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14. ABSTRACT The modern state of military simulation is limited in several key respects. Military simulators are structurally complex, interactively simple, and minimally applied to the development of operational art. The authors propose the development of a battlefield simulator that has none of these limitations. Such a simulator would include a digital environment that reaches across platforms and domains. It would allow for participation at both the tactical level and operational level. It would allow for the introduction of new platforms, whose attributes could be altered to enable not only the incorporation of developing platforms into existing tactical processes but also for the identification of requirements for platforms yet to be conceived. With this structure applying equally to enemy forces, it would enable the large-scale test and refinement not only of current concepts against existing real-world problems, but for future concepts against emerging problems as well. Such a warfighting simulator would use physics-based open-world software architecture, a massively multi-player construct, and big data to improve its modeling of the enemy and environment over time.

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Future War Paper

Military Applications for Modern Gaming and Simulation

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Introduction

Tactical and operational incorporation of new technology on the battlefield currently takes decades through lessons learned in combat, typically over the course of one or more major conflicts. This is because tactics development is best done empirically using the battlefield as a laboratory. Expedients exist. Exercises, wargames, and think tanks all strive to simulate the battlefield to this end. But these expedients are rarely fully leveraged. The quality of a simulation is always lower than real life. Because of this, there is risk in adopting tactics developed through simulation.

Modern technology, specifically modern digital battlefield simulation, has the potential to improve this process, especially with respect to wargames and exercises, but is still largely undeveloped.¹ The modern state of military simulation is limited in several key respects. First, military simulators are structurally complex procedural trainers designed from the ground up to establish baseline proficiency in individual operators or crews prior to having them execute in live exercises and later in combat.² This is because military simulators are designed with the sole purpose of reducing the front-end cost of training, rather than with the purpose of refining existing processes or improving upon proposed ones.

Second, military simulators are interactively simple. Simulators are rarely linked for the purpose of innovating new tactics. When they are, it is typically small in scope and limited to a single platform or domain.³ This precludes both large scale collective simulator training between platforms and cross-domain collective training necessary to execute on the modern battlefield.

¹ Michael Macedonia, "Games, Simulation, and the Military Education Dilemma," <https://www.researchgate.net>, 162.

² Tim Lenoir and Henry Lowood, "Theaters of War: The Military-Entertainment Complex," Stanford University, 2002, 8.

³ *Ibid*, 10.

This is related to the first limitation in that military simulators are developed a platform at a time, with a bottom up mindset, rather than with a holistic mindset starting from the top down.

Although ongoing efforts to link simulators are underway, these efforts are hampered by the proprietary nature of military simulator software and the fact that most simulator software is decades old and far from state of the art.⁴

Third, military simulators are not used to validate proposed tactics with platforms in development. With new platforms taking decades to develop, there is an overarching practical reason to test, develop, and refine such tactics in advance, thereby validating operational concepts in the process and ensuring that when a new platform is introduced to the battlefield that it is used to the maximum possible lethal effect with minimal refinement through lessons learned in combat. This would require a platform agnostic battlefield simulator built with collective, not individual learning as its object. No such simulator, leveraging state of the art technology currently exists, but it would be technologically feasible now.

The authors propose the development of a battlefield simulator that has none of these limitations. Such a simulator would not be a procedural trainer for any one platform. It would be a digital environment that reaches across platforms and domains. It would allow for participation at both the tactical level and operational level, permitting training across warfighting functions, including command and control, intelligence, and sustainment in addition to fires and maneuver. It would allow for the introduction of new platforms, whose attributes could be altered to enable not only the incorporation of developing platforms into existing tactical processes but also for the identification of requirements for platforms yet to be

⁴ Ibid, 32. Researchers realized the eventual potential to use simulators for large-scale collective task training as early as 1982. Despite generating significant interest after the Gulf War, simulator funding remains relatively small and focused on procedural rather than collective training.

conceived. Finally, with this structure applying equally to enemy forces, it would enable the large-scale test and refinement not only of current concepts against existing real-world problems, but for future concepts against emerging problems as well. Such a wargaming simulator would use physics-based open-world software architecture, a massively multi-player construct, and big data to improve its modeling of the enemy and environment over time (Figure 1).

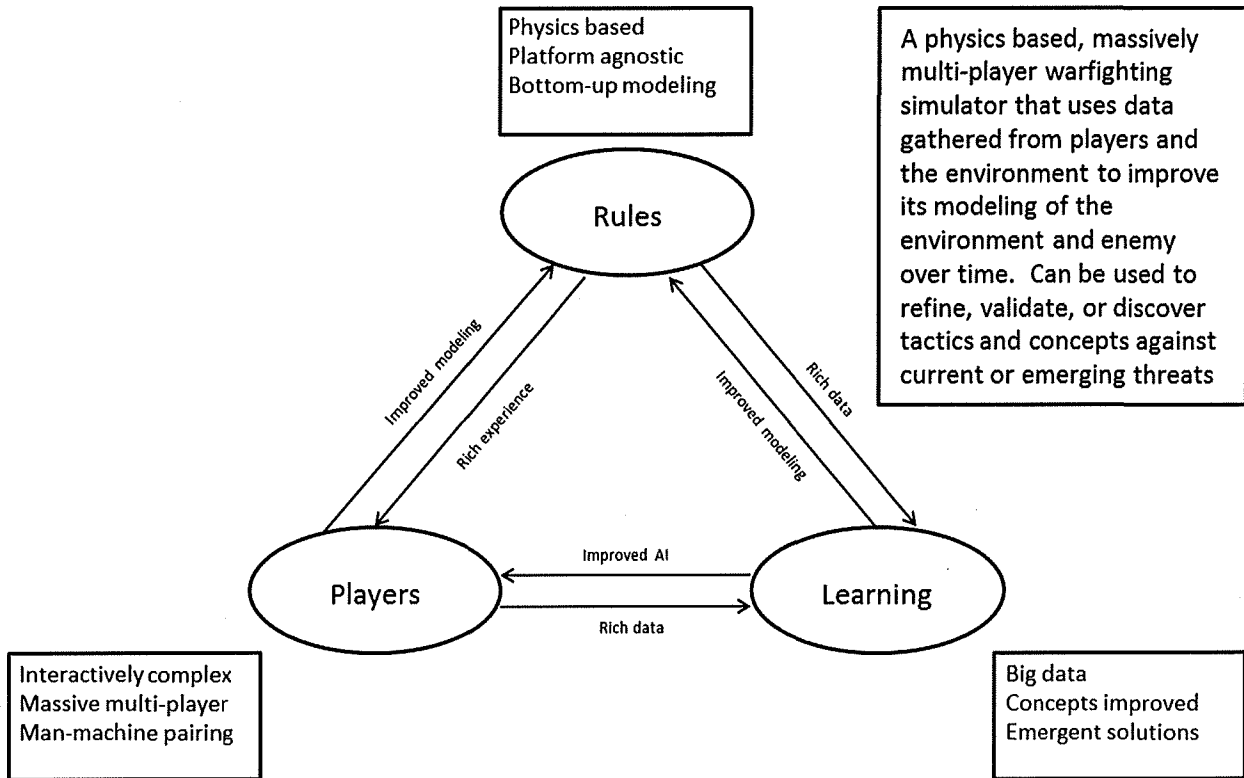


Figure 1 – Model for a modern wargaming simulator

Physics Based System

At the heart of every wargame are the rules that constitute it. The basic object of any wargame is to reveal the principles of warfare to its participants through feedback provided during play. The rules that govern wargaming are meant to model reality to ensure that feedback is true enough to life to be useful to the players in the future. There is an ever-present tension between the need to simplify these rules and the need for the rules to be complex enough to

simulate the environment in an effective manner.⁵ Create a complex wargame and it will take too long to learn the rules and cost too much to actually play and administer. Create a simple wargame and players will quickly learn the rules and devise tactics to exploit them. Rule exploitation itself is a good thing. But when rule exploitation results in actions that would be non-sensical in real life, the wargame is no longer useful.

The common solution to both of these problems is the proposed physics-based, open-world digital environment. The world itself is a physics-based, open-world environment. There is no rule book, and each participant simply has to go out in the world and discover what can and cannot be done. The environment is supremely useable as the participants are immersed in it every moment of their lives. Physics-based game engines are similarly useable. There is no rule book because there does not need to be one. Players, equipment, and platforms can all be programmed with properties that correlate with real life and the game can begin. In a properly constructed wargame, for example, there would be no look-up table for the rate of movement for a platoon through swampy terrain in game. The platoon would move as quickly as it could through the swamp that it is in. The planning factors would be the same as real life. The result is a game that would be both easy to use and only exploitable in the sense that the real world is exploitable – learn the rules, use them to your advantage, and win.

The biggest difference between a simulation and real life is the stakes of the game. Fear and violence cannot be simulated, but incentives can be put in place to force players to behave as if they were. Access to content could be governed by performance under a scoring system that placed a premium on mission accomplishment and survival but not either by itself. The most important incentive however would be simply that each player gets only one life in any given

⁵ M.G. Weiner, M. G., “An Introduction to War Games,” Santa Monica: The RAND Corporation, 1959, 12-14.

battle. This one rule, has proven time and again to radically change the behavior and playing strategies of players across gaming genres to emphasize survivability while still finding a way to win the game.⁶ It would be no different in a wargaming simulator.

Such a simulator should be made available for play either on console or personal computer, with a user-friendly interface, and available for around the clock play. Private industry has worked under bring your own device rules for years and gaming consoles are nearly ubiquitous in military barracks, obviating the need to distribute costly hardware to the operating forces.⁷ And it should be playable from home. A user-friendly interface is critical and represents a sharp departure from the procedural trainers that we call simulators today. The focus of the game would be collective tasks, not actual operation of equipment. The goal of this would be to allow any player to operate any platform or exercise command at any level after a relatively brief tutorial for the interface with follow-on tutorials detailing doctrinal tasks, tactics, techniques, and procedures. Tutorial completion would unlock gaming content, specifically eligibility to operate certain platforms or act in critical roles. Around the clock play strikes to a core deficiency of wargames up until now – the cost in both time and resources per repetition. An easy to access, easy to use, true to life simulation, focused on large-scale collective training achieves all of the goals of wargaming in a manner not yet attempted by the military to this date.

The impacts of such a physics-based simulator would be three-fold. First, the training potential of such a system is enormous. Current training systems do not adequately address the

⁶ In gaming culture, having only one life in game is referred to as “hardcore” or “roguelike” rules. Winning player character builds and playing strategies are radically different, typically focusing on defense, speed, and escape options rather than offense. In first person shooter games, normally played at a frenzied pace, the one life dynamic causes the spontaneous emergence of an “empty” battlefield.

⁷ Macedonia, 159.

need for collective task training, especially for officers.⁸ Nor do they adequately address the need for cross-domain training with such exercises being rarely performed and at enormous cost.⁹ Second, the performance and creativity of players would only increase over time by emphasizing force on force free play. Real decision making capability can only be developed under such conditions but due to time constraints and the cost associated with field training, opportunities for free play are few and far between. A free play simulator could fill this gap, serving as a powerful leadership development tool. Finally, the data gathered could be used to tremendous advantage. Most of this will be discussed in the section on machine learning, but there is also an immediate human impact. The ability to gather millions of data points on hundreds or even thousands of simulated battles with thousands of participants using relevant scenarios and employing plans crafted by actual operators could provide rapid, cost-effective, and useful feedback unavailable from any other source. Restricted to operators with appropriate clearance, wargames with thousands, rather than tens of participants, become a real possibility. This is important because no matter how accurately a wargame describes the physical environment, if it only has a handful of participants, it can never simulate the interactive complexity of combat.

Massively Multi-Player Construct

Human decision making on a massive scale drives warfare, thus wargaming simulations should account for it. A truer to life wargaming simulator will not only better simulate the physical environment, but simulate the human environment as well. The gaming industry already does this in Massively Multiplayer Online (MMO) games where thousands of people can

⁸ Lenoir and Lowood, 10.

⁹ Bold Alligator, a Navy-Marine Corps ESG level exercise, for example, is only performed every other year and never has full participation in terms of live platforms or participants

play together simultaneously. Often players or groups of players exhibit behaviors wholly unexpected by game developers and sometimes even have real-life applications.

For example, a 2005 disease outbreak in the game *World of Warcraft*¹⁰ caught the eye of epidemiologists who recognized several similarities between the outbreak in the virtual world and the real world SARS and avian influenza outbreaks in 2007. Epidemiologists recognized that even though there were differences between the virtual and real world, the study of in-game behavior could help understand real-life behavior in the face of future outbreaks.¹¹ No super computer then or now could simulate the massive number of decisions made in response to the in-game outbreak, revealing tremendous potential in the data generated by such online play. Essentially, *World of Warcraft*, inadvertently crowdsourced a simulated viral epidemic. A massively multiplayer wargaming simulator could crowdsource a simulated war.

Crowdsourcing is a data gathering technique that is currently used in the digital economy.

A definition of crowdsourcing was offered by Jeff Howe:

Simply defined, crowdsourcing represents the act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call...The crucial prerequisite is the use of the open call format and the large network of potential laborers (Howe, 2006)¹².

The military could use similar techniques in an effort to find emergent solutions to complex operational problems. A mission or scenario could be set up in the simulated environment which would then be played by a large number of participants. The best solutions in pursuit of the mission or scenario would be revealed statistically and available for further study and analysis. In this way, the crowd has performed the labor of finding the solution to the problem and thus

¹⁰ "Digital plague hits online game of World of Warcraft," Security Focus, September 2005.

¹¹ Ran Balicer, "Modeling Infectious Diseases Dissemination Through Online Role-Playing Games," *Epidemiology*, vol 18: 260-261

¹² J. Howe, 'Crowdsourcing: A Definition', *Crowdsourcing: Tracking the Rise of the Amateur* (weblog, 2 June), http://crowdsourcing.typepad.com/cs/2006/06/crowdsourcing_a.html

crowdsourced the solution. It is important to note that an array of solutions would be attempted in pursuit of achieving mission success. The number and variety of solutions are directly tied to the number and diversity of the players. The more players and iterations of gameplay would increase the number of emergent solutions that were potentially unforeseen.

The authors propose using four groups in a logical progression to crowdsource simulated solutions to complex military problems. These would consist of a control group, the crowd, a refinement group, and a man-machine pair group.

The first group would serve as the control group for the desired tactics to be developed or refined. The control group would consist of service operators who are familiar with current tactics. This is a group of subject matter experts who would interact in the simulation in order to validate the environment to include its accuracy in replicating the battlefield along with all associated equipment in use. Current tactics would then be validated and evaluated versus a simulated threat to establish a baseline of performance. This would serve as the control for testing the tactics which would emerge from the crowd.

The next group is the crowd which resides in the massively multi-player construct in pursuit of a large number of data points. The crowd would not be limited to current tactics, but would be free to execute the mission in the simulation in order to win the game. In fact, it would be essential that the crowd had little or no experience with the tactics used in the control group so that creativity and innovation would be maximized. Each individual in the crowd would find creative solutions to the problems presented in the game. The solutions that accomplished the mission could be statistically analyzed to find the best solutions based on the desired parameters. Security would be a concern as any information that the public has access to would also be accessible by outside agencies. Protocols would have to be put in place to protect the data

received.

The refinement group would be provided by the service's operational test community. The test operators would evaluate the statistical emergences from the crowd and further test those solutions against the scenario or platform. They would refine the solutions and match them against the control group's output. Once refined, the new solutions could be taken to reality and tested in the operational test environment with the actual platform against real-world threat replicators.

The final "group" in the process is the man-machine pair. It is recognized that emergent phenomena are valuable because of the potential to identify innovative solutions over a massive number of data points. However, those data points could also be recorded in an effort to teach the machine how to better predict and replicate human behavior. This man-machine pair consists of the crowd and the machine working together as a team. As the crowd interacts inside the physics-based environment, the machine is observing and analyzing the crowd's gameplay. In the course of its analysis, certain crowd behaviors and decisions associated with successful tactics and strategies will be identified. The machine then establishes a framework in which the most successful series of decisions would lead to mission accomplishment. These tactics and strategies could be refined iteratively by the refinement group. Additionally, the machine has the potential to provide a more realistic simulation by using its analysis of the crowd to modify the behavior of any computer controlled entities within the simulation to mimic the human behaviors of the crowd, which will be further discussed in the section on machine learning and big data.

The massively multi-player construct and crowdsourcing are only a means of harnessing the collective creativity of those that play the game. Those ideas and solutions that approach the scenario differently are those that may be the most successful in combat with varying

implications at the tactical, operational, and strategic levels. A historical example of this is World War II Luftwaffe fighter pilot, Erich Hartmann, who became the highest scoring ace of all time not by “dogfighting” other aircraft, but by diving in on unsuspecting prey and breaking contact before becoming vulnerable. His ruthless tactics are counter to the popular perception of a traditional “dogfight”, but they emerged as the most lethal and survivable solution for an individual aviator during World War II. In a massively multi-player simulation, players would reveal new disruptive tactics such as this on merit of the sheer number of games played. Furthermore, the operational impact of such tactics could be predicted in advance. This is all possible through the crowd playing, the machine observing and identifying a successful tactic, and analysis of data gathered over thousands of games played.

Big Data and Machine Learning

Data gathered from a massively multiplayer wargaming simulation also has real potential in the realm of concept development. With the ability to alter existing platforms and equipment, current and future doctrine and concepts can be validated and refined. By introducing new platforms and equipment into the simulation, providing a tactical or operational scenario, and letting the players play, future requirements can also be tested and validated. After hundreds, or even thousands of plays the data would be available to determine points of failure, allowing for developers to change the properties of proposed platforms in-game in order to refine the doctrine or requirements. It is not too much of a mental leap to then imagine optimizing such capability increases across a system of systems to accomplish the mission at minimum cost in real life. In addition, from a systems perspective, free play will be an important component of discovering new battle processes as relatively revolutionary capabilities are added to the battlefield in the future. No one really knows how to best employ any one, let alone a combination of dozens of

developing and emerging capabilities on the battlefield. Thousands of repetitions in simulations could be the single best way to inform future decision points.

Besides potential uses in test and concept development, perhaps the greatest use for data gathered from a physics-based, massively multi-player wargaming simulator lay in machine learning. By machine learning, the authors mean the machine automatically providing the data necessary for self-correction, self-improvement, and self-evolution. The machine actually correcting itself is a nascent concept in engineering and not technologically feasible for a project of this kind in the near term.

Big data can be used to improve the rules of the simulator itself. Currently, large scale operational simulators run relative combat power assessments to determine the outcome of engagements. These assessments are objectively crude, leveraging historical evidence and best guesses about a variety of intangible factors ranging from superior or inferior command and control, intelligence, training, etc. Data gathered in simulation, properly tagged and processed could be used to better model battlefield outcomes under a variety of conditions. With millions of data points gathered on individual, team, squad, platoon, and higher-level action, when there are not enough human operators to participate in a simulation, the models used in their place could be based on actual engagements under similar conditions.

Big data can also be used to discover outliers in battlefield outcomes. Perhaps the rate of success at a given task for players is overwhelmingly better than estimated. This could be because they developed a new method of solving the problem. Or it could be because the simulation is deficient or just incorrect in some aspect in which case it could be altered to better approximate real life.

Another underappreciated form of big data is community. Current game developers

release their games while still in development to gather feedback from thousands of players prior to release to the general public. This method allows developers to rapidly identify and correct bugs, glitches, and design flaws more rapidly than they could ever do on their own.

Acknowledging the impossibility of perfection, and ever-changing character of the battlefield this wargaming simulator would be in a constant state of development, using both big data and community feedback to constantly improve itself.

Another aspect of machine learning is Artificial Intelligence (AI) refinement. The authors do not mean AI in the sense of trying to develop a consciousness, but an AI that better emulates human behavior in-game. The gaming industry already uses data gathered from players to reprogram AI to behave in a more humanlike manner. Outcomes are evaluated based on players' ability to distinguish between other players and the computer in-game, a simple sort of Turing test.¹³ Using data gathered in-game, the simulator AI could be iteratively improved. This would be useful in two aspects. First, as AI improved, it would provide a more realistic simulation to players over time, allow for fewer players to be involved in large scale battles to simulate useful outcomes, and could potentially teach the AI to better cooperate with its human counterparts. With man-machine pairing to become a battlefield reality in the near future, a simple, cost effective system to teach both man and machine how to best cooperate may well be a simulator such as the one proposed here.

Case Study

The purpose of this case study is to demonstrate the utility of even a small scale, single domain application of the proposed simulator with the F-35B.

¹³ Christopher Moriarty and Avelino J Gonzalez, "Learning Human Behavior from Observation for Gaming Applications," in Twenty-Second International FLAIRS Conference, Orlando: Association for the Advancement of Artificial Intelligence, 2009, 439-445.

The current state of the F-35B program with respect to simulation in training and tactics development is well advanced beyond most simulators. The simulators are part of a larger system of training devices intended to teach pilots how to fly the F-35, then later how to employ it in combat. It is built around a series of single, federated simulators that include a replicated cockpit and a 360-degree immersive digital screen upon which the environment is displayed. It is one of the most advanced procedural trainers available today. Each individual simulator can be linked to others to learn basic skills such as formation flying and more advanced skills such as multi-plane suppression of enemy air defense. The number of F-35s in the simulation is limited by the number of physical F-35 simulators linked for the specific event. The enemy entities are replicated by software and controlled by either pre-programmed behavioral algorithms or real-time, limited human control. The number of enemy entities is limited only by the scenario and the replication of how a threat nation would employ its assets in that scenario. The threat tactics are limited by the computer's ability to process the pre-programmed responses with the human monitor occasionally taking control of single entities in order to ensure a learning point is achieved.

The F-35 simulator, is still limited in its scope and application because it was built first as a procedural trainer for an individual pilot, then linked with other simulators as a mission trainer for a multi-pilot effort. The only humans in the loop are the pilots themselves with occasional human monitor manipulation of enemy entities. The enemy replications are pre-programmed and linear in function and response to F-35 actions which in the end makes mission training formulaic and procedural as well. The F-35 simulator is therefore good for its intended purpose. It is good at procedural training. However, it is limited in the realm of tactics development to only those simulators that can be linked and those entities that can be programmed.

The authors' proposal would be a radical shift in the entire structure of F-35 tactics development. It is a proposal that is not dependent on individual procedural simulators linked in series. The vision of how F-35 tactics development could be structured begins with the environment. The proposed simulation concept is not a single mission environment, but a holistic, physics-based digital world in which F-35 simulations could interact. For example, the environment could have an area similar in geography and threat lay down as the Straits of Taiwan. The game would include a mission which requires projecting combat power across the straits into a threat nation for any of a number of reasons. This scenario would be scalable from as large as the theater level down to the F-35 mission level. Once set, the mission would be made available to the four groups working in parallel or in sequence in order to gain a systematic look into current and potential tactics.

The control group would work through the problem with current tactics and validate their ability to achieve mission accomplishment. This would be graded on established criteria such as target destruction, friendly losses, enemy losses, force to task ratio, risk to mission, and risk to force. Once this control has been set, the scenario could be given to the crowd for free gameplay. The crowd will have the freedom to play when they want and how they want. It is important to note that the crowd is not limited nor exposed to current tactics and procedures. They will look to find a solution based on their own creativity and ability to win the game. The computer program monitors the gameplay and gathers data throughout the scenario. The number of iterations is limited by the number of people attempting the mission and how many times they choose to play. Time is only a factor in that there needs to be enough time allotted for the crowd to go through enough iterations for a statistically significant number of times. Once a significant number of iterations has been performed, the analysts could look at what worked and what

failed. The tactics that worked would be further analyzed, distilled, and developed by the refinement group to determine feasibility, suitability, and acceptability.

Once the tactics have been refined, they would be tested against the control so that they could compare the tactics against the criteria established for the particular mission. Successful tactics would be accepted and unsuccessful tactics would be discarded. Throughout this effort, the computer would be monitoring and analyzing every iteration so that it could learn the human behavior in different scenarios while also running further iterations to fully develop new potential tactics. It would do this by running the tactics through a series of tests during which the program would change a variable, run the tactic, change another variable, run the tactic, etc. In this manner, further learning would occur from the human standpoint in the way of validation and the machine standpoint in the way of how human behavior interacts under different circumstances. The desired output of this process is an innovative solution in the form of a tactic, technique, or procedure that has been measured against a control and determined to be feasible, acceptable, and suitable.

Conclusion

Current military simulators are excellent procedural trainers. Some are even excellent single domain, small-scale, collective task trainers. They are excellent in these respects because they were designed to be so. Procedural trainers essentially teach a single user or small teams of users complex but mechanistic processes to solve problems. They are structurally complex but interactively simple and do not support the sort of innovation necessary to develop real operational art even at a small scale, let alone at the operational level across domains. This paper demonstrates that it is possible to create a simulator that supports real innovation but requires military professionals to rethink what a simulator could be in the spirit of wargames and test. It

requires a different kind of simulator, designed with innovation as its object rather than training in any one narrow set of tasks. The authors believe such a simulator will be structurally simple, interactively complex, and capable of leveraging data gathered over time to capture emergent solutions.

By structurally simple, the authors mean a single, physics-based operating environment, rather than a federation of dozens of propriety ones, with a user-friendly interface, that can be populated with whatever platforms and units necessary to test a battle plan or operational concept. By interactively complex, the authors mean involving hundreds, even thousands of users over time, with an emphasis on analysis of competitive human interaction rather than on individual performance. By being capable of leveraging data, the authors mean using the data gathered by this test bed to refine the simulation over time, validate current and future concepts, and to identify new operational art developed spontaneously by users over thousands of repetitions.

Users in the civilian gaming industry have already validated this model for simulation and are using it on countless servers globally for entertainment purposes. If the military co-opted this model, even on a small scale, it could improve the development of emerging tactics on next generation platforms such as the F-35B. If co-opted on a large scale, it could validate battle plans and operating concepts, provide invaluable operational level training to military officers, possibly reveal otherwise unforeseeable tactics, and even provide a platform for eventual man-machine training.

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