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Mission Engineering and Prototype Warfare: Operationalizing Technology Faster to Stay Ahead of the Threat

Matthew A Horning
Mission Engineering
US ARMY, TARDEC
Warren, MI

Robert E Smith, PhD
Analytics
US ARMY, TARDEC
Warren, MI

Shaheen Shidfar
Strategic Planning
US ARMY, TARDEC
Warren, MI

ABSTRACT

Prototype Warfare represents a paradigm shift in how the US Department of Defense (DoD) executes acquisition of defense systems in a manner that is significantly faster than traditional acquisition. At its core, Prototype Warfare shifts focus from large fleets of common one-size-fits-all exquisite systems to small quantities of rapidly fielded, highly tailored systems that are focused on specific capabilities within a specific theater to address a specific (and typically urgent) requirement. This paper does not address the programmatic or policy implications of implementing Prototype Warfare, but instead provides an approach to achieving Prototype Warfare from a technical perspective. The key to executing a Prototype Warfare program is to establish and execute a robust Mission Engineering practice that uses the operational context of a system to drive performance requirements, allowing the modeled end use of the system to be root of all requirements traceability.

"Success no longer goes to the country that develops a new fighting technology first, but rather to the one that better integrates it and adapts its way of fighting…." -The National Defense Strategy (2018)

INTRODUCTION

While the Army Futures Command and legislative changes attempt to streamline acquisition bureaucracy, the Army will still struggle to keep pace with the global commercial technology marketplace as well as innovate ahead of adversaries' own research programs. Reverse engineering and technology theft make it possible for adversaries to inexpensively copy DoD-specific technologies, potentially resulting in a negative return on investment of DoD research dollars. The US adversaries' pace of innovation further compounds the challenge. Thus, the Army must not only equip the force to defeat what is anticipated, but equip the force to defeat an adaptable enemy in a wide variety of environments. This paper proposes a framework that will enable identification of strategically relevant problems and provide solutions to those problems at the speed of relevance and invert the cost asymmetry.

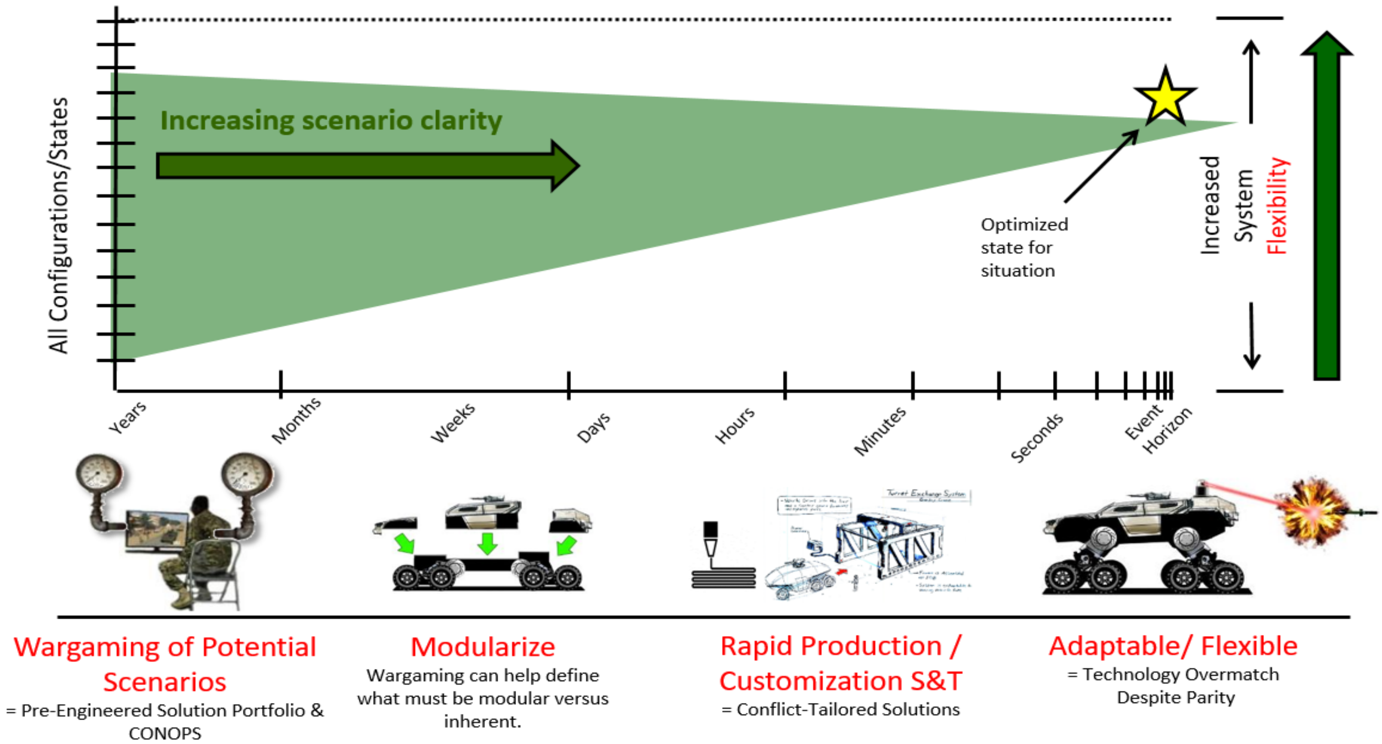

Figure 1 The Time/Flexibility Paradox**.** The closer to the event horizon a scenaio scenario becomes, the less flexible a solution needs to be. Prototype Warfare aims to operate as far to the right as possible, requiring the least amount of reaction time to develop a solution.

To continue to maintain battlefield superiority, the future Army and the rest of the DoD, must learn to continually assimilate, produce, and operationalize technologies considerably faster than our adversaries to gain a time-domain overmatch where a technologically pure overmatch is not possible due to reverse engineering and technology theft. In other words, the nation that brings operationalized technology to the fight first will achieve dominance, and reducing development times to months instead of years operationally makes an impact. The overarching goal is to create an environment that US adversaries cannot duplicate: timely integration of advanced technologies with skilled Soldiers and well-trained teams. The intersection of two high level concepts, Office of the Secretary of Defense's (OSD) Mission Engineering[1] and Robert Leonard's Prototype Warfare[2] pave the way to increasing the rate of innovation by operationalizing technology faster to stay ahead of the threat, while simultaneously reducing the cost of technology overmatch.

MISSION ENGINEERING

The OSD Mission Engineering concept, proposed by Dr. Robert Gold, calls for acquisitions to treat the end-to-end mission as the system to optimize in which individual systems are components. Further, the concept utilizes an assessment framework to measure progress towards mission accomplishment through test and evaluation in the mission context. In fact, all actions throughout the capability development

[1] Gold, Robert. "Mission Engineering." 19th Annual NDIA Systems Engineering Conference, Oct. 26, 2016, Springfield, VA

[2] Leonard, Robert R. The Principles of War for the Information Age, Presidio Press (2000).

cycle must tie back to the mission context through the assessment framework. It goes beyond just sharing data to consider functions and the strategy for trades, tools, cross-cutting functions, and other aspects of developing a system or system-of-systems (SoS).

Consider the example mission objective of an airfield seizure. Traditional thinking and methods would identify an immediate needed capability for two identical air droppable vehicles, therefore starting with a highly constrained platform engineering solution. Mission Engineering would instead start by asking: what is the best way to seize an airfield? What mix of capabilities are required to do so? What mix of vehicles, Soldiers, exoskeletons, robots, etc. might you need within space and weight constraints of the delivery aircraft? What should the individual performance requirements be for each piece of equipment?

Mission Engineering breaks down cultural and technical “domain stovepipes” by optimizing for the mission using a SoS methodology instead of a ground, aviation, or cyber specific solution. By focusing on mission success parameters instead of traditional system-function constructs to drive requirements, untapped innovation space between

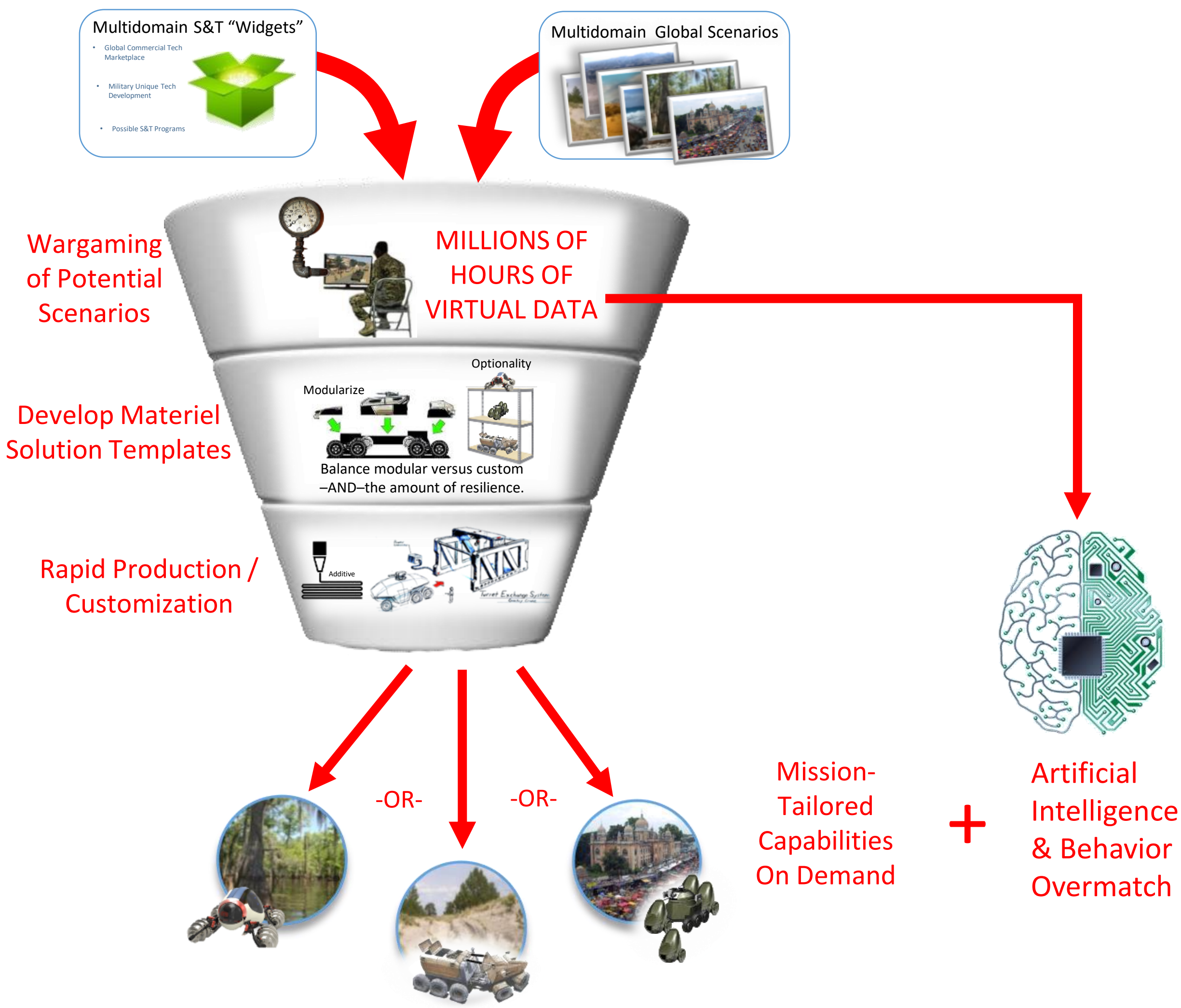

Figure 2 Prototype Warfare Framework

the conventional domain seams can be realized. For example, ground-based vehicle concepts could explore aviation-like solutions like motherships, deploying exoskeletons, drone swarms, or other ideas that have not been identified or presented because they have no clear home in a particular domain. It warrants stating twice that there are a series of mission optimized solutions that have not been identified or presented because they have no clear home in the current construct. Focusing the enterprise on the mission context of the problem set, instead of within traditional domain-based focus, will enable solutions development that is not only relevant and timely but also novel in ways not previously explored.

PROTOTYPE WARFARE

Prototype Warfare represents a paradigm shift from fielding large fleets of common-one-size-fits-all systems to rapidly fielding small quantities of tailored systems. Tailored systems focus on specific functions, specific geographic areas, or even specific fights and are inexpensively produced and possibly disposable. For example, vehicle needs are different for urban, desert, and mountain terrains. A single system is unlikely to excel across those three terrains without employing exotic and expensive materials and technology (becoming expensive and exquisite). They could comprise the entire force or just do specific missions, such as Hobart's Follies during the D-Day landings.

A further advantage of tailored systems is that they will force the enemy to deal with a variety of unknown U.S. assets, perhaps seen for the first time. A tank platoon might have a heterogeneous mix of assets with different weapons and armor. Since protection and lethality will be unknown to the enemy, it will be asymmetrically challenging for them to develop tactics, techniques, and procedures or materiel in a timely fashion to effectively counter such new capabilities.

ENABLING PROTOYPE WARFARE

Three key technological advances present the opportunity to implement the Mission Engineering and Prototype Warfare concepts. Early Synthetic Prototyping (ESP), artificial intelligence (AI), and rapid manufacturing each provide ways to achieve these concepts. Individually, each would present significant opportunities, but when applied within the Mission Engineering / Prototype Warfare framework they create the synergy for a potential innovation revolution.

The first of these advances, ESP, is under development by United States Army Capabilities Integration Center (ARCIC) and United States Army Research, Development and Engineering Command (RDECOM). ESP is a physics-based persistent game network that allows Soldiers and engineers to collaborate on exploration of the materiel, force structure, and tactics trade space.[3] According to a 2015 Survey data from an ESP pilot study, ESP will generate over one million hours of digital battlefield data per year.[4] The use of ESP

Figure 3 While wearing a tracked, head-worn display, a mechanic to complete a maintenance task inside an LAV-25A1 armored personnel carrier.

[3] Smith, Robert E. and Vogt, Brian. "Early Synthetic Prototyping Digital Warfighting for Systems Engineering." Journal of Cyber Security and Information Systems 5.4 (2017),

[4] Vogt, Brian; Megiveron, Michael & Smith, Robert E. Early Synthetic Prototyping: When We Build It, Will They Come? Interservice/Industry Training, Simulation, and Education Conference. Orlando. (2015).

for Prototype Warfare would allow new equipment and tactics to be trialed in a synthetic environment for improved requirements generation and faster timelines from capability need to technical solution.

Beyond the ESP engine itself, investment is needed in cutting edge research in machine learning and big data techniques needed to derive useful data on tactics and technical performance from the data. Understanding human intent and behaviors is difficult work for current computers, but the payoff is truly disruptive. Also, as robotic systems become more prominent on the battlefield, the country with the best AI (artificial intelligence) to control them will have a great advantage. The best AI depends on having a robust data set sourced and fused from multiple domains including doctrinally-, experimentally-, and digitally-generated data. Mission Engineering also provides benefits for the challenging problem of testing the system safety aspects of AI by providing mission context, problem space, and an associated assessment framework.

To achieve this vision, the Army needs to invest in technology that allows rapid problem identification, engineering, and fielding of tailored systems. For over two decades, the Army has

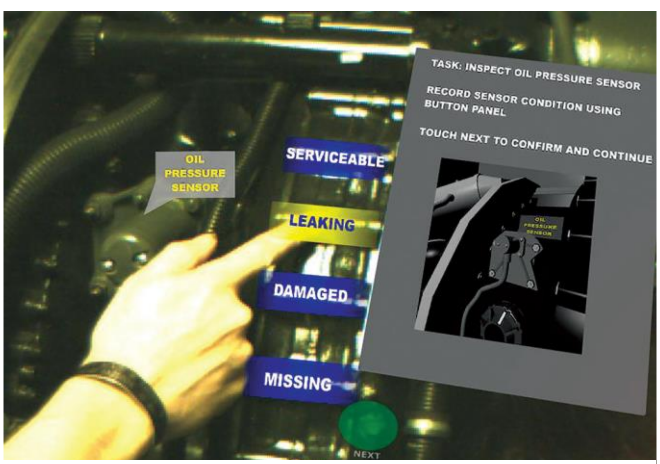

Figure 4 A user manipulates 3-D virtual buttons while receiving haptic feedback from the underlying grooves of an engine compression section.

touted modularity to achieve system tailoring and flexibility. However, modularity adds interface burden and complexity. A specific-built system purpose built for the problem set will always outperform a modular system under the same circumstances. Research efforts are needed to understand the trade-offs of custom production versus modularity to better understand when and where to apply a custom solution versus a modular solution. The DoD also needs to strategically grow investment in rapid manufacturing techniques (to include 3D printing) and open architectures with industry.

With all these elements integrated, an optimized prototype warfare solution, potentially a disposable solution, can be developed to solve environmentally-specific problem set at a faster pace than an exquisite system that is capable of being reused to solve a wide array of problem sets but at less effectiveness. By focusing development efforts on problem sets that actually exist instead of problem sets that may exist, an increase in the development efficiency and speed is realized.

CHALLENGES TO PROTOYPE WARFARE

New challenges are created when there is a varied fleet of tailored systems, especially for logistics, training, and maintenance. One key is to develop a well-tracked digital manufacturing database of replacement parts. For maintenance, new technologies such as augmented reality might be used to show mechanics who have never seen a system how to rapidly diagnose and make repairs.

New Soldier interfaces for platforms should also be developed that are standardized and simplified so it is intuitive for a soldier to operate different systems in the same way it is intuitive to operate an iPhone to reduce and possibly eliminate the need for system specific training. For example, imagine a future soldier gets into a vehicle and inserts his or her common access card. A driving display populates with the Soldier's personalized widget configuration, similar to a smartphone display. The displays might also help soldiers understand vehicle performance envelopes. For example, a line might be displayed over the terrain showing how sharp a soldier might turn without a rollover.

SYSTEMS ENGINEERING REVOLUTION

To achieve the goals of Prototype Warfare, a change in how the US develops, produces, and implements new military capabilities is needed; however a discussion of the legal or regulatory framework required is beyond the scope of this paper. But in parallel to the laws and the policies changed needed, the DoD must also shape how it engineers solutions to the problem sets it's faced with, and the adjustments required are nothing short of a revolution. This is not a revolution in the specific practice of Systems Engineering (in fact the processes within the Systems Engineering discipline are well suited to this approach), but a revolution on where and how Systems Engineering practices are applied.

Engineering organizations should develop or reinforce its Mission Engineering and its enabling capacities such as Modeling and Simulation (M&S) and Digital Engineering. Engineering organizations must seek to staff personnel organic to the organization with significant military operational experience with a variety of backgrounds, not just those that have backgrounds in the traditional domain of the organization. The integration of operational expertise as early as possible in the engineering lifecycle is critical to developing solutions that have operational utility. The integration of this operational experience goes beyond what is provided through the Capability Developer within an Acquisition program. Dedicated personnel with a focus on translating operational need to technical solution are needed.

Additionally, engineering organizations should implement a robust Digital Engineering practice. Digital Engineering, referred to as Model Based Systems Engineering (MBSE) in some circles, is an "integrated digital approach that uses authoritative sources of systems' data and models as a continuum across disciplines to support lifecycle activities from concept through disposal."[5] A Digital Engineering approach is a required capability to Prototype Warfare because the problem set can be iterated on in a digital environment, prior to physical implementation, significantly faster than a traditional waterfall approach.

Implicit in implementing a Digital Engineering approach coupled with Prototype Warfare is also the need to revamp the Systems Engineering Technical Review (SETR) requirements and expectations to be suitable to a time-sensitive, model-based process. A logical break occurs between the traditional System Functional Review (SFR) and Preliminary Design Review (PDR) where traditional systems go from functional development and modeling to physical development and modeling. For a Prototype Warfare focused program, the program itself exists in a perpetual SFR state with mission tasks and system logical functions mapped and continually improved over time. When a specific scenario-specific solution is needed, the scenario requirements collapse all possible solutions to a specific implementation that rolls out of the solution-agnostic model set and is sent on its own track toward implementation, including SETRs from PDR and beyond.

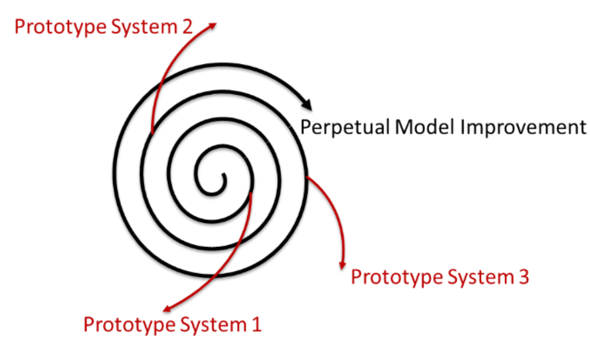

Figure 5 Prototype Warfare Digital Engineering Model

[5] Peterson, Troy. "Digital Engineering." Presentation to TARDEC Leadership. Warren, MI. (2018).

CONCLUSION

The globalization of technology allows any organization with the right resources to purchase cutting-edge commercial technology that can be modified or used in a military application. This changes the way we think about the ability to generate combat power to compete internationally from the physical domain, to the time domain. Through the proposed Mission Engineering and Prototype Warfare framework, the DoD can assimilate and operationalize technology quicker to create an ongoing time-domain overmatch and invert the current cost asymmetry which is adversely affecting the public's will to fight. Applying human thought and other resources towards finding new ways to understand mission context and field new solutions will provide capability at the speed of relevance and help reduce operational surprise through a better understanding of what is possible.

FURTHER READING

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[5] Peterson, Troy. "Digital Engineering." Presentation to TARDEC Leadership. Warren, MI. (2018).