Decision Support using Mission Simulation and Modeling Tools

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Study Objectives

- Provide tools to support mission model application
  - Model agnostic to extent possible
  - Guide data gathering and input scenario definition
  - *Eventual Goal: Integration with JOEF (Joint Operational Effects Federation)*

- Explore suitable mathematical approaches
  - Statistical tools for experimental design
  - Mathematical/statistical methods for results analysis
  - *Eventual Goal: Automated optimization of alternatives*
Study Context

• CB Protection requires complex decisions, e.g.,
  – Placement of critical assets
  – Deployment of sensors
  – Policy regarding MOPP usage

• JOEF contains a sophisticated Discrete Event Simulation model for CB effects on military missions
  – Application to many practical situations may be complex due to detailed simulation processes
    Rapid data acquisition may be difficult
    Definition of appropriate scenario set may not be apparent

• Analysts may sometimes lack resources to apply JOEF simulation applications efficiently
  – Complex questions requiring numerous runs
  – Inability to obtain sufficient, accurate data
  – Short time to implement (Order of 1-2 weeks at most)
Simulation as Complex Decision Support

- Simulation predicts critical MOE under scenarios reflecting mission goals
- MOE comparisons drive decision outcome
- Large numbers of variables, scenarios and limited time are critical challenges
- Efficient “experiment” design may allow more effective/complete simulation by reducing number of combinations required
Mission Scenario Definition

- Templates to be developed by user interaction
  - Interviews with candidate users
  - Specified as “templates” of typical model applications

**Planning/Analyst Domain**

- Analyst Input (Problem Description)
- Situational Description
- Facility Description

**Simulation Parameters**

- Template Based Translation
- “Characteristic” mission templates

**Environmental Variables (Distributions)**

- Mathematical Descriptions

**Model Variables (Assumptions/Ranges)**

**MIT LL Development Program**

**Scenario Template: Control Variables**

<table>
<thead>
<tr>
<th>Scenario Name:</th>
<th>Illustrative Air Sortie Generation – Fighter Aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission Description:</td>
<td>Dispatch a series of 12 fighter aircraft at two minute intervals beginning at approximately 24 hours after receipt of task order.</td>
</tr>
<tr>
<td>Analysis Question:</td>
<td>Under what circumstances would it be beneficial to require staff to wear full MOPP?</td>
</tr>
<tr>
<td>Location:</td>
<td>Hypothetical air base</td>
</tr>
<tr>
<td>MOE:</td>
<td>Number of aircraft dispatched in 50 minutes (50 A/C x 1 minutes); Percent on schedule; Mean schedule delay; Variance of schedule delay.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mission Task</th>
<th>Variable</th>
<th>Range</th>
<th>Distribution Type</th>
<th>Parameter 1 Value</th>
<th>Parameter 2 Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan Mission Location</td>
<td>Facilities Location</td>
<td>Fixed</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MOPP Level</td>
<td>0-5</td>
<td>Fixed</td>
<td>Level</td>
<td>~0</td>
<td>Duration Multiplier</td>
</tr>
</tbody>
</table>
CB Decision Flow

- Mission Commander
  - Requires input regarding appropriate CB protection measures

- Chemical Officer
  - Responsible for recommendations on CB Protection

- Supporting Analyst
  - Responsible for analysis to support recommendations

Focus of Mission Templates

Direct beneficiary of simulation tools
MIMIC* System Concept

* Mission Impact Model for Incident Characterization
Statistical Design of Experiments

• Mathematical techniques to enhance experimental efficiency
  – Represents “Gold-standard” for testing cause and effect relationships
  – Reduces required number of experiments
    Grows rapidly with number of variable/levels
    Just 10 variables at 2 levels requires ~1000 tests to explore effects fully
  – Controls loss of information
    Reduces number of experiments
    Provides prior knowledge and selection of information loss

• Widely applied in numerous applications
  – Industrial experiments
  – Laboratory experiments
  – Medical trials
  – Agricultural
  – Software validation testing

• Application to simulation input designs is relatively recent theory
  – Most literature within past decade
MIT LL Testbed

- Simple simulation model
  - Applied as surrogate for more sophisticated tools during development
  - Interfaced to existing hazard model (HPAC/JEM)

- Illustrative mission is aircraft sortie generation
  - Major steps to dispatch aircraft
  - Rough parameter estimates (accuracy not necessary for developmental purposes)
MIT LL Testbed Architecture

- **Attack Scenarios**
  - HPAC/JEM
  - Concentration Profiles

- **Mission Description**
  - Operational Impact Computation (OPNET/Proto-C)
  - Geographic Interpretation (MATLAB)
  - Mission Discrete Event Simulation (DES)
  - Mission Simulation (OPNET)
  - Post-processor (MATLAB)

- **Batch computation**

- **MOE**
Initial Mission Simulation

- **Mission definition:**
  - Dispatch 20 fighter aircraft
  - Schedule departures at 1 minute intervals, starting 12 hours after task order
  - Total mission duration 24 hours

- **Selected MOE:**
  - Number of flights departed
  - Mean delay in flight departure
  - Percentage of flights departing on time
Scenario Concept

Security Perimeter

Man-portable attack

Rocket Attack from Outside Perimeter

Office/Meeting Areas

Housing

Taxiways

Hangers/Maintenance Areas

Munitions Assembly

Munitions Storage

Runways
Preliminary Mission Structure – Fighter A/C Departure

- **Air Task Order** (Target, Timing, Objectives, #Sortie, A/C type)
- **Battlestaff/Wing Commander/Designee**
- **Assign/Prepare Crew**
  - Mission Briefing
  - Target Study
  - Route
  - Threat
  - Intelligence
- **Detailed Mission Planning** (e.g., Flow, Timing, Weapon type (if not in order))
- **Assign/Prepare Aircraft**
  - Maintenance
  - Fuel
  - Preflight
- **Build/Load Munitions**
  - Assemble
  - Load
- **Final Preparation**
- **Departure**

- **Taxi Sequence**
- **Departure Sequence**

**Note:**
- **Time Delay**
- **Event (negligible duration)**
- **Data/Status Item**
- **Finite Resource**

*Issue Air Task Order ~ 24 Hours prior to mission*
Preliminary Mission Structure – Aircraft Preparation Detail

- Aircraft Fleet
- Assign Aircraft (Primary)
- Assign Spare Aircraft (~25% Reserve)
- Crew Chief/Assistant Resource
- Maintenance Supervisor Resource
- Assign Crew Chief/Assistant (1 per A/C)
- Assign Maintenance Supervisor (1 per 6 A/C)
- Prepare A/C (Fuel; Provision)
- Pre-flight Inspection (Maintenance)
- Note: Assignments may be specific/grouped by munitions load
- Specialty Maintenance Crew (e.g., Avionics, Engine, ECM)
- Correct Anomalies
- Maintenance Required
- A/C Ready for Crew/Munitions
- From crew preflight
- Time Delay
- Event (negligible duration)
- Data/Status Item
- Finite Resource

Specialist Dispatch (As Needed)

Cooling/Hydraulic/Pneumatic Support (As Needed)

AGE Resource

Dispatch AGE

Connect AGE

MIT Lincoln Laboratory
Protective Scenarios

• Initial analysis considers alternative MOPP deployment policies
  – Not deployed for any mission
  – All critical missions
  – All critical missions during heightened alert
    Alert level established by intelligence
  – Operations in “high-risk” areas
    E.g., near facility perimeter
    Areas to be identified using threat simulations
  – Operations in “high-risk” areas only during heightened alert

• Implication of MOPP usage
  – Simple tasks require 1.5 times nominal time to complete
  – Complex tasks require 2.5 times nominal time to complete
  – MOPP assumed to provide complete protection

Current presentation
Simulation Parameters for Example Mission

Control Variables

- MOPP Policy
- Critical Facility Placement
- Size of Security Perimeter

Environmental Variables

- Attack Type
- Attack Location
- Agent
- Weather

Model Variables

- N/A

Define Feasible Policies

- MOPP/No MOPP at mission start
- Alternative locations for critical activities

Translate to Policy Simulation Scenarios

- Code MOPP delay/effectiveness
- Code alternative locations in DES

Statistically Minimize Simulation Scenarios

- Select scenarios by Factorial Design
Simulation Parameters for Example Mission

Control Variables

- MOPP Policy
  - None
  - Routine
- Critical Facility Placement
- Size of Security Perimeter

Environmental Variables

- Attack Type
- Attack Location
- Agent
- Weather

Model Variables

- N/A

Define Expected Distributions

- Define/ code attack types (e.g., Sprayer, Rocket Launcher)
- Specify attack likelihood
- Specify weather distribution

Reduce Simulation Set

- “Intelligent” scenario selection
- Random sampling
- “Space-filling” designs
Random Attack Model

Case 1: “Random” (40) attacks, distributed evenly around the security perimeter
- Majority of attacks (97.5%) affected areas in which no people or critical actions were taking place
- Minimal effect on mission predicted
- Assumes little to no planning/intelligence by attacker

Case 2: “Intelligent” attack set, directed at operational and/or populated areas
- All of the attacks affected at least one area important to the mission
- Mission effect much more significant
- Likely more realistic representation of potential attack threat

Random sampling of attack space is inefficient

Intelligent sampling of attack space is more appropriate

Future efforts will examine applicability of statistical techniques to enhance simulation efficiency (i.e., reduce number of scenarios)
Consequence is highly dependent on attack location and wind direction.
Average Predicted MOE (Illustrative Example)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Mean Departure Delay (Minutes)</th>
<th>Departures on Schedule (Percent)</th>
<th>Average Flights Departed</th>
<th>Max Sortie Generation Rate** (Sorties/Minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Attack*</td>
<td>0.1</td>
<td>92.7%</td>
<td>20</td>
<td>0.2</td>
</tr>
<tr>
<td>Sprayer* Attack</td>
<td>16.1</td>
<td>87.8%</td>
<td>19.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Rocket* Attack</td>
<td>32.3</td>
<td>83.8%</td>
<td>18.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Always in MOPP</td>
<td>73.8</td>
<td>0.06%</td>
<td>20</td>
<td>0.08</td>
</tr>
</tbody>
</table>

* Without MOPP
**Predicted maximum possible rate based on ability to prepare aircraft for mission

Based on simple averages, using MOPP at mission start causes more delay than worst case attack……..BUT…
Example Decision Issues
(Illustrative Example)

- On average, MOPP is detrimental in terms of delay
- Application of MOPP increases variability in MoE

Well targeted attacks can cause much worse delays than MOPP

For the example case, approximately 10% of attacks affected critical facilities sufficiently to benefit from MOPP application

- Effective decision strategies must consider not only average performance, but consequences of specific scenarios
  - Likelihood of attack on most critical (“worst case”) operations
  - Information fusion techniques may be applicable
Summary

- Core program objective is to provide tools to enhance simulation application and result analysis
  - Agnostic to particular mission simulation tools
  - Eventual integration into JOEF suite

- Initial activities have provided a “testbed” simulation tool and concepts for mathematical toolset
  - Discrete event simulation for illustrative mission linked to hazard assessment tool
  - Provides an example against which to test candidate scenario design and analysis concepts

- Interviews are in progress to characterize key decision processes and possible roles of simulation
  - Advance understanding of potential JOEF applications
  - Guide development of supporting mathematical tools
  - Delineate key issues in interpreting simulation outputs