The Impact of High Accuracy Target Geometry in Modeling and Simulation to Support Live-Fire Test & Evaluation

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Overview

• Analysis Background

• Modeling Process Overview
  — The MUVES-S2 Model for Ballistic Vulnerability / Lethality (V/L) Analysis
  — The Model Process
  — The Importance of Highly Detailed Target Geometry

• Target Geometry Development
  — System Representation
  — Shot-Line Sequence
  — Conversion of Vendor CAD Files
  — Building High-Fidelity CAD Geometry

• Conclusions
• All vulnerability/lethality efforts follow the same “general” analysis procedures.

• Inputs, models, and methodologies are tailored to fit particular needs of the customer:
  — acquisition decisions (PMs / PEOs, LFT&E Community)
  — system design / armoring initiatives (PMs, rapid fielding initiatives)
  — personnel survivability studies (PMs / PEOs)
  — AoAs, Army Studies (AMSAA, TRADOC, CAA)
  — weaponeering decisions (JTCG)

• Fidelity of analysis varies from a high level of detail, as in component-level analyses, to a lower level of detail as dictated by customer requirements.

• Benefits of modeling and simulation (M&S) to the LFT&E community:
  — Provides a “global” interrogation of the target, utilizing results of live-fire events to validate MUVES-S2 M&S results.
  — Supplements (not substitutes) the LFT&E process with a more global interrogation of the vehicle.

• Results are highly dependent on the fidelity of the inputs.
  — Computer aided design (CAD) geometry is the foundation of these inputs.
Modeling Process Overview
The MUVES-S2 Model for Ballistic Vulnerability/Lethality Analysis

Target geometry

Criticality analysis of subsystems

Component vulnerability

Personnel data

- Avg. mass groups
- Avg. velocities
- No. of fragments
- Avg. shape factor

Fragmenting Munitions

- Spray Zones

MUVES-S2 Analysis

Residual penetration
Personnel incapacitation
Component damage
Subsystem capabilities
Remaining system utility
User-defined criteria etc.

Shaped charge Jet

Kinetic energy
long-rod penetrator

Behind-armor debris

User-defined criteria etc.
The Model Process

Construct 3-D solid-geometry model of system
- Native CAD Conversion (Vendor Provided)
- Vehicle Interrogation (Measure/Build – Metrology)

Characterize target/threat interaction
- Penetration Tests
- Behind-Armor Debris Tests
- Shock/Pressure Characterization

Model effect of damage on components
- Component Tests for Various Damage Effects

Characterize effect of component failure on subsystem capability (Fault trees)
- Controlled Damage Tests
- Subsystem Tests
- Intelligence Data
- Manuals

Characterize system functionality (Mobility, Firepower, …)

Target Geometry Development

Threat/Armor Characterization

Engineering Criticality Analysis

Analysis Input/Output & Deliverables
• MUVES-S2 analyses interrogate the target utilizing multiple shot-lines. Examples include:
  — Artillery rounds create multiple shot-lines that generate more opportunity to interact with subtle details of the geometry.
  — Behind armor debris evaluates interior components of the vehicle as the threat and all secondary effects interact with the vehicle geometry.

• Accurate geometry is essential to generate quality results.
Target Geometry Development
System Representation

Abrams Tank on Aberdeen Test Center Test Pad

Construct 3D solid geometric model of system
High-Detail
BRL-CAD™ Representation
Sample Shot-Line Sequence

Glacis Armor
Armor-piercing Rounds
HE Round
Fire Wall
Engine
Starter
Transmission Sump
Fan
Rear Armor
Conversion of Vendor CAD Files

- Native CAD files provide ARL/SLAD with higher resolution source data that facilitates the conversion into higher resolution BRL-CAD™ for M&S analyses.
  - Vendor CAD files are preferred method of geometry development.
  - ARL/SLAD has the tools to receive and convert multiple formats of CAD.
Conversion of Vendor CAD Files

- A highly detailed component model, comprised of multiple solids, is reliant on a thorough understanding of that component’s design.

- The quality of the resulting BRL-CAD™ geometry is highly dependent on the quality of the CAD that is provided.

- Accurate component characteristics to include dimensions, thickness, and materials is desired and achievable with CAD files that include more detail than just surfaces (i.e., non-shrink wrapped source CAD).
• Utilization of various metrology equipment facilitates a high degree of accuracy in data collection.
  — This process requires an extended period of time with the vehicle in a “stable” or semi-controlled environment.
  — In order for the data collection process to be efficient, multiple personnel with various pieces of equipment are required.

Data Collection on M1151A1 HMMWV in ARL/SLAD Facility

Raw Data Collected In Commercial CAD Software
While not the preferred form of geometry development, data collection through metrology equipment has seen advancements.
— Longer lead-time than conversion, but faster and much more accurate than older “hand measurement” techniques.
— Facilitates conversion from commercial CAD packages to BRL-CAD™ (necessary format for MUVES-S2 simulation).

M1151A1 HMMWV Subsystems Solids in Commercial CAD Software

Completed M1151A1 HMMWV Vehicle in Commercial CAD Software
Conclusions

• Modeling and simulation can supplement, but is not a substitute for, live-fire testing to provide a more thorough evaluation of vehicle vulnerabilities and armor design.
  — Provides a “global” interrogation of the target, saving assets (minimizing cost) as well as maximizing data while minimizing the test schedule.

• Accurate target geometry is the foundation to a MUVES-S2 analysis.
  — Accuracy is achieved by attaining quality vendor CAD geometry to convert into BRL-CAD™.
  — Adequate time on a representative asset is required to facilitate the necessary vehicle interrogation for geometry development.
Questions?