Boosting System Reliability

Through Modeling and Simulation

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To maximize return on investment (ROI) in the face of increasing budget constraints and failure of half of all Army programs to demonstrate established reliability requirements, test and evaluation (T&E) programs must be executed more efficiently and incorporate more aggressive reliability growth techniques. One way to accomplish this is by leveraging existing modeling and simulation (M&S) tools, including purely computer-based as well as hardware-in-the-loop (HWIL) tools.

ROI for Reliability Improvements and Test Efficiencies

The ROI benefits can be characterized as cost savings or avoidance, shortened schedule, better performance and increased safety. Greater ROIs can be realized when improvements are made early during the design-for-reliability phase of development. Based on numerous analyses across many military platforms, any investments in reliability improvement almost always are paid back over the system life cycle with very large returns.

Efficiency-driven T&E decisions should be considered in light of the near- and long-term ROI and capability changes. Such analyses often can be performed quickly and at little cost. The analyses provide overall context and justification for the efficiency choices selected.

Early design-for-reliability activities, including finite element modeling, dynamics modeling and simulation, and component fatigue analysis can help predict failure

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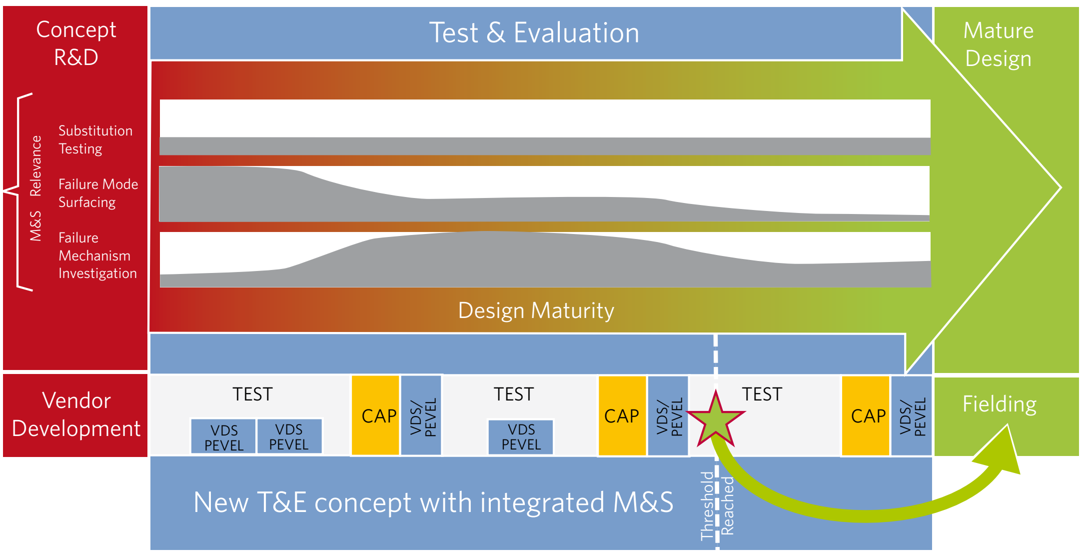
Figure 1. M&S Utilization in the Reliability Test and Evaluation Paradigm



modes based on a number of mechanisms and also can be used to evaluate efficiency of proposed design changes. Early incorporation of physics-of-failure analyses will allow reliability improvements during the design-for-reliability phase of development when they are much easier and cheaper to do. Design changes become more expensive and difficult to complete as the system matures and becomes more hardened.

Proposed Integration of M&S Capabilities

High system reliability is achievable through robust design for reliability, expedited surfacing of system failure modes through efficient and targeted testing, and effective failure mode management to design and/or implement highly effective fixes. In conjunction with traditional reliability testing, both computer-based and physical vehicle-simulation capabilities provide an opportunity for better failure mode surfacing, investigation and resolution. Figure 1 illustrates how, in conjunction with traditional durability testing, U.S. military vehicle simulation capabilities can be leveraged to expedite reliability T&E. By leveraging M&S to expedite failure mode surfacing, investigate failure modes, and to engineer more timely and effective fixes, the opportunity exists to achieve early required system reliability, allowing for a potential off-ramp and early fielding.

Design Maturity and Complexity: Tailoring the M&S Approach

As a U.S. Army wheeled vehicle program progresses through the acquisition cycle, use of M&S capabilities to surface, investigate and target failure modes needs to be re-evaluated to yield maximum ROI. As illustrated in Figure 2, design complexity and maturity need to be considered for a particular system.

For instance, Joint Light Tactical Vehicle (JLTV) can be considered a complex prototype. Whereas, Family of Medium Tactical Vehicles rebuy is a less complex and highly mature system. In the latter case, system reliability characteristics are well known, lending to targeted testing of known areas for reliability concern to evaluate manufacturing changes that come with alternative vendor selection. In the same respect, this paradigm could also apply to Engineering Change Proposals.

Leveraging Existing Army Vehicle M&S Capabilities

Programs that utilize the Army's computer-based and HWIL M&S tools have many benefits: They improve initial system-level reliability for start of the engineering and manufacturing phase, accelerate surface failure modes, improve accuracy of failure mode root cause analysis conclusions, promote accelerated reliability growth, improve the likelihood of

Vehicle Durability Simulator Testing at Aberdeen Testing Center in Maryland.
U.S. Army Photo.

demonstrating system reliability requirements (i.e., reduce program risk) and reduce the traditional "wheels-to-dirt" mileage for vehicle testing.

Reconfigurable N-Post Simulator Testing at the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) in Warren, Michigan.
U.S. Army Photo.

Computer-Based M&S Tools for T&E of Vehicles

The Army Materiel Systems Analysis Activity (AMSAA) and the Army Research and Development Centers (RDECs) use physics-based computer-aided engineering software to model, simulate and analyze mechanical and electrical systems in response to reliability questions from the T&E and Acquisition communities. This reliability analysis process enabled by computer-based M&S is known as Physics-of-Failure (PoF).

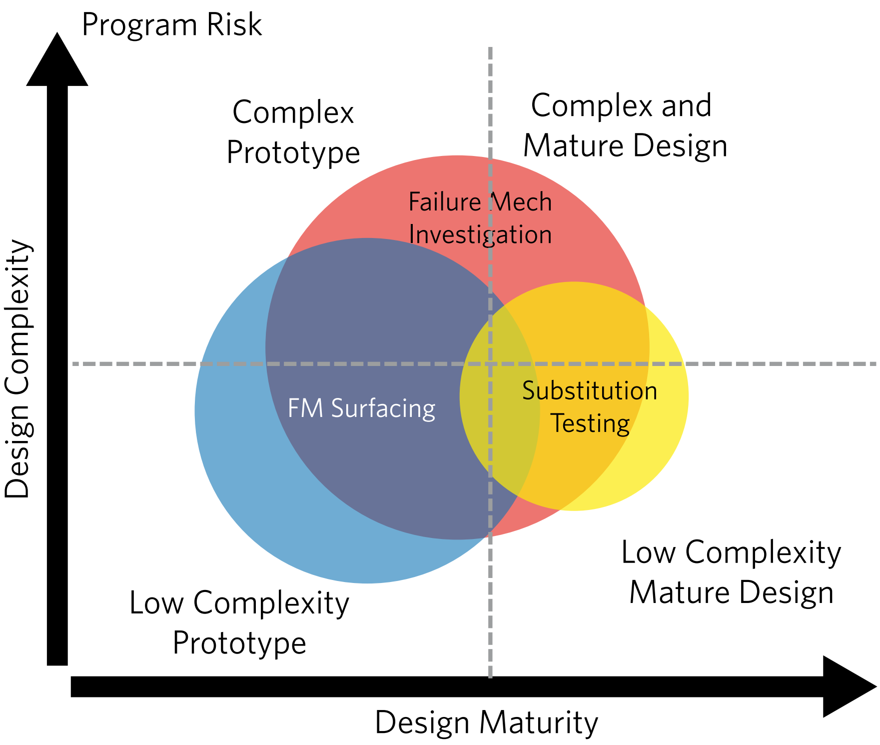
Decision makers utilizing PoF analysis support consist of representatives from the T&E and Acquisition communities for platforms including, but not limited to, Abrams, Stryker, Mine-Resistant Ambush Protected (MRAP), Chemical and Biological Protective Shelter, Dry Support Bridge, M1000 trailer, Small Unmanned Ground Vehicle and various Tactical Vehicles. Analysts apply PoF M&S to identify the impact to component or system reliability when equipment or usage changes. Additionally, PoF M&S can be used to predict the root cause of failure for components failing in reliability testing or in the field. New materiel systems also are analyzed to develop baseline reliability predictions that provide focus areas for initial design and testing. Regardless of application, utilizing PoF M&S in product development and T&E reduces decision risk.

In addition to computer-based M&S tools, HWIL M&S capabilities also are essential. Numerous HWIL facilities exist that simulate realistic operational environments and stresses in order to identify potential failure modes and reliability issues. Four of the Army's simulators are outlined below.

Army Vehicle Physical Simulation Capabilities

Power and Energy Vehicle Environment Lab (PEVEL): The PEVEL is located at the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) in Warren, Michigan. The PEVEL is a climatic dynamometer test laboratory. The climatic chamber has the capacity to produce a wide range of temperatures, humidity levels, wind speeds and solar loads and handle both wheeled and tracked vehicles. The PEVEL system was designed for vehicle cooling system evaluation, road load simulation, and accelerated life testing of power-train systems.

Figure 2. Tailored M&S Usage: Considering Design Complexity and Maturity

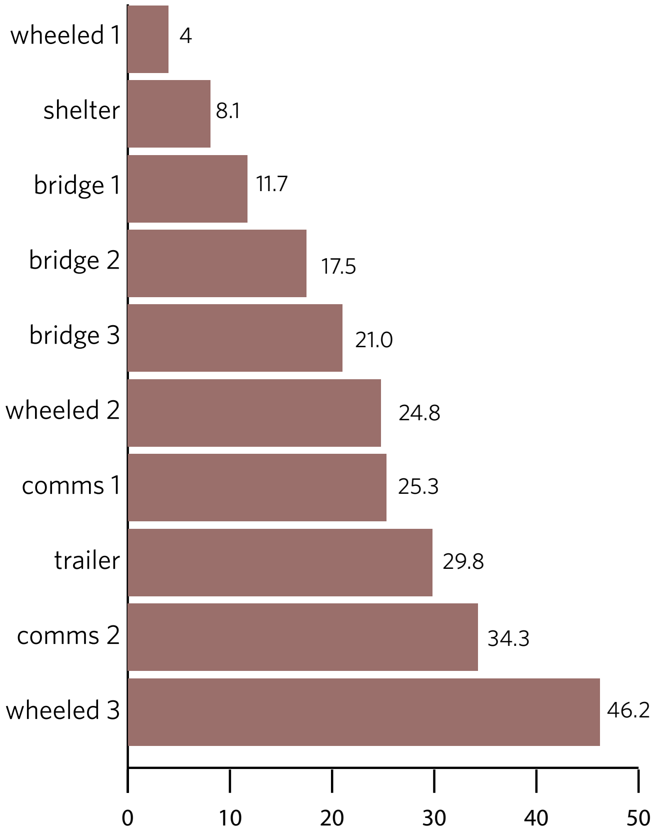


Reconfigurable N-Post Simulators (RNPS): The Ground Vehicle Simulation Laboratory at TARDEC contains two types of hydraulically powered RNPS capable of performing whole-vehicle durability tests on a wide range of military vehicles. The laboratory has performed tests on High Mobility Multipurpose Wheeled Vehicles (HMMWVs or Humvees), MRAPs, Strykers, Light Armored Vehicles, and other vehicles, to validate and verify the durability of whole-vehicle and component systems such as armor kits, frames and suspensions. The simulators use sophisticated control methodologies to reproduce structural dynamics experienced from actual field data or virtually generated terrain displacement profiles replicating multiple terrain types including Aberdeen Proving Ground (APG) Maryland, and Yuma Proving Ground (YPG) Arizona terrains. The RNPS simulators consist of a small HMMWV-class simulator and a significantly larger heavy-duty-class simulator, which can be configured to support a two to six-axle vehicle.

Roadway Simulator (RWS): Aberdeen Test Center (ATC) Roadway Simulator is the world's largest vehicle dynamics test simulator. It is a vehicle-in-the-loop simulator that replicates ground velocity vectors beneath each vehicle tire, thereby satisfying Newton's equations of motion. Test capabilities include steering and handling, power train performance, shock and vibration, braking and fuel economy. The RWS has performed tests on HMMWV, JLTV and several other military vehicles, as well as a variety of commercial vehicles.

Performance Validation Testing in the Power and Energy Vehicle Environment Lab at TARDEC.
U.S. Army Photo.

Figure 3. Returns on Investment Based on Army Materiel Analyses Systems Analysis Activity



Vehicle Durability Simulator (VDS): The Vehicle Durability Simulator has the capability to replicate six degree-of-freedom wheel forces and accelerations experienced on the test course. The laboratory has performed several tests on HMMWV vehicles, a proof of concept on a JLTV prototype during the technology demonstration phase, and a MRAP All-Terrain Vehicle rear suspension test. The simulator replicates field data collected at military proving grounds.

Conclusion

M&S has significantly benefited numerous programs across many military platforms. M&S has accelerated fielding, verified design enhancements and reduced testing costs. M&S continues to result in substantial ROI as shown in Figure 3.

For any major weapon system, a 10 percent improvement in reliability results in tens of millions to billions of dollars in savings over the life cycle. Yet, not every program is fully taking advantage of M&S tools. As more programs reach out and use best-of-class M&S methods, the military will reap significant ROI through increased reliability and reduced life-cycle costs.

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