Using IMPRINT to Translate Human Performance into System and Mission Effectiveness

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The Defense Acquisition Management Framework

System and Mission Effectiveness

\[ \approx f(\text{Human Performance}) \]

The Challenge

Human Performance Modeling

Technology Opportunities & User Needs

- Process entry at Milestones A, B, or C
- Entrance criteria met before entering phase
- Evolutionary Acquisition or Single Step to Full Capability

The Defense Acquisition Management Framework

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
Human performance is challenging to predict

Many Variables

Too Dangerous

Concept System

Field Study Not Feasible

System Performance $\cong f(\text{human performance})$
INPUTS

- Time and accuracy of each task
- Consequences of “poor” performance

OUTPUTS

Measures of effectiveness

Gathered from such sources as existing data, algorithms, and estimates from SMEs

Not descriptive models, but predictive models

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
Is the human overloaded with tasks?

Will training improve human and system performance?

How to allocate tasks between human(s) and automation?

What are the performance tradeoffs with different system designs or levels of operator experience?
IMPRINT is…
• a Human System Integration tool
• a dynamic, stochastic discrete event network modeling tool

http://www.arl.army.mil/IMPRINT
What can you do with IMPRINT?

• Set realistic system requirements
• Identify future manpower & personnel constraints
• Evaluate operator & crew workload
• Test alternate system-crew function allocations
• Assess required maintenance manhours
• Assess performance during extreme conditions
• Examine performance as a function of personnel characteristics and training frequency & recency
• Identify areas to focus test and evaluation resources
• Quantify human system integration risks in mission performance terms to support milestone review
• Represent humans in federated simulations

IMPRINT is a trade-off analysis tool
Build Operations Model with IMPRINT

Mission Name
Time and Accuracy Standards
Performance Criteria

Function Names
Task Names
Branching Logic (serial, multiple, prob., tactical)

Time & Accuracy Standards & Estimates
Operator Assignments
Workload, Taxons

Characteristics, Training, & Stressors
Workload Thresholds

Many Options

Identify Mission
Build Task Network
Enter Task Data
Set Options
Run Model
View Reports

Time Performance
Accuracy Performance
Workload
- Mission Performance
  - Predicted time & success rate of mission
- Function Performance
  - Predicted time & success rate of individual functions
- Task Performance
  - Predicted time & success rate of individual tasks
- Operator Workload
  - Workload over time for each operator
  - Tasks performed over time and associated workload
Army Research Laboratory
Conduct human system analysis using tools such as IMPRINT, C3TRACE, FAST, JACK

Program Managers, Combat Developers
Redesign systems to overcome issues validated during test & evaluation

Army Test and Evaluation Center, Army Research Laboratory
Implement issues found during analysis into test plans

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
• Rely on heavy armor and artillery to protect the forces

• Heavy, large systems are difficult to deploy rapidly

• Rely on situation awareness to protect the forces

• Lighter, smaller systems are easier to deploy rapidly

**NEED TO REDUCE CREW SIZE TO SUPPORT SMALLER, LIGHTER VEHICLE**
Future Tank Manpower Example
Modeling Approach

- Identified functions to be completed - knowledge elicitation
- Set up experimental conditions to model based on varying function allocations
- Built models
- Validated models by walking-through with Soldiers
- Completed runs and prepared results

Four Conditions
- Gunner-Driver and Commander
- Commander-Driver and Gunner
- Commander-Gunner and Driver
- Commander, Driver and Gunner

<table>
<thead>
<tr>
<th>Function Name</th>
<th>Condition 1 GD and C Function allocation</th>
<th>Condition 2 CD and G Function allocation</th>
<th>Condition 3 CG and D Function allocation</th>
<th>Condition 4 C and G and D Function allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive</td>
<td>GD</td>
<td>CD</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>Hindrance</td>
<td>GD</td>
<td>CD</td>
<td>D</td>
<td>D</td>
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<tr>
<td>Remediate</td>
<td>GD</td>
<td>CD</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>Engage</td>
<td>GD (C)</td>
<td>G (CD)</td>
<td>CG</td>
<td>G (C)</td>
</tr>
<tr>
<td>Local Security</td>
<td>C</td>
<td>G</td>
<td>CG</td>
<td>C and G</td>
</tr>
<tr>
<td>External Com</td>
<td>C</td>
<td>CD</td>
<td>CG</td>
<td>C</td>
</tr>
<tr>
<td>Crew Commo</td>
<td>GD &amp; C</td>
<td>CD &amp; G</td>
<td>CG &amp; D</td>
<td>C &amp; G &amp; D</td>
</tr>
</tbody>
</table>
**Future Tank Manpower Example Results**

**Commander - Driver** and Gunner
Highest workload of all conditions

**Gunner - Driver** and Commander
No shooting on the move

**Commander - Gunner and Driver**
Best two crewmember function allocation; single vehicle commander

**Commander, Driver and Gunner**
Two crewmembers scanning; allows hunter-killer philosophy
Future Tank Manpower Example
Analysis Impact

2 Soldier crew considered **HIGH RISK**

- Changed the crewmember requirement for Operational and Organizational (O&O) Concept Document and the Operational Requirements Document (ORD)
- Role of third crewmember changed to gunner in prime contractor design concept.
Provides BLOS support to Infantry Platoons

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
## Function-by-Function Deconfliction Procedures (North & Riley, W/Index)*

<table>
<thead>
<tr>
<th>Response</th>
<th>Visual</th>
<th>Auditory</th>
<th>Manual</th>
<th>Verbal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visual</strong></td>
<td>HIGH CONFLICT (.7-.9) Directly competing resources (e.g. two search functions; less if functions adjacent or on same display areas)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Auditory</strong></td>
<td>LOW CONFLICT (.2-.4) Noncompeting resources (e.g., search and listening).</td>
<td>HIGH CONFLICT (.7-.9) Highly competitive resources; some time-sharing if discriminability between inputs is high</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Manual</strong></td>
<td>LOW CONFLICT (.1-.3) Noncompeting resources.</td>
<td>LOW CONFLICT (.1-.3) Noncompeting resources.</td>
<td>HIGH CONFLICT (.7-.9) Competing resources such as two tracking functions or discrete choice functions have shown high-dual decrements.</td>
<td></td>
</tr>
<tr>
<td><strong>Verbal</strong></td>
<td>LOW CONFLICT (.1-.3) Noncompeting resources.</td>
<td>MEDIUM CONFLICT (.4-.6) More interference if task requires voiced output.</td>
<td>LOW CONFLICT (.2-.4) Noncompeting resources (e.g., tracking and voice input).</td>
<td>HIGH CONFLICT (1.0) Requires complete serial output; e.g. giving two messages or voice commands.</td>
</tr>
</tbody>
</table>

## Cognitive Building Blocks

<table>
<thead>
<tr>
<th>Position</th>
<th>Continuous Functions</th>
<th>Discrete Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monitor Driver</td>
<td>Local Security</td>
</tr>
<tr>
<td>PL</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>PL MCS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crew Chief</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>Driver</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>PSGT</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>PSG MCS</td>
<td></td>
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<td>P</td>
</tr>
<tr>
<td>Driver</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>VC</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>MCS</td>
<td></td>
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<tr>
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<td>Driver</td>
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### TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
• Crew chief (Gunner) has two primary functions
  • Local Security
  • ARV monitoring
• Both visual search tasks
  • 90% penalty in accuracy on one of the two concurrent functions
  • If local security than 9 out 10 targets might be missed
    • 9 out of 10 times MCS potentially hit and destroyed
• HRED experiment* looking at concurrent performance of a gunner’s and robotic operator’s tasks in a simulated MCS environment supports that local security will be the function degraded.

Impact of Predictions on Mission Performance

<table>
<thead>
<tr>
<th>Mounted Supported by Dismount</th>
<th>Urban/Mout</th>
<th>Defensive Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tactical Move</td>
<td>Attack</td>
<td>Hasty Defense</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
<td>Tactical Move</td>
<td>Hasty Defense</td>
</tr>
<tr>
<td></td>
<td>Defend</td>
<td>Counterattack</td>
</tr>
</tbody>
</table>

Platforms
Library of blocks

MCS PLT, ICV PLT, Co HQ, ICV PLT
Overall Mission Impacts

- Three tanks in future concept platoon
  - 2 of the 3 vehicles have gunners monitoring robotic systems
  - 2 of the 3 vehicles have gunners potentially missing 9 out of 10 threats
  - 10% survivability
- Tank platoon mission is to provide fires for an infantry platoon
- Infantry platoon has reduced protection
- All vehicles may not arrive at attack start point
- Company mission may be degraded
• IMPRINT Tool
  ➢ No cost to government employees and government contractors.
  ➢ Email IMPRINT-INFO@arl.army.mil

• Analytical support
  ➢ Assistance with structuring analysis.
  ➢ Analyses completed for customers.
  ➢ Email diane.k.mitchell@us.army.mil