Exploratory Analysis – Using All the Tools in Our Kitbag

76th Military Operations Research Society Symposium
10-12 June 2008

Robert S. Alexander
robert.s.alexander@saic.com

Michael E. Garrity
michael.e.garrity-2@saic.com

NOTE: The views expressed in this presentation are those of the authors, and do not represent the FFW program, the Department of Defense, or the U.S. Government.
**Exploratory Analysis Using All the Tools in Our Kitbag**

**Author(s):**
SAIC - Science Applications International Corp

**Supplementary Notes:**

**Security Classification:**
- Report: unclassified
- Abstract: unclassified
- This Page: unclassified

**Distribution/Availability Statement:**
Approved for public release, distribution unlimited

**Abstract:**

**Subject Terms:**

---

*Standard Form 298 (Rev. 8-98)*
Prescribed by ANSI Std Z39-18
A classic error in Operations Analysis is to use the tool we are most familiar with to solve every problem that comes our way…

The better way is to assess each problem and design a methodology to solve the problem with whatever tools are most suitable.

Exploratory Analysis* is a methodology designed to solve a certain class of problems, using a whole range of tools:

- Human-in-the-loop wargaming
- Simulation
- Regression Analysis
- Costing
- Spreadsheet and Database Analyses
- Mathematical Programming

* not to be confused with a similarly-named analysis approach developed by RAND Corporation. This approach is based on analysis methods developed at USACAA for Value Added Analysis.
Example Analytical Study

Future Force Warrior* – Exploratory Analysis

- Capital budgeting / cost effectiveness analysis
- Considers about 15 possible proposed Soldier and platoon capabilities (e.g., enhanced Night Vision, Blue Soldier Tracking, Platoon UAV, etc.)
- Combat model runs generate platoon effectiveness measures for various combinations of capabilities
- Regression analysis estimates marginal effectiveness of each capability and pair of capabilities.
- Final analysis is done with an integer program that maximizes force effectiveness subject to cost, weight, and power constraints.

*FFW was an Army ATD run by Natick Soldier RDEC from 2002 through 2007 that investigated various individual Soldier technologies in a platoon context.
Future Force Warrior Program Goals

There were many candidate capabilities and technologies to investigate for the Infantry Small Combat Unit.

The Program had a dual nature:

- The *engineering* and *experimentation teams’* goals were to build and demonstrate actual systems:
  » Does it work?
  » How mature are the technologies?
  » Does it contribute to combat effectiveness as expected?

- The *analysis team* also had the goal to determine what capabilities are actually important and cost-effective:
  » So what?
  » Does a given capability contribute to combat effectiveness?
  » What are the most cost-effective contributors to combat effectiveness?
Future Force Warrior’s “Exploratory Analysis” process

MAPEX
(User Reps define how to operate as an FFW SCU)

Simulation
(dismounted platoon in a 24-hr MOUT mission)

- Blue Casualties
- Red Casualties
- Msn Success
- Msn Timeliness (for each run)

Costs
Weights
Mission Duration
Power Consumption
Combat Effectiveness (Benefits)

Cost-Benefit Analysis

(Regression)
(Math Programming)
MAPEX Activities

“Brief, Wargame, Discuss, Survey”

- Wargame selected tactical tasks in the context of the MOUT vignette

Tactical Subject Matter
Experts are “role-playing”
“Gamers”

Gamers’ version of the operation is used to guide simulation scripting
Simulation: Estimates Contributions to Combat Effectiveness

- Design a run matrix that prescribes runs using various combinations of the capabilities under consideration
- Run multiple replications of each “case”
- Do regression analysis on the results
- A capability’s regression coefficient represents its marginal contribution to overall combat effectiveness
# Run Matrix Example

<table>
<thead>
<tr>
<th>System / Run</th>
<th>00</th>
<th>01</th>
<th>02</th>
<th>03</th>
<th>04</th>
<th>05</th>
<th>06</th>
<th>07</th>
<th>08</th>
<th>09</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>NVG</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>HUD</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Body Armor</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Blue Soldier Tkg</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cooperative Eng</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Plt UAVs</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Squad SUGVs</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Digital Radio</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Thermal Scope</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Soldier Sensor</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Haptic Alerts</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>IFF</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

This presentation has been cleared for public release.
Regression: Combat Effectiveness Estimation Methodology

- **EXPERIMENTAL DESIGN:** Vary the mix of capabilities in each run; experimental design specifies which capabilities to represent in each run.

  Specifies $X_{ik}$ (presence of capability $i$ in run $k$)

- **SIMULATION:** measures force effectiveness for each replication.

  Computes $Y_k$ (realization of MOE for run $k$)

- **SYSTEM EFFECTIVENESS ESTIMATION:** Fit a hyperplane to the results of the combat model; “Slopes” of the surface estimate each capability’s marginal contribution to force effectiveness.

  Solves for $\beta_i$ (contribution of capability $i$) and $\beta_{ij}$ (contribution of pair of capabilities $i$ and $j$) such that $\sum_k (\varepsilon_k^2)$ (or $\sum_k |\varepsilon_k|$) is minimized in $Y_k = \beta_0 + \sum_k \beta_i X_{jk} + \sum_k \beta_{ik} X_{ik} X_{jk} + \varepsilon_k$
Mathematical Program: Cost-Benefit Analysis

- Maximize combat effectiveness

- Subject to:
  - Life-cycle cost
  - Soldier load
  - Power consumption
  - Duration of mission
Results: A Range of Alternate Solutions

Each bar represents a single optimization case that:
- Maximizes Combat Effectiveness
- Subject to:
  - Platoon Procurement Cost Limits
  - Rifleman Load Limits
  - Mission Duration Requirements

NOTE: Results are illustrative only; actual analysis results were not for public release.
Summary

- Exploratory Analysis was used by the Future Force Warrior program to assess cost-effective technologies for the dismounted Infantry Platoon.

- EA used a variety of tools to solve the particular problem being addressed.