

Project Proposal

**Ground Combat Systems Survivability Robustness Analysis through Model Based Systems Engineering (MBSE)**

For

Professor Gene Paulo

SI0810 Integrating Project

Naval Postgraduate School

By

SE311-114G Vehicle Survivability

20 November 2012

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for

MSSE CAPSTONE - VULTURE PROPOSAL

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# Introduction

Combat vehicles have historically balanced the “iron triangle” of protection, lethality, and mobility in design to meet the requirements of affordable force effectiveness. To date, increasing protection has meant adding armor (or other technologies such as soft and hard kill active protection and signature management) and adding weight, which decreased mobility and adding significant cost.

# Purpose

The purpose of this research effort is the implementation of MBSE design methodology that uses functional allocation of requirements to physical form as the initial sizing and synthesis tool architecture basis. The framework will be implemented in a software environment useful for concept exploration and design, especially as a first level tool to allow government designers to explore concept possibilities. The method implements design in a “solution neutral” environment that allows the designer to allocate function to form in various ways. As an example, vehicle platform-specific considerations may be analyzed, such as wheels versus tracks, as well as system of system considerations for possibly a maneuver unit of action.

The capabilities that have an effect on mission effectiveness are not independent or separable. Use of MBSE methods and tools allows the mapping of the interconnections to be defined, studied, and arranged providing insight into how the design may best be accomplished. The ability to identify functions in a solution neutral sense allows designers from various disciplines to proceed in their own process of mapping function to form, allowing the design team to work independently. If the system-level interconnections are understood, then the dependencies can be accounted for in the process, and the resulting design will have a more even fidelity across the needed design disciplines, and concept exploration can come closer to achieving a total system solution.

The MBSE approach means that the system mission capabilities and operational scenarios are defined in conjunction with probabilistic MOEs, which are then linked to appropriate functions related to protection, lethality, and mobility as determined by the team. The combat vehicle platform is designed to include combat and weapon systems integrated and mapped through functional allocation. This methodology identifies functions requiring fulfillment, presents physical design parameters to meet these needs, and maps their interrelationships.

Our team of researchers at Naval Postgraduate School (NPS) will utilize a multi-disciplinary MBSE approach to model and develop a methodology that leads to the output analyses of the combat systems effectiveness as inputs for the design process. This effort leverages recent NPS research sponsored by the Office of Naval Research (ONR) in support of ship design. The effort will be led by students and faculty from the Systems Engineering department. The FY13 objective will be to integrate processes and tools such as systems architecting and development, various simulation technologies, and statistical design of experiments. The data generated from these modeling experiments will be used to generate an evaluation matrix for the effects of combined combat vehicle design attributes on operational criteria that affects vehicle and crew survivability. The impacts of combat system capability and technology trade-offs will be examined and include consideration of cost, risk, and system effectiveness in multiple criteria survivability trade space analysis. The objective will be to model survivability of the vehicles and crew members in the context of two different mission scenarios. For the longer term, the team will develop a methodology for effectiveness-based engineering design that includes that integration of system of systems architecture, combat systems and combat operations, as well as related life cycle cost concerns from the perspective of multiple missions and unit types. This methodology will be tailorable to meet the needs of the user, by identifying the necessary process, tools, data and resources required.

For the purpose of our modeling and analysis survivability we will consider *survivability* to mean the ability of a system to minimize the impact of a finite disturbance on value delivery. The *system* in our case can be a vehicle, convoy (network), or an extended system of systems that includes remote sensors and fixed assets as well as vehicles. The *finite disturbance* historically takes the form of rocket or mortar fire, buried improvised explosive devices (IEDs), gunfire, sensor jamming, and physical barriers or alterations to the terrain. In a net-centric warfare context, disturbances also include overt and covert network attacks, surveillance, and communications anomalies (disruptions and unauthorized access). *Value delivery* refers to the preservation of the assets necessary for mission success with an emphasis on force protection.

We will research and model methods to reduce both the likelihood and magnitude of a disturbance and will focus on the effects of trading attributes beyond armor (e.g., stealth, agility, speed, or resilience[[1]](#footnote-1)). By carefully considering a properly selected range of attributes we will be able to help guide and inform choices about the composition of vehicles supporting warfighter operations at the Battalion level from an outcome-based perspective.

# Problem

The idea that increasing lethality or mobility would also increase protection has been supported with professional military judgment, but no analytic metrics have been developed that can trade the weight of armor protection for increased mobility or increased lethality. Improvements in protection must be understood and quantified from a systems perspective, specifically in understanding the associated trade-offs. Materiel components and non-materiel functions and features that can be incorporated into vehicle designs and organizational activities comprise the trade space that will be studied. Combining the impacts of these trade space parameters on the statistical operational performance of the organization’s missions is crucial for the decision maker to cost effectively define needed and desired combat vehicle capabilities and to develop integrated doctrine, organization, training, materiel, leadership and education, personnel and facilities adjustments (DOTLMPF) that will effectively and efficiently support tactical ground maneuvers for combined arms mission scenarios.

Systems engineering is a key to effective, affordable system design. The proposed research effort described here supports the holistic systems approach by formulating a model-based systems engineering (MBSE) design process method that allocates mission capabilities to operational activities to functions and requirements, and finally to alternative physical forms. The method is defined to support implementation in a software design environment for concept exploration and design, especially for early stage first level studies that allow government designers to explore mission related possibilities and provide input to prospective engineering decision makers and combat vehicle developers

# Scope

The specific scope of work is bounded by the statement of work for Determining Combat Vehicle Occupant Force Protection and System Survivability through the Linkage of other Operational Requirements (Aug 20, 2012), developed in conjunction by the NPS faculty advisors Dr. Gene Paulo, Dr. Doug Nelson and Paul Beery with Ted Maciuba, PE, Deputy Director, Mounted Requirements, US Army Maneuver Center of Excellence.

Apply MBSE methodology focused on the survivability of a family of systems comprised of combat vehicles typically used in combined arms force elements supporting multiple operational missions. Examine the capabilities to be provided by this combat vehicle and further examine all aspects of that design, to include alternate platforms and systems that could perform the functions required to support the operational mission performance requirements. .The functional and physical architectures developed as part of this effort will provide a framework that can be used as a foundation for advanced development projects linking system architecture to operational requirements using higher fidelity simulation models representative of evolving vehicle design technologies, combat vehicle support systems and operational mission contingencies.

Develop an initial operational effectiveness model (OEM) through the conduct of an independent operational analysis of a notional ground combat system in an appropriate mission scenario, focusing on platform survivability. This will be accomplished through Operations Research (OR) student theses, utilizing MANA, an agent based model, to serve as a simulation tool.

Integrate the above student theses and capstone projects into a “Dashboard” that provides decision makers with a dynamic means of examining the trade space from both the operational and physical system perspective. This will be led by a PhD student, with support from a Simulation and Efficient Experimental Desisn (SEED) center research assistant.

# Research Objectives

1. Using techniques from the NPS systems engineering masters program, develop a procedural framework to integrate combat systems specific design attributes, cost, and organizational integration features into a set of simulated life cycle operational mission performance context models.
2. Analyze US Army operational mission profiles and multi-level scenario descriptions for combined arms units to develop major combat operations (MCO) and Peacetimescenarios applicable to the desired operational mission performance capabilities.
3. Generate scenario attributes that represent the measures of effectiveness for the operational mission performance requirements.
4. Develop configuration models for data structures and data input and output repositories that will be used for modeling the system attributes and features in simulations.
5. Implement vehicle system and sub-system design components and organizational attributes into simulated models of scenarios representative of the operational mission requirements.
6. Develop life cycle cost models for each of the system and sub-system design and organizational attribute components.
7. Perform sensitivity analysis of model data results to determine key factors in combat system design and unit operations for operational survivability.
8. Archive the modeling data inputs and outputs, constraints and mechanisms for future analysis and incorporation into acquisition decision support systems applicable to design and organizational integration for ground combat vehicle systems.
9. Provide recommendation for path forward including challenges faced and possible improvements to the process
10. Identify requirements including necessary data and inputs for altering the process to expand the mission sets and unit variants

# Methodology

Model based systems engineering (MBSE) as defined by INCOSE is “the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.” A model based approach provides many advantages including the ability to develop a process that is traceable and repeatable because it is captured via interrelated models as opposed to paper. In addition, this provides the ability to trace requirements back to the source documentation, as well as store that information to ensure that traceability and rationale for requirements is maintained. As the process and structure is further defined the use cases and architectures will be captured in diagrams that will be integrated with each other to provide a cohesive view of the overarching architecture. These models will allow for the team to identify points of interface that would need to be defined. One important caveat to the process we will be implementing is the current toolset is not fully integrated, however, we will be utilizing a configuration control process to ensure the two tools, CORE and ExtendSim have the same information and data specifications.

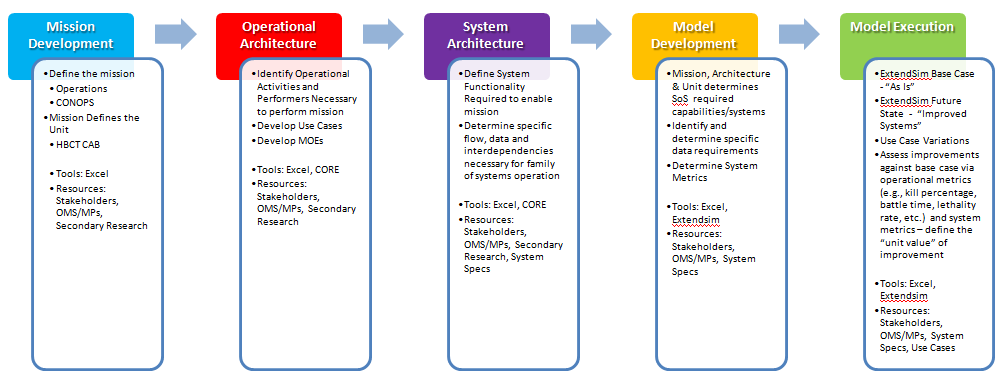
Figure X depicts the overall five step process that the team will be implementing in terms of a model based systems engineering approach. Each of these steps will need to be detailed and recorded as they are fully defined. The team will be executing the requirements analysis through modeling and simulation phases, however it is important to note that the key deliverables of this project are going to be a repeatable process that can be implemented in multiple scenarios, models, reports, simulation data, and a path forward recommendation. The team will not be developing a hardware solution or the follow-on implementation tool for this process, which has in the initial stages of the MCoE SOW been identified as a “dashboard”. We will be looking to develop the process and identify the necessary information, data and metrics associated with this process to be input into a tool, in addition the team will look to help identify the initial specifications for a “dashboard” system. 

Figure 1: Ground Combat Systems Survivability Robustness MBSE Process

The initial phase of this process is the mission development. Due to the fact that the team is developing a process and integrated modeling approach to evaluate the overall survivability of a unit from the operational perspective, the requirements analysis phase will be routed in the specific mission sets identified to be evaluated. Within this step the team will identify the missions to be analyzed, the types of operations, the unit type and the systems included in that unit. This will allow us to define the baseline by which to provide a sound traceability back to the requirements analysis. In addition, the team will be working with the appropriate stakeholders to identify key aspects of concern, the high level needs and begin to prioritize the requirements.

The second phase will be the development of the operational architecture. It is in this phase that the team will begin to detail out the operational activities and necessary performers for those activities. Since the unit and mission will have been identified, the team will focus on decomposing to the appropriate level and diagramming the architectures to identify interrelationships and dependencies. This diagramming will include the development of the specific use case models and which requirements they are directly linked to. Finally, through the decomposition of Operational Activities and the Requirements Analysis phase, the team will determine the high level MOEs at which we will be assessing the modeled information.

During the System Architecture Phase the team will determine the appropriate system functionality to be mapped to the operational activities and performers, which will be linked through the use cases and back to the requirements. This activity will set the foundation for the system of system baseline architecture that will be modeled in the upcoming phases. In addition, this information will begin at a high, generic level so that it can be altered and tailored for future missions, units and operations. The architectures will include the interactions and process flows between systems and external factors to enable the development of the modeling process in the follow on phase. In addition to the architectures, the team will define the specific system metrics that will be addressed and evaluated. This will allow the team to look at the specific design aspects within a given system or system of systems and then implement a change to see how the outcome rolls up to impact the overall Survivability MOEs of the unit.

The Model Development Phase will utilize the inputs from the first three phases to define the specific layout of the model to include what capabilities, systems, relationships and variables need to be modeled. The team will utilize this information to identify the necessary data required to be input into the model. The key element of this modeling process will be to identify the interactions and relative relationships between and within systems, because the data itself will not be completely accurate due to security reasons. However, the ability to take a model and identify which relationships need to be measured and evaluated and what type of system data is required to make an accurate model will allow follow on efforts, For Official Use Only or Classified, to alter the model to meet those standards, without the need to reinvent the wheel.

Finally, phase five of this initial effort will be Model Execution. This phase includes the actual running of the model, identifying a baseline with baseline results, integrating system improvements and use case variations to evaluate the effects on the overall survivability of the unit. This will allow the team to analyze what are the key areas of design and which system qualities attribute most greatly to the overall survivability of the unit, thereby providing the most likely trade space to work within.

The outputs of this process will include the models, analysis results, data requirements and architectures that can be reused to model different scenarios and missions. In addition, the team will look to identify the necessary inputs to the follow-on “dashboard” effort that will allow the customer the ability to have a graphical user interface (GUI) by which to analyze the results. The team will also look to make recommendation on how to improve the process and what challenges we faced.

# Evaluation Measures

# Deliverables

* MBSE Process
* Architecture Models
* Use Case Diagrams
* Simulation Models
* Simulation Results
* Data Requirements for “Dashboard” development
* Analysis of Alternatives

# References

<http://ses.gsfc.nasa.gov/ses_data_2011/110301_Osvalds.pdf>

1. These are examples only. It will require considerable analysis to determine the attributes most effective for our research. [↑](#footnote-ref-1)