Extending a Missions and Means Framework (MMF) Demonstration to Vulnerability/Lethality Data Production

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# Extending a Missions and Means Framework (MMF) Demonstration to Vulnerability/Lethality Data Production

**Date Covered:**
DEC 2005 to 00-00-2005

**Performing Organization:**
U.S. Army Research Laboratory, Computational and Information Sciences Directorate, White Sands Missile Range, NM, 88002

**Notes:**
Modeling and Simulation Conference, 2005 Dec 12-15, Las Cruces, NM
Objective

To present the data production process for the 2005 MMF demonstration and how lessons learned can be applied in the future.
Outline

- MMF: What’s different
- Demonstration Models and Data
- Data Development Process
- Status
- Implications
MMF Demonstration: What’s Different?

- Direct application of war fighter tasks.
- Demonstration of network-centric effects that features SoS-level fault trees

**Degraded Capability States (DCS) at both platform and component levels**

Dynamic effects of vulnerability, reliability, repair, …

Alternative courses of action
Traditionally
- System developer, user and evaluator determine a Damage Assessment List of critical Line-Replaceable-Units (LRU).
- A conclave is formed to assign a weighting to each LRU representing the loss to mission effectiveness across all scenarios and environment conditions.
- Limiting metrics; mobility, firepower, communications and catastrophic.
- Developmental test information was not incorporated into V/L modeling.

What’s NEW
- Data development is directly correlated to the Army Universal Task List (AUTL), Joint Universal Task List (UJTL) or Lead System Integrator tasks.
- Expanded metrics support a robust system representation required for a system of systems evaluation and training.
- A closer communication between the modeling, testing and soldier community.

What’s missing is metric validation via developmental testing.
MMF Demonstration: Models and Data

MTBF, MTTR, MCD; #platforms, #comp/platform → Component Status Vector Generator → Event history of comp. state changes → MUVES O₂,³ Mapper → Event history of changes in DCS

Fault Trees for each platform type’s Degraded Capability States

Capabilities

Requirements

Vignette: Mission/tasks/standards, Threat force, Friendly force

Vignette Engine (Storyboard Model “core”) → Event history of task execution attempts (both success and failures) → Statistics Postprocessor

Human readable text files, info to feed into viewgraphs

Graphics Postprocessor → Human viewable replay (map, health meters)
1. Determine platform engineered capability elements (engineer/design contractor).

2. Perform criticality analysis and develop system fault trees (engineer/analyst).

3. Determine semantic and design constraints (engineer/analyst).

4. Develop the DCS partially ordered set (Poset) given the constraints (analyst).

5. Determine the appropriate tasks typical for platform (AUTL/UJTL).

6. Determine the required DCS for each tasks and color code acceptability (TRADOC System Manager).

7. Bin the platform poset by tier and acceptability.

8. Calculate the probability of available capability at 3 levels (red, amber, green) for each platform task per threat (analyst).

Process requires closer communications between the modeling, analysis, testing, and training communities.
Degraded Capability States: 
Basic Elements

Mobility (5)
M0 No Mobility Degradation
M1* Reduced Maximum Speed
M2 Reduced Maneuverability
M3* Stop After T Minutes
M4 Reduced Acceleration
M5 Total Immobilization

Firepower (12)
F0 No Firepower Degradation
F1 Lost Ability To Fire Buttoned Up Main
F2 Degraded Delivery Accuracy of Main
F3 Degraded Initial Rate of Fire of Main
F4 Degraded Subsequent Rate of Fire of Main
F5 Degraded Maximum Range Main
F6 Lost Reload Capability
F7 Total Loss of Firepower Main
F8 Lost Ability to Fire Buttoned Up Secondary
F9 Degraded Delivery Accuracy of Secondary
F10 Degraded Initial Rate of Fire of Secondary
F11 Degraded Subsequent Rate of Fire of Secondary
F12 Total Loss of Firepower Secondary

Communication (8)
X0 No Communication Degradation
X1 Reduced Range
X2* Lost Line-of-Sight (LOS) Data (ex. JTRS)
X3* Lost LOS Voice
X4* Lost Non-LOS Data (ex. SATCOM)
X5 Lost NLOS Voice
X6 Lost Internal Communications
X7 Lost External Communications
X8 Lost All Communications

Survivability (6)
S0 No Survivability Degradation
S1 Lost NBC Protection
S2 Lost Ability to Deploy Obscurants
S3 Lost Silent Watch Capability
S4 Lost Active Protection System
S5 Lost Threat Warning Capability
S6 Lost Fire Suppression Capability

Target Acquisition (3)
A0 No Acquisition Degradation
A1 Lost Daylight Sights
A2 Lost Night Sights
A3 Lost Range Finder

Surveillance (4)
Z0 No Surveillance Degradation
Z1 Lost Primary Sensor
Z2 Lost Secondary Sensor
Z3 Lost Tertiary Sensor
Z4 Lost All Surveillance

Crew (7)
C0 No Crewmember Incapacitated
C1 Commander Incapacitated
C2 Squad Leader Incapacitated
C3 Driver Incapacitated
C4 Operator 1 Incapacitated
C5 Operator 2 Incapacitated
C6 Gunner Incapacitated
C7 Loader Incapacitated

Passengers (1)
P0 No Passengers Incapacitated
P1 Passengers Incapacitated

Other (3)
01 Lost Situational Awareness
02 Lost Unmanned System Control
03 Lost Automated C2

Catastrophic Loss (1)
K0 No Catastrophic Loss
K1 Lost Every Capability

* assigned degradation factor according to the variation in components affecting speed or bandwidth.
Data Development Process: Determine Engineered Capabilities

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>ARV (RSV)</th>
<th>UAV</th>
<th>C2V</th>
<th>NLOS-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m1</td>
<td>reduced_maximal_speed</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>m2</td>
<td>reduced_maneuverability</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>m3</td>
<td>stop_after_t_minutes (leaks)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>m5</td>
<td>total_immobilization</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Firepower</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>f1</td>
<td>lost_ability_to_fire_buttoned_up_main</td>
<td>x</td>
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<td>f2</td>
<td>degraded_delivery_accuracy_main</td>
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<td>f3</td>
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<td>f4</td>
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<td>f12</td>
<td>lost_secondary_armament</td>
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<tr>
<td>Communications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>x2</td>
<td>lost_external_data</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>x3</td>
<td>lost_external_voice</td>
<td></td>
<td>x</td>
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<tr>
<td>x6</td>
<td>lost_internal_comms</td>
<td>x</td>
<td></td>
<td>x</td>
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<tr>
<td>x8</td>
<td>lost_all_commo</td>
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</tr>
</tbody>
</table>
NLOS-C mobility is increased by hybrid electric technology.
Data Development Process: Determine Constraints

- SEMANTIC constraints imply loss by definition.
  i.e., if $x_7$ then $x_1, x_2, x_3, x_4, x_5$.

- DESIGN constraints imply loss of capability by the engineered component relation.
  i.e., if $x_2$ then $x_3$

<table>
<thead>
<tr>
<th>ID</th>
<th>COMMUNICATION CAPABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_0$</td>
<td>No Communication Degradation</td>
</tr>
<tr>
<td>$X_1$</td>
<td>Reduced Range</td>
</tr>
<tr>
<td>$X_2$</td>
<td>Lost Line-of-Sight (LOS) Data</td>
</tr>
<tr>
<td>$X_3$</td>
<td>Lost LOS Voice</td>
</tr>
<tr>
<td>$X_4$</td>
<td>Lost Non-LOS Data</td>
</tr>
<tr>
<td>$X_5$</td>
<td>Lost NLOS Voice</td>
</tr>
<tr>
<td>$X_6$</td>
<td>Lost Internal Communications</td>
</tr>
<tr>
<td>$X_7$</td>
<td>Lost External Communications</td>
</tr>
<tr>
<td>$X_8$</td>
<td>Lost All Communications</td>
</tr>
</tbody>
</table>

Constraints reduce the number of possible DCS.
Data Development Process:  
Develop Partially Ordered Sets

Of the $2^5 = 32$ subsets of \{m_1, m_2, m_3, m_4, m_5\}, the constraint preclude all but these 16:

- **tier 0**
  - \{ \}

- **tier 1**
  - \{ M1 \}
  - \{ M2 \}
  - \{ M3 \}
  - \{ M4 \}

- **tier 2**
  - \{ M1 M2 \}
  - \{ M1 M3 \}
  - \{ M2 M3 \}
  - \{ M1 M4 \}
  - \{ M2 M4 \}
  - \{ M3 M4 \}

- **tier 3**
  - \{ M1 M2 M3 \}
  - \{ M1 M2 M4 \}
  - \{ M1 M3 M4 \}
  - \{ M2 M3 M4 \}

- **tier 4**
  - \{ M1 M2 M3 M4 M5 \}

The possible states ordered bottom-to-top by set containment:

\{m_2, m_3, m_4\} \supseteq \{m_3, m_4\}

16 states in 5 tiers

How the NLOS-C mobility states compare for capability.
Requires (approval or) buy-in from the user community.
## Data Development Process: Platform Tasks to Capability Matrix

**Current tasks** determine which states are adequate.

<table>
<thead>
<tr>
<th>Time</th>
<th>Platform</th>
<th>Task Description</th>
<th>Min Performing Task</th>
<th>MOBILITY (ART 2.2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>02:00-03:40, 03:51-04:17</td>
<td>ART 2.2</td>
<td>*LSI A1.2 Conduct Tactical Maneuver ART 2.2</td>
<td>126</td>
<td>m0 m1 m2 m3 m4 m5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.25</td>
<td>(m1 + m2)</td>
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<tr>
<td>03:41-03:51, 04:20-10:00</td>
<td>ART 2.5</td>
<td>LSI A1.5.2 Occupy an Attack/Assault Position ART 2.5.2</td>
<td>350</td>
<td>m0 m1 m2 m3 m4 m5</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0.68</td>
<td></td>
</tr>
<tr>
<td>03:41-03:51, 04:15-04:25</td>
<td>ART 3.3</td>
<td>*ART 3.3.1.1 Conduct Surface to Surface Attack</td>
<td>20</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0.04</td>
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<tr>
<td>03:47-03:52, 04:22-04:27, 04:38-04:43</td>
<td>ART 3.3</td>
<td>MTP 06-5-A008 Conduct Fire Missions</td>
<td>15</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0.03</td>
<td></td>
</tr>
</tbody>
</table>

Total minutes working tasks for NLOS-C in vignette = 511

* MMF Demonstration

93% of the NLOS-C mission required some mobility.
Data Development Process: Bin poset for Each Task

For task ART 2.2 LSI A1.2 Conduct Tactical Maneuver.*

* MMF Demonstration
Data Development Process:
Task-based Fault Tree Development
### Data Development Process: Calculate Probability of Degradation

#### TASK

<table>
<thead>
<tr>
<th>TASK</th>
<th>Threat A</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>A</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>ART 2.2 Conduct Tactical Maneuver</td>
<td>.11</td>
<td>.15</td>
<td>.74</td>
</tr>
<tr>
<td>ART 2.5.2 Occupy Attack/Assault Position</td>
<td>.13</td>
<td>.14</td>
<td>.73</td>
</tr>
<tr>
<td>ART 3.3.1.1 Conduct Surface to Surface Attack</td>
<td>.21</td>
<td>.15</td>
<td>.64</td>
</tr>
<tr>
<td>MTP 06-5-A008 Conduct Fire Missions</td>
<td>.21</td>
<td>.15</td>
<td>.64</td>
</tr>
<tr>
<td>Mission Health Average</td>
<td>.17</td>
<td>.15</td>
<td>.68</td>
</tr>
</tbody>
</table>

#### Threat A

<table>
<thead>
<tr>
<th>Capability</th>
<th>Threat A</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>A</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>Mobility</td>
<td>.20</td>
<td>.08</td>
<td>.72</td>
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<tr>
<td>Communications</td>
<td>.01</td>
<td>.04</td>
<td>.95</td>
</tr>
<tr>
<td>Crew</td>
<td>.00</td>
<td>.03</td>
<td>.97</td>
</tr>
<tr>
<td>Catastrophic</td>
<td>.04</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Ballistic vulnerability as it relates to mission tasks.

Ballistic vulnerability as it relates to platform capability.
Data Development Status

- Battlefield Operating Systems (BOS) have been mapped to platform subclasses, individual platforms in those classes, and associated tasks; database of this information is under development.

- ARL will be visiting Combined Arms Command (CAC) and the Futures Center to foster collaboration (BOS and AUTL/UJTL to platform assignment).

- There are plans to collaborate with TRADOC schools.

- ARL is developing MMF data for select Current Force systems.

- Several related M&S tools are under development to improve input development and results analysis.

The T&E community can leverage from these activities.
Implications

- AUTL used for MMF can be used to support Operational Testing, i.e., what the system is supposed to do.

- Information from Developmental Testing can be incorporated into V/L modeling and validate Degraded Capability States.

- The same V/L modeling can be used to provide pre-shot predictions and support post-shot analysis during LFT&E.

- Low level tasks derived from an authoritative source such as the AUTL could be incorporated into Force-Level scenario development.

- The V/L data that supports the Force-level modeling could also be based on the same AUTL.

**System evaluation would have an auditable trail while reducing inconsistency and risk.**