PEO Land Systems Marine Corps has a continuing requirement for the development of an integrated suite of non-proprietary multi-variable modeling and simulation (M&S) tools. These tools must leverage existing ground vehicle simulation tools and enable M&S-based acquisition and lifecycle management of tactical ground vehicles to include cost data. The ultimate value of a fully integrated M&S toolset will be the ability to maximize the effectiveness of limited resources through simulation-based acquisition, while bringing optimized, focused capabilities to the Warfighter.

Computer-based simulation of the actual functions of tactical vehicle systems must be expanded to shorten development time and reduce program risk/cost. Currently, not enough components are accurately simulated and few are simulated together as a system (co-simulation). A fully integrated simulation-based acquisition approach that incorporates co-simulation tools will:

▶ Enable virtual vehicle designs to be functionally tested on computers

▶ Optimize vehicle prognostics and performance tools

▶ Assess candidate vehicles against critical performance parameters

▶ Inform the requirements process by identifying system requirements that are realistic and achievable

▶ Inform life-cycle cost (LCC) estimates and significantly reduce the total LCC of the system

▶ Save money by reducing design, as well as test and evaluations costs

▶ Allow high-fidelity requirements trade-offs with accurate predictions of costs, schedule, and performance (CSP)

▶ Evaluate potential new technology insertions and their effects on CSP

### 5.3.1 PEO LS Future M&S Vision

#### The Challenge

PEO LS has a need for a universal M&S aggregation tool that is verified, validated and has a high degree of fidelity. This tool will collect and aggregate industry component and platform data for various vehicle systems/platforms, assess the aggregated data through scenario-based simulation, and provide normalized CSP output that will allow leadership to confidently assess the value of a proposed system or upgrade (See Figure 5.3-1).

The development of a universal modeling and simulation aggregation tool will provide:

▶ Provide a streamlined and standardized approach for assessing CSP of future Ground Combat Vehicles (GCVs) and proposed upgrades/modifications

▶ Provide a single integration tool capable of assessing multiple platforms and multiple configurations
Allow plug-and-play capability for upgrade or alternative component comparison, as well as future modernization programs

Use requirements-based scenarios to assess total LCC and performance for each platform/configuration and upgrade

Establish standardized interfaces for industry to design component models, as well as establishes acceptable credibility assessment levels for key design aspects

Provide decision-making tools for acquisition leadership with a known confidence level

Reduce total ownership costs, while maximizing limited S&T resources

5.3.2 Shaping the Future of M&S

Framework Assessing Cost Technology (FACT)

Marine Corps Systems Command commissioned the development of FACT (Figure 5.3-2) as a framework to tie together disparate component and platform modeling efforts. FACT is an M&S framework, enabling real-time collaboration in a web environment, primarily geared towards conducting real-time trade space analysis for complex systems-of-systems. FACT uses Systems Modeling Language (SysML) to define complex systems. SysML expands upon the unified modeling language and
goes beyond software-centric design to include hardware components. The specification provides a formal means to describe a system, most notably the decomposition and organization of the system components, as well as the parametric relationships between value properties distributed throughout the systems.

### 5.3.3 Ongoing M&S Efforts

#### AAV Survivability Upgrade M&S

Utilizing high fidelity computational physics-based M&S of blast events, the AAV Survivability Upgrade vendor designs were evaluated against performance requirements.

#### Human Body Model

Current Advanced Technology Demonstrators (ATDs) used to predict human injury risk in live-fire blast testing have several limitations due to a lack of biofidelity and limited injury assessment capability. The ATD is composed of metals, rubbers, and plastics, and the majority of injury metrics associated with the ATD were developed under automotive crash loading scenarios.

Development of a human body model is underway; leveraging the recent advances in high-fidelity computational physics-based M&S of explosive events against armored vehicles. This major advancement in the ability to accurately predict human injury risk will allow vehicle designers and evaluators to predict risk of injuries across the severity spectrum experienced in the real world, supplement ATD results with prediction of injuries beyond fracture, expand injury risk assessments beyond the 50th% percentile and support theater event reconstruction and deliver injury causation determination. Beyond the scope of the PEO LS effort focused on injury prediction in Improvised Explosive Device (IED) events, this model could be used in the areas of ballistic protection, blast overpressure, burn injuries, and non-lethal munitions.
Post IED Damage SBIR

Following a vehicle IED event, it is critical to make informed, accurate decisions for damage assessment and repair. Unnecessary repairs lead to vehicle downtime and wasted maintenance manpower. Conversely, the reintroduction into service of a vehicle with significant internal damage, unseen through visual inspection alone, can put warfighters at higher risk for injury or death.

Two companies are currently in Phase II of SBIR contracts to develop the capability to systematically gather and store data from the vehicle and scene post event and process it into a format that allows the vehicle Program Management Office (PMO) to assess risk of repair vs redeployment.

SURVICE is developing an integrated, low-cost ruggedized, and portable tablet-based 3-D capture tool kit to guide and facilitate the assessment of battle damage to combat vehicle platforms.

The tool kit will include:

- Development and integration of ruggedized, low-cost indoor/outdoor 3-D scanning technology
- Procedural forms and checklists
- Photo and video documentation
- Expandable framework to incorporate other NDI technologies

Corvid Technologies is developing Battle Damage Assessment Visualizer (BDAV) software, which is run on ultra-portable devices and allows quick-time access to a database incorporating hundreds of IED and multi IED-event scenarios. By comparing the damage produced by the incident to a database of simulated vehicle damage, the software determines the closest match and calculates the risk of redeploying vs. repairing the vehicle structure. The tool will also allow for event-reconstruction, identifying the most likely threat scenario that led to the damage. An alternative to visual-only inspection, BDAV provides a more data driven, consistent way to determine vehicle repair levels required, lowering risk to the Warfighter, while simultaneously reducing unnecessary vehicle downtime. BDAV software relies on robust surface capture and data storage capability being developed under this same SBIR topic.

High Fidelity Computational Physics Blast Modeling Improvements

Utilizing FY2013 Rapid Innovation Funds, further development of high-fidelity computational physics-based methods, tools, and models is on-going. The capability to model explosively formed penetrators (EFPs), fragmenting IED, and littoral mine threats will be developed under this effort. Additionally, research will be conducted to allow for improvements to the already well-established underbody mine and IED vs. armored vehicle simulation capability. Improvements will be seen in material models of soils and a progressive damage model for structural composite materials will be developed. These capabilities will allow improved M&S support to survivability improvement initiatives and aid in the design and evaluation processes required to meet occupant-centric protection objectives.

JLTV Blast M&S

The objective of this effort is to develop and execute a physics-based model able to account for both soil/structure interaction and gross vehicle response. CORVID Technologies has prepared high-fidelity models for the Marine Corps JLTV Program Office. The UBB M&S efforts will:

- Provide Joint Project Office (JPO) insight into force protection levels (initially from a structural standpoint and evolving to a crew-response standpoint)
Support engineering design analyses and modifications

Provide supplemental information to support key performance parameter analyses. The JPO also plans to use M&S for future evaluations of vehicle design modifications and Engineering Change Proposals.

Additional M&S projects supporting PEO LS include:

- Tactical Wheeled Vehicle (TWV) Modernization Study is developing plan that synchronizes the strategies and actions involved in lifecycle management of the Marine Corps TWV requirements, procurement, integration, sustainment, and management.

- Material Characterization of Energy Absorbers (EA) focuses on material for blast modeling, which is being tested to determine models used to define EA component response. Components to be modeled include seat Energy Absorbers (EAs), cushions and blast mats.

- Light Tactical Vehicle Technology Advancement Rapid Innovation Fund seeks to improve design methods and simulation tools to enable optimum performance, reduce expensive “trial and error” tests, and result in lighter, more survivable and cost-effective vehicles.

Potential Solutions

ONR Efforts

ONR has a broad mix of projects, many focused on ground vehicle programs, which add to the development of a comprehensive suite of M&S tools for the Marine Corps:

Energy Absorbing Structures for Blast Mitigation Light Tactical Vehicles

The objective of this effort is to develop lightweight energy-absorbing structures for incorporation into Marine Corps ground systems to enhance occupant survivability. The project includes a review of potential energy-absorbing structures for incident angles, computational evaluation of design parameters for selected mechanisms, LS-DYNA simulations of standoff, hull shape, energy absorber characteristics, manufacture, and test selected energy-absorbing mechanisms into a prototype and then blast tests to validate the modeling and utility of the selected design. The focus has been on designing a surrogate V-hull to be compatible with use of Energy Absorbing for the light tactical vehicle design. Researchers intend to develop and demonstrate the use of energy absorbing structures mounted between the blast hull and the crew compartment of a general class of tactical vehicles (5–15 ton) that substantially mitigates crew injuries.

Detection Avoidance Material and M&S Development

This project will investigate materials and develop improved M&S for advanced camouflage application.

TARDEC Efforts

Virtual Experiments Capability (VEC)

Researchers will develop a process for modeling innovative TARDEC technologies and inserting them into the Army Capabilities Integration Center (ARCIC)-led Early Synthetic Prototyping (ESP) environment in this effort. ESP is an ARCIC-led effort to develop a persistent video game environment that soldiers want to play, allowing researchers to evaluate emerging military technologies.
**Warrior Injury Assessment Manikin (WIAMan)**

This project will conduct cadaveric research to establish a scientific and statistical basis for evaluating skeletal injuries to occupants during Under Body Blast events. Warrior Injury Assessment Manikin will also develop an improved blast test manikin that incorporates the medical research, which provides an increased capability to measure and predict skeletal occupant injury during Under Body Blast events.

**Modular Active Protection System (MAPS)**

MAPS demonstrates Soft-kill (SK) and Hard-kill (HK) Active Protection Systems (APS), that are compliant with a modular approach, to defeat Rocket Propelled Grenades, Recoilless Rifles and Anti-Tank Guided Missiles. Affordable Lightweight Materials/Structures (ALMS).

This effort will demonstrate best practices in cost-conscious, multi-material design for structures to reduce ground vehicle weight. This effort uses and evaluates design tools, advanced materials, manufacturing, and assembly technologies to develop a lightweight structure and enhance core competencies. It supports a demonstrator weight savings of approximately 20–30% beyond Ground Combat Vehicle’s baseline. It will also evaluate the current technical capability of the material supply chain.

**Virtual Proving Ground**

The Virtual Proving Ground project will develop a comprehensive and integrated Autonomy M&S toolkit strategy, positioning TARDEC to lead the push for more unified/interoperable M&S capabilities and will also:

- Engage with on-going M&S tool development efforts (e.g., AiOE and TVEC), identify the best of breed M&S tools available, and perform a gap analysis to identify areas for future tool enhancement

- Expand M&S work being done via AiOE Cong Add project to include non-ACO use cases (e.g., Wingman and SUGV)

- Develop and extend M&S tools to address shortcomings identified in the gap analysis (e.g., integrate best-of-bread tools together and expand functionality/robustness)

- Manage the integration of existing/future M&S tools into the toolkit to reduce duplication of effort and maximize the value of M&S outputs

The M&S Focus Area Charts on the following pages highlight critical efforts monitored and supported by the PEO LS S&T Director.

**Autonomy in Operational Energy**

This program’s intent is to develop the M&S and analytical techniques required to effectively conceptualize, assess, and then specify and create autonomous capability for the tactical wheeled fleet. This effort will also advance the M&S framework of the TARDEC Digital-Physical thread to address behavior M&S.