System of Systems Survivability, Lethality, Vulnerability Assessment (SoS SLVA):

Ballistic Vulnerability Modeling Demonstration

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To present a concept of a System of Systems SLVA and a demonstration to support methodology development.
Outline

• Concept of System of Systems SLVA
  – Our concept of a SoS
  – System-of-System Survivability Simulation (S4)
• Methodology
  – New metrics
  – Decision making process (DMP) in S4
• Demonstration overview
• Benefits to Test & Evaluation community
• Summary
Our Concept of a SoS

A design connecting multiple levels of decision makers and assets through which decision makers at every level can adapt the application of their assets to achieve their purpose.

The Physical Systems:
  e.g., Future Brigade Combat Team (14+1+1).

The Leaders
  Capabilities conceptualized as combat power, a term that encompasses all means available to a given unit at a given time.
  Leaders at the center, enabled by information, execute the six traditional warfighting functions.

The Context
  While we can discuss each of the above abstractly, a domain context grounds the assessment.
  Within this context, assessment is a critical component of the SoS.
• “Doing the correct thing well”.
  – Assesses an ability to reach the chosen position of attack, or to maintain formation and arrangement of forces, etc.
  – Is more about the physical situation, and focuses more on the internals of a unit.

• “Doing the correct thing”
  – Traces the flow of information (e.g., an enemy spot report) through the network to its consumer (a leader); thence, to an observable domain impact upon a war fighting function.
  – Is more about the information system, and looking outward from a unit.

• SoS effectiveness is a joint result these measurements.
I. Identify customer questions.
II. Define the concept that addresses customer questions.
III. Determine simulation requirements and develop model configuration.
IV. Generate metrics from simulation results.
V. Apply analysis methods to address customer question.
• S4 is a small-unit force-on-force Agent based simulation designed to assess SoS effectiveness.

• As an Agent based model, the approach to decision making is very different than current Army force-on-force models.
  – Emphasis is placed upon the military decision making processes (DMPs) and the communications network that link these DMPs within a SoS.
  – Each DMP represents human decision makers on the battlefield that is dynamically driven by the information available during simulation execution.

Simulate in S4
Mission definition
Analyze results

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
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Roots of the approach—
The vulnerability/lethality “taxonomy”

1. Interactions
   - physics, penetration models, ...

2. Component status
   - engineering, criticality analysis, ...

3. Functional status
   - operations research, missions, scenarios, ...

4. Task-success status
## Level 2

<table>
<thead>
<tr>
<th>Crew</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c_1$ Commander Incapacitated</td>
</tr>
<tr>
<td>$c_2$ Squad Leader Incapacitated</td>
</tr>
<tr>
<td>$c_3$ Driver Incapacitated</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Passengers</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_1$ Passenger 1 Incapacitated</td>
</tr>
<tr>
<td>$p_2$ Passenger 2 Incapacitated</td>
</tr>
<tr>
<td>$p_3$ Passenger 3 Incapacitated</td>
</tr>
<tr>
<td>$p_4$ Passenger 4 Incapacitated</td>
</tr>
<tr>
<td>$p_5$ Passenger 5 Incapacitated</td>
</tr>
<tr>
<td>$p_6$ Passenger 6 Incapacitated</td>
</tr>
<tr>
<td>$p_7$ Passenger 7 Incapacitated</td>
</tr>
<tr>
<td>$p_8$ Passenger 8 Incapacitated</td>
</tr>
</tbody>
</table>

## Level 3

<table>
<thead>
<tr>
<th>Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_{1.1}$ Reduced Maximum Speed 20%</td>
</tr>
<tr>
<td>$m_{1.2}$ Reduced Maximum Speed 40%</td>
</tr>
<tr>
<td>$m_{1.3}$ Reduced Maximum Speed 60%</td>
</tr>
<tr>
<td>$m_{1.4}$ Reduced Maximum Speed 80%</td>
</tr>
<tr>
<td>$m_{1.5}$ Reduced Maximum Speed 100%</td>
</tr>
<tr>
<td>$m_{2.1.1}$ Reduced Acceleration 20%</td>
</tr>
<tr>
<td>$m_{2.1.2}$ Reduced Acceleration 40%</td>
</tr>
<tr>
<td>$m_{2.1.3}$ Reduced Acceleration 60%</td>
</tr>
<tr>
<td>$m_{2.1.4}$ Reduced Acceleration 80%</td>
</tr>
<tr>
<td>$m_{2.1.5}$ Reduced Acceleration 100%</td>
</tr>
<tr>
<td>$m_{2.2.1}$ Reduced Steering 20%</td>
</tr>
<tr>
<td>$m_{2.2.2}$ Reduced Steering 40%</td>
</tr>
<tr>
<td>$m_{2.2.3}$ Reduced Steering 60%</td>
</tr>
<tr>
<td>$m_{2.2.4}$ Reduced Steering 80%</td>
</tr>
<tr>
<td>$m_{2.2.5}$ Reduced Steering 100%</td>
</tr>
<tr>
<td>$m_{2.3.1}$ Reduced Braking 20%</td>
</tr>
<tr>
<td>$m_{2.3.2}$ Reduced Braking 40%</td>
</tr>
<tr>
<td>$m_{2.3.3}$ Reduced Braking 60%</td>
</tr>
<tr>
<td>$m_{2.3.4}$ Reduced Braking 80%</td>
</tr>
<tr>
<td>$m_{2.3.5}$ Reduced Braking 100%</td>
</tr>
<tr>
<td>$m_{2.4}$ Reduced Visibility (driver’s sensor)</td>
</tr>
<tr>
<td>$m_{3.1}$ Stop After 60 Minutes</td>
</tr>
<tr>
<td>$m_{3.2}$ Stop After 30 Minutes</td>
</tr>
<tr>
<td>$m_{3.3}$ Stop After 10 Minutes</td>
</tr>
<tr>
<td>$m_{3.4}$ Stop After 1 Minute</td>
</tr>
</tbody>
</table>

### Catastrophic Loss

- $k_1$ Fuel/Ammo

## Level 4

### Loss of Function
- MLOF Mobility Loss of Function
- FLOF Firepower Loss of Function

## Firepower

- $f_1$ Lost Ability To Fire Buttoned Up Main (RWS)
- $f_2$ Degraded Initial Rate of Fire of Main (RWS)
- $f_3$ Degraded Subsequent Rate of Fire of Main (RWS)
- $f_4$ Total Loss of Firepower Main
- $f_{12}$ Total Loss of Firepower Secondary

### Communication

- $x_{1.1}$ Reduced Range (antenna loss)
- $x_{1.2}$ Reduced Range (power amp loss)
- $x_2$ Lost Line-of-Sight (LOS) Data
- $x_3$ Lost LOS Voice
- $x_4$ Lost Non-LOS Data
- $x_5$ Lost External Communications
  - $x_{7.1}$ Lost Encryption Capability
  - $x_{7.2}$ Lost Channel/Frequency Selection Capability

### Target Acquisition (‘sensing’)

- $a_1$ Lost Daylight Acquisition
- $a_2$ Lost Night Acquisition
- $a_3$ Lost Range Finder Capability
The $x_6$ fault tree… cutting it degrades the system with **lost internal communications**
S4 Decision Making Process (DMP): use of EFD data

- Awareness of EFDs
  - Perception Manager
  - Report Manager

- Adaptation
  - Platform
  - Company
  - Platoon
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I: Identify Customer Questions

- How can Mission-based analysis support cost effective test planning, i.e., Live-Fire shot selection and Developmental/Operational Testing?
  - What EFD are critical to operational testing ($O_{3,4}$)?
  - What performance parameters are important to capture in developmental testing?
  - What are the platform vulnerability issues to assess with MUVES-S2?
- How can the impact of a test event be shown in a mission context?
  - What EFDs impact mission success?
  - By contrast, for which EFDs can the unit compensate?
- Can unknown SLV issues be revealed (discovered) via simulation involving adaptive agents?
Demonstration objective was to put ballistic damage into mission context.

- O_{3,4} in a controlled environment:
  - Assess task execution to “attack by fire”
- O_{3,7}
  - Assess EFD impact on mission
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Mission-based T&E

MBT&E Framework – v2

Process/Products

Commander’s Task to Subordinates

Mission Analysis
- Higher Commander’s Intent
- Restated Mission
- Task to Subordinates

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- Higher Commander’s Intent
- Restated Mission
- Task to Subordinates

System Attributes

Systems Engineering
- Functional Baseline
- Allocated Baseline
- Product Baseline

Capability = Set of Tasks + Desired Result

Desired Mission
Task Results

Desired Military
Condition Results

Mission End-State Measure

Evaluated by

Mission End-State Measure

Mission Task Capability

Operations (Mission Tasks)
- UJTLs
- Service TLs
- Implied Tasks

Desired Mission
Task Results

Task Capability
Measure

Desired SoS
Task Results

SoS Task Capability

System-of-Systems Tasks
- Service TLs
- Implied Tasks
- Collective/Individual Tasks

Desired SoS
Task Results

System Performance Capability

System Performance
- Functions (shall do)
- “shall be’es”

Desired System
Performance Results

System Performance
Measure

MUVES-S2

MUVE-S2

S4

Enables

Enables

Enables

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
System representation (for each variant)
- Criticality analysis:
  - List of elements of functional degradation (EFD).
- System (critical categories and EFD) representation.
- Identified tasks.
- Task to requirement capability mapping.

Model results analysis
- Cell-by-cell
  - Probability of each EFD per threat.
  - Probability of task failure.
- Bar charts
  - Probability of each EFD per threat.
  - Probability of task failure.
- View average tables
  - Probability of each EFD per threat.
  - Probability of task failure.
- Identified critical categories/components and EFD driving vulnerability.

Damage assessment and post-shot analysis report
- Identified critical categories/components and EFD driving vulnerability.
- Correlate ballistic damage to mission essential task failure.
For each platform

- Cumulative time that the platform spent with each EFD.

For each platform type

- A count of the total number of hits on platforms of each type by all munition types.
- Correlation of critical category to EFD.
- The absolute mean time a platform of a given type spends in each EFD.

Results for cc antenna (1) vs EFD m1.2 (1):
Sample size = 5
Prob (Y | X) = 0.75
Raw data
1 0
1 3
mean and std dev for X = 0.8 0.39999999999999997
mean and std dev for Y = 0.6 0.4898979485566356
Covariance of X and Y = 0.12
Correlation of X and Y = 0.6123724356957946
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• Integration of higher fidelity V/L data within the SoSA process has been demonstrated.

• DMPs have been enhanced to utilize additional information provided by higher fidelity V/L data.

• In light of the Mission-based T&E strategy, the community can benefit from higher fidelity V/L data and SoSA capability development in SLAD.