose from. For example, players may choose between a COA that minimizes the stretching of logistical capabilities or a different COA that minimizes the impacts of a strike on the lines of communications. This aide de camp helps the players to design their own solution more quickly.

5.5.1 A Word About User Experience (UX) as a Design-for-Effect Priority

Most, if not all, business models put the customer – and not the product – in the center of the design, not the technology. The product itself is one answer to a specific business problem. In the serious game design world, we usually focus on a solid and comprehensive model for the crisis situation. We value the credibility of our model in the eyes of our sponsors. The player's experience may come second in the design priorities. Wargames designers should take advantage of UX as a design-for-effect priority and always consider that immersion of the player as well as ease of access to the game functions (giving orders, displaying the results etc.) should be an important design goal for the design team.

5.5.2 Including AI in Wargaming Increases the Need of New Skills in the Design Team

We can anticipate that the more complex agent-based systems are involved in the preparation and the execution of the game, the more the wargaming process needs a new profile to the team: the **AI interpreter**. This role is non-specific to the wargaming field as it may be applied to any field of expertise where a decision system is unmanned, or partially unmanned. In order to limit the "black box" effect, the players need to understand properly how the Sense-Think-Act process is working. It is a matter of plausibility for the game itself. It is during the run of a game session that a human-AI interpreter may shine. This new role in the design team could also join the animation team so that her or his task is to explain how the autonomous part of the game infer their course of actions.

Wargames can contribute to and illuminate the worst and best-case scenarios, help test and improve policy thinking. Their proven assistance in those fields is undisputed but they still take time to prepare, run and debrief. More wargaming sessions mean more opportunities to impact leaders and stakeholders. Thus, increasing the turnover of wargames run within a year is still an issue for many organizations. The use of artificial intelligence techniques within the design (preparation tools) and running process of a game (capturing data, assisting players, etc.) may contribute to how fast a game is prepared and, thus, can be run multiple times.

Given the various impacts of the COVID-19 on our capabilities to run wargaming sessions, intelligent-based systems may be an option to counterbalance the difficulty of gathering more players within the same location. Intelligent agents could act as a substitute or 'bots' completing player teams.

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Part III – COMPLEMENTARY RESEARCH METHODS

III.1 COMPLEMENTARY RESEARCH METHODS

In addition to applying advances in automation and autonomy, the SAS-139 research group looked at several research methods used in operations research and the decision sciences that could be used in conjunction with wargaming.

Operations research (or operational analysis as it is commonly known in the military) is a scientific discipline that uses mathematical and systems engineering techniques to explore operational efficiency. Operations researchers and analytical wargaming researchers share a common interest in producing rigorous findings that can improve military outcomes. The two disciplines require many of the same skills, including an understanding of the scientific method, and professionals in both disciplines use multiple methods to address a particular problem set. For example, in the U.S., the Military Operations Research Society (MORS) includes both operations research and wargame professionals. And many NATO countries use findings from campaign analyses and other forms of modelling and simulation to inform war game design and vice versa. In a background paper that informed SAS-139 research efforts, Jaime Bestard describes U.S. Air Force Research Laboratory efforts to integrate modelling and simulation products into wargame preparation, play, adjudication, and analysis [1].

Similarly in two other SAS-139 background papers, Polski argues that methods used in the decision and complexity sciences such as game theoretic analysis, agent-based modelling, and experimentation can be fruitfully employed to complement analytical wargaming [2], [3]. Her papers situate wargaming in a broader research context, and describe and compare methods based on rigor, research purpose, and objectives.

Other methodological opportunities that the SAS-139 team did not have time to explore include using policy analysis tools such as the Institutional Analysis and Development (IAD) framework as a guide in specifying war game design [2], [3].[1] Similarly, tools and methods from the computational and data sciences could be employed in wargaming, such as artificially intelligent analytics that can crawl through "big data", network analyses, multi-dimensional visualization tools, and data simulation methods [5][2]. For example, wargamers may find data mining and network analysis tools useful for analyzing war game data; Monte Carlo and graph theory could be useful for diagnostic problems; cellular automata and agent-based models could be employed in modelling data; and genetic algorithms and particle swarm optimization may be useful for synthesis.

The papers in this part examine a number of methods drawn from operations research and decision science that have been or could be used in conjunction with analytical wargaming. In Chapter 6, Pennell and Fridheim explore structured processes for scenario design and make parallels between scenarios and principles of scientific modelling. For problem definition they consider the application of NATO Alternative Analysis techniques or Multi-Criteria Decision Analysis (MCDA), and for scenario structuring they apply General Morphological Analysis. They also comment on the importance of scenario validation. In Chapter 7, Coutts, Williams, and Knoll discuss in detail the implied analysis tasks in wargaming and link more Operations Research methods such as Soft Systems Methodology (SSM), Strategic Options Development and Analysis (SODA), the Analytical Hierarchy Process and Causal Modelling. In Chapter 8, Sokri argues that game theoretic analysis can complement wargaming that addresses strategic level problem sets, and in Chapter 9, Caffrey reflects on some of the challenges associated with integrating modelling and simulation and wargaming methods.

[1] For background on the IAD framework see Ref. [4].

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Chapter 6 – THE DEVIL IS IN THE DETAIL: WHAT MAKES A GOOD SCENARIO FOR ANALYTICAL WARGAMING?

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6.1 INTRODUCTION

The scenario is one of the core elements of a wargame. The term scenario is often used broadly, but it can be useful to break it down and differentiate between the setting, the scenario, and vignettes [1]. In short, the setting is the designed geographic and strategic situation in which the game will take place, the scenario is the description of the specific situation or crisis the game will cover, and vignettes are discrete actions within or a subset of the scenario. Combined, the setting and the scenario (including vignettes) provide the immersive environment in which all game play takes place [2]. Here, we generally use the term scenario broadly to include setting and vignettes also, but we differentiate where necessary.

Following on these definitions, scenarios help raise relevant challenges in wargames and provide immersive environments where players can act constructively and work to achieve the game goals and objectives. In analytical wargames, where the results of the game inform decision-making, scenarios also help enable analysis results that are valid outside of the game. In practice, though, we often find that scenarios used in analytical wargaming are unsatisfactory for these purposes. We have written this chapter to discuss why this is the case and what we can do to avoid it.

Our approach is to firstly examine recurring issues in scenario development from the literature and from our own experiences. We then propose that considering aspects of a model-based approach to scenario development may help identify and overcome some of the issues. Lastly, we discuss how simple tools and broader appreciation of a systematic, model-based approach can help create scenarios that are relevant, credible and help provide valid analytical results.

The authors of the chapter have both civilian and military experiences in wargaming and scenario design, development and application gained within national, Alliance, academic and commercial contexts, although the views we express are personal rather than those of our institutions or of NATO. While we primarily discuss analytical wargames, much of the discussion on scenario design and development is also relevant for wargames used for training, education, or exploration. The discussion is also relevant for other uses of scenarios, not least scenario-based planning.

6.2 HOW SCENARIO DESIGN CAN GO WRONG

6.2.1 Effective Scenario Design?

The challenges of effective scenario design in wargaming (and in general) are not new. It is perhaps more surprising that research in the field remains limited. While most agree in general what a scenario is and what it is for, it is still much less clear how it should be reliably designed and developed.

Grunnan and Fridheim describe several issues that can arise during scenario design and development, based on a review of 12 conducted games and exercises [3]. Some of the identified issues were internal to the scenario team:

- The scenario design and development process was ad hoc and unstructured, if one was used at all.
- The scenario team did not interact much with the customers and stakeholders of the game.
- The team re-used old scenarios without tailoring them properly for the new game.
- The scenario team was too optimistic about the players' ability and time to prepare for the game and study read ins and large scenarios in advance.

Other issues were external to the team:

- The customer did not know why they wanted a game (i.e., unclear game goals and objectives).
- The customer had chosen a scenario (setting or situation) before deciding on the game goals.
- Different stakeholders pulled in different directions during scenario development.
- Stakeholders wanted too much detail in the scenario.

In sum, the identified issues not only made scenario design and development both far less efficient and far more time-consuming than it needed to be, but they also affected the scenarios negatively. In many cases, the resulting scenarios displayed many of the "scenario pathologies" described by Weuve [4]. These included scenarios with too much (or too little) detail, meaning players have access to unrealistic information, unrepresentative of the real-world actor they are supposed to portray, or irrelevant to game objectives. Scenarios containing overly specific information also focus attention on participant actions that may not be appropriate in the real world.

Weuve also identifies two problems related to time. Firstly, that a scenario may be too extensive, leaving players insufficient time to evaluate courses of action and make meaningful decisions. Alternatively (and even, in some scenarios, additionally) the scenario may be set out with too short a time horizon, meaning there is no ability to explore the cumulative results of player actions and interactions. Scenarios with these characteristics are unlikely to be fit-for-purpose for wargaming or useful for getting valid results to support decision-making afterwards.

6.2.2 Weak Design Processes and Creativity Run Wild

Writing a scenario can be a fun and creative task, and those involved want to help produce the best possible scenario. This is true whether the scenario is made new from the ground up, adapted from existing scenarios or inspired by historical situations and real-world parallels. So why is the result sometimes scenarios that not only impact negatively on, but in some cases even sabotage the purpose of a wargame? Based on our own experiences, we would highlight the following issues.

The scenario is designed and developed without due consideration of the goals and objectives of the game. This is one of the key findings in Grunnan and Fridheim [3]. There are many reasons why this happens, not least the issues in the bullet lists in Section 6.2.1 above. The study found that surprisingly often, the goals and objectives of a wargame are unclear, ambiguous, or contrary to one another, due to weak initial problem structuring or stakeholder involvement.

Related to scenarios, another common issue is the scenario team working in its own bubble, without sufficient interaction with the game designers, the analysis team, or wider stakeholders. Writing the scenario takes a life of its own, separate from the other game design activities, without addressing the game goals and objectives.

The scenario is designed and developed without a structured process. In many cases, we see scenarios made by what we would describe as "creativity run wild." Subject matter experts come to a meeting room to brainstorm ideas, toss possible story elements around and suggest which challenges, vignettes or injects to

include in the game, without any apparent structure. There are few (if any) attempts made to break down the game goals and objectives and link these directly to parts of the scenario. This may happen when scenario is seen purely as story writing. Of course, scenarios tell stories about the situation that the game should cover. However, there is a danger that the creative fun of writing an exciting story takes a life of its own. The result is a "narrative drift," where story elements are added to the scenario and where old scenarios are re-used whether they are relevant for the game or not.

Thus, we get scenarios that collect all the fads of the day and current issues weighing on the scenario developer's mind. We also get scenarios that can be just as complex as the real problems they are intended to give insight into, without simplifying matters for the players. Whether these scenarios match the game goals and objectives is often a matter of chance. Additionally, weak scenario design processes are vulnerable to confirmation bias among the designers, where the resulting scenario ends up reinforcing existing beliefs rather than challenging them. There is also a danger that the scenario is intentionally designed to influence decisions and provide specific outcomes, by tweaking story elements and conditions in the scenario in certain directions.

Even if a structured process is used during scenario design, it may be one that is ill-suited for the game. Scenario design can take many shapes and sizes. Van Notten [5] identifies two principally different macro-level approaches to scenario design: analytical or intuitive. Analytical approaches to building scenarios are often rigorous and systematic, often quantitative and include the use of model-based techniques and desk research. Intuitive approaches are freer, but not necessarily unstructured. They use qualitative knowledge and insights as sources from which scenarios are developed, often using creative techniques in a workshop setting.

Van Notten does not say that one approach is superior to the other, but he argues they have different primary uses: Intuitive designs are common in support of exploratory exercises, while analytical designs are common for pre-policy-making research exercises in support of decision-making. Seen in the context of wargaming, Van Notten's proposal boils down to suggesting that if wargames are to provide analytical results in support of decision-making, purely intuitive scenario design may not result in appropriate level of detail or highlight the most relevant issues. If the game is to enable creative exploration of possible futures, an analytical scenario design process may be too limiting.

Looking at analytical wargames in particular, choice and design of scenarios will directly influence on the validity of the analysis results. If the scenario design process is suboptimal or wrong for the given problem, the game results may be less valid simply because the scenario promotes irrelevant discussions and decisions.

6.2.3 Summary

Different approaches to and choices made during scenario design and development determine whether a scenario is fit for the purpose of a wargame. We argue that the chance for success increases if development follows well-suited scenario design approaches, based on a clear understanding of the goals and objectives of the game.

In the rest of the chapter, we look at ways to make this happen, by considering how the discipline of scientific modelling may assist. We also look at different tools to support the analytical design process.

6.3 SCENARIOS AS MODELS

Van Notten's taxonomy of intuitive and analytic design approaches [5] echoes the idea that scenarios can be seen as both narrative (intuitive) and model (analytic). A model is a representation of a system (or situation) intended to allow practitioners to learn something about the system or about interactions with it. In the extreme case, a mathematical or engineering model would be the product of a purely quantitative analytic

design process as described by Van Notten. However, we believe that even in situations more relevant to wargaming, examining scenarios as models in more detail does give some useful insights. The following section covers some scientific modelling principles as they pertain to scenario development.

6.3.1 Simplicity

The notion of simplicity is a core principle of scientific modelling, drawing on the Occam's razor tradition [6]. We argue that such an approach should be core to scenario design, which thus should include only the required degree of detail and complexity necessary to achieve game objectives. The tendency to over-elaborate in scenario building appears irresistible and was identified as early as the 1950s by Thomas and Deemer [7]: "We should deplore the tendency to introduce the trappings and ornaments in simulation to gain the 'appearance' of reality, when it is the 'essence' which we need." However, this simplification process is far from straightforward, particularly when scenarios are designed to serve multiple objectives or stakeholder needs. Effective simplification will require some wargame objectives (and thus scenario features) to be prioritized. Assumptions and simplifications will therefore have to be made in other areas.

6.3.2 Relevance vs Realism

According to Quade, the principle of simplicity in model building is complicated by two competing tensions between relevance and realism [8]. Models where relevance is prioritized focus on the issue to be investigated (the problem statement). Models with realism uppermost are more focused on portraying all aspects of the system, to be in a position to answer not just a single question, but other questions about the subject as well. Designs prioritizing realism may be criticized by those who see the additional scenario features irrelevant or distracting from the scenario objectives. Additionally, increasing the level of realism of any scenario almost inevitably increases its complexity. Conversely, a scenario designed with relevance to a specific problem in isolation may appear to lack realism, and may not achieve stakeholder "buy-in." Every scenario design is therefore a balance between relevance and realism ([8], pp. 34-35). The tension between relevance and realism picks up Van Notten's description of competing design processes [5]. Where realism is the priority, scenarios may benefit from a more intuitive design process, while scenarios designed for relevance may favor an analytical process.

Using this analytical framing, we can re-examine some of Weuve's "scenario pathologies" critique introduced earlier [4]. Weuve is more concerned with scenario relevance and does not specifically address the issue of credibility or realism. It is, however, not coincidental that the term "scenario" is drawn from the domain of the arts: the idea of the scenario as a narrative or story. Even in an analytical wargame, a scenario should be more than simply a dry description of a crisis in terms of its starting conditions. Ideally, a scenario motivates participants to perform "as if" they are engaged within the scenario rather than merely observers of it, as Brown et al. describe [9]. A scenario which fails to engage participants and encourage appropriate behaviors, will fail to give valid or useful analytic results just as surely as one which has not addressed the core problem at hand.

6.3.3 Problem Definition

In Section 6.2 we considered the importance of problem definition in scenario design. Paying due attention to problem definition is equally a tenet of model building. In thinking of scenario-as-model, however, we need to think of problem definition in a slightly different sense, or rather that the "problem" to be defined has a slightly different character. This is principally due to the involvement of human participants in wargaming. These are required to interact with the scenario, and each other, to generate the required wargame outputs. Thus, these interactions form part of the "problem space" which the model must capture, in addition to the explicit goals set down by sponsors. In practical terms this means that attention should be paid in scenario design to realistic and useful participant objectives or strategies. Player goals should incentivize player behaviors (given engaged, motivated participants) and it should be clear that changing these player goals

would likely have significant impact on wargame outcomes, just like changing any other scenario parameter. Thus, player goals must be usefully selected to support wargame objectives, and it should not be assumed that even engaged players are able autonomously to select appropriate goals to support these objectives.

Analytic wargaming with military participants adds a further layer of complication as these participants may be more familiar with training wargames, in which the overall objectives frequently are training objectives for the participants. Experience suggests that scenarios can often be re-used in training wargames to address similar training objectives, and also that the inclusion of unplanned (yet credible) scenario elements can have valuable training benefit [10]. This is, however, much less often true for analytic wargames where the unplanned scenario elements can detract from and sometimes confound analytic findings.

6.3.4 Verification and Validity

Relevance and realism issues in scenarios also find a useful corollary in the discipline of model verification and validation. Verification is a mainly technical/logical process of determining whether a model has been built as designed. Clearly, in an engineering or computer model this can be determined through formal testing. In the scenario-as-model construct, verification is a (necessarily) less formal process of tracking through from analytic requirements through to scenario elements designed to address them – its relevance (per Quade [8]). This is a non-trivial process requiring a decomposition of the overall problem into its constituent elements, or the consideration of multiple scenario elements concurrently. In a simple example, problems concerning the employment of amphibious forces are unlikely to be investigated in a scenario which is geographically set in a landlocked state. However, the mere presence of the opportunity to explore a specific issue or problem is insufficient in itself; in reality, a combination of features including adversary threat capabilities, own force level of air superiority, and mission objectives must all be considered concurrently. Tools or approaches to assist in scenario design often focus on this area of analyzing how wargame goals can be traced to scenario elements, see Section 6.4 below.

Although it is a necessary and useful process, verification has more limited value in scenario design than in other model building, due to the difficulties introduced by the interactions between scenario elements and participants [11]. These are necessarily more challenging to examine prior to implementing the wargame, such as the participant interactions highlighted already.

Model validity expresses the degree to which the model adequately represents the intended problem and provide useful insights. Considering an analytical wargame scenario as a model means its validity cannot be assessed without due consideration both of its relevance (per Quade) but also the degree to which participants consider the scenario as credible (Quade's realism). However, the converse is not true; however credible and compelling players find a particular scenario, this cannot compensate for a lack of relevance.

6.3.5 Vignettes, Injects, Scripting and Framing

In some circumstances, specific attention or greater detail is required on aspects of a problem. This often prompts the creation of "vignettes" or scenario sub-elements which are consistent with the overall scenario but permit a greater focus on the desired issues.

Generally, the design of vignettes conforms to the principles of overall scenario design already set out. The main drawback with vignettes in analytical wargames is that they are often purely incidental to the main scenario and are thus afforded only peripheral attention and engagement by wargame participants, leading to lower quality insights and analytical outputs. Further issues may arise when the vignette demands a different tempo or other time considerations than the main scenario, highlighting another of the pathologies identified by Weuve [4].

Another method of prompting wargame participants to address certain desired issues is through the design and implementation of "injects" or other scripted events by game controllers. Strictly, it might be argued that these items are not scenario elements and actually form part of wargame execution; nevertheless, to be successful they must be closely coordinated with scenario design. The use of this approach must be handled carefully as the injects may appear unrealistic or excessively detailed when compared to the rest of the scenario. Vignettes and Injects may also exert a powerful framing effect on participants as they are often evidently introduced to provoke specific actions, meaning they receive greater attention than they might do in more representative circumstances. Vignettes and Injects may therefore have greater utility in educational and training wargaming where specific participant reactions have to be stimulated to achieve desired training objectives.

6.3.6 Summary

Scenarios are often considered as stories or narratives. However, it is also apparent that, particularly in analytic wargaming, there is some utility in considering them from a modelling perspective as scenario design and scientific modelling share core principles of simplicity and validity. However, because human participants are key to analytic wargaming, the "scenario-as-model" perspective requires not just a list of parameters and starting conditions, but also consideration of the interactions between participants and the scenario. Good scenario design and development balances relevance to the problem with narrative realism.

6.4 TOOLS FOR SCENARIO DEVELOPMENT

This section describes a range of tools that may assist in the process of scenario development for analytic wargaming. It is a personal selection by the authors and should not be regarded as a comprehensive overview of the field. In many ways, this reflects part of the challenge in this chapter; much of the literature is far from recent, and much research seems to be more oriented towards the broader field of foresight analysis or futures studies.

Based on the issues discussed in Section 6.2, this section recognizes four aspects of scenario development and implementation and supporting tools:

- Tools to support problem definition, clarify stakeholder priorities and better articulate wargame goals.
- Tools for identification, selection and visualization of scenario parameters and values.
- Tools for assessing scenario validity.
- Tools for implementation and management of scenarios.

For simplicity and brevity this section focuses on the first 3 areas, while acknowledging that NATO experience in wargaming for training purposes has led to development over several years of tools which assist in the fourth: that of scripting and implementing scenarios (such as the Joint Exercise Management Module, JEMM) [12].

6.4.1 Category 1: Problem Definition

Tools in this category are not only useful for scenario development but rely on a shared appreciation that the problem or purpose that a scenario is designed to address merits an investment of time and resources of this type. While most readers who have made it this far in the chapter are already (hopefully) convinced this is true, it may not be the case for wider stakeholders, particularly in the military domain who may believe that their own decision-making processes (e.g., the NATO Operational Planning Process) are sufficient alone.

There are many approaches and tools to engage with stakeholders and structure, rank and/or prioritize their input, ranging from formal Multi-Criteria Decision Analysis (MCDA) tools to "softer" techniques presented in NATO Alternative Analysis Handbook [13]. A possible limitation is that some of these approaches often produce a narrow evolutionary extrapolation of extant factors, rather than reflecting strategic shocks. This despite the rather evident fact, that "…despite the attendant astonishment when devastating surprises occur, they are in fact quite often inevitable." (Attributed to Schwarz, in Lane [14]).

At any rate, an important initial step in scenario design is for the scenario team to engage with stakeholders, including problem owners, game designers and the analysis team. This is necessary to establish goals and objectives for the game (or clarify whether these are missing or insufficient), plan deliverables, manage expectations and conduct initial problem scoping. In many cases, either this interaction does not happen or the outcome is not helpful to guide the scenario development.

Malerud and Fridheim [15] describe a problem structuring approach using a simple questionnaire/checklist to guide the conduct of initial meetings between scenario designers and other stakeholders, in addition to remind the scenario team that such a meeting is a good idea in the first place. The checklist is in Appendix 6.1 and covers several issues, from defining the problem the scenario should help address, to sorting out necessary resources for the scenario work and getting input to the scenario contents. It may be a simple tool, but one should "…never underestimate the power of a well-structured checklist" [10]. The list has helped make the initial problem structuring for scenario design far more efficient than the unstructured meetings of old, in addition to speeding up the process of developing the scenario since there is clear guidance from the start. The questionnaire has also proven useful for novices who look for assistance on how to start designing scenarios.

6.4.2 Category 2: Scenario Structuring

The ideal outcome of problem identification during initial analysis is a set of scenario features (factors or parameters) which should be developed in order to address the problem or wargame goals, thus addressing the relevance aspects outlined in Section 6.3.

Perhaps the most obvious and available tool or approach used to develop scenarios in a military wargame context is the standard military planning toolset (for example, the NATO Operations Planning Process as outlined in Ref. [16] or similar). This has the advantage of being readily familiar to most military stakeholders, and, as it is also a process designed to develop a product (in this case, a plan) to achieve specified objectives, appears to have some relevance to the scenario development challenge. However, it is perhaps this familiarity to military audiences which leads to disappointment in most use cases. A scenario is not a plan, even if it is designed to facilitate the achievement of certain objectives. If we develop the "scenario-as-model" argument from Section 6.3, the scenario represents the context within which a plan might be executed, providing some of the planning process inputs, stimuli and constraints. There is no *a priori* reason why it should be able to stimulate the process, as it were, in reverse – taking the plan objectives as inputs and assembling the relevant features of the scenario as outputs. Moreover, given that the military planning process is largely only familiar within military stakeholder circles, it is not particularly open to radical innovation or inputs from non-military participants. Despite these apparent critical shortcomings, it is nevertheless still widely used as part of wargame scenario design.

One alternative approach is instead to consider as many as possible scenario options which include identified relevant parameters. A scenario parameter in this context is an aspect of the scenario (such as level of adversary threat, or environmental characteristics) which could take on a range of possible values or categories. A scenario parameter considering the environment in which the wargame is set could take on category values such as temperate, arctic, jungle or mixed (for example). In this example the parameter values vary across different categorical descriptions but could equally be numerical. Thus, a specific scenario can be considered defined by a particular configuration of parameters and associated values.

Considering scenario development as refinement of a set of parameters with associated values lends itself readily to the approach of Fritz Zwicky's General Morphological Analysis (GMA), popularized in the mid-20th century.[3] GMA structures the set of all parameters and associated values as a complete description of the problem space, within which simple comparison techniques can be applied to rapidly reduce complexity and identify possible solutions. French scenario/futures research pioneer Michel Godet – whose "devil is in the detail" caution to scenario-builders provides the title of this chapter – highlights several scenario development case studies using GMA techniques [17]. These are implemented using spreadsheet models or proprietary software. Ritchey [18] sets the GMA approach within a broader context of problem structuring methodologies, sensing perhaps that GMA's simplicity can mean its power is underestimated.

One strength of GMA, proponents argue, is that it caters well with uncertainty, incompleteness of information and parameter interdependence: all highly likely in scenario development. GMA makes use of cross-consistency matrices (CCMs) to rapidly reduce many *possible* scenario configurations to a much smaller number of *feasible* options. This is done by first eliminating options which contain logical inconsistences in specific parameter value pairings, and then by further identifying parameter-pairs which, while not strictly inconsistent, are of less interest or relevance to the issue at hand. Godet describes how, in developing scenarios for an infantry weapons procurement program, GMA approaches reduced the field of over 15000 possible scenario configurations to a "long list" of 50 for further evaluation [19].

Limitations of GMA include the difficulty of identifying omitted or redundant parameters, and in defining appropriate level of detail in parameter value/categories, particularly if problem identification analysis has not been thorough in Step 1. In reality, the benefits of removing unfeasible or undesirable parameter options using GMA can be overstated, as in many cases such superfluous configurations can be identified and eliminated through common sense. NATOs Alternative Analysis (AltA) handbook identifies the "creative combinations" technique as a simplified version of GMA [13]. It still maps out parameters and values relevant for the problem but does not depend on the full cross-consistency check of all parameter values. Instead, the table of parameters and values can be used as a scenario laboratory, where scenario developers can play around with different combinations and identify a range of possible and probable feasible solutions.

Both GMA and creative combinations also combine well with other techniques into multi-method approaches covering both problem identification and scenario structuring. A recent study of future needs for strategic aeromedical evacuation depended on expert inputs in scenario-based discussions and simple wargames [20]. Due to time restrictions, the scenario design and development process was simple, but structured:

- A quick literature review mapped out the current capacity, historical cases, and possible future challenges for strategic aeromedical evacuation.
- A group of SMEs helped set up a creative combinations table, with key parameters and values for the problem.
- The table was used as a scenario laboratory to develop simple scenario outlines with different characteristics (likely, high-consequence, novel / "test the boundaries"), based on these parameters: What is the given security situation, which actors are involved, how many evacuees are there, where from/geography, what are the specific operational challenges.
- The scenario outlines were starting points for more detailed scenario generation, where additional information was developed through simplified What-if (how could we end up here) and Pre-mortem analysis (how could our plans fail).

The approach was an exercise in methodological "corner-cutting," in the sense that both time and available expertise was limited, not least since many experts were working from home during the COVID-19

[3] For more details, see the La Prospective website: http://en.laprospective.fr/methods-of-prospective/softwares---cloud-version/5-scenaring-tools.html.

pandemic. The What-if and Pre-mortem analyses were simplified and done by individuals, not groups, and the analysis steps were less formalized than described in NATO's AltA handbook [13]. Still, the approach allowed for the quick development of nine fit-for-purpose scenarios, and the structured approach supported by various AltA techniques were critical for avoiding a standard BOGSAT-based story writing of cool ideas with questionable relevance for the study.

There is little doubt that a GMA approach (whether in full or part) can support scenario development, and it is perhaps surprising that it has not been more routinely adopted, especially when compared to the widespread use of standard military planning tools. One possible explanation is the lack of widely available software suites to support the GMA process, not least the sometimes time-consuming work of identifying and removing inconsistent combinations. GMA software tools exist, ranging from simple spreadsheets to specially designed modelling suites like CASPER[4], but they are as a rule proprietary and non-commercial.

6.4.3 Category 3: Scenario Validation

Validation of scenarios for wargaming poses a particular problem compared to validation of other models. It is tempting but erroneous to validate the scenario only by considering how realistic it appears, rather than by attempting to assess the quality of the results it stimulates, especially when these are not easily comparable to "real-world" observations (for example, if the scenario is intended to explore the future).

Moreover, the "scenario as designed" will inevitably differ from the "scenario as implemented," due to the complex and unpredictable interactions between scenario, other mechanisms of wargame implementation, such as rules and game control, and most importantly, participant reactions. Participant reactions in particular may be partial and misleading. An effective scenario which addresses intended game outputs may in practice pose uncomfortable dilemmas to participants, and lead to criticism from them that the outcomes therefore lack validity, or even a kind of unrealistic, defensive "gameplay". By contrast, a scenario which is more familiar and comfortable, but which merely confirms preconceptions, may receive greater participant approval even if it fails to rigorously address game objectives.

Such challenges mean a wider perspective on the validation process is needed. The process should encompass both verification aspects (analogous to requirements tracing from scenario parameters back to game objectives,) as well as feedback and lessons captured during implementation of the scenario, which may also offer insights into scenario design. These might prompt re-examination of the theoretical links between game objectives, scenario elements and participant interactions, or modification of parameters and values. Thus, validation should draw, where possible, on the widest range of data available, including structured participant feedback through interviews and surveys and an appropriate level of so-called "play-testing."

Despite the inherent difficulties in scenario validation, some tools may assist. If GMA has been used in the previous steps, then the intended linkages between scenario parameters and game objectives should be readily traceable, even though there is unlikely to be a one-to-one relationship.

The field of formal requirements validation may also have some utility as an approach to wargaming scenario validation, although little progress appears to have been made in this respect since the work of Whitworth and others trying to formalize an architectural approach to scenario development and validation [21], [11].

6.4.4 Summary

A wide range of tools and approaches exist, or have been proposed, to support various stages of wargaming scenario development and validation. The first obstacle is persuading stakeholders that the process of

[4] Computer Aided Scenario and Problem Evaluation Routine, an in-house GMA software tool at FOI, Sweden.

scenario design merits investment in time and resources and overcoming the prevailing view in military applications that military planning tools are intrinsically suited to, and sufficient for, developing scenarios, particularly for analytic wargaming. Thus, it should be clear that the issue of tools for scenario development is much less about the tools themselves and much more about fostering a culture of care and attention to the overall design process.

6.5 RECOMMENDATIONS

We have discussed effective scenario design and development in relation to wargaming in general and analytical wargaming in particular. Key issues discussed are:

- Scenario design and development for analytic wargaming requires investment in time and thought or can easily simply become an exercise in creative writing.
- Scenarios are more than narratives. For analytical wargaming, they can usefully be considered as scientific/analytic models to facilitate achievement of goals.
- Problem definition is key to scenario design and development, but the "problem scope" must include consideration of the interaction between participants and the scenario.
- Military operations planning techniques have limited utility in scenario design. Other analytic approaches such as GMA or "creative combinations" may have broader value in helping to maintain scenario relevance.

The challenge of effective scenario design is not new. While most agree what a scenario is and what it is for, and the main issues (or pathologies) are well known, it remains much less clear how scenarios should be reliably developed. This is also a challenge for NATO, which is why we end the chapter with the following recommendations:

- Building on many decades of wargaming experience within NATO and among Allies, specific guidance on scenario design principles should be collated in a NATO endorsed wargaming manual.
- Similarly, a suitable lead agency or body, beyond the narrow scientific community, should be identified to act as a central focus for Alliance-wide wargaming.

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Appendix 6-1: CHECKLIST FOR SCENARIO STRUCTURING

The purpose of Table 6A1-1 is to have a structured approach to the initial dialogue with stakeholders. This helps establish goals, plan deliverables, manage expectations and get input to scenario design and development [15].

Table 6A1-1: Checklist for Scenario Structuring.

Problem Definition	
Activity	What are the scenarios for? Which activities should they support? Games/exercises, (risk) analysis, future studies, etc.
Stakeholders	Who are the problem owners, users of the scenario, target groups, etc.? Who are the players, what interests them? Who are the game and scenario designers/developers, analysis team, support staff, etc.?
Input plans/ specifications	What are the guiding documents, existing plans, orders, directives, specs… for the activity?
Goals	What are the goals and objectives of the activity? Are they clear, unambiguous, coherent, non-competing, etc.?
Deliverables and outcomes	What are the expected deliverables and products after the activity? What are the desired outcomes of the activity? Exploration, decision-making, analysis, entertainment, education, training ++
Collaboration	What is the desired/necessary collaboration between different stakeholders?
Available Resources and Time	
Time	When are the scenarios to be used? When should the scenarios be available? Drafts, final versions
Budgets	What budgets are available? How much money? How many hours?
Expertise	Who are available to support scenario design and development? Which subject matter expertise is necessary to support the scenario work?
Contents **Remember to link back to goals and objectives. "Why?" is a good guiding question.**	
Details, Relevance v. realism	On which level should the scenarios raise issues? Tactical, operational, strategic. Political, military. Local, sector, national, international, global, etc.
	How extensive should the scenario context/setting be? Is there a need for one? What are relevant geographical, political, economic, sociocultural, demographic, security factors/parameters?
	What level of detail/realism is necessary?
	What classification is necessary/max?

Contents (cont'd) **Remember to link back to goals and objectives. "Why?" is a good guiding question**	
Issues/problems	Should/must specific challenges or problems areas be included in the scenario? Relevant, possible, interesting, new, desired, required, etc.
	Should/must specific challenges NOT be included in the scenario? Covered elsewhere, too sensitive, not plausible, unlikely, irrelevant, etc.
Incidents	Should/must specific incidents be included in the scenario? Should/must specific incidents NOT be included in the scenario?
Time horizon	Should the scenario cover past, current, or future situations?
Fiction/non-fiction	Should the scenario describe real or fictitious settings/situations/actors?
Dynamics	Should the scenarios be static or develop over time? Should the scenarios be scripted or allow for developments based on player actions/decisions?
Existing scenarios	Can existing scenarios be used/tailored during the scenario development process? Are there clear historic parallels that can be used for inspiration?
Format	How should the scenario be presented for the user, in which format? Audio, presentation, written, video, model, etc.

Chapter 7 – ENABLING ANALYTICAL WARGAMING THROUGH OPERATIONS ANALYSIS

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7.1 INTRODUCTION

Analytical Wargames are designed and conducted within a scientific framework to gather evidence about systems, concepts, and structures in order to analyze complex problems in an adversarial environment. This emphasis on addressing questions within a wargame prioritizes data collection in a form suitable to generate knowledge or evidence. Most wargame systems (consisting of rules, adjudication models, process etc.) provide an understanding of possible outcomes, potential points of friction and dilemmas for the situation being considered and, in some cases, this may be sufficient to address the analytical objectives.

Where a wargame's analytical objectives require a deeper understanding of the factors contributing to these outcomes (an understanding of the decision-making processes or the mental models that participants bring toa wargame) a more rigorous, campaign approach to data collection and analysis is required. Here, wargames combine their strengths – generating hypotheses, identifying points of failure [1] and refining analytical questions – with other analytical methods to deliver the required depth of knowledge. Operations analysis techniques provide a natural pairing with analytical wargaming to address this need. Indeed, within military OA circles, analytical wargaming is seen as a key OA technique [2], [3], [4]. However, it is stressed that the adoption of any supporting OA method should be determined by the requirements of the problem being addressed not on any mandated template for analytical wargames.

This chapter considers how selected OA methods can enhance knowledge generation in analytical wargames. Five methods are presented to address three analytical tasks that are applicable across the five wargame phases. The focus is on providing illustrative examples across the wargame phases, rather than specific recommendations on preferred methods or a template on their conduct. Each of these structured methods require some additional analytical effort prior to, during and following an analytical wargame event. While the additional effort required is not extensive, the challenge is to balance this with the analytical requirements of the wargame and the available analytical resources[1].

7.2 ANALYTICAL WARGAME PHASES AND TASKS

The UK Ministry of Defence Wargaming Handbook [6] defines the wargame process in terms of a lifecycle that comprises five steps: Design; Develop; Execute; Validate; and Refine. Here, the Refine step leads back to the Design step to support continuous improvement. An analytical wargame process has been developed by the Work Group, informed by this model, to reflect two additional key phases of analytical wargaming: Initiate (to ensure the problem is understood and the right question addressed); and Analysis (to combine all sources of evidence to address those questions). The intent of the Validate and Refine phases are subsumed within the Analyze phase. Figure 7-1 illustrates these five key phases within an Analytical Wargame activity: Initiate, Design Develop, Conduct and Analyze.

The intent and key activities within these phases are discussed in the following sub-sections.

[1] Where analytical resources are constrained, the reader is referred to a range of lower burden methods detailed in Refs. [5] and [3].

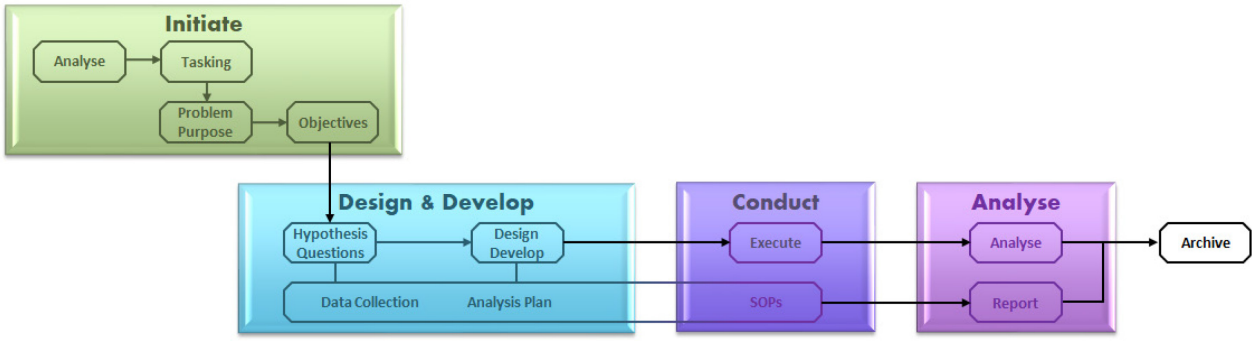

Figure 7-1: Analytical Wargame Phases and Implied Tasks – SAS 139 Work Group.

Another view of this structure is displayed in Figure 7-2 in which the cyclic and continuous learning nature of analytical wargaming is emphasized in a fashion similar to Ref. [6].

Figure 7-2: Analytical Wargame Phases and Implied tasks Model – Cyclic View.

7.2.1 Initiate

The focus of the Initiate phase is to establish a clear understanding of the problem in the context of the key objectives and issues of the stakeholders. This will guide the design of the activity, and indeed confirm if an analytical wargame is appropriate for the problem. It will set the scope of the analysis; and result in the development of a high-level analytical plan that can be discussed with sponsors and stakeholders. An agreed analytical plan will then enable key tasks such as a data capture and management plan to be created and model development to commence.

7.2.2 Design

Based on the outcomes of the stakeholder engagement and problem structuring in the Initiate phase a range of detailed design tasks can then commence:

- Carry out literature review on the analytical problem. This could include relevant historical sources, relevant analyses, and appropriate wargame systems (rules etc.).

- Design Scenario(s): identify key scenario dimensions (e.g., physical/human terrain; mission; capabilities and/or operating concepts to be employed; threat etc.)
- Select or design appropriate wargame rules (adjudication system, movement system etc.) appropriate for the scenario and analytical objectives.
- Assess and identify mitigation strategies for potential biases that may impact on the analysis [2], [4].
- Produce an experimental plan that incorporates objectives and questions, describes the scenario, and defines player roles, explains process, and outlines detailed data collection requirements. A simpler, tailored, form of this plan should be developed as a player guide.

7.2.3 Develop

During this phase wargame and analytical tool development is completed and then tested and refined. This includes playtests of the wargame as well as the data collection plan. In particular, the data collection method (tools, questions etc.) should be tested on a representative group to ensure that it is easily understood by participants (trial analysis).

7.2.4 Conduct

This phase encompasses the execution of the wargame and primary data collection events. This data collection may be directly associated with the wargame or in separate, related, sessions. For example, participants may be asked to complete surveys at the end of key phases in the wargame. While some analysis may occur during the phase, this is generally confined to analysis directly supporting the wargame process (adjudication, etc.).

7.2.5 Analyze

This phase will include a range of analyses as determined by the Data Collection and Management Plan (DCAM) [7]. Noting the strengths of analytical wargaming – generating hypotheses, identifying points of failure, and refining analytical questions – this will primarily involve qualitative methods. However quantitative data may be available from some wargames (e.g., some computer-based wargames) and quantitative analysis may be used to complement the qualitative analyses.

7.3 OA METHODS AND ANALYTICAL TASKS

A wide range of OA methods are available that could support analytical wargaming. NATO's Judgement-based OA report [3] identifies 21 methods ranging from cognitive and causal modelling to various problem structuring methods. Alternative Analysis [5] also identifies 21 methods within four broad categories of techniques: Structuring, Creative, Diagnostic and Challenge. For the purposes of this chapter, we identify three categories of analytical tasks (problem scoping; problem understanding; and problem refinement) that could be addressed by different OA methods and applied to support various phases of an analytical wargame. These categories represent key knowledge generation tasks within an analytical wargame and can be addressed by a range of OA methods.

7.3.1 Problem Scoping

This refers to methods applied to address unstructured problems, involving numerous actors, their various perspectives and associated uncertainty, which are designed to support group-based decision making. Examples of the many Problem Structuring Methods (PSMs) that may be applied in this task include Soft Systems Methodology (SSM) and Strategic Options Development and Analysis (SODA) [3]. The intent

here is to ensure that the analyst and sponsor appreciate the broader context of the problem and address the right questions. They are most effective when applied at the Initiate and Develop phase of an analytical wargame in situations where the key problems are poorly understood and impact on multiple domains and involve multiple stakeholders. However, they can also be useful during the Conduct phase to help players in decision making or to address new problems identified in the wargame.

7.3.2 Problem Understanding

This refers to methods applied to enable a wargame analyst to capture and explore the problem through the course of a wargame in a way that develops tangible knowledge and understanding. They also develop analytical artefacts that support some level of counterfactual analysis of the problem. For example, a causal model developed during an Analytical Wargame may capture sufficient understanding of relevant factors and interdependencies to enable an exploration of situations not directly addressed in the wargame. This class of methods include morphological techniques, influence diagrams and causal models.

7.3.3 Problem Refinement

The nature of problems addressed by wargaming generally precludes a complete solution. As stated earlier in the chapter, the strength of wargaming is its ability to generate hypotheses, identify points of failure and refine analytical questions; not to provide a definitive answer. Nevertheless, analytical wargames, combined with other quantitative methods, may be used to support a selection or ranking of alternatives. Methods that may be applied to this task include Multi-Criteria Decision Analysis (MCDA) methods and option ranking and clustering methods (e.g., the Analytical Hierarchy Process or ELECTRE).

The way in which OA methods may be applied to these tasks within an analytical wargame is illustrated in Table 7-1. Here different analytical tasks are shown as relevant to different Analytical Wargame phases. Problem scoping methods may be employed to structure thinking about, and improve shared understanding of, the analytical problem. An important outcome from these methods are some conceptual models of the problem that can guide the design of the analytical wargame.

Table 7-1: Relevance of OA Tasks Across Wargame Phases.

OA Tasks	*Initiate*	*Design*	*Develop*	*Conduct*	*Analyze*
Problem Scoping	⟷	⟷		⟷	
Problem Understanding		⟷	⟷	⟷	⟷
Problem Refinement				⟷	⟷

Having established a conceptual understanding of the broader problem, Problem Understanding methods can be used to provide a more structured representation of the dimensions of the problem space. In the Design phase this can help clarify wargame and vignette design and associated data collection. The products developed by these methods are further improved through the testing that occurs in the Develop phase. In the Conduct phase they may be employed to help guide decision making in the wargame. For example, identifying which branches should be explored in more detail during the wargame and to help identify potential break points. Finally, the products produced through these methods can be used during the Conduct and Analyze phases to consider counterfactual questions related to but not directly addressed in the wargame.

Problem refinement methods are generally applied during the Conduct phase as part of the data collection plan and used to provide preliminary insight to inform this phase, or as part of the wider analyses performed during the Analyze phase. These are primarily quantitative methods that can be used to inform decisions on preferred options or provide a complimentary methodology that can improve understanding of the issues identified in the wargame via triangulation [8].

7.4 EXAMPLES OF APPLYING OA METHODS TO ANALYTICAL WARGAMING

The following sub-sections provide four examples of the application of OA methods to enable Analytical Wargaming across the OA tasks and wargame phases discussed previously. This is not intended to be a comprehensive list and indeed there may be better methods available to achieve the same effect. Instead, these examples are intended to illustrate how OA methods are incorporated into an analytical wargame and the benefits that this can provide.

7.4.1 Problem Scoping

A commonly used Problem Structuring Method – used often for problem scoping – is the Soft Systems Methodology (SSM) [9]. SSM arose from systems engineering as that discipline began to grapple with the 'messy,' non-technology-based problems often encountered by decision makers. The methodology focuses on learning about a complex situation, developing a common understanding of the problem and identifying meaningful action rather than finding a solution.

There are seven stages involved in an SSM analysis [9]:

1) Select a problem situation.
2) Express the problem situation.
3) Formulate Root Definitions of relevant systems of purposeful activity.
4) Build conceptual models of the systems named in the Root Definitions.
5) Compare conceptual models with real world.
6) Define possible changes that are desirable and feasible.
7) Take action to improve situation.

The intent here is to use and adapt relevant components of SSM where appropriate to Analytical Wargaming rather the rigidly apply all stages of the methodology. The first three stages, in which the problem situation is explored and defined, are relevant to the aims of the Initiate phase of an analytical wargame. This then leads to creation of a conceptual model informed by the root definition(s) at the beginning of the Design phase which then informs the overall design of the activity.

Establishing Root Definitions (RD) is the most important step in the process. The root definition is developed from a PQR analysis which asks what the process is intended to accomplish, how this is to be done and why do this in the first place. Checkland and Poulter [10] express this as: "do P, by Q, in order to achieve R". The PQR analysis is a powerful tool in its own right and has successfully been applied to address novel problems such as evaluating concepts [11].

A 2019 wargaming-focused analytical campaign investigated the impact of non-kinetic changes to the Joint Land Fires System. This system encompasses the supporting weapons (artillery, mortars, aircraft, etc.)

delivering fires in an engagement as well as the associated, sensors, communication systems and command, control, and coordination enablers. At issue was the relative importance of investing in network reliability within the joint fires kill chain, as compared to more kinetic elements. To establish a shared understanding of a proposed analytical activity on the Joint Land Fires System, we applied a PQR analysis and established from the sponsor that we would:

- Assess the military value of non-kinetic improvements to the kill chain (P), through a combination of analytical wargaming and causal modelling (Q), to inform capability modernization priorities (R).

This analysis is extended via the additional elements of the CATWOE mnemonic. Here we are interested in the broader analytical problem of improving the Joint Land Fires System. Each of the elements is explained in the following dot points [9] and applied to Analytical Wargaming.

- Customer (C). People who are the beneficiaries (or, rarely, victims) of the system activity. In the context of the analytical wargame, this refers to the sponsor of the activity and key stakeholders. In many cases, not all of the stakeholders will be immediately obvious. In our Joint Land Fires example, the Customer is the Land Fires capability manager.
- Actors (A). People who do the activities. In the context of an analytical wargame, this refers to the forces (including capabilities and technologies) involved – friendly, neutral, and enemy.
- Transformation Process (T). The purposeful activity of the system. As applied to the Joint Land Fires problem, this refers to the transformation desired and hence the context in which a force (structure), capability or concept will be tested within the wargame. For example, in the joint fires example mentioned previously: Increasing network reliability will improve lethality and decrease unintended harm.
- Weltanschauung (W). The worldview that makes this definition meaningful. Again, using the joint fire example, the world view of the sponsor and key stakeholders might be that arguments in favor of spending to improve network aspects of the Kill Chain will only be successful if convincing independent analysis is provided that addresses both lethality and unintended harm.
- Owner (O). The person/people who could stop the activity. In the joint fires context, this could refer to the key stakeholders within the capability development process who assess the merits of new capability proposals.
- Environment Constraints (E). The accepted constraints imposed on the system by the environment. In a wargame context, this refers to constraints imposed by the scenario(s) to be explored. This includes physical, human, and informational terrain and other constraints related to missions such as timelines, rules of engagement etc. It also includes constraints to the analytical resources available for the analytical wargame, including available subject matter experts, funding, analysts, etc.

A conceptual model can then be constructed from the root definition, incorporating assumptions of the "system" being explored through wargaming. For instance, in applying this approach to the joint fires example, you might produce the conceptual model in Figure 7-3. Approximately one day of analytical effort was required from one analyst, in consultation with appropriate subject matter experts, to complete this process and produce a conceptual model.

7.4.2 Problem Understanding

There are many methods that could meet the requirements of problem understanding, however we have focused on two illustrative approaches as they are applied to Analytical Wargaming: Causal Modelling and Morphological Analysis.

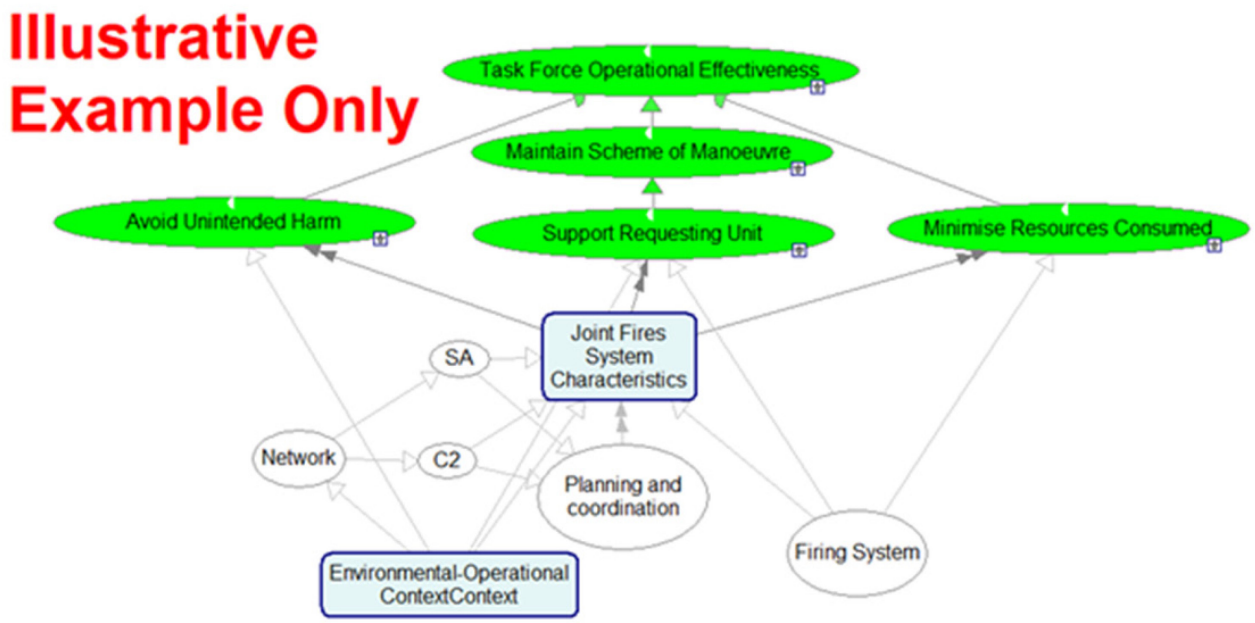

Figure 7-3: Example Conceptual Model for a Joint Fires Analytical Wargame.

7.4.3 Causal Modelling

The pairing of causal modelling and wargaming can provide a powerful means to capture, visualize and explore knowledge gained and so enhance problem understanding and the utility of the wargame insights. Causal models, specifically Probabilistic Graphical Models (PGM), represent causal relationships mathematically within a specific system. These relationships may be based on empirical data, simulation data or knowledge elicited from experts. They enable inferences to be made regarding causal relationships in a population of interest and can provide a means to extend the external validity of statistical data. PGM models contain probability data regarding the counterfactual behavior of a system; and contain information regarding the dependence or independence of model variables [12]. These visual and probabilistic representations of complex processes can be used to predict the effect of an intervention without enacting it [13]. PGM's employ causal diagrams [3] (graphs) to encode the analyst's and subject matter expert's knowledge of causal relationships and dependencies between variables of interest.

Early in the design of the 2019 Joint Land Fires activity (discussed previously) the decision was made to pair the analytical wargame with the creation of a causal model. This model sought to both capture the key casual factors identified by the wargame participants and to use the resulting model to consider counterfactual questions about the joint fires system. A Qualitative Bayesian Belief Network (BBN) model [14] was selected for this purpose.

A BBN model is a PGM described, using Sucar's dimensions [15], as:

- Directed (acyclic graph) – that is causality flows in only one direction;
- Static – that is the model represents variables at a specific point in time; and
- Probabilistic – meaning that all of the variables in the model are probabilistic variables.

BBN deliver many of the analytical strengths of PGM to analytical wargaming in an easy to understand and intuitive representation [16]. In particular, they allow an exploration of situations not addressed in a wargame due to time constraints as well as the "so what" of hypotheses and insights developed during play. Despite the strengths, a key challenge of BBNs is that they can be very challenging to initially construct and populate

these models with the required conditional probabilities. For example, a binary "child" node with three binary "parent" nodes (causes) will require 23 (8) conditional probabilities to be elicited. This increases exponentially with the number of parents.

Qualitative BBN are a subset of BBN that enables the rapid creation of causal models by imposing substantial assumptions, constraints, and limited categories of causal interaction [14]. If these constraints and assumptions are accepted, they can provide an effective mitigation to the probability elicitation challenges of BBNs. Nodes within this Qualitative BBN model are binary variables and represent statements about the real-world situation under consideration.

The model was developed during an analytical wargame activity and combined with other OA methods to complement the analytical insights generated and improve the confidence in the results. A four-step method was employed to construct and develop the model, integrated with the conduct of the analytical wargame, as detailed below:

1) Develop an Interview Ready Model (IRM) – Pre-Analytical Wargame.

A small subject matter expert workshop was conducted to develop an IRM structure from the conceptual model developed during the Problem Scoping phase. Having developed the initial structure based on SME input, the analysts then test the internal consistency of the model (logical validation).

2) Refine the IRM – During the Analytical Wargame.

Review and correct the IRM model structure and review initial conditional probabilities with participants. This was achieved by scheduling two short modelling sessions as part of the week-long wargaming schedule. This first session introduced the model intent and structure and sought initial feedback and improvements/corrections from the participants. A second session mid-way through the week enabled them to review the modified structure and populate the model with probabilistic data.

3) Validate the Model – End of the Analytical Wargame.

Review Model and correct conditional probabilities with participants. A third modelling session conducted at the end of the event enabled the players to test the model against their own experience and historical examples. Initially the model was configured for known historical examples and the model outputs considered and discussed. This led to some adjustment to the model. Participants were then requested to propose relevant operational vignettes, described as a set of model inputs, and corresponding outcomes. This data was captured in validation tables. Post the wargame activity the model was tested using the validation cases developed by the participants and where justified (major gaps in the causal logic) additional changes were made to the model.

4) Analyze Model – After the Analytical Wargame.

Having completed model validation, model analysis was directed at:

- Identifying critical/highly sensitive nodes in model; and
- Applying the model to conduct counterfactual analysis – that is explore important situations not directly addressed during the wargame
- Potentially triangulate results with other data sources for similar situations

A representation of the model developed in the activity is displayed in Figure 7-4. Overall, this required two days of preparation by two analysts familiar with Qualitative Bayesian modelling prior to the wargame and additional two days of effort during and post the wargame.

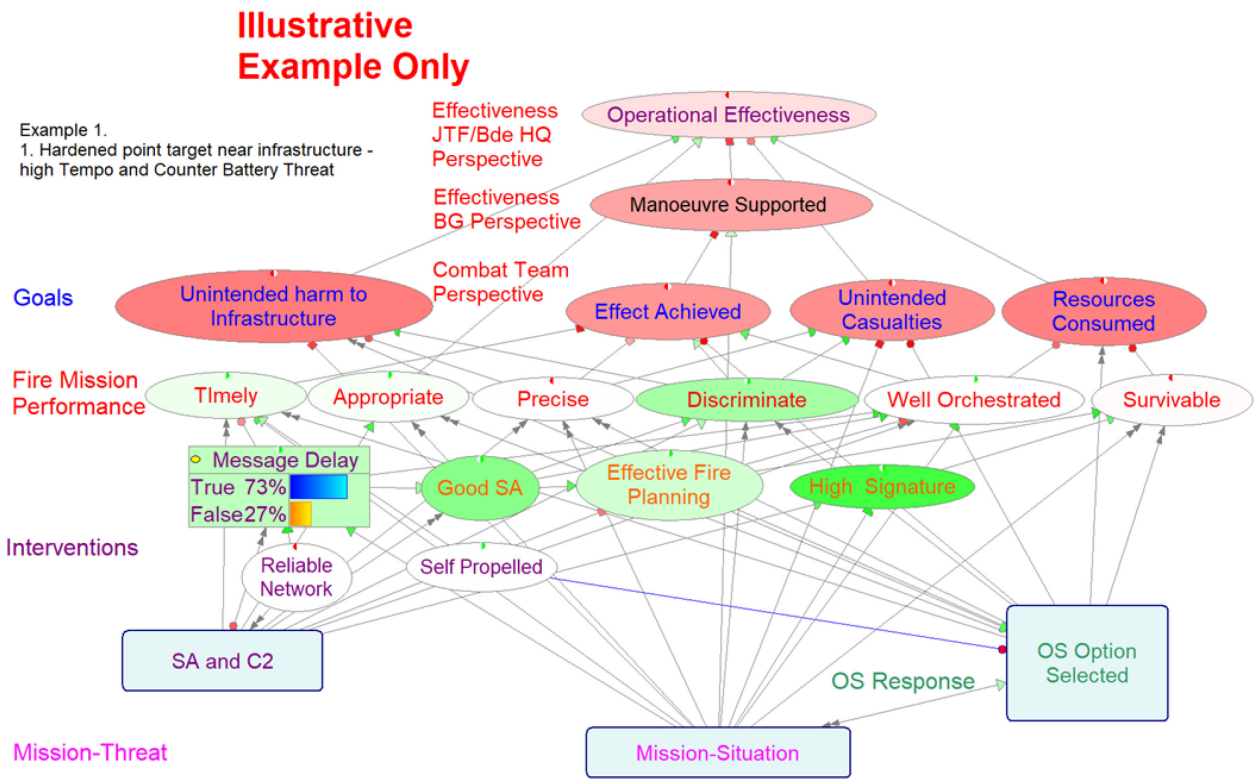

Figure 7-4: Illustrative Example of a Qualitative BBN for Joint Fires (Blue Boxes Represent Hidden Submodels).

7.4.4 General Morphological Analysis

General Morphological Analysis (GMA) is a method used to explore the possible (or feasible) states in a problem space, given these states are composed of a number of dimensions which can each take on a number of values. (For example, a shape may take the *form* of a square, triangle, circle, or hexagon, can be of small/medium/large *size* and be *colored* red, orange, green or violet. This yields 4x3x7=84 possible shapes, or states.) In complex, real-world problems the number of states to analyze can become prohibitively large. GMA provides a number of techniques to help the analyst explore them.

Different applications of general morphological analysis [17] have been designed to support problem understanding within an Analytical Wargame context. Either explicitly or implicitly, analytical wargaming typically explores a range of parameters, or dimensions: Blue force size; Red force size; specialist enabler capabilities; or even different mission sets. Where the aim of the wargame is to consider the performance of some system, structure or concept across these dimensions, the morphological space can be far too expansive to effectively measure in detail – especially considering that a single experimental activity might only run through a limited number of individual wargames.

In these cases, the analyst may aim to find the break points of the experimental force (Blue) in order to map the Feasible Scenario Space (FSS) [18]: the set of all combinations for which the side will likely be successful. This necessitates evaluating which combinations of enemy parameters generate a threat on par with the abilities of the friendly forces.

Given that only a small subset of the whole morphological space can be sampled, the analyst must choose to either concentrate in a small region, or else spread the testing sparsely across the entire space. Thus, there is little guarantee (effectively none) that the most accurate mapping of the FSS will emerge.

In order to present the analyst with the best opportunity to probe along the break points during a single activity, a Dynamic Morphological Exploration (DME) Tree [4] can be constructed a priori and used throughout the exercise to guide subsequent wargames, based on the results of the previous iterations. The core concept is to consider all the potential outcomes of a given wargame and (within the context of the previous wargame results) determine the best combination within the morphological space to test next (see Figure 7-5).

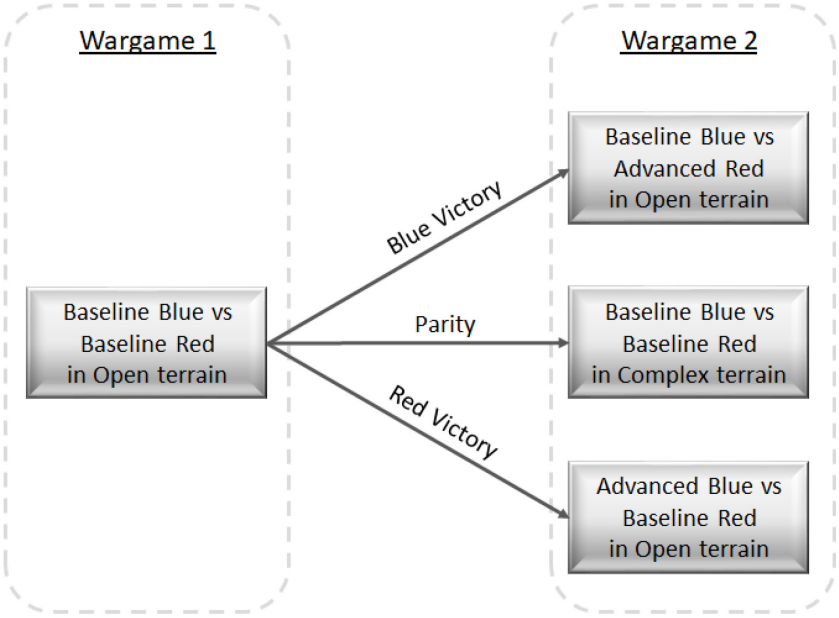

Figure 7-5: Wargame Results.

This process continues for as many branches as there will be individual wargames and forms a decision tree (see Figure 7-6). The outcome is that the DME Tree will allow the analyst to sample across large regions and focus more effort in localized areas as required; combining the best of both approaches discussed above.

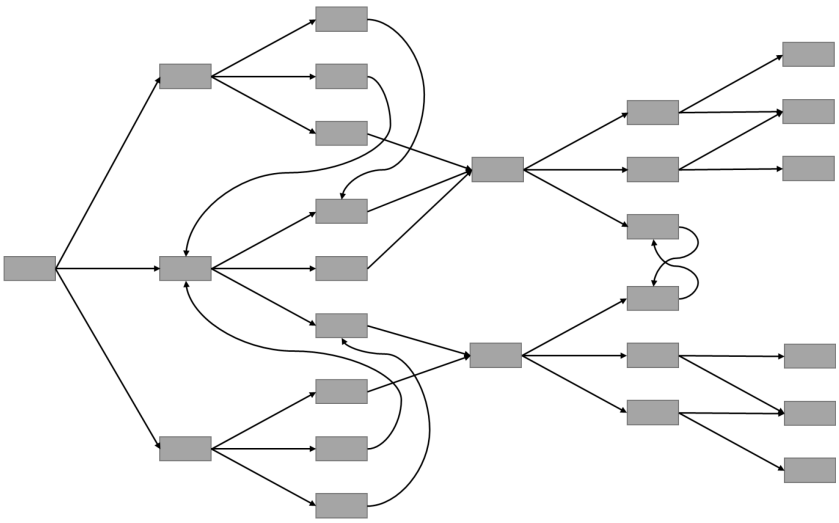

Figure 7-6: Example Structure of a full DME Tree.

DME Trees have a number of limitations, which constrain when and where they can be used. Foremost among these is that the analyst must be able to evaluate (even subjectively) an outcome very quickly after a wargame run and the wargame set up must be responsive or able to be pre-determined (changing of ORBATs, systems, map, etc.).

7.4.5 Problem Refinement

Methods for problem refinement are generally quantitative in nature and are used to inform decisions on the ranking of options under test or reducing option sets. They are most often applied during the Analyze phase – using results and insights generated from the wargaming activities to populate data sets – but can also be applied during an activity to inform subsequent wargame runs.

For example, an analytical wargame aims to help refine options for a new anti-tank guided missile system and four are being considered. At the end of each wargame, the participants are probed using the Analytical Hierarchy Process (AHP) to compare the options against a range of tactical situations. After a just a few runs, it is discovered that Option C has a distinct (and untenable) weakness in densely vegetated environments. Due to this limitation, it is then removed by the analysts and sponsor from the rest of the activity, freeing up valuable time and focusing the subsequent analysis. During the analysis phase, AHP data of the remaining options might be used to inform the final recommendations of the study. However, it is important to stress that while an analytical wargame can inform an overall selection process, and arguably is necessary in order to consider an adversary's responses, it is generally insufficient to select between candidate systems.

In this section we introduce MCDA as a relevant OA discipline to address these problems and present two examples of relevant methods within MCDA that can be employed within Analytical Wargaming: AHP and ELECTRE.

7.4.6 Multiple Criteria Decision Analysis

Decision Analysis (DA) [19] provides a logical and fundamental approach to balance factors that influence decision making and provides a relevant framework from which to consider various approaches to analyze decisions. DA incorporates "uncertainties, values, and preferences in a basic structure that models the decision" and typically "includes technical, marketing, competitive, and environmental factors" ([19], p. 5). DA can be narrowly defined as the decomposition of a decision problem into smaller, solvable, problems that can then be recombined to inform the decision. Implicit in the decision analysis approach is that, as the decision maker is required to make many explicit judgements as part of the process, an audit trail is produced that explains why a particular decision was made. MCDA extends DA to cover multiple and conflicting criteria and provides a means to formally incorporate them into the decision process [20].

MCDA is a branch of Operations Research which lends itself well to the analysis of Defence systems, specifically in ranking options. That is, in situations where it is critical to weigh up the strengths and weaknesses of different options to determine which ones are 'best.' Within this context, 'best' is often quite subjective and can vary depending on the particular nation, the mission sets and even the geography. While MCDA models can be easier to create than PGM, one limitation is that they do not allow for interdependencies between criteria.

MCDA encompasses a range of methods that are distinguished by the way they assess criteria, how weightings are determined and applied, the way in which user preferences are captured and presented, how stakeholders participate and the uncertainty in the available data [21]. Analysts can select an appropriate MCDA method using criteria developed by De Montis et al. [21].

Two relatively quick and simple techniques are presented here to illustrate some of these differences and how they might be employed to assess options within a wargame setting: the AHP; and ELimination Et Choix Traduisant la REalité (ELECTRE).

7.4.7 Consistent Structure

Both methods will assess a set of Alternatives (or options) against a set of weighted and independent Criteria (or attributes) to produce recommendations for their relative utility. The results produced through these methods will be inherently subjective and must be scrutinized before accepting them. Alternatives are compared in a pairwise fashion across each of the Criteria and then an algorithm is selected to generate the results.

7.4.8 Key Differences

The main difference between the AHP and ELECTRE is that the AHP is a ranking method and ELECTRE is an outranking method. That is, the former yields a normalized score for each Alternative, whereas the latter will cluster Alternatives of similar utilities into distinct tiers.

A second (and not insignificant) difference is that ELECTRE contains a 'veto threshold' concept as part of its evaluation process. This means that an Alternative can be deemed strictly less valuable than another if it 'fails' at just one Criteria so long as that failure is by a suitably large margin. Conversely, the AHP uses a variety of weighted mean methods and so an extremely poor faring in one criterion is able to be compensated for by consistently high results everywhere else.

7.4.9 Data Capture

For all MCDA techniques, data is captured during the execution phase and analyzed both during the activity and in more detail during the analysis phase. Both of these techniques can be completed using paper-based or electronic means. It is important to note, however, that the size of the AHP questionnaires grow geometrically with respect to the number of Criteria in question and so it is only feasible to have around six or fewer Criteria.

ELECTRE can handle objective and quantitative data as well as subjective, and this can speed up (and increase confidence in) data collection. Whereas, for the AHP, experiment participants are required to subjectively compare every pair of Alternatives against every Criteria.

7.4.10 Analysis

In both cases, the mathematics behind the assessment process is relatively rudimentary and can be completed by dedicated software or even Excel essentially instantaneously once all the data is captured.

7.5 SUMMARY AND OBSERVATIONS

This chapter has sought to illustrate where selected OA methods enhance knowledge generation in analytical wargames. Five methods were presented from three OA categories that are applicable across the five wargame phases. In particular, this chapter has emphasized the value of adapting problem structuring methods to help define the wargaming problem, develop a shared understanding amongst stakeholders and support effective activity design (problem scoping). It has also proposed the benefits of pairing causal modelling and analytical wargaming to capture, represent and explore the knowledge gained and highlighted the importance of characterizing and dimensioning the analytical wargaming problem space through general

morphological analysis (problem understanding). Finally, where there is a need to extend the outcomes of an analytical wargame beyond refining questions and generating hypotheses, the chapter proposed two MCDA methods to help rank or select a preferred option quantitatively (problem refinement).

While there are clear advantages in employing these methods within an analytical wargame, they cost time and effort in preparation and application. Problem scoping methods will require that the analyst conduct a small workshop or structured discussion with the sponsor and stakeholders prior to the wargame. This could prove a burden to the sponsor and stakeholders, however the key challenge in any analysis is to understand the problem and address the right question. Consequently, structured analytical effort applied in problem structuring may prove worth additional analytical effort. Problem Understanding methods will require substantial preparation prior to the wargame and access to participants within what may already be a busy activity schedule. For an activity with limited goals this may be prohibitive. However, where the problem area is representative of a wider class of problems, time spent in developing a deep understanding of the problem will improve the immediate analysis as well as provide longer term analytical benefit. Problem refinement methods may require some input from the participants during the activity to set up the analysis, however they represent key analyses that are fundamental to the core problem.

In all cases, the analyst should determine what is needed from any OA method based on the nature of the problem, associated uncertainties, and the relative importance of the outcomes of the activity to the sponsor.

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Chapter 8 – HOW AND WHEN GAME THEORY CAN BE USED FOR WARGAMING

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CANADA

8.1 INTRODUCTION

8.1.1 Wargaming

Wargaming involves a wide range of decision-making techniques used to explore and understand the military adversarial challenges at relatively low cost. These techniques use logical or physical representations to explore, assess, and refine courses of action, combat interactions, and new command decision making. Wargames can be divided by their purpose into two main categories: Analytical and educational wargames. Analytical wargames specify the subjects of analysis and create way to examine them. They benefit from the creativity of participants and the variability of results to generate new ideas. A planning wargame is a good example of analytical wargames. An educational wargame specifies the training objectives and creates safe-to-fail learning environment to achieve them. A dual purpose (analysis and education) may also arise [1], [2].

Wargames can also be divided into three main formats according to their adjudication style: Matrix game, Kriegsspiel (wargame in German), and seminar game. At each turn of a matrix game, a team provides a specific action or argument for the success of a given activity or plan and the other teams make counter-actions/arguments. At each turn of a Kriegsspiel, a team uses its human judgment to give orders to its troops to meet a given objective. A seminar game is a structured discussion in a small group of experts to analyze new and complex issues and create consensus. These formats are commonly used to raise questions not to provide a single optimal answer [2], [3], [4], [5], [6], [7].

8.1.2 Current Limitations in Wargaming

While wargames have been viewed by NATO and Five Eyes nations as key analytical capabilities for concept development and experimentation [8], they still suffer from several methodological shortcomings that limit their usefulness [9], [10]. The first limitation in the current generation of wargames is their labor intensity. Players are usually organized into teams and their number can go from one to thousands. In addition to players, a typical wargame would need a designer, analysts, a game controller, an adjudicator, a facilitator, and a sponsor representative. The second limitation is their non-replicability. A wargame is generally a single scenario with particular results. It cannot be repeated even under identical physical conditions. Wargaming is applied more as an art than a science and its results are inherently not predictive, not reproducible, and rarely computerized [11], [2].

8.1.3 Game Theory

Game theory is the theory of rational play [12]. It uses mathematical models to understand the strategic interactions between two or more players. Since the ground-breaking work of von Neumann and Morgenstern [13] and Nash [14], [15][1], game theory has been used in many areas including politics, economics, warfare, marketing, international fisheries and pollution control [16], [17]. Many elements of a

[1] John Nash was awarded the 1994 Nobel Prize in Economics for his work on game theory and was honoured with the famous film “A Beautiful Mind” in 2001.

wargame are similar to those of a game theory. A game, for example, is defined in both disciplines as a scenario-based interaction between two or more players with specific goals and a set of rules and constraints. Its outcomes affect, and are affected by, the decisions made by the players [2], [18]. Table 8-1 depicts the four common basic components of a game in the two disciplines [19]:

Table 8-1: Basic Components of a Game in Game Theory and Wargaming.

Elements	Examples
A set of players or decision-makers	Countries, armies, firms
A set of all possible actions or strategies for each player	Attack, defend, no action
A set of payoff functions	Loss, benefit, utility
A set of constraints	Parameters, possible states of natures

There are, however, significant dissimilarities between the two disciplines. Game theory uses mathematical equations and formal charts instead of structured safe-to-fail environments to understand subjects. Game theory can go beyond raising questions. It can provide the optimal answers to derive robust insights. Instead of human actors, players in game theory are notional. These theoretical agents are invented by the analyst to provide an optimized answer set to the research questions within a replicable framework. If we consider game theory in its large sense, any military problem involving a strategic interaction can be analyzed using a game-theoretic model [20], [21].

8.2 LITERATURE REVIEW

The existing literature on the relationship between wargaming and game theory can be divided into two main categories of publications: 1) Game theory in military conflicts and 2) Wargaming as a scientific field.

8.2.1 Game Theory in Military Conflicts

Since the seminal models by Lanchester [22] and Richardson [23], game theory has been recognized as a sound theoretical foundation for modelling arms rivalry. Lanchester used two differential equations to model the mutual attrition of weapons in combat situations between two military forces. Richardson [23] used two differential equations to model the arms race between two opponent nations [24], [25]. The two models have been refined and used in optimization problems to describe the dynamics of many game theoretical models. Sokri [26], for example, used a Lanchester-like combat model to demonstrate that matrix games offer a valid approach to examine NATO peace enforcement operations. Different combinations of wargaming and game theory have also been used in problems involving conflict and cooperation. Billyard et al. [27], for example, used a game in strategic form to examine future alternative scenarios for the Canadian Arctic.

8.2.2 Wargaming as a Scientific Field

This category of literature tries to show how to turn analytical wargaming into science. As shown in Table 8-2, there are at least five reasons why wargaming should adhere to scientific standards [28], [10], [29]. The conceptualization of wargaming would, for example, attract scholars, students, and practitioners from other fields and develop new collaborative projects. This bridge between practitioners and the academic world would provide a plurality of methods and perspectives. The long-term nature of this collaboration can serve to theorize analytical wargaming, train and qualify wargamers, and make wargaming activities less vulnerable to changes in government, funding priorities, and individual preferences.

The first column of Table 8-2 presents five main theoretical challenges that will face the establishment of a scientific field of analytical wargaming [28], [10], [29]. One significant challenge, for example, is the definition of a robust analysis plan that allows for peer-review and validation of game-derived insights. This analysis plan should be able to connect research questions to data collection and data interpretation to produce insights about the real world. It should also integrate wargaming methods with other analytical methods and tools from other fields. A successful wargame in a scientific field of wargaming would be characterized by four main factors:

1) Its validity (based on input from the right sources);
2) Its reliability (its outcome is based on players' strategies);
3) Its replicability (the same procedures will provide similar findings); and
4) Its consistency (coherence between its design, execution, and outcome).

Table 8-2: Theoretical Challenges and Opportunities for Analytical Wargaming.

Challenges	Opportunities
Clearly start with a research question	Conceptualize and theorize wargaming
Define a robust analysis plan	Serve to train and qualify people
Describe the used methodology	Be less vulnerable to changes in government
produce insights about the real world	Connect practitioners to academia
Integrate wargaming with other analytical methods	Make the best use of existing disparate research

8.3 AIM

The objective of this chapter is twofold: 1) To show how game theory can improve player decision making and 2) Demonstrate how it can replicate wargame interactions. The chapter builds a bridge between the two disciplines and support efforts to make analytical wargames more automatic where insights are supported by data.

8.3.1 Structure

The chapter is organized into four sections. Following the introduction, Section 8.4 demonstrates how wargaming can benefit from game theory. In Section 8.5, a formal military example is presented to illustrate the link between the two disciplines. Concluding remarks as well as future research directions are indicated in Section 8.6.

8.4 POTENTIAL SYNERGY BETWEEN WARGAMING AND GAME THEORY

Game theory can translate wargaming interactions into well-defined mathematical equations with clear assumptions and rules. Since game-theoretic models are theoretically grounded and their logic supports their conclusions, they can easily make wargames more automatic. By combining human intuition with the processing power, they can reproduce wargames and reduce cognitive load on players. They can also approximate game-derived insights when analytical solutions are unreachable [30]. As shown in Figure 8-1, the game-theoretic formalism can be adapted to model the wargame decision-making process, replicate its interactions, update its inputs, and validate its conclusions [31]. Game theory can also be used as a probabilistic risk method to portray what would happen to the overall wargame results if the major sources of uncertainty vary. More importantly, game theory can be used as a triangulation method to compare insights from different games and sources.

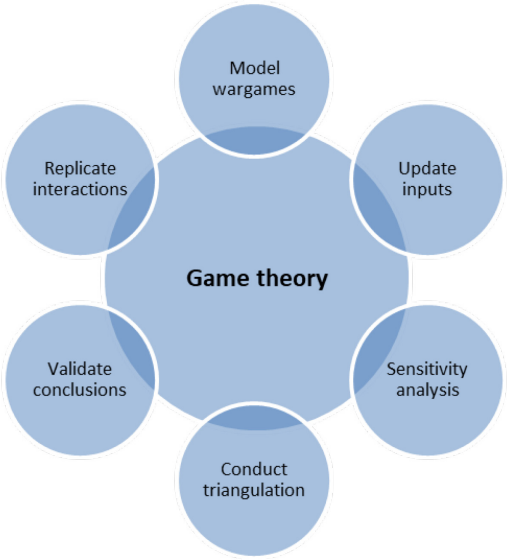

Figure 8-1: How Game Theory Can Support Wargaming.

As shown in Figure 8-2, game theory can ensure the passage from wargaming to computer-based simulation. This synergy between the three disciplines will offer increased opportunities for data capturing, handling. Information technology will allow participants to access data captured in-game, analyze it, read digital reports, forecast events, and make informed decisions. The current COVID-19 pandemic environment has forced many wargame professionals to leave traditional/co-located wargaming approaches and work remotely. This shift that seems to be permanent will act as a forcing function towards an increasing use of digital technologies and computer simulations. In a geographically dispersed game, automation will not only allow participants to interact in a real-time collaborative environment, but also to benefit from in-game qualitative and quantitative analyses. More importantly, digital data captured in-game will be of particular value for the analyst to review the game when performing a post-game analysis. The audio and video recordings, for example, can be of particular value when analyzing the impact of human factors on players' interactions [32], [17]. It is worthwhile to note, however, that game theory should be seen more as an approach of exploring, understanding, and conceptualizing wargames. Wargaming can benefit from its theoretic rigor without being overly reliant upon it [33], [34].

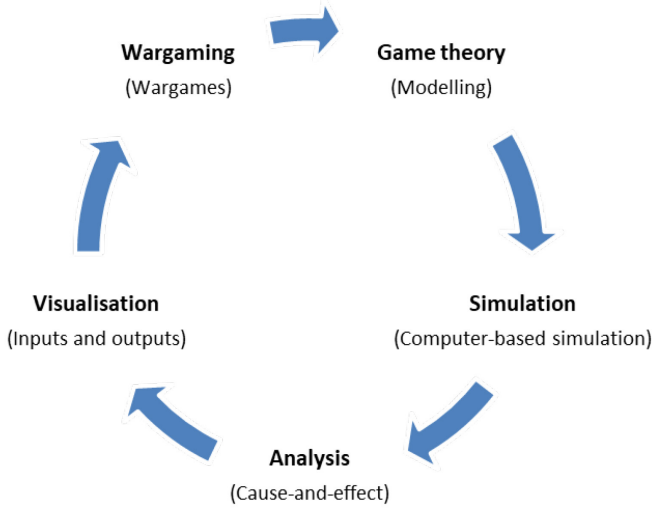

Figure 8-2: Process to Make Wargames More Automatic.

8.5 ILLUSTRATION GAME

A good example to provide an intuitive understanding of the utility of game theory in wargaming is the extensive form.

8.5.1 Formal Representation

The extensive form is a decision tree that describes for each player (e.g., P1 and P2) the available decisions at different points in time (e.g., A, B and C, D). As shown in Figure 8-3, the payoffs are displayed at the end of the corresponding branches (e.g., (P_{1A}, P_{2C})). Because of its structure, the extensive form is particularly suitable to sequential games. If players know exactly all the events that have previously occurred and where they are in the tree, the game is called *of perfect information*. If the players do not perfectly observe the actions of the other players or forget their own actions, information is called *imperfect.* In this case, we use a dashed line uniting two or more nodes to represent this uncertainty. This case is similar to a simultaneous game and corresponds to a strategic form. Backward induction is usually used to solve sequential games in extensive form to find the equilibrium strategies.

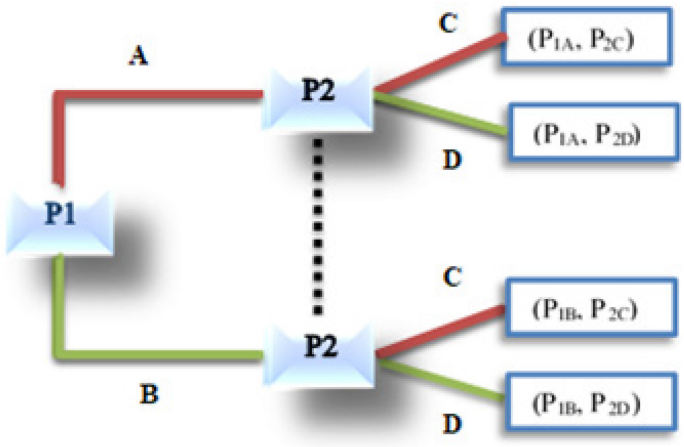

Figure 8-3: Example of Game in Extensive Form.

8.5.2 Military Example of Game in Extensive Form

In this game, we consider a hypothetical postcolonial conflict in a former French colony. The territory T is situated on the west coast of central Africa. It is bordered by State S_1 to the north, State S_2 to the east and south, and Atlantic Ocean to the west. The conflict erupted when State S_1, with a large and well-equipped military, took control of the territory after the French withdrawal. State S_1 invoked the deep ancestral political and cultural connections to justify its property rights over the territory and its natural resources. After the incursion, a guerrilla-style Organization O claimed sovereignty over the territory and called for an independent country. State S_2 is a landlocked country for which the access to the Atlantic Ocean is of vital importance. To help the territory in its self-determination, State S_2 provided Organization O with political and military support. It also hosted the organization base and many of its refugee camps.

In this example, the status quo is a situation where State S_1 periodically faces protesters backed by State S_2 in the streets of the territory T. In the status quo, S_1 receives the benefit b and incurs the cost of repression c_r. Protesters incur the cost of protestation c_p. Since the protesters and Organization O are under the total control

of State S_2, the main players in this conflicting interaction are actually the two opponent states S_1 and S_2. To deal with this conflicting situation, S_1 has two solutions: 1) to escalate at the cost of war, or 2) to bargain with S_2 with a loss in political influence.

- **In the escalation scenario**, S_2 can escalate or concede. If S_2 escalates, S_1 will receive the benefit πb and incur the cost of war w_1, where $\pi \in [0,1]$ is the probability of winning the war. S_2 will receive $(1-\pi)b$ at the cost of war w_2. Alternatively, if S_2 concedes, the status quo will prevail.
- **In the bargaining scenario**, the interaction has two outcomes: First, a credible compromise where S_1 receives the share of benefit xb and S_2 receives $(1-x)b$, where $x \in [0,1]$. In this case, State S_1's initial payoff will be reduced by $(1-x)b$. The value of x will depend on the power asymmetry between the two belligerents. Second, a bargaining failure with the status quo remaining in place.

The decision three in Figure 8-4 is the extensive form of this interaction with complete information. Under conditions of complete information, the players are assumed to know each other's preferences. Under incomplete information, results would be slightly different [35].

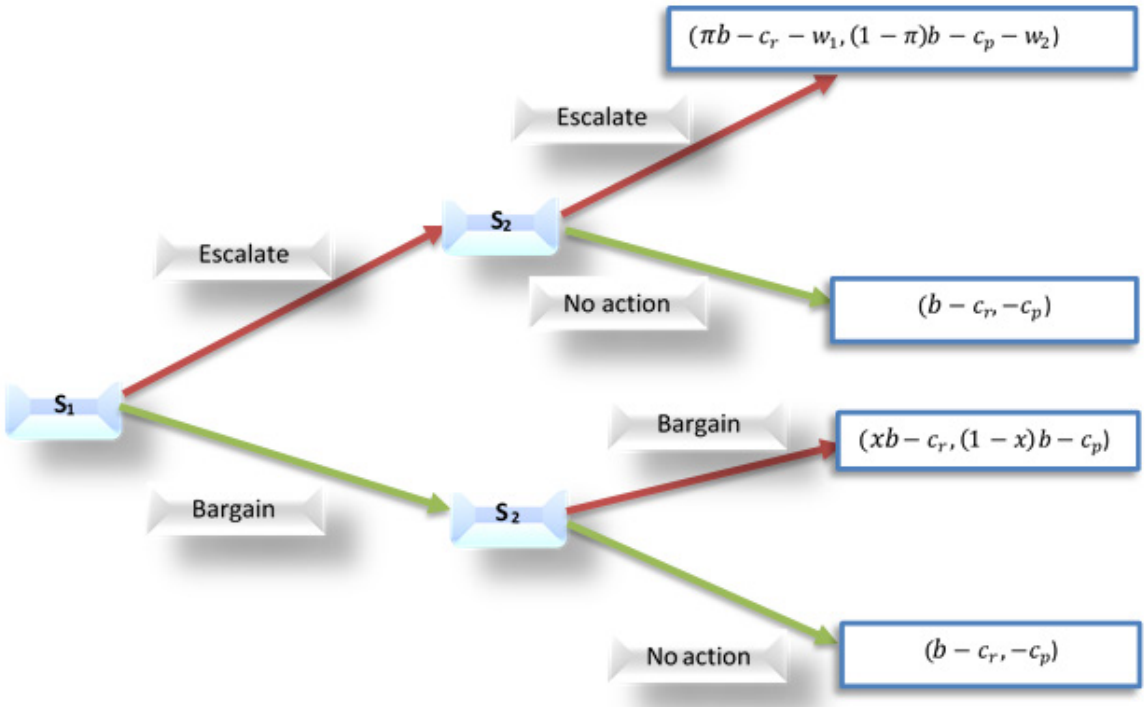

Figure 8-4: Extensive Form of the Game.

The two-component vector in Figure 8-4 describes S_1 and S_2's payoffs for each possible outcome. Propositions 1-4 characterize the parameters that affect the strategic interaction between the two main players. A backward induction approach or, equivalently, subgame perfection will be used to solve this strategic dilemma [36], [37]. In backward induction, the game is solved starting at the last decision node. In this approach, players start by comparing their payoffs at the terminal nodes [38].

Proposition 1. If State S_1escalates, State S_2 will escalate if and only if:

$$1 - \pi > \frac{w_2}{b}. \tag{8-1}$$

Proof. State S_2 will choose to escalate only if the expected payoff of war is greater than the payoff of standing down. That is,

$$(1-\pi)b - c_p - w_2 > -c_p. \tag{8-2}$$

Equation 8-2 is equivalent to:

$$1-\pi > \frac{w_2}{b}. \tag{8-3}$$

Proposition 2. Assuming that $\pi \approx x$, if $1-\pi > \frac{w_2}{b}$, it will be rational for State S_1 to bargain.

Proof. As shown in Proposition 1, when $1-\pi > \frac{w_2}{b}$, State S_2 will escalate if State S_1 escalates.

State S_1 will choose to bargain if:

$$xb - c_r > \pi b - c_r - w_1 \tag{8-4}$$

Assuming that $\pi \approx x$, it is straightforward to show that inequality, Equation 8-4 is equivalent to:

$$w_1 > 0 \tag{8-5}$$

which is always true.

Proposition 3. If State S_1 decides to bargain, State S_2 will decide to bargain and share the benefit drawn from the territory T.

Proof. Observing that:

$$(1-x)b - c_p > -c_p$$

leads to the result.

Proposition 4. If $1-\pi < \frac{w_2}{b}$, it will be rational for State S_1 to escalate.

Proof. On one hand, Proposition 1 shows that if $1-\pi < \frac{w_2}{b}$ and State S_1 decides to escalate, State S_2 will concede instead of escalating and State S_1 will end the game with the payoff of $b - c_r$.

On the other hand, Proposition 2 shows that if State S_1 decides to bargain, State S_2 will decide to bargain and State S_1 will end the game with the payoff of $xb - c_r$.

Since $x \in [0,1]$, it is straightforward to see that $b - c_r > xb - c_r$ which indicates that it would be beneficial for State S_1 to escalate.

By Proposition 1 we have defined the conditions of bilateral escalation. This proposition shows that State S_2 will escalate only if its probability to win the open conflict, $1-\pi$, is greater than the cost-benefit ratio of escalation, $\frac{w_2}{b}$. Assuming equivalence between State S_1's negotiation power, x, and its military power, π, Proposition 2 indicates that when S_2 is willing and ready to escalate, State S_1 will decide to bargain. Proposition 3 shows that State S_2 will prefer bargaining if State S_1 uses diplomatic means.

Proposition 4 shows that if the State S_2 cost-benefit ratio of escalation is higher than its probability to win the war, State S_1will decide to escalate. In this scenario, the strategy combination (Escalate, No action) is the equilibrium of this game. In this outcome, S_1 would succeed in deterring S_2 from escalatory response, and thus keep its position in territory T only to the costs of protests and escalation risks. This will be a stronger political position (higher Benefit) than having to share its influence with S_2 in the Bargaining outcomes. This equilibrium would represent the worst payoff for S_2 as it has no other influence than through protests. Neglecting the cost of escalation without war, the equilibrium is the closest outcome to status quo. This last conclusion indicates that not taking any action seems to be a third playable strategy for S_1.

This game-theoretical model illustrates how game theory can support wargaming. The model is parsimonious but general enough to characterize many crises between neighboring countries and between regimes and protesters. The example shows that wargaming reasoning is well-suited to wargaming. By affecting values to the model parameters, it will be easier for game theorists and wargamers to determine the dominated strategies and remove them from any potential scenario. There are, however, many challenges to this statement that should be acknowledged. These challenges particularly include (but are not limited to):

1) The level of abstraction (i.e., how to balance the game theory abstraction and the wargaming realism);
2) The level of complexity (i.e., real-world interactions are inherently complex and hardly tractable); and
3) The validity of assumptions (e.g., the common knowledge assumption).

This work should be seen as a first move made in a thousand-mile journey towards a real collaboration between the future generations of game theorists and wargamers.

8.6 CONCLUSION

This chapter showed how the game-theoretic formalism can be adjusted to support wargaming. To make wargaming of value to decision making, the chapter suggested combining human and computer cleverness. In this combination, interactions were modelled using game theory and translated into playable strategies. This approach was technically designed to make the game-theoretic models more tractable and wargames more repeatable. By using this approach, wargamers would be able to make informed decisions and reduce their cognitive effort by using stored data, data gathered in-wargame, and digital reports. This would have the advantage of leaving room for collecting and analyzing in-game data and producing more robust post game analysis.

A hypothetical territorial game played between two neighboring regimes was presented to illustrate the potential connection between game theory and wargaming. An extensive form of the conflict game was used to show the set of possible player choices. A backward induction approach was used to determine a rational outcome of the conflict. A formal discussion was carried out to describe the strategic interaction between the two belligerents and identify conditions under which they would escalate, bargain, or concede. Results indicate that *the probability to win the conflict* and *the cost-benefit ratio of escalation* are the key decision-variables in this territorial conflict.

The game-theoretic formalism can be adapted to support various wargaming scenarios. The territorial game, for example, can be refined to deal with other real-world situations such as:

- Interaction with imperfect information;
- Interaction with the presence of a third-party threat;
- Interaction where each player has the possibility to make the first move;

- Interaction with a bounded rationality of player;
- Interaction with other variables in the objective function; and
- Interaction with a regime factor that characterizes each country (e.g., democratic, or nondemocratic, similar, or different economic characteristics).

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Chapter 9 – WARGAMING VS. MODELING AND SIMULATION: ANCIENT ROOTS, MODERN OVERLAP, RECENT FRICTION AND POTENTIAL SYNERGIES

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9.1 INTRODUCTION

Today there exists the potential for Modeling and Simulation (M&S) software to enable wargaming to be more effective, faster than ever before and for wargaming to point M&S software toward its most impactful applications. This has not always been so.

9.1.1 Definitions

Before we begin to follow the path, these techniques took to the present let's make sure all of us understand the same thing by these terms:

- **Model**: A static, proportional representation of reality. A model can be two dimensional, a map, three-dimensional, model aircraft, or an equation, $E = MC^2$.
- **Simulation**: To act on models over time producing outcomes that are proportional to outcomes of similar actions on the entities the models represents; placing model wings into a wind tunnel produces lift and drag proportional to that generated by full-size wings at the same wind speed.
- **Game**: A competition between multiple parties.
- **Wargame**: A competition between multiple parties engaged in, or the threat of, armed conflict.

9.2 ANCIENT ROOTS

We can trace today's wargames, models, and simulations to and before the dawn of civilization. The first physical evidence that early humans had developed the capability of speech are small versions of adult tools and weapons. These first toys, these first models, were likely used by the adults to enable their children simulate, hence learn, the skills they would need as adults. For thousands of years these were the only toys – until the advent of civilization. Abstract wargames have been found during archaeological digs at the sites of the earliest cities. Various abstract wargames were found in civilizations separated by thousands of miles and hundreds of years. That they were found only in the homes of the rulers provide a clue to their use. It is likely that just as models of adult tools were used to simulate tasks performed by hunter gatherers so these abstract wargames were used to teach the children of Kings, Pharaohs and Emperors how to outthink the children of the neighboring states.

9.3 MODERN OVERLAP

The evolution of wargaming from its abstract roots to its modern form was enabled by developments in modeling and simulation. The emergence of modern charts and maps (two dimensional models of the theatres of conflict) provides the playing board for modern wargames. Advances in mathematics, particularly probability, statistics, and mathematical modeling, enabled wargames to simulate real world combat. Much

more recently, the networking of previously stand-alone flight simulators into virtual battlespaces has enabled the creation of virtual wargames. Yet despite the debt wargaming owes to modeling and simulation there has been friction between the two fields.

9.3.1 Friction

Post-World War II modeling and simulation increasingly transitioned from the physical to computer code. Where physical model aircraft had been placed in physical wind tunnels to simulate the lift and drag of possible future aircraft increasingly code run on computers were used. This evolution, in time, produced better data, faster.

However, when attempts were made to apply computerized modeling and simulation to wargaming two types of problems occurred.

The first problems as computer M&S over promising and under delivering due to the immature state of the art. Simply put, early computers were big, expensive, and unreliable. Participants in wargames typically only had a limited, fixed amount of time to dedicate to the wargame. There were cases when the software would not run until after all participants had to return to their regular duties. Also, early computer interfaces were so, "user hostile" that a manual wargame could be executed while the computerized one was still being input. While these problems of cost, dependability and time needed to interface got smaller over the decades (as have computers) they have yet to go away completely.

The second problem is more enduring. In war each echelon makes decisions that are faster and more detailed than the decisions made by the echelon above them. For decades, no modeling and simulation software used to adjudicate moves on wargames included any provision for the initiative of lower headquarters, many still do not. This was not always a problem. If the decision was ever made to execute the Single Integrated Operations Plan (SIOP) there would have been little time or inclination for subordinates adjusting the plan's execution. However, for conventional theatre campaigns, such adjustments are doctrinal and would have been widespread. Not depicting those subordinate headquarters could lead to absurd results, as a computerized wargame executed in Asia in the 1990's illustrated. The computer software continued to fly sortied against enemy forces for days after the enemy had withdrawn. While the introduction of Artificial Intelligence (AI) into an increasing number of wargame support programs is shrinking this problem also, the current state of the art of AI is insufficient to fully solve this limitation. Specifically, AI is better at making the common-sense decisions of subordinated (example, a pilot returning to base before running out of fuel) they have been less successful in replicating decisions made by a spectrum of adversaries under a range of circumstances (example, a UK AI program that demonstrated a high correlation in anticipating tactical decisions by Soviet ground forces demonstrated no correlation at all when used to anticipate ground tactics by the Taliban).

9.4 TOWARD POTENTIAL SYNERGIES

Even given the current state of the art there is much that can be done to enable wargaming as well as modeling and simulation to synergize each other. As a start folks who work in Modeling and Simulation (M&S) and those who work in wargaming need to learn about the other field. It is not surprising that they do not know as M&S and especially wargaming are almost guild disciples, with practitioners learning their craft from colleagues who are more experienced in the field. Instead of cursing the darkness, let's shed a little light now.

Modeling and Simulation (M&S) 101: Modeling and simulation should be dear to the hearts of all aviators, given its role in the invention and progress of flight. In 1901 Wilber Wright predicted it would take an additional 50 years to perfect the airplane. Why was Wilber so wrong? Up to that time the Wrights would improve their aircraft, take it from Dayton to Kitty Hawk, test it, and then bring it back to Dayton for further

refinement. Each cycle of improvement would take a year. What Wilber was really saying was that the aircraft was fifty cycles of improvement away from a practical device. The Brothers shortened the time of each cycle by building both scale models of their winds and other components as well as a wind tunnel. The Wrights then simulated airflow over the wings, noting changes in drag and lift. Their wind tunnel did not perfectly predict the qualities of their full-size aircraft, but it was close enough for them to complete fifty cycles of improvements in just two years, achieving their first flight in 1903.

There are few physical wind tunnels today. Most work is done with computer models and computer simulation. The effect of this change is to further increase the speed of development. For example, while the Wrights physical wind tunnel allowed them to compress their development time from decades to years, so the computer modeling of an advanced magnetron, being tested through simulation, cut the development time from many months to a few weeks.

Wargaming 101: In the early 1800s Prussia invented modern wargames, expanding their use from royal children to the royal army. Following Prussia's surprising victories during the German wars of unification, wargaming spread to militaries would-wide – including the United States. Wargaming helped the Navy develop their carrier capabilities and Germany develop the Blitzkrieg. Wargaming has been part of formal U.S. defence planning since the Eisenhower administration, playing a key role in the planning for both Desert Storm and Operation Iraqi Freedom.

While the details of wargaming can be complex, in principle the process is simple: given a starting condition (scenario) the sides in an armed conflict plan their next actions, a determination is made of the net effect of those actions, all sides are told what they would actually know of the new conditions, and the process is repeated. Wargames can be used to support decision making within a specific decision cycle, or to develop people (tacticians and strategists), processes, or material concepts.

There have been some individuals in the wargaming and M&S communities who have worked together for decades. The proceedings for a 1961 conference on defence wargaming suggested criteria to determine when to computerize elements of the adjudication of the outcome of moves and when to perform the calculations manually. (Adjudication is the term used by the wargaming community for the process of determining the net outcome of decisions made by both sides.) Political/Military (POL/MIL) wargames conducted at the National level have often identified the need for further investigation through M&S and wargaming. The Military Operations Research Society's annual Symposium includes working groups in both wargaming and M&S, as well as joint presentations.

Still, greater cooperation between the fields can enhance the effectiveness of both, ultimately benefiting our decision makers and our nations (Figure 9-1). Some cross-discipline initiatives are occurring today. For example, wargames use performance data to guide their estimation of outcomes. There is no performance data on systems that do not yet exist. Just as the Wrights were able to use their wind tunnel to anticipate the impact of changes to their wings, so M&S can calculate the likely effectiveness of future systems, providing a basis for the wargamer's adjudication. Similarly, M&S depend on their sponsors to identify their highest payoff M&S tasks. Wargaming can provide an initial indication of the needs and opportunities M&S can further explore. (For example, wargames can help identify which anticipated adversary capabilities may be easily counter by adapting tactics and which need in-depth analysis, including M&S.)

Further progress is likely to be gradual. We need to ensure our M&S professionals are taught about wargaming and our wargamers are taught about M&S. As little league Jointness encouraged services to learn each other's strength, so, in the short term we need to consider if wargaming should be included in every M&S project and if M&S should be included in every wargame endeavor. The answer in both cases will often be "no" but if we don't ask the question, we will never identify those cases when the answer is resoundingly "yes." Finally, when the relationship of wargaming and M&S reaches maturity, we will see benefits we can only guess at today.

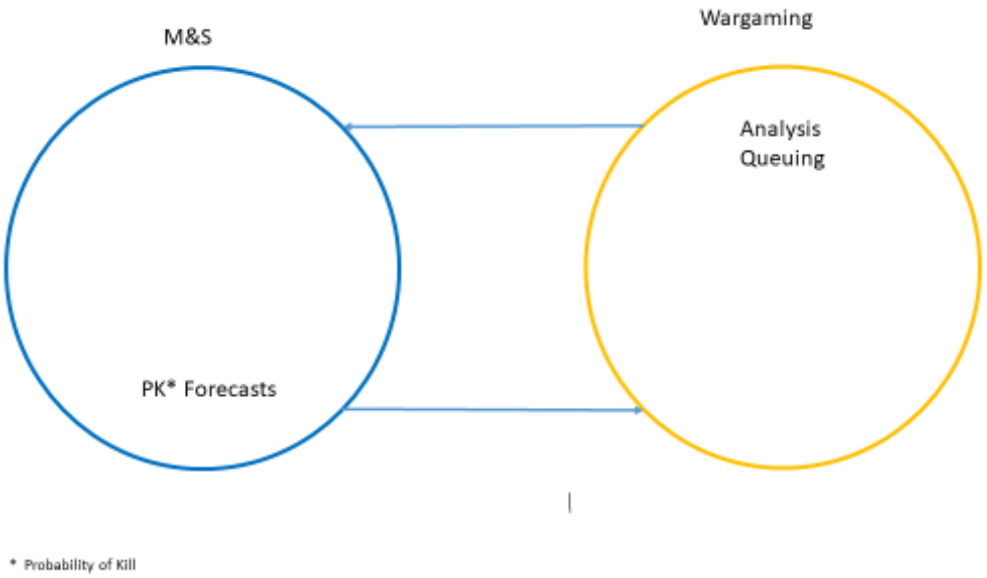

Figure 9-1: Feedback Between Wargaming and Modelling and Simulation.

9.5 BENEFITS

Those benefits may be significant. While DC based POL/MIL wargames attract exceptionally qualified participants, junior force members who would like to use wargaming to explore their innovative ideas have not been able to secure participants. M&S artificial intelligence routes could allow us to push wargaming down to the level where the innovative new ideas originate. The young engineer who first envisions an innovative application of emerging technology and the junior operator that envisions a potentially disruptive tactic do not have the resources to assemble the teams of expert participants required for a traditional wargame, but they can make the time to employ M&S software with AI standing in for many of the wargame's participants. As we return to an era of major power competition exploring long-term competition is vital. M&S can enable wargames to both execute faster and facilitate distributed participation making wargames deeper into conflicts feasible. Finally, M&S with embedded friendly and opposition artificial intelligence could allow conflicts to be run hundreds of times, allowing the relative likelihood of plausible outcomes to emerge. This was tried before with traditional M&S, but without AI unrealistic actions would occur; friendly forces would continue to attach where the enemy used to be, opposing forces could continue to fight long after they would have surrendered. Initially, placing decision makers "in the loop" was tried, but the time needed to make decisions and interface with the software sometimes resulted in such wargames running slower than they would without M&S. Improvements in AI will allow us to limit the use of humans to those decisions beyond the current state of the AI art. This will NOT allow us to run executions at fully machine speeds but it will allow us to both identify which operations are more risky (good and bad outcomes with similar likelihoods) and to identify those occurrences that contribute to negative outcomes (that we would then work to make less likely) and those occurrences that contribute to positive outcomes (that we would then work to make more likely).

Just as each service is unique; it is clear from the above that wargaming as well as modelling and simulation are unique. Just as there are some missions that are best accomplished by one service there are, and always will be, some tasks best accomplished by one method. Still, as both communities gain a better appreciation of the others capability direct collaboration (M&S integrated into wargames) and indirect support will become more common – to the benefit of both fields, and more importantly, to the benefit of our common defence (Figure 9-2).

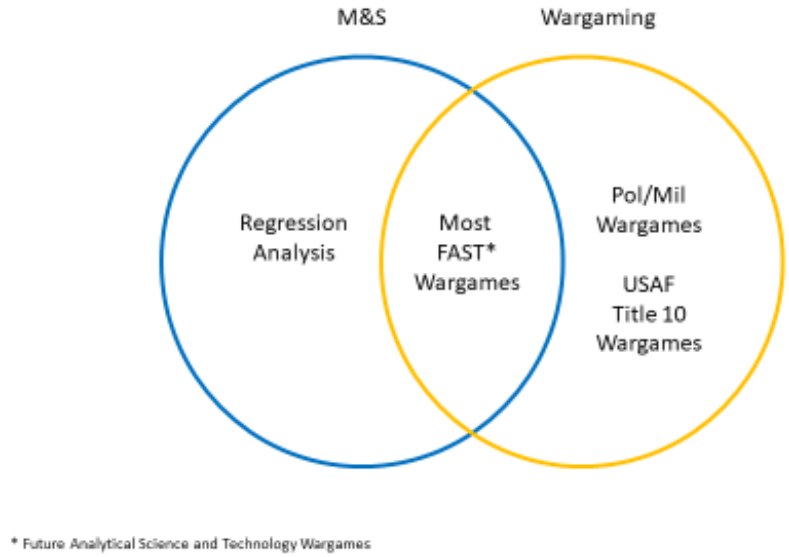

Figure 9-2: Intersection Between Wargaming and Modelling and Simulation.

9.6 CONCLUSION

Wargaming and M&S both have long histories of contributing to the national defence. Neither provide all the answers to our efforts to innovate faster and with greater impact then our adversaries. Still, functioning jointly they can provide insights that are both more valuable and faster than either can alone. Wargaming and M&S each contributed our Alliance winning the Cold War. Jointly, they can help us avoid the next war if we can, or win it if we must.

Part IV – DISTRIBUTED WARGAMING

IV.1 DISTRIBUTED WARGAMING

Casting an eye toward online commercial entertainment games, wargamers have been experimenting with forms of distributed gaming for a number of years. The COVID pandemic generated new interest in ways to wargame without meeting in person. The papers in this part of the report provide a foundation for exploring the opportunities and challenges associated with distributed analytical wargaming.

The primary characteristic of distributed wargaming is that participants are not co-located and they rely on virtual communication channels. Players and game controllers can be geographically isolated or clustered, and they can play at the same time (synchronously) or at intervals (asynchronously). Distributed communication channels include postal mail, email, online channels including computer-based software used on closed or open networks or mobile applications, virtual conferencing, and in-person meetings. Other aspects of design are similar for both distributed and in-person wargaming. For example, distributed and in-person wargame formats include mass-produced "games in a box" like "Battleship," custom-designed games, and hybrids that customize a mass-produced product.

While it is tempting to assume that distributed wargaming is less expensive and more effective than in-person wargaming, the objectives of commercial and military wargaming are quite different. Commercial producers aim to make a profit; they seek ways to make their games entertaining and addictive. They count on players trying to game the game and once hooked, returning to buy new versions. By contrast, military producers aim to educate, provide essential experience in decision making and command, and build knowledge about complex warfighting issues. Moreover, while the cost structures of in-person and distributed wargaming differ, there is insufficient research on these differences to support assumptions about relative costs and benefits.

Many wargamers designed and executed distributed wargamers during the COVID pandemic – often for the first time. Leveraging this natural experiment, Hoehl and Price surveyed professional wargamers and enthusiasts in operations research, academia, and the military about their experience (Chapter 10). Taking a slightly different tack, Marston (Chapter 11) leverages his own expertise as a professional military wargamer. He identifies desirable characteristics of wargames and then estimates the potential impacts – positive and negative – of executing a wargame in a distributed environment.

Analytical wargames are fundamentally quasi-experiments in decision making that help us understand why people make the choices they make, what constraints they face in particular contexts, and what opportunities they see to create new approaches to a particular problem set. As Lantto points out in Chapter 2 in Part I, analytical wargaming is one way to research military assumptions embedded in concepts and plans. And the research standards articulated in Bastings and Collins paper in Chapter 3, require careful control over anything that could pose a threat to validity.

Taken together, the papers in Part III identify a number of control and player experience challenges for analytical wargaming in distributed environments. Geographic separation inhibits control over who is participating, what players are doing, how they are playing the game, what references (if any) they are using to inform decision making, the suitability of player moves for adjudication, player engagement levels, and so on. While better designed for control, as Ruestchmann suggests in Part II, Chapter 5, distributed online games with rigid adjudication pose the risk that players will simply try to out-game the adjudication model for the sake of a short-term dopamine rush or other rewards, rather than cognitively engage to address a problem set. Similarly, reliability issues, the absence of physical cues, and opportunities to hide or deceive in virtual communications limit the ability to control game experience and engagement, understand why players are making the choices they make, and rigorously extract insights and observations.

Academic success using online games to gather empirical evidence to support theories about strategic behavior such as Charles Holt's Veconlab show promise for creating distributed analytical wargaming.[1] However, considerable innovation and investment is required to develop a methodology for designing and executing rigorous, distributed wargames at tactical, operational, and strategic warfare levels.

[1] The University of Virginia hosts Veconlab, provides the opportunity for researchers to conduct distributed, online experiments to investigate economic and other strategic theories, and for educators to demonstrate decision making. See, for example http://veconlab.econ.virginia.edu/games.php. For information about the founder, Professor Charles Holt see https://economics.virginia.edu/people/profile/cah2k. Note that Dr. Holt does all the programming required to support this site on a volunteer rather than paid basis.

Chapter 10 – REFLECTIONS ON DISTRIBUTED WARGAMING FROM RECENT PANDEMIC FORCED EXPERIENCES

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10.1 INTRODUCTION

The COVID-19 pandemic affected all walks of life, including the conduct of wargames in Defence. Although many wargames for tactical forces training have long been distributed, in recent years the analytical community had been relying almost exclusively on in-person games. Working from home and social distancing requirements were a watershed and organizations had to rethink how they conduct their work. Running games in a distributed environment quickly became a hot topic mid-way through the SAS-139 project.

The people in the analytical and education wargaming communities that serve Defence were affected by the pandemic in different ways. Working from home became the norm for most, although some, especially in Headquarters (HQs), moved to shifts with social distancing. Many planned games were cancelled or postponed; others underwent quick adaptations to make them playable under the new conditions – with both successes and failures. Due to forced working from home, or out of necessity, many in the community explored, tested, and innovated within the distributed wargaming space. However, despite all the different impacts, everyone had an opportunity to learn and reflect.

This chapter presents the collected reflections from Defence wargamers across multiple countries, organizations, and disciplines. Information was gathered from structured interviews with Subject Matter Experts (SMEs), supplemented by related papers and articles. SMEs were drawn from multiple disciplines, including Operations Research, Academia, and the Military, with roles ranging from full-time gamers through to enthusiastic advocates. They generously shared their experiences with developing, testing, and conducting distributed games, including comparisons to in-person games.

This chapter is a collection of those reflections in relation to distributed gaming, focused on analytic games for defence purposes. It does not pretend to provide a definitive guide or even best practices; it does capture a broad sample of reflections related to undertaking distributed games from very real and recent experiences.

10.1.1 Structure of the Chapter

The reflections have been grouped into common areas of discussion, covering; Game Design and Characteristics, Facilitation and Gameplay, Enabling Tools and Technology, Resources (e.g., Time and Cost), and Collaboration and Participation. In areas, Peter Pellegrino's thinking on a Distributed Wargaming Taxonomy has been used to frame discussions. Throughout the paper, nuggets of real-world experiences are interspersed to illuminate specific areas.

The reflections have deliberately not been sanitized to the point of only keeping those where everyone agrees but expose situations both where SMEs have had common experiences as well as where they differ. Also captured within the reflections are areas where there may be permanent change due to a preference for the new way of doing things over the old.

10.2 GAME DESIGN AND CHARACTERISTICS

This section contains reflections on game design and the characteristics that influence its ability to run in a distributed manner. Those interviewed had a broad range of experience in design of distributed games, ranging from many years to none before the pandemic. Examples were given of existing face-to-face games that had been modified, and of games that had been designed from the beginning to be played distributed, plus hybrids in-between. Many interviewees had embraced the opportunity to try new ways of wargaming, and re-appraised what aspects of each game were important. Pragmatism in terms of resource and technology constraints was a significant consideration for many.

Reflection 1: Geographic and Time Separation help characterize distributed games. The interviewees described a range of different game characteristics that influenced the distributed nature of their games. From individuals working alone at home, to small teams co-located at their workplace collaborating on each game move. Some of these took place in real-time while others took place over many weeks. Pete Pellegrino [1] has encapsulated these different approaches in his taxonomy, Geographic Separation, and Time Separation. They are described in Figure 10-1 and Figure 10-2.

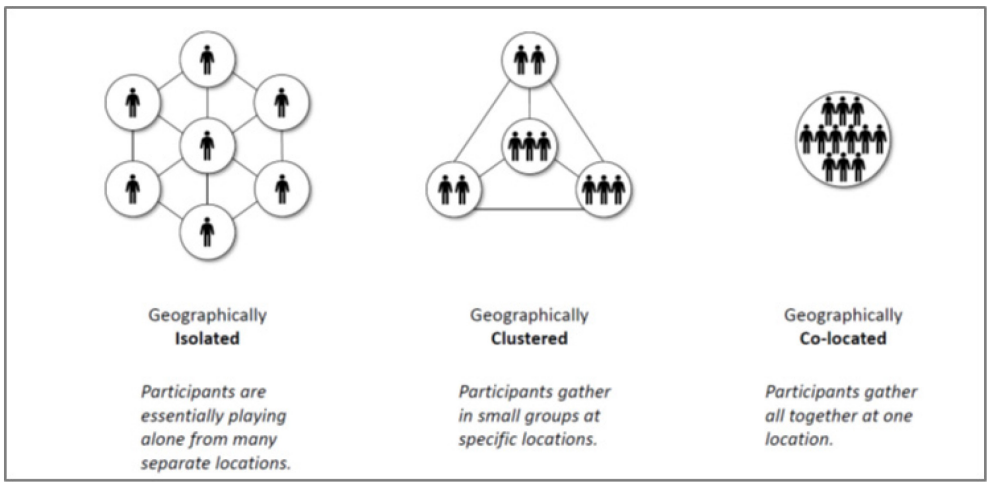

Figure 10-1: Geographic Separation Characteristic.

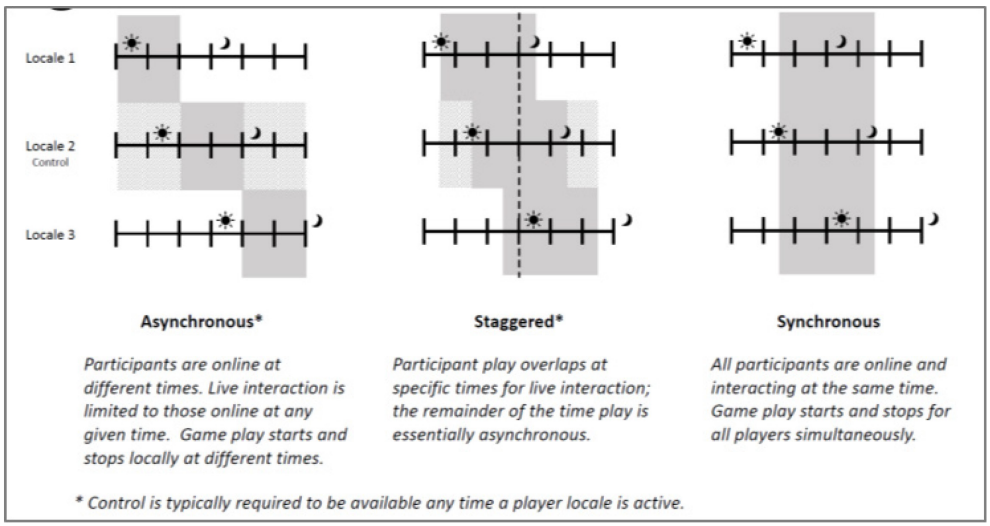

Figure 10-2: Time Separation Characterization.

Reflection 2. There are characteristics of games that make them more or less appropriate to distribute. From the combined experiences of interviewees, the following attributes make a game type [2] more likely to be successful in a distributed environment:

- **Seminar:** as primarily a discussion based game, Seminar games run in a distributed fashion avoid many of the issues from use of complex rules, and map boards encountered by other types of game.
- **Course of action:** these are more successful in a distributed environment when at the tactical force-on-force level where the concern is on what the Force does – a much simpler game. At the strategic and operational level, where the decision-making process is important, it becomes difficult to get as much value out of the debate.
- **Matrix:** these can be undertaken as distributed games, although taking significantly longer, and are hampered by a loss of the human interaction aspects of the game (See discussion under Facilitation and Gameplay.)
- **Kriegspiel:** For example, with hex map, playing pieces and counters is more difficult to conduct in a distributed manner. In particular, the size of the visualization becomes important – detailed enough for the game, but still viable on different platforms, as well as the level of facilitation needed. (See discussion under Facilitation and Gameplay.)

> ***Example: Navy 360 – A distributed wargame by design [3]***
>
> Navy 360 is a series of US Navy Wargames designed to examine ways to implement emerging Navy concepts while operating the fleet as it is today. It uses a distributed game design, digitally enabled (play-by-mail inspired), with an emphasis on thought. Players participate in small groups from their own commands. It is run on existing classified networks using collaboration technology to enable in-briefs, discussions, and debriefs with clusters of participants around the globe. It has been running since 2012 and continued during the recent pandemic, albeit with some impact on game time due to work force restrictions in the Player and Adjudication Teams.

Reflection 3: Game classification needs to be decided early, informed by appetite for risk. Classification requirements have a significant knock-on impact on many aspects of distributed games and their design, including locations, networks, tools, participation. In general, a mature classified distributed gaming capability requires significant time and investment, an unlimited distributed game using free commercial software played at home on personal devices can be much faster and cheaper to develop. This fast and cheap option was often the entry-level point for experimentation and development of distributed games during recent times.

The classification for the game was a significant issue in the Defence analytical community, in part influenced by the respective community's appetite for risk. Greater risk was taken during initial development as new solutions were trialed and tested. However, there may remain a minimum threshold for declassification, particularly for games that support analysis, as even unclassified games can quickly become classified in a given context.

> ***Example: Preparation versus time-of-need***
>
> Two related experiences on streaming games highlight issues around pre-planning for distribution and the appetite for risk with defence games and their level of classification:
>
> One interviewee described how they had cameras set-up to stream a game room – to allow sight of a game board and enable some level of distributed play. The cameras were set-up some time ago and streamed through the existing facilities VTC set-up within their Defence network.

One interviewee described investigating short-term measures to change an existing planned game to be distributed, using a commercial-off-the-shelf game and webcams. Although technically achievable, the game was ultimately cancelled due to the risk appetite for streaming over the internet, as a secure approach using government networks was deemed essential.

Reflection 4: Keep it simple. There was consensus that the more complex the game, the harder it is to run remotely. Interviewees described experiences of having to simplify games to enable play in a distributed manner, or even selecting games with simpler rule sets or less complex interfaces. Example were also given of simplifying the feedback mechanism for players, with the use of indicators rather than maps in crisis gaming.

Reflection 5: Large group dynamics do not function as well. Large groups or plenaries are not efficient when working online from both a technical and practical perspective. One interviewee noted that "shouting works best when you're [physically] all in the same room!" It was observed that the reflection process was more successful when it took place in syndicates rather than in plenary as it gave more people the opportunity to contribute.

Reflection 6: Carefully consider team size. When playing team-based games, the general rule of thumb appears to be small groups of 2 to 3 people per 'virtual' room – less than in equivalent face-to-face gaming. However, dedicated facilitators can affect this, whether participants know each other, and if participants have played the game before.

Reflection 7: Education and training is a more forgiving arena. Within education and training, there is a greater emphasis on process and decision making. As a result, when things go wrong, especially from a technical perspective, these can often be transformed into learning opportunities. This is not always preferable or possible when conducting analytical or research gaming.

Example: Teaching arena is more forgiving with distribution mishaps (Tom Mouat, UK Defence Academy)

A distributed game was being used in support of an academic course, with Students connecting using a variety of hardware. After the game, the teacher asked them how they found it. One student said that they were using a tablet and could not get the game to work properly so just watched. A second student using a tablet said they worked out they could either move or shoot, but not both at the same time. Noting the game had no ammunition limitations, they found a suitable location at one end of a corridor and spent the entire game shooting anything that came down it. The student had demonstrated an ability to adapt to circumstances – a win in the academic world, but perhaps not if the game were played for analytical purposes.

Reflection 8: Distribution can make games more realistic. Interviewees discussed a small number of games that had been played in a distributed, or partially distributed, manner for years. These included the Navy 360 example, as well as a game in an academic setting to teach students skills about juggling issues – and that the one in the wargame may not be the only issue demanding their attention. In both these instances, distribution added an element of realism to the game. There are already growing elements of decision making with regard to military operations that take place online and at a distance, distributed games may have a growing place going forward if there is a push for increasing realism in specific areas.

10.3 FACILITATION AND GAMEPLAY

This section covers a variety of different requirements and pressures for facilitation, and the dynamics of gameplay in a distributed environment. The most common observation was the loss of visual and social cues for facilitation, making for a different facilitation experience.

Reflection 9: Visual and social cues are unavailable for facilitators of distributed games. While video communication is designed as a direct replacement for this, it is more opaque than traditional face-to-face communication and, in some cases, may not be practical. Without this feedback from participants, facilitators are discovering new ways to gauge interest, understanding, and where and when to interject. This was a sharp learning curve for many facilitators.

Reflection 10: Stronger facilitation is needed for distributed gaming. A number of interviewees felt that distributed gaming required additional, and/or stronger facilitation. Strong and authoritative facilitation can help speed up the games. While skilled facilitators were needed in more locations – often per Team – making it harder to get away with a central authority. The result in an increased need for rehearsals and training.

Reflection 11: Distributed gaming can make games more robust. Some of the interviewees highlighted greater access to information, because of being in front of a computer or in a non-classified environment, as a positive. It was felt that this made the games faster and more dynamic, as players are not limited to the information provided to them by the facilitators. Further, there was the opportunity to lean more heavily on facts or other external information that is not traditionally available, helping to make the games more robust.

> ***Utrecht Institute for Crisis and Conflict Simulation (UICCS) [4]***
>
> When Utrecht University went online due to the pandemic, nearly 30 students reorganized themselves into an online inter-disciplinary think tank, the UICCS. They subsequently created and played various wargames on the impact of (governments' responses to) the pandemic and the Chinese Belt and Road Initiative in East and South Asia, publishing their findings. The format of matrix games was specifically chosen as it converted to online use. Around 100 students from different classes and departments were eventually involved or otherwise participated in this experiment, playing games, collecting, and analyzing data, forecasting events, and writing reports; with a desire to continue on this path even after the course came to an end.

Refection 12: Control over the game environment is reduced for distributed games. Distribution brings challenges for facilitators to control the environment and for players to remain fully engaged. When players are isolated, especially at home, there are distractions that are removed in a controlled face-to-face game. Games using small-distributed groups, often in their own work location, have similar issues – surrounded by other work tasks and colleagues, often with no dedicated game area.

Reflection 13: Keeping Players engaged needs additional thought. Interviewees highlighted an increased risk of players becoming disengaged, reasons included less ability to interact with the game (no board or map directly in front), less control over the environment (home and office distractions), as well as player fatigue when operating from behind a computer. A variety of mechanisms had been tried to overcome these issues; easy use of Collaborative workspaces for example interactive white boarding, having the ability for player to move their own counters on a virtual map, game scheduling with more breaks and/or shorter games.

Reflection 14: Distributed gaming offers benefits in recording game moves and outputs. The necessity to use tools to enable the game results in an often more complete game record. This enables easier post-game exploitation and analysis, even permitting additional iterations to be run offline. After-action reviews are also

typically easier, depending on the type of game, with one interviewee observing that review material could automatically be created by taking snapshots at the end of each turn. There may also be archived video, voice and chat logs that can be exploited.

Reflection 15: Opportunity for different personality types to come to the fore. Some, but not all, of the interviewees thought there was a difference in social dynamics when games are conducted remotely. Remote play may offer an opportunity for a broader range of personality types to more freely engage. It was noted, "Everybody's icon is the same."

10.4 ENABLING TOOLS AND TECHNOLOGY

Interviewees were asked about the tools they used to facilitate distributed gaming, their criteria for selecting them, their experiences and what they had learned. Their responses told of a pragmatic approach often leading them to develop or learn new skills to address the shortcomings of what was already available. Free-to-use solutions were frequently the starting point for many of those interviewed.

It was clear that there has been a "digital logistics hurdle" with implementing distributed gaming; however, it is unclear how this very recent hurdle may have colored people's perceptions.

Figure 10-3 is from Pete Pellegrino thinking about a taxonomy for distributed wargames [1], and describes the three main aspects that need to be considered for distributed Game; 1) Tools for basic collaboration; 2) Tools to support the productivity of the game; and 3) Specific dedicated tools for Gaming.

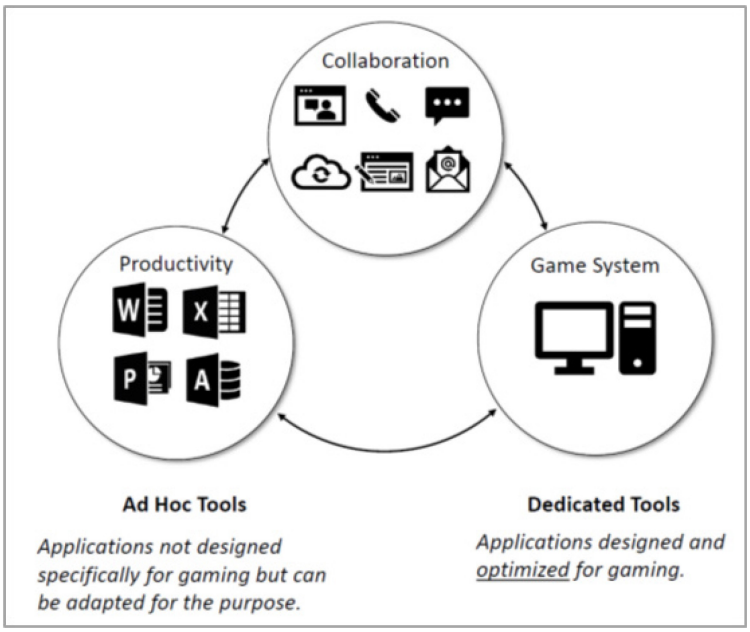

Figure 10-3: Types of Game Tools Required for Distributed Games.

Reflection 16: There are many tools that can support distributed gaming; acceptability is driven by the type of game, as well as the hardware and networks that will be available. Over 20 different tools were mentioned during the interviews. Choice was impacted by the hardware and networks that were to be used – with most experimenting with free tools over the internet that could be utilized on multiple devices. However, this was mostly a result of the forced pandemic situation rather than a consideration of the best tools to enable distributed gaming going forward.

Distributed wargaming going forward in Canada – EDGE (Ben Taylor, Murray Dixson, CORA)

In Canada, even before the pandemic there was a desire to do more wargaming, but as a direct result of experiences/tests/investigations and games during the pandemic, they are now developing EDGE, the "Experimental Distributed Gaming Ecosystem." EDGE uses videoconferencing and other real-time tools to simulate an in-person experience suitable for various types of serious gaming. EDGE enables them to maintain the benefits of distributed gaming they discovered, namely 1) Ability to run a game from anywhere with anyone; and 2) Investigate different things with different people. Moving forward with a distributed gaming capability will help in overcoming the vast geographical distances that can hamper participation in-person in Canada.

Reflection 17: Minimize the technical burden. Everyone discussed the need to be mindful of the technical burden on players. During the pandemic, those forced to move hastily to distributed games, aimed to achieve the lowest possible technological denominator to reduce the barrier for participation. This included minimizing the need to install software and create user accounts, use of pre-configured accounts to minimize upfront problems and provide consistency (such as pre-assigned roles, screen layout and user settings), and a preference for use of free tools. Use of personal devices opens up a vast array of different potential configurations, from hardware specifications, to interface restrictions, to bandwidth constraints, to the technical expertise of the players. These combine to increase the technical burden on not only the players but also those hosting and facilitating the game as well.

AFTERSHOCK, now available for distributed gaming (Rex Brynen, McGill University)

AFTERSHOCK is a popular Humanitarian Crisis Game board game, designed for in-person play with 2 – 4 players. Since the pandemic, versions have been developed by enthusiasts to enable distributed play, one on TableTop Simulator, and another on VASSAL.

Reflection 18: Free tools are beneficial for development, but can become limiting. In general, those interviewed initially used free tools to explore experiment and develop distributed gaming solutions. They allowed rapid prototyping of solutions, were typically user-friendly, and are widely available to players on a range of platforms. However, these tools quickly became too limiting, often requiring upgrades to offer the full functionality required or necessitating alternative workarounds.

Reflection 19: Use of approved networks and infrastructure. If games are to be played over government networks, for example due to classification requirements, it was preferable to stick to already approved solutions. This bypasses the need for the often troublesome and time-consuming approval process. For similar reasons existing infrastructure should also be exploited, i.e., approved video teleconference facilities. In the longer-term, having a (deployable) classified network infrastructure would overcome many of these restrictions but it takes investments in time and money, as well as buy-in from stakeholder communities.

Reflection 20: Test, test, and test again. Distribution, often enabled by multiple technologies, increased the importance of testing and rehearsals. Testing helps to identify difficulties and deficiencies that are introduced by the addition of an extra layer of complexity. Using rehearsals to ensure that facilitators and technical staff are properly prepared was highlighted as important given the change in game dynamics.

Example: Importance of Testing Tools (Anja Van Der Hulst, TNO)

When Utrecht A governmental-level game was planned for Departments of Defence, Justice, and Foreign Affairs. Microsoft Teams was chosen as the primary tool as all participants had and used it. However, despite a lot of testing, the different configurations proved an insurmountable barrier to connectivity. Defence had both Secure and Public instances of the tool – the public instance did not work and the secure version was too limited to be useful. The game had to be cancelled after 6 months of preparation. Even when the technology and infrastructure appear to exist there are often unseen restrictions, this is especially true for military participants/networks.

Reflection 21: Dedicated technical support streamlines the experience for everyone. When a player or team are struggling due to issues with technology, it can be useful to have a dedicated back channel to assist without disturbing the whole game. In particular, having dedicated technical support decreases the burden on the facilitator who can concentrate on running the game, although this solution may not be viable for practitioners with limited resources.

10.5 RESOURCES (E.G., TIME AND COST)

This section reflects on the impact on resources – money and time – when planning, preparing for, and conducting distributed games. There was a consensus of a significant impact on time; however, there is insufficient information to make a judgement on costs.

Reflection 22: Playing distributed games takes longer…probably. There was near consensus that distributed gaming takes longer, a rule of thumb was twice as long as equivalent face-to-face games when participants are geographically isolated. There were a range of speculation on the reasons for this including: virtual communication taking longer than in-person conversations, less ability to multi-task, additional time taken swapping between virtual communication rooms.

Specific impacts of the pandemic also increased the time required for a well-established distributed US Navy wargame, Navy 360. The game is played 'by email,' with distributed teams – or clusters – from their home stations. These clusters were constrained by social distancing influencing the time taken for both players to prepare their turns and for the adjudication team; an extra turn was played due to the slower pace and the pandemic situation. Overall, the game time increased by 50% [3].

However, some of those interviewed questioned whether the extra time could be explained by a lack of familiarity with the processes, tools and/or games themselves. One interviewee describing this effect as a "cultural lag," and noted that after the initial learning curve students, more familiar with operating in the virtual environment, noticed no slowing of games due to distribution.

Reflection 23: Be mindful of where the costs lie. Initial thoughts were that distributed gaming would be a money-saver compared to face-to-face gaming, principally because of reduced travel and hosting costs. However, other factors are also in play; 1) Additional effort spent upfront preparing the games for distributed play; 2) Additional facilitators may be required; 3) Costs for technical support; 4) The length of game is likely to increase; and 5) Cost of software licenses.[2] The cost profile of distributed games is undoubtedly different, but it is unclear if overall it is cheaper or more expensive.

[2] The impact of additional work force costs may be dependent on the internal cost model employed by the organization running the game. i.e., customer-funded and vote-funded organizations will likely have different attitudes towards the cost profile.

10.6 COLLABORATION AND PARTICIPATION

Efforts at collaborative, distributed gaming have been ongoing for some time; however, the shift to working from home and the lack of international and regional travel has acted as a catalyst for many practitioners. Most notably, resistance from leadership and others in the community has reduced. It has now been proven both possible and practical, opening the door for greater investment and increased collaboration opportunities in the future.

Reflection 24: Distributed games allow for greater breadth of participation. A key benefit of distributed gameplay is its increased flexibility, particularly with respect to scheduling and player setting. Carrying out games across multiple time zones can prove problematic, although many enthusiasts described happily staying up very late to participate in games played thousands of miles away.

Reflection 25: Distributed gaming offers opportunities for greater collaboration. The opportunity to collaborate in gaming has not suddenly appeared with the recent pandemic, however interviews highlight that the pandemic has stimulated both greater international and domestic collaborative gaming. Many of the interviewees highlighted this as a positive and were keen to keep the collaboration going post-lockdown.

> ***Example: A successful distributed Campaign wargame (Lt. Col Arnel David, ARRC) [5]***
>
> In April 2020, Special Operations Command–Europe (SOCEUR) conducted a COVID-19 Grey Zone Wargame to stress test potential and plausible alternative futures of a COVID-19 pandemic environment against adversaries employing grey zone tactics. The game was quickly adapted from an existing in person game and used Slack as the main tool (plus Zoom and WebEx). The distributed matrix game was played virtually over two days, with approximately 50 players from multiple countries and backgrounds, forming four teams. The insights and outputs of the game were shared in Europe command channels, with reports also to US Special Operations Command (USSOCOM) Commanding General and others in the US Department of Defense.

Reflection 26: Unclassified distributed gaming helps break organization restrictions and thinking. The push to move gaming online, and the rapid proto-typing using commercial or free-to-use tools and public networks that followed, had a positive side effect. It was noted by some of those interviewed that a wider community of interest could be engaged. Most notably those without a security clearance, thereby allowing a wider array of academics and subject matter experts to participate. These participants increase the cognitive diversity adding creativity, alternative perspectives, and robustness to games.

Reflection 27: Communities of interest are a valuable resource to enable distributed game development. A number of those interviewed described how they had leveraged existing communities of interest to trial their distributed gaming efforts. Having a ready and willing group of experienced gamers meant that they were able to focus on the technical aspects when developing solutions. The pre-COVID resurgence in wargaming, and ongoing efforts to institutionalize it within the military community, have paid dividends with a number of interviewees referring to networks, clubs and brown-bag events that have helped to develop and trial their distributed gaming capability.

10.7 FINAL THOUGHTS

There has been significant activity, thought, development, and experience gained in distributed gaming in recent months. It is clear from the reflections in this paper that distributed gaming presents different challenges and requires a different toolset – not just the physical tools and networks which are a significant issue, but also in terms of game design and facilitator skills.

What is not clear is what the future will bring, where there is a spectrum of possibilities. There is one line of thought that this is a blip until normal interactions can be resumed – one interviewee commented "distributed gaming won't replace traditional gaming until holodecks[3] are invented." There is also activity to include 'distribution' is another characteristic of wargames to be considered along with others. At the other end of the spectrum is that the pandemic has accelerated an already ongoing revolution in communications and the idea of going back to normal is a fallacy, 'distribution' will continue, with face-to-face becoming infrequent.

In a touch of irony, the pandemic, which has led to social distancing and measures to keep people apart, has acted as an incentive for wargamers across great distances to increase collaboration. These collaborations have enabled experimentation and exchanges of ideas that will benefit the community for years to come.

10.8 REFERENCES

[1] Pellegrino, P. (2020). Distributed Gaming Taxonomy with Pete Pellegrino. Presentation at Connections US 2020, August 2020.

[2] UK Ministry of Defence (2017). Wargaming Handbook. Development, Concepts and Doctrine Centre. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/641040/doctrine_uk_wargaming_handbook.pdf.

[3] Startin, W. (2020). Navy '360 Wargaming' During COVID-19, Connections 2020 Presentation, Booz Allen Hamilton, August 2020.

[4] Goudriaan, T. PAXsims, Utrecht Institute for Crisis and Conflict Simulation, June 2020, https://paxsims.wordpress.com/2020/06/15/utrecht-institute-for-crisis-and-conflict-simulation/.

[5] PXR Webinar, Special Operation Command – Europe: Grey Zone Wargame, May 2020.

[3] The Holodeck is a fictional device from the television franchise Star Trek. It is a stage where participants may engage with different virtual reality environments.

Chapter 11 – HOW TO SUCCESSFULLY DELIVER WARGAMES WITH DISTRIBUTED TEAMS: A FRAMEWORK FOR THE WARGAME DESIGNER

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11.1 INTRODUCTION

This chapter provides guidelines and methods to ensure analytical rigor and meaningful data capture specifically when designing and delivering wargames with distributed teams. A distributed team is a group of co-workers who work remotely[1], either nearby or far away. **The co-workers communicate via online means**.

The chapter: A) Sets out the key characteristics of a wargame; B) Discusses how each characteristic might be impacted (both positively and/or negatively) when the wargame is delivered using a distributed team; and C) Suggests actions to mitigate for issues arising due to the use of a distributed team (where possible).

A, B and C, above, are presented within a systematic framework (Table 11-1).

This chapter should be read in conjunction with Refs. [1] and [2].

Table 11-1: Systematic Framework for the Wargame Designer.

Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Sets out the key characteristics of a wargame. These characteristics have been drawn from Ref. [2].	Provides a more detailed explanation of each of the wargaming characteristics. These descriptions have also been drawn from Ref. [2].	Positive: lists how the use of a distributed team will likely positively affect the wargame[2].	Negative: lists how the use of a distributed team will likely adversely affect the wargame[3].	Offers potential actions that might go some way to ameliorate the negative impacts[3].

This framework can be used by the wargame designer (the target reader) to:

- Pre-empt issues/differences when designing a wargame that uses a distributed team.
- Communicate these issues/differences to the wargame sponsor/director/team to ensure that there is a shared understanding of the challenges.
- Attempt to overcome some of these challenges.

Please note that some of the suggested actions that mitigate for issues arising from the use of distributed wargames might also be beneficial when conducting other types of wargames.

[1] Similar to Geographically Isolated as per Figure 10-1: Geographic Separation Characteristic.

[2] Note that this is not an exhaustive list.

[3] Note that many factors apply equally to distributed and face-to-face wargames. Such instances are not stated repeatedly in the table.

11.2 FRAMEWORK TO INFORM THE DESIGN AND DELIVERY OF WARGAMES WITH DISTRIBUTED TEAMS

Table 11-2: Framework to Inform the Design and Delivery of Wargames with Distributed Teams. All images (unless otherwise stated) have been designed and provided by LBS Consultancy Limited.

Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Structured Discussion 	Wargames are a structured discussion among experts or students to elicit insights. Wargaming can be applied to analytical/research and education/training contexts.	P1. The distributed format can be structured to support more focused discussion. P2. There is less potential for work to be disrupted by irrelevant cross-table conversations. P3. It can be structured so that only one person can speak at a time, which can make it easier to ensure that everyone hears that person's contribution. P4. It can be structured so that people and organizations are more identifiable.	N1. Wargames can take longer as only one person can speak at a time and *'only one thought can be on the table.'* N2. There is less potential for dynamic cross-conversation. N3. Wargame agendas can become overly rigid,[4] with less opportunity to explore emerging insights.	N1. Program longer wargames or consider making use of asynchronous techniques.[5] N1. Ensure clarity of the questions being considered. N1. Use a system for recording insights outside of the direct voice / video media. N2. Use well-configured online chat tools, which allow for multi-layered communication. N2. Use shareable, interactive, online documents to gather insights.

[4] e.g., one person speaking at a time; 'voice procedure' (see: https://en.wikipedia.org/wiki/Radiotelephony_procedure), enforced time periods during which participants speak, etc.

[5] Asynchronous techniques involve participants being online at different times, and live interaction is limited to those who are online at any given time. The gameplay starts and stops locally at different times. Also see Ref. [3].

Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Structured Discussion (cont'd)				N2 and N3. Create short-term sub-groups for discussion and insight gathering.[6] Build in time to flex away from the agenda.
Act of communication 	Wargames are an act of communication between people; principally players[7], but also sponsors, SMEs, analysts, and Control. Eliciting, understanding, and capturing this conversation is critical.	P1. There is an increased availability of the required (and often more diverse) attendees.	N1. Thoughts might not be verbalized because people: a) Are unwilling to interject. b) Do not consider minor points worth raising. c) Feel time-pressured. N2. The use of only chat tools can lead to dominance by SMEs or those more familiar with the technology.	N1. Implement methods for capturing points that have been insufficiently discussed (or not raised at all), e.g., 'car parks'[8], follow-up interviews, surveys etc. N1. Encourage the use of online chat tools, with small sub-groups, to record and expand discussions. The use of chat tools in parallel with verbal discussion allows for the capture of the thoughts of those that may be reluctant to contribute or are unwilling to interject.

[6] Groups of up to nine work best, based on the Nominal Group Technique (NGT) (see: https://en.wikipedia.org/wiki/Nominal_group_technique). However, often, groups of larger than nine are required for various reasons. In instances where the group size is greater than 15, it's recommended that the group be split, as this is likely to maximise overall output.

[7] *"The true source of useful information and insight available in a game derives from the conversation among the players as they communicate by both word and action,"* [4], p.175.

[8] The 'car park' or 'parking lot' is a simple facilitation technique. It is a placeholder for capturing ideas that should be followed up at a later date outside of the meeting. It is used for effectively dealing with distracting but important non-agenda items that arise during the course of your meeting.

Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Act of communication (cont'd)			N3. Conversations can become unstructured, informal and 'chatty.'	N2 and N3. Consider the role, appropriate configuration and sub-processes required to ensure effective chat tools.[9] N3. Ensure that participant chat is carefully moderated. Set out chatroom rules and guidance at the outset. Also, consider making players anonymous (e.g., when there is a big disparity in ranks etc.).
Time-limited 	Wargames are usually time-pressured.	P1. Asynchronous distributed technologies[10] enable players to participate at times convenient to them.	N1. Anecdotal evidence suggests that distributed wargames can take two to five times longer to execute than face-to-face games. This can impact on how thorough (e.g., number of turns) and wide-ranging the game can be.[11]	N1. Consider splitting the game into sub-games of shorter durations over several days and/or using asynchronous technologies. N1. Define, then adhere to, the scope of the wargame in agreement with the sponsor.

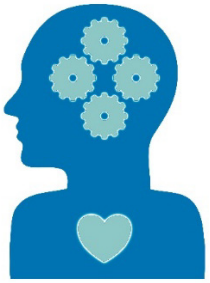
[9] For example, participant chat must be carefully moderated/managed. Clear rules and procedures must be set out at the outset. If possible, allow Control to assign speaking rights, delete messages etc.

[10] For an example see Ref. [5].

[11] Note that, sometimes, distributed wargames take around the same time (and in some cases are faster), but there needs to be mitigation in the game form, or different (simpler) game organisation, breaking out things previously done verbally into structured shared documents and (critically) using automation in shared systems, e.g., Google Sheets.

Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Time-limited (cont'd)				N1. Strictly bound time for: a) Analysts' clarifications. b) Follow-up questions. c) Exploration of emerging insights. N1. To the extent possible, conduct pre-game training on the technical apparatus, so unfamiliarity with it slows the game less.
Analysis (and data capture) 	Analysis is a 'golden thread' that runs through all activity from conception through design, execution, and refinement. Post-game analysis – of both analytical and training wargames – can only take place if sufficient relevant data has been captured in-game.	P1. Data capture is significantly enhanced. Online tools can be used to record players' conversations, which promotes clarity and reduces translation errors. *This is a major factor, not just 'another positive.'* P2. Online voting tools[12] and surveys can be used.	N1. Scribes might be limited to audio output due to a lack of (or poor) video feed. N2. Recording and storing player transcripts may cause additional confidentiality and permission issues.	N1. Implement procedures for players and cells to record their thoughts themselves. Consider whether scribes are even needed, given the use of digital recording methods. N1. If required, schedule follow-up engagement with analysts to clarify the capture of any player thoughts that are unclear. N2. Seek advice from an Ethics Officer to ensure procedures are in place to address data and privacy concerns.

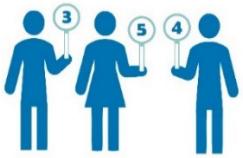
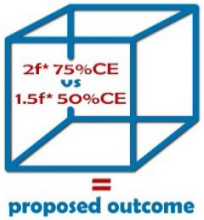
[12] e.g., Mentimeter (https://www.mentimeter.com/features/live-polling).

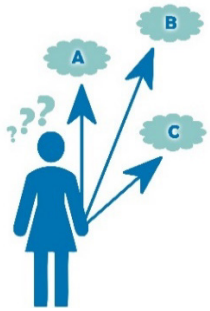
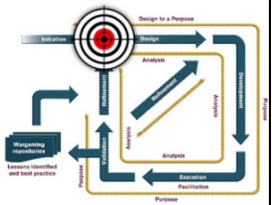
Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Simplicity 	Wargames should be as simple as possible.	P1. While distributed wargames can add varying levels of complexity, they can also reduce some types of complexity; e.g., transportation, billeting, food services, etc.	N1. Certain wargame formats (for example, formats that use sophisticated computer simulations or manual games with complicated components) might be harder to run remotely. N2. Games that are too simple are susceptible to 'mini-maxing.'[13]	N1. If possible, consider using simple game formats. N1. Game components must be *clear* and *simple*. Images and graphics can be counter-productive in the virtual environment unless all participants have the resolution to view them properly. N1. If using a webcam to display a game board, all components must be as simple and visible as possible. Use a good quality camera.
Engagement/ immersion 	Challenge and professional satisfaction should be inherent in all games, but wargames should also, where appropriate, be fun. Engagement, through active learning, leads to better internalization of training lessons and greater analytical insight.	P1. A robust chat feature, if guided into discussion of game state / planning, helps keep people engaged without disrupting the game itself, where extensive side conversations might disrupt a live game.	N1. Participants could be distracted due to: lengthy periods between player inputs and having access to local distractions such as emails, pop-up notifications/tasks, etc.	N1. Minimize periods of player inactivity, for example with rapid 'action-reaction-comment' cycles to ensure constant engagement. N1. 'Down time' (if any) can be used by players to record insights and prepare for upcoming activity. N1. Set up parallel strands of activity where possible to maintain engagement.

[13] A style of play where players attempt to minimize undesired outcomes and maximise desired ones, for example by applying maths.

Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Engagement/ immersion (cont'd)		P2. Levels of immersion could increase if players were able to participate from the command post / environment that they would use during an actual incident/situation.		N1. Encourage person-to-person interaction via chat tools etc. N1. Use attractive visuals. N1. Use an assistant facilitator[14].
Control (including facilitation)  	Control is the minute-by-minute activity that ensures the wargame proceeds as required and objectives are met. A balance must be struck between the principles of control and the primacy of player decisions. Facilitation ('to ease a process') is one (essential) element of control.	P1. A distributed game can be structured so that Control has the ability to centrally mute speakers when necessary!	N1. Distributing Control personnel risks the cohesion and effectiveness of the crucial Game Controller / Facilitator / Lead Analyst relationship. N2. Control team must simultaneously monitor several player feeds as well as lead the game process, making it difficult to 'read the room.'	N1. Use a parallel Control communications network – or even multiple networks – for back-channel discussion. N1. Have an assistant facilitator within each player cell, who is on the Control communication system. Assistant facilitators must be as well-trained as the primary facilitator. N2. Provide Control with large, multiple displays. N2. Consider Control ergonomics. Having too many windows open or switching between media systems is a significant overload on Control, who should be managing the game, not the technology.

[14] A facilitative role that sits within a player cell but works for the control team. Acts as a 'host' for the player cell to look out for any player problems and can inform the control team or request assistance.

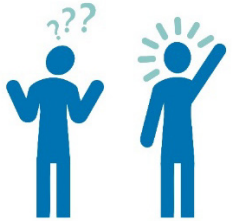
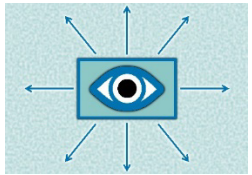
Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Appropriate adjudication 	Adjudication is the act of determining the outcomes of players' decisions. The approach used, and the supporting methods, models, and tools, must be appropriate to the real-world and the wargame's level of discovery.	P1. Crowd-sourced adjudication can become easier in some cases due to the use of simple, widely-available polling/crowdsourcing apps. P2. Adjudicators are likely to have greater access to SMEs, who might be needed to inform certain decisions, due to the SME not needing to be physically present at the game.	N1. Free, consensual, and crowd-sourced adjudication can be slower, with collaboration between adjudicators more difficult.	N1. Design, rigorously test and rehearse simple adjudication sub-processes.
Transparency 	Simulation and adjudication outcomes, and the reasons for these, should be clear and open to scrutiny. This allows participants to understand the dynamics of a situation and the factors at play.	P1. The distribution of game parameters, systems and procedures are easier, which can aid transparency. P2. The nature of online platforms is such that all participants have the opportunity to hear all explanations.	N1. Players can have less sight of, and confidence in, the impartiality of the adjudication and Control team. N2. It can be more difficult to facilitate 'open' games, which are more transparent than 'closed' games.	N1. Have a (well-trained) assistant facilitator within each player cell, who has access to the Control communication system. N1. The Control team methodology should be documented and easily accessible, either in the form of map screen shots or pre-prepared feedback formats with space for explanation where appropriate. N1. Use simple adjudication methods to aid transparency.

Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Primacy of player decisions 	Players are the protagonists. Their combined behavior should determine the course of a wargame. However, noting player decisions is not enough: understanding the rationale for decisions and the factors considered is essential.	P1. The requirement for clear, written, inputs to a distributed game allows player decisions to be explained and interrogated more easily in post-game analysis.	N1. Constrained communication can reduce the ability to understand player decisions.	N1. Implement methods for capturing player decisions, e.g., player self-capture of rationale, shared-access documents, follow-up interviews, surveys, etc.
Design to a purpose 	Wargames must be designed to a clear, achievable purpose (akin to following a mission statement). Well-considered aims and objectives are the start point for all discussion and a point of constant reference throughout the wargame lifecycle.	P1. Playtesting opportunities increase due to the ease of convening remotely.	N1. Constrained face-to-face design and development meetings can result in mis-communication.	N1. Have more frequent meetings and, where possible, use video communication tools in conjunction with visual aids (e.g., PowerPoint).

Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Wargaming within a wider context [15] 	Wargames provide greatest utility when used iteratively within a wider decision-making process that employs a multi-technique, integrated approach. This applies to an analytical campaign or training progression.	P1. Greater numbers of observers can silently note insights that might have relevance for other activities.	N1. The potential ease of involvement of participants from different organizations can lead to the niceties of hosting, explanation and follow-up being truncated, generalized, and appearing perfunctory.	N1. Ensure proper thanks are provided to the participant's chain of command, and fully communicate game results and lessons.
Small, cheap, and frequent 	While some wargames are necessarily large, a 'small, cheap and frequent' approach maximizes learning opportunities and allows insights and innovations to be developed in – and help shape – subsequent games.	P1. There is more opportunity to convene participants regularly.[16] P2. Smaller events can encourage more involvement and therefore engagement.	N1. Distributed participants might get pulled away due to demands of their day jobs, so might not be present/available for the whole of the game. N2. There is a technological requirement on participants, who need the appropriate equipment and user knowledge. N3. The perceived importance of small and frequent games can be reduced.	N2. Set out the technology specification for participants at the outset, making it clear that participation require a certain minimum level. N2. Provide clear guidance to appropriate online learning tools. N3. Schedule games at regular intervals, and use invites to prompt participation.

[15] Modified image provided from: https://www.professionalwargaming.co.uk/OnceAndFuture-Perla.pdf (Accessed April 2021). 'The Cycle of Research' was introduced by Peter Perla in 'The Art of Wargaming' first published in 1990.

[16] For example, see Ref. [6].

Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Human factors within participants (including visualization)  	Being a people-centric act of communication, wargames pivot on the interactions between participants, formal and informal. They are also hard work!	P1. Computerized 3D imagery on screens, including Line of Sight (LOS) visualization can assist player understanding. P2. Introverts and those who ponder more before sharing a thought are more likely to contribute to chat forums.	N1. There is potential for cognitive overload of both players and Control.[17] N2. Until VR improves, computer screens offer a limited field of view.[18] N3. Socialization and team building benefits are reduced. N4. Small misunderstandings and requests for clarification that could normally be handled with an aside, while the other players carry on, can arrest progress because everyone has to listen to repeated explanations.	N1. Program regular breaks. N1. When and where possible, use video communication tools. N1. Limit the number of IT tools that people use, and use tools that people are comfortable and familiar with. N1. Use tools that are appropriate for the task and have the functionality necessary to meet the game objectives. Training and preparation might be required. N2. Use effective maps and schematics. These can be computer-generated or hand-drawn, as long as they are clear and simple and only contain the level of detail necessary for the game.

[17] Anecdotal evidence suggests that the cognitive burden from distributed games is greater than that of face-to-face games. In the absence of body language, participants can strain their other senses to compensate for the loss of visual clues. In addition, manipulating objects on a screen and monitoring multiple media can be fatiguing.

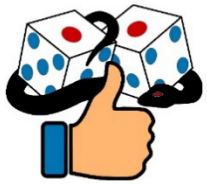
[18] "When the object is to portray units positioned on a map, computer monitors and data projectors are actually less effective than physical maps and counters on one or more large tables, since their fixed resolution and limited field of view frustrates employment of the human eye's wonderful combination of central acuity and breadth of vision," [7], p. 26.

Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Soft, non-kinetic and human factors within the game[19] 	A wargame that does not consider soft factors, non-kinetic capabilities and human terrain must be questioned (unless designed to examine strictly bounded kinetic actions).			
Uncertainty 	Uncertainty and the 'fog of war' are fundamental characteristics of warfare, and should be considered in a wargame. Experiencing them fosters a robust mental capacity among players, better allowing them to deal with adverse outcomes. It often leads to new, and unexpected, situations and insights.	P1. Implementing fog of war and double-blind wargames is easier using virtual means.		

[19] Image provided by Cranfield University.

Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Adversarial 	Wargaming is a competitive intellectual activity. The primary challenge is usually provided by combative players representing active, thinking, and adaptive adversaries and competitors; and/or controllers using the level of threat as a variable.	P1. The potential ease of accessing Red Cell SMEs on the phone / via the internet can enhance adversarial game play. P2. The virtual environment, and the fact that the players are not co-located, provides an easier environment in which to deliver double-blind adversarial games. In addition, this environment makes it easier for Red and Blue to experience the same fog of war constraints, etc.		
Oppositional 	'Oppositional' means 'something that acts as an obstacle to some course or progress.'[20] This encompasses Clausewitzian 'friction,' biases and any 'spanners in the works.'	P1. The availability of critical/creative thinkers is potentially increased.	N1. The constrained time for, and ease of, communication limits critical thinking and challenge activities.	N1. Ensure sufficient time is programmed for challenge activities and/or consider the use of asynchronous techniques. N1. Ensure critical thinking challenges are written down and their rationale explained. This will aid post-game analysis.

[20] Oxford English Dictionary.

Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Diversity and inclusion[21] 	Experience and social science shows that diversity can generate better results in analysis, insight, and professional decision making. It is also simply the right thing to do. No one should ever feel excluded or less welcome because of sex, race, ethnicity, religion, disability, or background.[22]	P1. The availability of more diverse attendees is potentially increased. P2. More observers can attend virtually (including people who want to learn about wargaming).	N1. The level of friction in diverse and inclusive teams is higher (at least initially) than culturally homogenous teams, so diverse teams tend to take longer to reach decisions.	N1. Allow more time, rather than penalize teams that are slower at making decisions.
Freedom to fail 	Wargames provide a safe-to-fail environment, where 'thought experiments' are undertaken with no fear of failure. Wargames that involve undue assessment of participants stifle innovation, risk-taking and the opportunity to learn.	P1. Because of the potentially lower set-up costs, the ease of attendance, and the improved ability to capture data, distributed games have greater potential for repeatability; encouraging innovation and risk-taking.	N1. The potential more robust and complete data capture and record keeping in virtual games might make players feel less safe to fail.	N1. Leadership is required to encourage innovation and risk-taking, as in any wargame. N1. Consider whether making players anonymous (e.g., through coded logins) might help them feel safer to fail.

[21] Image provided by Derby House Principles [8].

[22] Extract from Derby House Principles [8].

Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Chance 	Chance is an ever-present characteristic of warfare, and so must feature in wargames. It is an expression of risk, which is a fundamental concept that all personnel should be experienced in calculating and managing.	P1. Many online random number generators are readily available. P2. In a distributed game, it is easier to hide outcomes in a 'black-box,' if appropriate.		
Appropriate supporting technology 	All wargames require simulation, be this manual, computer-assisted or computerized. Computer and manual simulations each have strengths and weaknesses and are usually complementary. All types of simulation should be considered, and an appropriate solution determined.	P1. The use of asynchronous techniques can leave more time for the running of simulations, which can result in the use of more complex simulations, the ability to run multiple iterations, etc.	N1. There is increased technical risk: distributed systems can partially or wholly fail for some, or all, participants. N2. The technology required to support distributed wargames is significantly greater than for face-to-face games.	Murphy's Law applies.[23] N1. Rigorously test IT systems to pre-empt issues. N1. Hold technical rehearsals involving all participants, if possible. N1. Have a PACE[24] plan to provide resilience in the case of IT failure. N1. Take account of the necessary internet bandwidth and/or wifi capability.

[23] If something will go wrong, it will.

[24] Primary – Alternative – Contingency – Emergency.

Characteristic	Description	Potential Impact(s) on Characteristics When Using a Distributed Team		Potential Mitigation(s) for Negative Impacts
		Positive	Negative	
Appropriate supporting technology (cont'd)				N2. Ensure the 'scaffolding' is in place to support participants: a) Ensure participants work from a computer with a keyboard and a screen. Wargaming using a tablet or a phone is not good enough. b) Where participants are working from home, they must use a wired connection. Wifi is too unreliable and dependent on environmental conditions. c) Increase the size of the Control team, potentially implementing a 'technical facilitator' role. d) Ensure training is provided on the necessary equipment (never overestimate the participants' technical abilities).

11.3 CONCLUSION

This chapter provides advice on how to ensure the success of a distributed wargame, and how to mitigate for various risks.

Distributed wargames have come to the fore this year, due to the prevalence of COVID-19. However, as can be seen from the table within this chapter, as well as providing challenges that need to be overcome, they can also offer opportunities and benefits.

Indeed, going forward, it might be that distributed wargames and asynchronous techniques (i.e., techniques that enable participants to be online at different times) are used more and more. Distributed games and asynchronous techniques would make it easier for wargames to include players from across the globe, without the players needing to be co-located, and without them needing to work outside of their countries' daylight hours.

When wargames are looking to simulate, say, an international (e.g., NATO nation) response to a potential situation, having the players who are representing the individuals from particular nations actually be from those nations can only be a good thing, as such players are likely to have the best understanding of how these individuals are likely to respond.

In addition, when hosting wargames that require the involvement of multiple, very senior personnel (e.g., high-ranking officers), asynchronous techniques could enable all of these people to have input into the game without needing to be available at the same time.

Obviously, distributed wargames require players to be familiar with, and competent at using, collaboration tools (e.g., Microsoft Teams, Zoom, Discord etc.). While levels of familiarity and competence with these products was likely to have been patchy and inconsistent pre-COVID-19, a positive consequence of the pandemic has been that people have had to rapidly upskill themselves in this area. In addition, COVID-19 has seen these collaborations tools become more sophisticated, with increased capabilities that can be used to support the delivery of remote wargaming. COVID-19 has also forced classified institutions to put measures in place to enable the safe use of such tools.

To summarize, distributed wargames can provide challenges but also present opportunities, and this chapter seeks to help the wargame designer both overcome these challenges and maximize the opportunities.

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[8] PAXsims. Derby House Principles. Available at https://paxsims.wordpress.com/derby-house-principles/ (Accessed Apr 2021).

[26] Also see https://warroom.armywarcollege.edu/wargaming-room/swarm-gaming/ (Accessed Apr 2021).

Annex A – A GUIDE TO YOUR CONTINUING DEVELOPMENT AS A WARGAME PRACTITIONER

Matthew Caffrey
US Air Force Research Laboratory
UNITED STATES

In 1869 an officer who understood war better than most, General William T. Sherman, addressed the graduating class at West Point. He eloquently told the new officers that they had only just begun to learn what they needed to know to pass a future test of arms. If the Military Academy cannot teach their cadets all they need to know of war over four years we certainly cannot teach you all you need to know of wargaming in a few hours. This "read after" will provide you with some tips on how you can continue to develop yourself as a wargame practitioner.

Brown Bag, Meetings and Conferences

MORS Wargame Community of Practice (COP) Brown Bag Series: The easiest way to stay in touch with developments in the field of wargaming. By getting on their email list, you automatically get the speaker's slides and call in number each month. Then call in, listen to the speaker over lunch and, if you wish, participate in the post talk discussions. Contact Elizabeth Marriott, liz.marriott@mors.org, for info on the next Brown Bag.

Connections US: Since 1993 Connections has been working to advance and sustain the art, science, and application of wargaming by bringing together all elements of the wargaming field to learn from each other. You can learn the location and dates of the next Connections from their website https://connections-wargaming.com.

Connections UK: Since 2013 Connections UK has been working to advance the same mission as the original Connections but with a much more international group. You can learn the location and dates of the next Connections UK from their website www.professionalwargaming.co.uk.

Australia, The Netherlands, Canada, and France also hold Connections conferences. If a future assignment makes participating in any of these conferenced productive and feasible check the Connections US site for a link.

The Military Operations Research Society (MORS) Symposium: This annual conference brings together all branches of the defence Operations Research community, including wargaming. See their web site for information on the next symposium; location, dates, registration fee, clearances required. http://www.mors.org/events/symposium.aspx.

Online Videos

Here are some videos you watch online:

Hosted by Kings College London, Wargaming Network

Edward Stringer, "Advancing the UK's Analytical Tools to Address Strategic Competition and Deterrence."

Dr Yuna Wong, "Developing an Academic Discipline of Wargaming."

Peter Perla, "The Art and Science of Wargaming to Innovate and Educate."

Patrick Ruestchmann, "Wargaming to Out Think and Out Compete."

Hosted by the Georgetown University Wargaming Society.

Mark Herman, "The Intersection of Professional and Commercial Wargaming."

Hosted by the US Naval War College – a Wargaming Design Crash Course presented by Pete Pellegrino:

- **Lecture 1** Introduction to War Game Design
  - https://www.youtube.com/watch?v=FuNdtYEzXrE (2:53 total, lecture is only 1:10)
  - This first presentation strives to establish a foundational understanding of war games, their uses and key design concepts.
- **Lecture 2** Introduction to Matrix Games
  - https://www.youtube.com/watch?v=rlfgdB6_oe4 (1:26 total; lecture is less than 1 hour)
  - This presentation addresses a type of gaming called "matrix games," and discusses their design and use.
- **Lecture 3** Problem Statements and Dealing with Sponsors
  - https://www.youtube.com/watch?v=A_Rnr-WGcDc (1:27 total; lecture is less than 1 hour)
  - In this presentation we tackle problem statements and their relationship to objective and purpose, and some of the ways external game sponsors can have a negative impact on the game design process.
- **Lecture 4** Better Visual Communications with PowerPoint
  - https://www.youtube.com/watch?v=rSAgl-v38NA (1:27 total; lecture is 1 hour)
  - While not specific to war games, PowerPoint is often used to conduct war game inbriefs or report out war game results. Unfortunately, poor use of basic visual design principles dramatically reduces the effectiveness of these presentations. This lecture presents some techniques to improve the impact of presentations built with PowerPoint.
- **Lecture 5** Distributed Gaming Taxonomy
  - https://www.youtube.com/watch?v=itL0nhdDAhc (0:24 total; no Q&A)
  - The lecture was first presented at the Connections US war gaming conference in August 2020. As a result of travel and social restrictions resulting from the COVID-19 pandemic, the interest in distributed online war gaming has dramatically increased; however, "distributed gaming" does not mean the same thing to everyone. This presentation outlines an organizational taxonomy to help game designers, sponsors, and players 'get on the same sheet of music' when talking about distributed games.
- **Lecture 6** Modeling and Games
  - https://www.youtube.com/watch?v=iFkqGUfE6ME (2:03 total; lecture around 90 minutes)
  - In this video, Pete discusses the use of "models" in war games. In this case, a model is loosely defined as anything that represents something the player interacts with that is not another player, and not just mathematical combat models. These are models you can build with Excel and be used by designers, players, and adjudicators.

AFIs

Air Force Instruction 10-2801, 23 October 2014, Operations, Force Development Concepts.

Books

On Wargaming

On Wargaming, Matthew B. Caffrey Jr., US Naval War College Press, 2019. What the history of wargaming tells us about application of wargaming today and tomorrow. Available for free download from: https://digital-commons.usnwc.edu/newport-papers/43/.

The Art of Wargaming, Dr. Peter P. Perla, Naval Institute Press, 1990. Still the best single book on the integration of analysis and wargaming.

Simulating War, studying conflict through simulation gaming, Dr. Philip Sabin, Continuum, 2012. Though the book's focus is the use of designing and developing wargames as a way to deeply understand the subject conflict, it is also the best contemporary book on wargame design.

Wargame Design, by the Staff of Strategy and Tactics Magazine, Simulations Publications Inc., 1977. This is still the best practical guide to wargame design.

Wargames Handbook, Third Edition: How to Play and Design Commercial and Professional Wargames, by James Dunnigan, 3rd edition, 2000

The Fundamentals of War Gaming, Francis J. McHugh, US Naval War College Press, 3rd edition, 2012. Amazon.com: Francis J. McHugh: Books, Biography, Blog, Audiobooks, Kindle.

Zones of Control: Perspectives on Wargaming, edited by Pat Harrigan & Matthew G. Kirschenbaum, MIT Press, 2016

Wargaming Handbook, The Chiefs of Staff, Ministry of Defence, United Kingdom, 2017. This is Britain's official doctrine for wargaming. Very readable and insightful. It can be downloaded for free from Connections UK's website, http://professionalwargaming.co.uk.

Successful Professional Wargames: A Practitioner's Handbook, by Graham Longley Brown, John Curry (Editor), Peter Perla (Foreword), History of Wargaming Project, 2020.

How to Master Wargaming: Commander and Staff Guide to Improving Course of Action Analysis, Center for Army Lessons Learned (CALL), 2020. Available for free download from: https://usacac.army.mil/sites/default/files/publications/20-06.pdf.

The Matrix Games Handbook: Professional Applications from Education to Analysis and Wargaming by John Curry (Author), Peter Perla (Editor), Chris Engle (Editor) by The History of Wargaming Project (http://www.wargaming.co/).

Conversations with Wargamers, Peter P. Perla and Michael C. Markowitz, Center for Naval Analysis, 2009.

Supporting Skills

Theory of Fun for Game Design, by Raph Koster. Understanding the role of decisions and engagement in game play.

Rules of Play, by Katie Salen and Eric Zimmerman. *The* textbook for understanding human play.

Game Theory, A Very Short Introduction, by Ken Binmore. If you hang out a game design shingle, someone is going to eventually ask you about game theory.

Thinker's Toolkit, by Morgan Jones. We're often gaming for analytic value, yet many game designers can't name 3 analytic techniques.

Gamestorming, by Sunni Brown. What makes you think a war game is the right way to generate insight? There are other ways...

Slide:ology, by Nancy Duarte. At some point you're going to reach for PowerPoint to communicate about your game. This book promises to help you do so more effectively.

Speaking PowerPoint, by Bruce Gabrielle. Where once a game report would suffice, now everyone wants a PowerPoint deck. Don't make another bad one.

On War, in general + air and space power

Army, T.F. Engineering Victory. Johns Hopkins Studies in the History of Technology (2016).

Campen, A.D. The First Information War: The Story of Communications, Computers, and Intelligence Systems in the Persian Gulf War. Afcea Intl Pr (1992).

Dupuy, T.N. Numbers, Predictions and War. Hero Books (1985).

Ethell, J. and Price, A. Air War South Atlantic. The Air Combat Trilogy Book 3 (1984).

Nordeen, L.O. Air Warfare in the Missile Age. Smithsonian Books (2010).

Snow, D.M., and Frew, D.M. From Lexington to Desert Storm Desert Storm and Beyond. M.E. Sharpe (2020).

Periodicals

Decision Games publishes three magazines of potential value:

Strategy & Tactics, since the early 1970s "S&T" has been providing insights into military decisions; from ancient to near future, from articles to wargames to articles on wargaming.

Modern War, covers potential, contemporary and recent military conflicts.

World at War, covers military developments from the beginning of WWI through the end of WWII. All three magazines come with a print wargame typically on the conflict described in their lead article. Does the practical application of: here's the situation, here's how a pro cheaply and quickly wargamed it, and then a short discussion on why he wargamed it that way. Kind of a tutorial for designing/selecting wargames to fit a spectrum of needs.

Web site, https://www.decisiongames.com.

There are two scholarly journals that focus primarily on modeling but also publish articles on gaming and specifically on wargaming, they are:

- *Simulation & Gaming*
- *Defense Modeling & Simulation.*

There are also several publications on military subjects that occasionally publish on wargaming:

- *Phalanx*
- *Joint Forces Quarterly*
- *Naval War College Review*
- *Air and Space Power Journal* (Previously Airpower Journal)

Articles

"Toward a History-Based Doctrine for Wargaming," Lt Col Matthew B. Caffrey Jr., USAFR, *Aerospace Power Journal*, Fall 2000. A good history of wargaming up to the late 1990s. It can be downloaded from http://www.airpower.maxwell.af.mil/airchronicles/apj/apj00/fal00/caffrey.pdf.

"The Epistemology of War Gaming," Robert Rubel: https://digital-commons.usnwc.edu/nwc-review/vol59/iss2/8/.

"Why Wargaming Works," Peter P. Perla and Ed McGrady: https://digital-commons.usnwc.edu/nwc-review/vol64/iss3/8/.

"Wargame Pathologies," by CNA (C.A. Weuve, P.P. Perla, M.C. Markowitz) and the Naval War College (R.C. Rubel, S. Downes-Martin, M. Martin, and P.V. Vebber) https://www.cna.org/CNA_files/PDF/D0010866.A1.pdf.

"Your Boss, Players, and Sponsor: The Three Witches of War Gaming," by Stephen Downes-Martin. https://digital-commons.usnwc.edu/nwc-review/vol67/iss1/5/.

On why wargames (or any simulation game) are effective educational tools see: http://www.goodgamesbydesign.com/Files/WhyGamesWork_TheScienceOfLearning_CMurphy_2011.pdf.

"War Games Shed Light On Real Strategies," David Banks, Navy Times, April 2019. Good overview of the spectrum of topics covered by commercial wargaming. It can be downloaded from, https://www.navytimes.com/news/your-navy/2019/04/19/war-games-shed-light-on-real-strategies/.

Web Pages

Connections-Wargaming. An online reference to wargaming; people, vocabulary, briefings on wargaming. Go to: http://connections-wargaming.com/.

PAXSims. A source of articles on wargames applied to conflict resolution, and military operations. Go to: http://paxsims.wordpress.com.

King's College Wargaming Network: UK based with a global prospective.

War on the Rocks (WOTR): Contemporary military prospective, many articles on wargaming.

Strategy Bridge: Strategy, National Security and Military Affairs

RAND maintains a page on wargaming at its principal website. Synopsizes of many of their important articles and reports on wargaming are provided. Go to: http://www.rand.org/topics/wargaming.html.

Center for Applied Strategic Learning, National Defense University's wargame department maintains an excellent online set of references for their faculty. Go to: http://casl.ndu.edu/References/BibliographyofStrategicGaming.aspx.

Wargaming – Connections. Principally a site with dialogues between wargame practitioners. Go to: http://wargamingcommunity.wordpress.com/.

The (online) Journal of the Serious Games Society. The Serious Games movement works to apply wargame and wargame like techniques and technologies to a broad spectrum of uses. The Journal provides scholarly articles about the state of play of several aspects of this activity. Go to: http://journal.seriousgamessociety.org/index.php?journal=IJSG.

Strategy Page: This cite covers contemporary military affairs, military history and wargaming – defence, recreational and some educational. Go to: http://www.strategypage.com/.

grogheads.com	Hard core paper wargames
boardgamegeek.com	Info on all forms of paper simulation games, including wargames
consimworld.com	Site on commercial wargames, primarily paper
gamasutra.com	Mainly articles on game design – some specifically on wg design.
militarywargaming.com	LBS Consultancy, a source of articles on military wargaming, primarily in the UK. Go to http://lbsconsultancy.co.uk.

http://www.militaryfactory.com Open source site on military hardware worldwide.

Guide to Technology Readiness Levels, see: http://en.wikipedia.org/wiki/Technology_readiness_level.

Wargame Courses

Air Force Material Command Wargame Course: Covers; wargaming for leaders, being a wargame consumer, wargaming and innovation, effective wargame participation, managing a wargame function and executing the wargame cycle. Course transitioning to an AFIT course.

The Naval Postgraduate School offers courses on wargame design and application; both an 11 week in-residence course and a compressed 1 week course provided at the requesting organization by a Mobile Training Team.

Naval War College: A weeklong course. Lead instructor, Shawn Burns.

Halsey Alpha wargame elective: Students dive deeply into scenarios of importance to the Navy while receiving an in-depth understanding on wargame design and execution.

US Army Command and General Staff College, Wargame elective: Each student creates a wargame as part of their course grade.

MORS Certificate in Wargaming: Focuses on analytical wargaming.

MORS Certificate in Cyber Wargaming: Name says it all.

AFRL/AQ Wargame Course: Designed to teach scientists and engineers about wargaming, concept development and the application of wargaming to military research.

The Game Design Initiative at Cornell University.

Professor Philip Sabin's class on wargame design at Kings College London.

Courses on War

While any Professional Military Education (PME) course includes information of relevance for effectively participating in a wargame the below are of particular value and as short courses are much easier to attend then an in-residence PME course.

Contingency Wartime Planning Course

Joint Air Operations Planning Course

Information Operations Fundamentals Application Course

Steady State Support Planning Course

See Air University's online catalogue for more info on each course.

Federally Funded Research and Development Corporations (FFRDCs)

FFRDCs support DoD. Some have significant wargaming capabilities.

RAND was the first and is arguably the most famous of the FFRDCs. Many of the red team and wargame processes of today were developed by RAND in the 1950s. They are back to pushing the boundaries of wargames today.

The Center for Naval Analysis (CNA) is sometimes called the Navy's RAND. CNA has consistently advanced wargaming across the decades and across the Defence community, including the Air Force.

MITRE is currently working on modular, scalable capabilities for supporting MDO-related TableTop eXercises (TTXs) and Wargames.

In some cases, FFRDC support is prepaid centrally and requesters compete for support. In other cases, they can be contracted with in a way that is different from but similar to the process for a for-profit company.

Experience

The best way to develop as a wargame practitioner is to participate in as many wargames as practical. The most instructive wargames are typically those conducted by the military. However, there are only so many wargames and so many slots for participants. As you can read books and articles for professional development on your own time so you can play wargames. Some very good wargames are available free. For example, Tactical Airpower Visualization (military version of the commercial wargame Modern Air Power) is freely available for official use by ANY US Air Force unit or organization (i.e., a junior force council). For more info contact the Squadron Officers College. Even some commercial wargames are free, for example Modern Air Power (MAP) is free on Android and are available at Apple AppStore for iPads and from publisher for MS PCs. (BTW MAP is the commercial version of the Squadron Officer School's Theater Airpower Visualization.) The cost of new and used print, miniatures and computer based wargames vary between $5 and $220, with many around $40. Many commercially available wargames include innovative elements encouraged by a competitive marketplace. Each wargame you play increases the speed and quality of your military decision making skills. Also, by playing different types of wargames you build up your mental toolkit of wargaming methods you can draw from if you are ever tasked (or volunteer) create a wargame for your unit. If you are very lucky you may even find a wargame that can be used as-is by your unit. This is uncommon but not unknown. Far more frequent are cases of commercial wargames that can be modified for military use, sometimes with little time or cost. To find commercial wargames that fit your needs I recommend three sources:

1) The attached guide to joint forces wargames at the strategic through operational levels.
2) The attached guide to primarily airpower wargames at the operational through tactical levels.
3) The Strategy Page and other web pages (described above).

Acknowledgements

My thanks to all those in the wargaming community who helped make this bibliography a robust reflection of community resources. Contributors include Bill Simpson and Pete Pellegrino, USMC, Elizabeth Bartels, RAND, David O. Ross, AFRL/XPT, Catherine Lea, CNA and Tim Moench, AF Global Strike Command.

Finally, this is very much a work in progress. If you spot a source of information on wargaming that should be added please email the information to me at matthew.caffrey.1@us.af.mil.

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NATO Analytical War Gaming – Innovative Approaches for Data Capture, Analysis and Exploitation

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This report documents the findings of the Task Group SAS-139 (System Analysis and Studies Panel) regarding best practices and innovative approaches for NATO Analytical Wargaming.

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14. Abstract

SAS-139 was a research task group that ran between 2018 and 2021, named NATO Analytical War Gaming – Innovative Approaches for Data Capture, Analysis and Exploitation. Its aim was to conduct research to advance NATO's capability for Analytical Wargaming – that is wargames that are designed to rigorously address a specific research question or set of questions. Members conducted research into artificial intelligence and automation for wargaming, how to improve wargame rigor by using experimentation principles, mitigating for bias, and pairing established Operations Research and Analytical methods to wargame design and analysis. The research group also investigated and demonstrated the use of technology for wargaming, and established a NATO Wargaming Community of Interest. Work was disrupted due to the COVID-19 pandemic, but SAS-139 found an opportunity to research and learn early lessons from the exponential rise in Distributed Wargaming. Each chapter of this report has been designed to be read as a stand-alone paper so readers can skip ahead to what interests them the most.

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