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

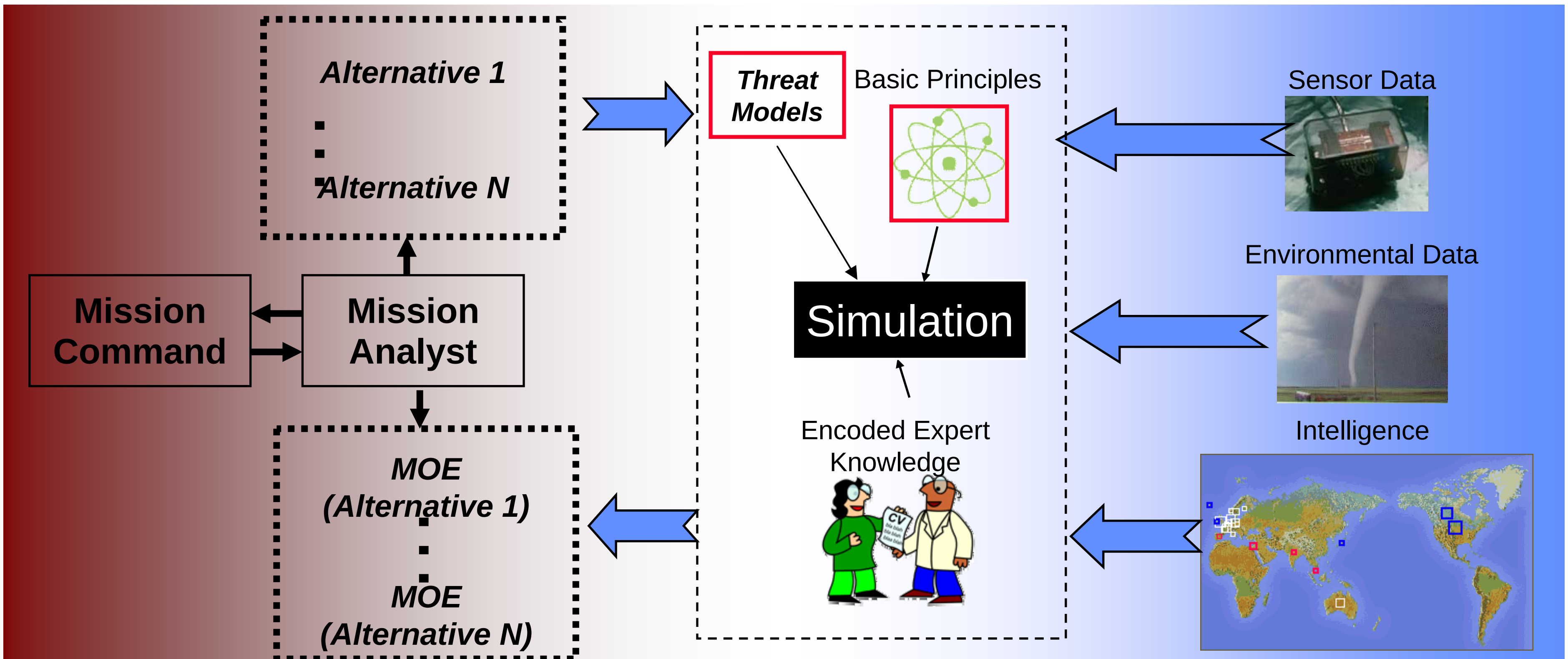
- **CB Protection requires complex decisions, e.g.,**
  - Placement of critical assets
  - Deployment of sensors
  - Policy regarding MOPP usage

- **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

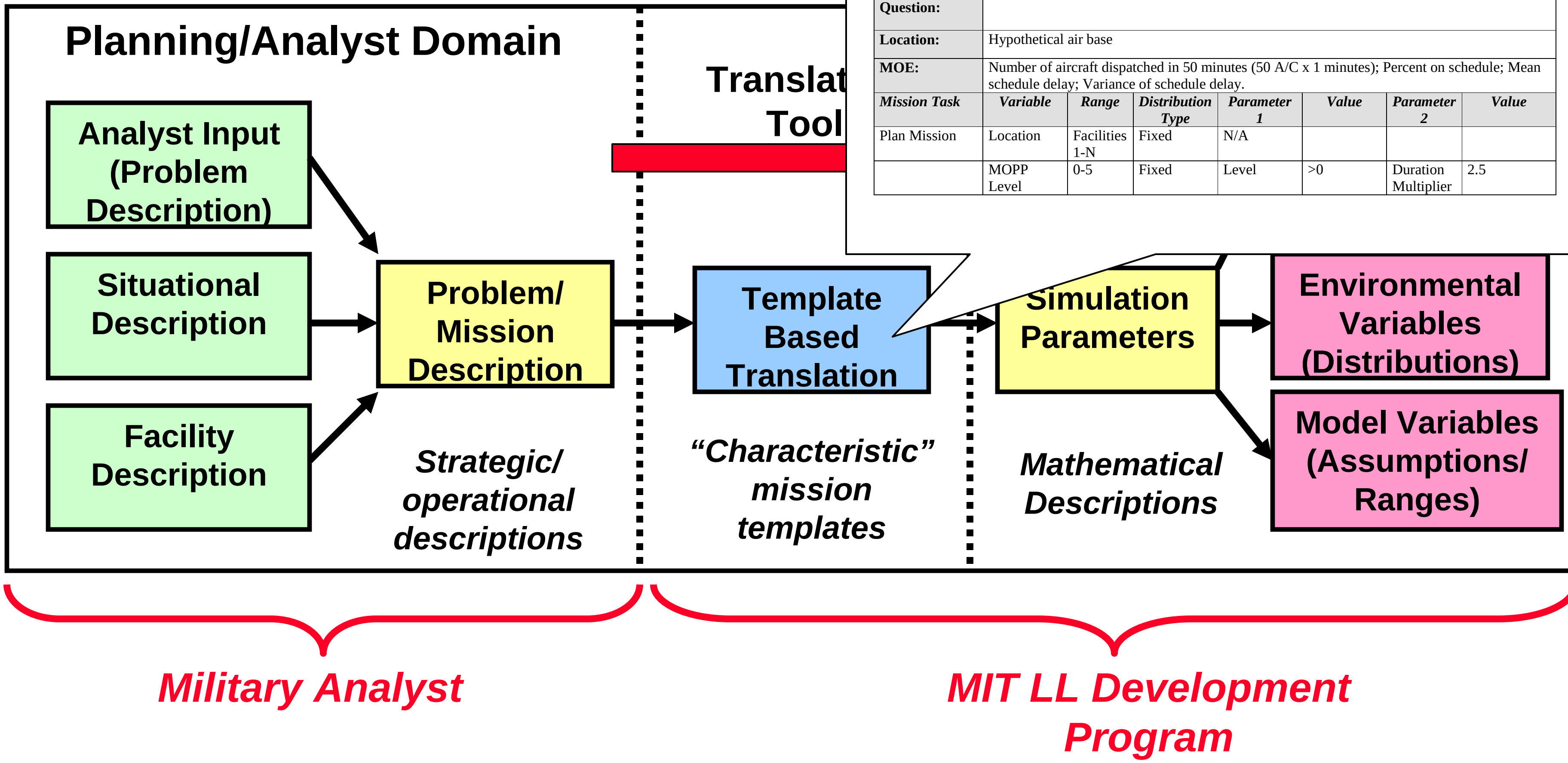
- **Analysts may sometimes lack resources to apply JOEF simulation applications efficiently**
  - Complex questions requiring numerous runs
  - Inability to obtain sufficient, accurate data
  - Short time to implement (Order of 1-2 weeks <u>at most</u>)

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



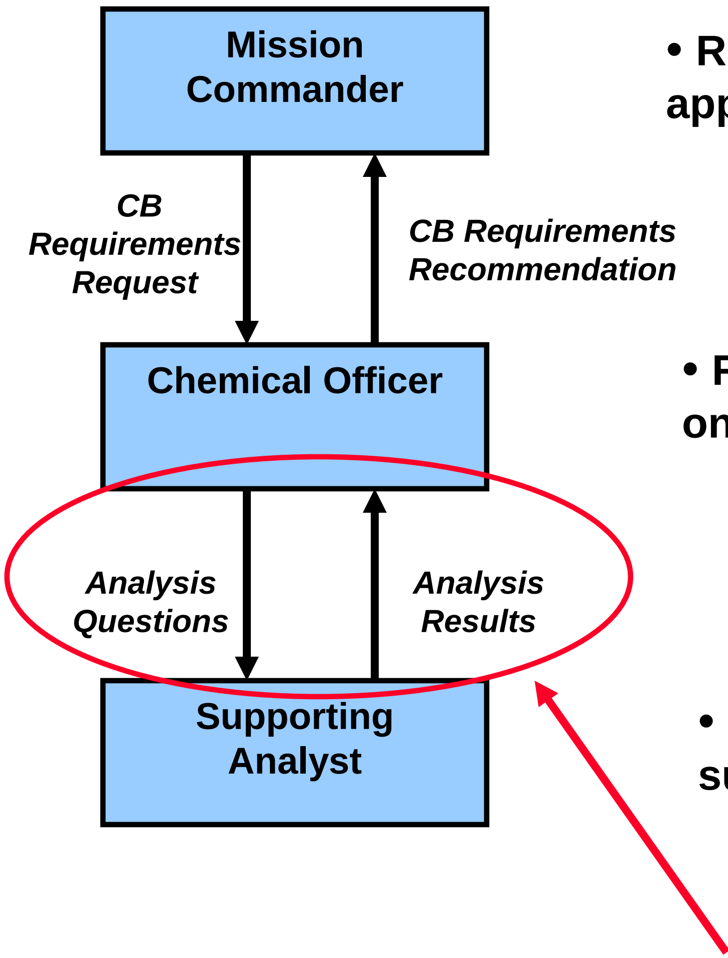
Mission Scenar



Scenario Template: Control Variables							
Scenario Name:	Illustrative Air Sortie Generation – Fighter Aircraft						
Mission Description:	Dispatch a series of 12 fighter aircraft at two minute intervals beginning at approximately 24 hours after receipt of task order.						
Analysis Question:	Under what circumstances would it be beneficial to require staff to wear full MOPP?						
Location:	Hypothetical air base						
MOE:	Number of aircraft dispatched in 50 minutes (50 A/C x 1 minutes); Percent on schedule; Mean schedule delay; Variance of schedule delay.						
Mission Task	***Variable***	***Range***	***Distribution Type***	***Parameter 1***	***Value***	***Parameter 2***	***Value***
Plan Mission	Location	Facilities 1-N	Fixed	N/A			
	MOPP Level	0-5	Fixed	Level	>0	Duration Multiplier	2.5

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

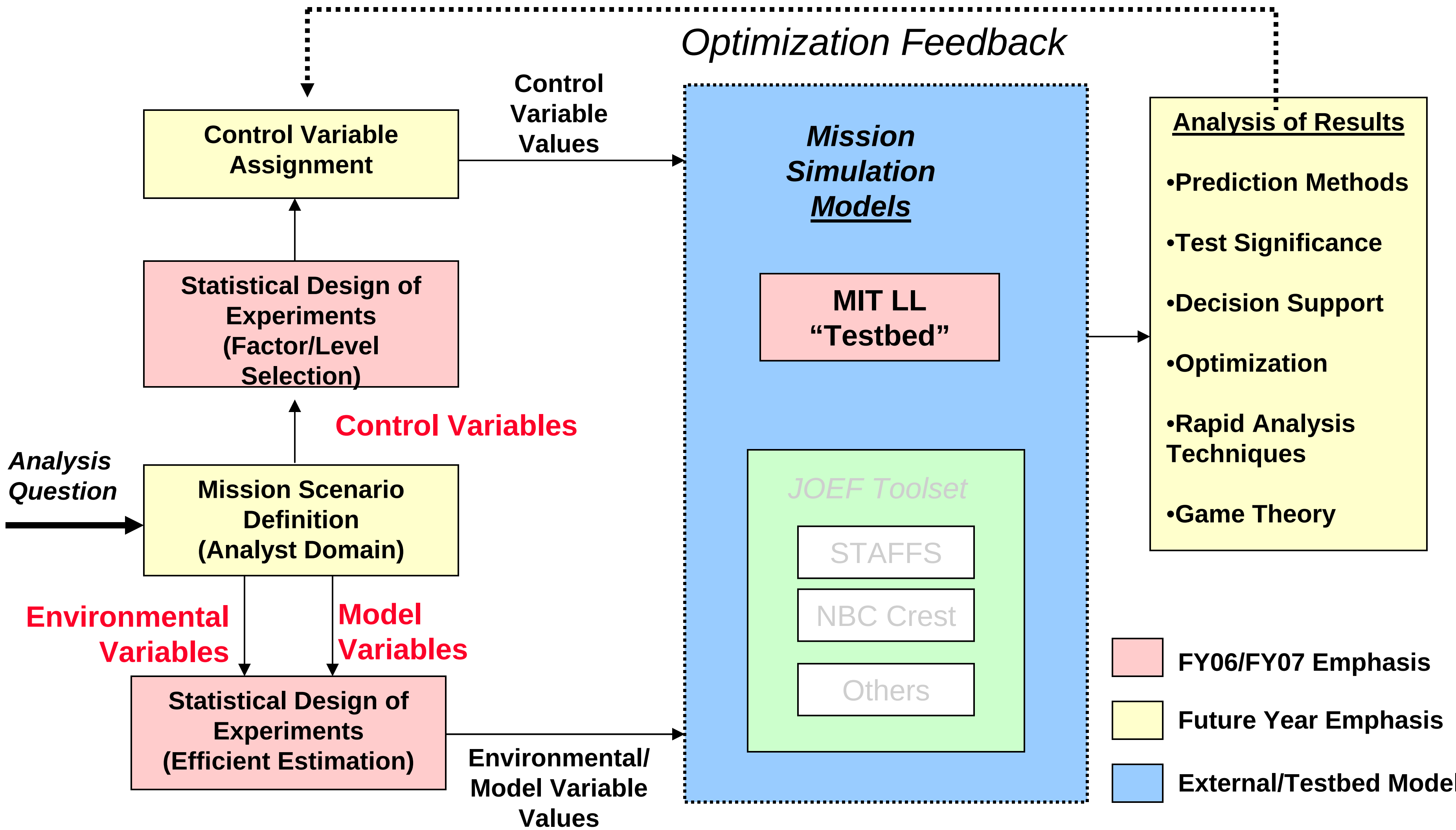
CB Decision Flow



- Requires input regarding appropriate CB protection measures
- Responsible for recommendations on CB Protection
- Responsible for analysis to support recommendations → ***Direct beneficiary of simulation tools***

Focus of Mission Templates

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

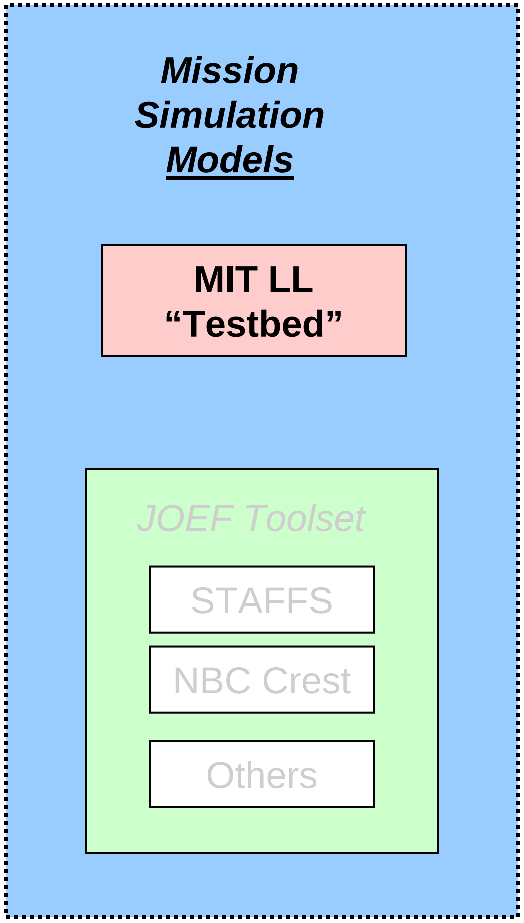
- Widely applied in numerous applications
  - Industrial experiments
  - Laboratory experiments
  - Medical trials
  - Agricultural
  - Software validation testing

- Application to simulation input designs is relatively recent theory
  - Most literature within past decade

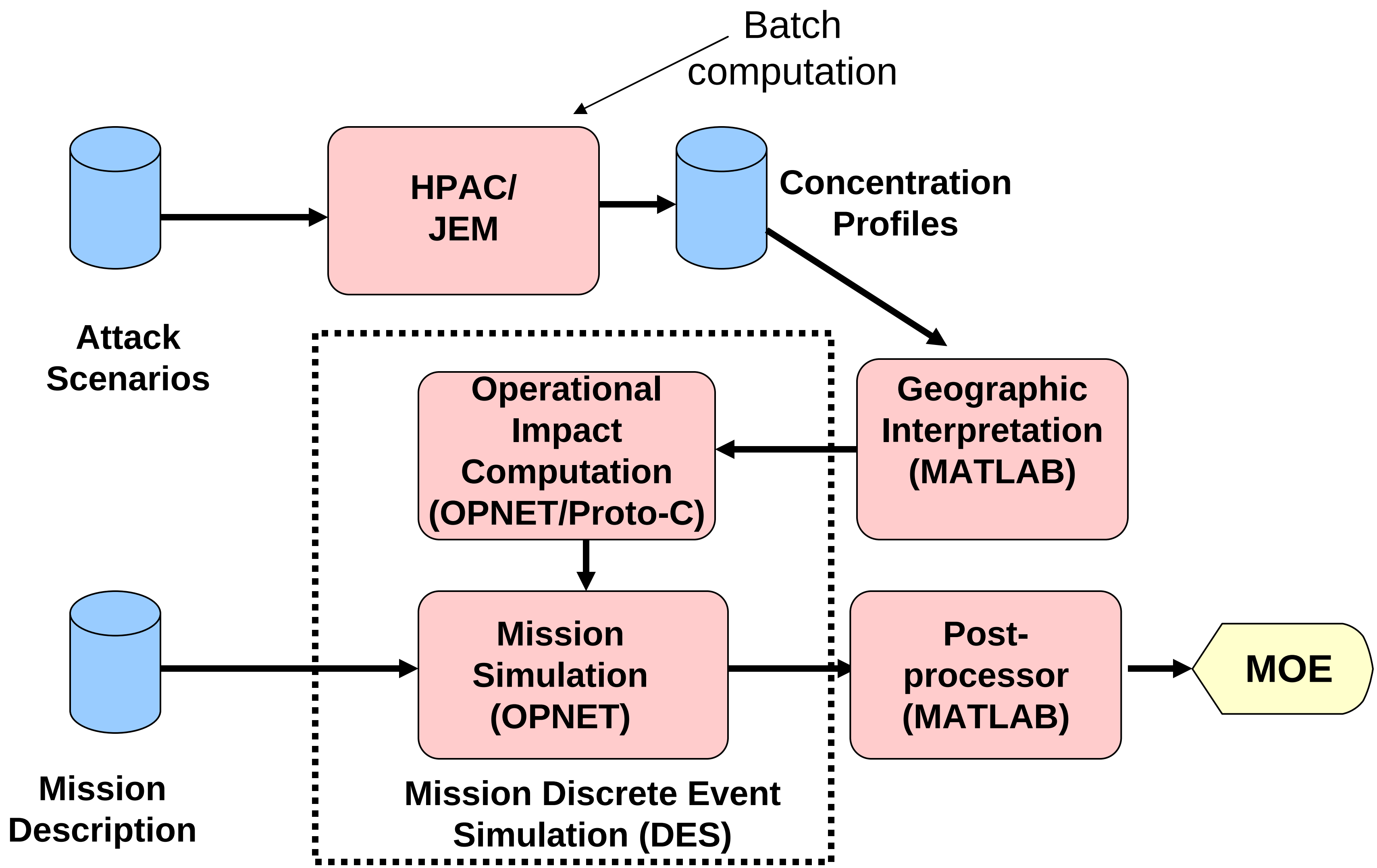
MIT LL Testbed

- **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

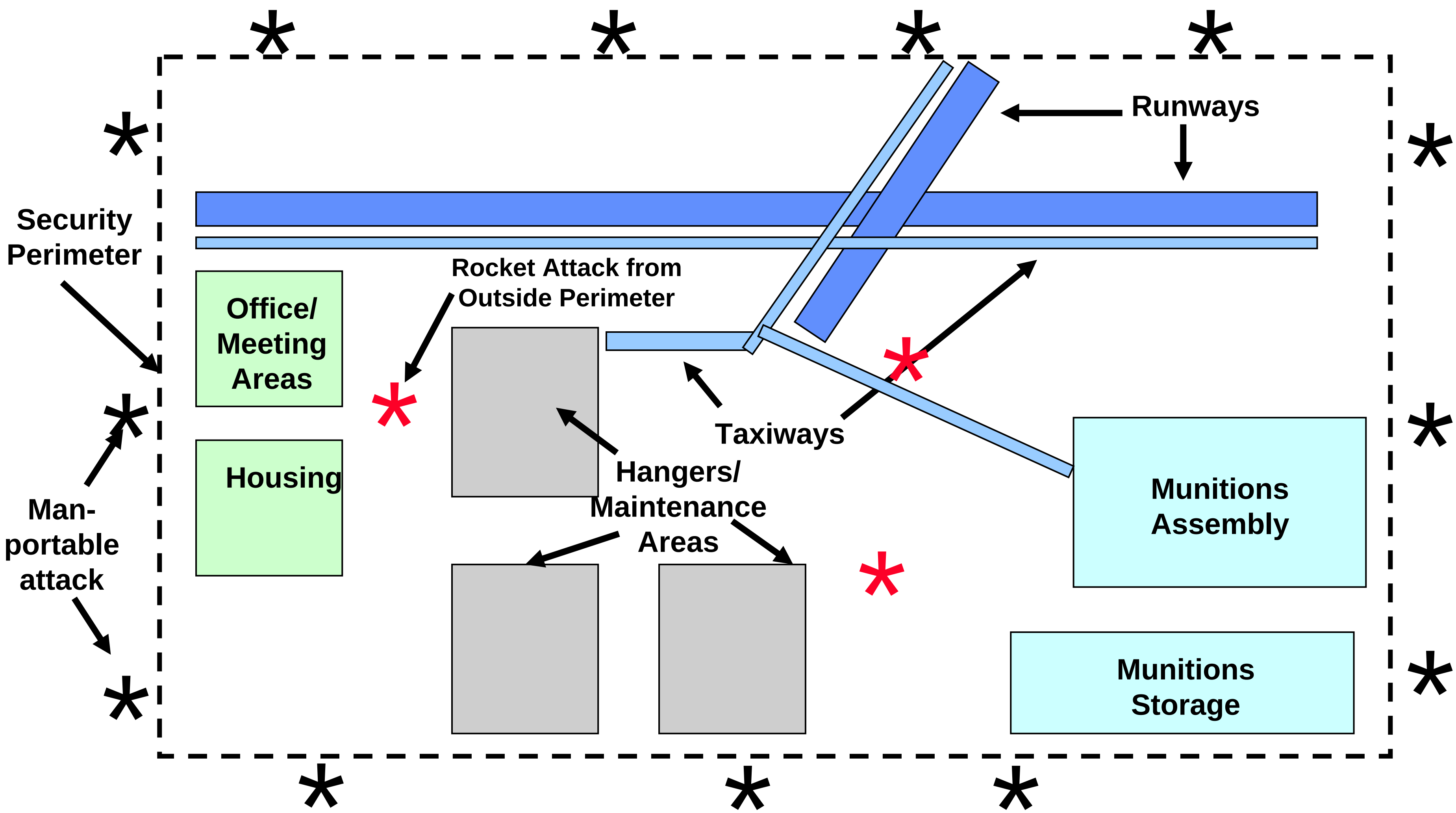


Initial Mission Simulation

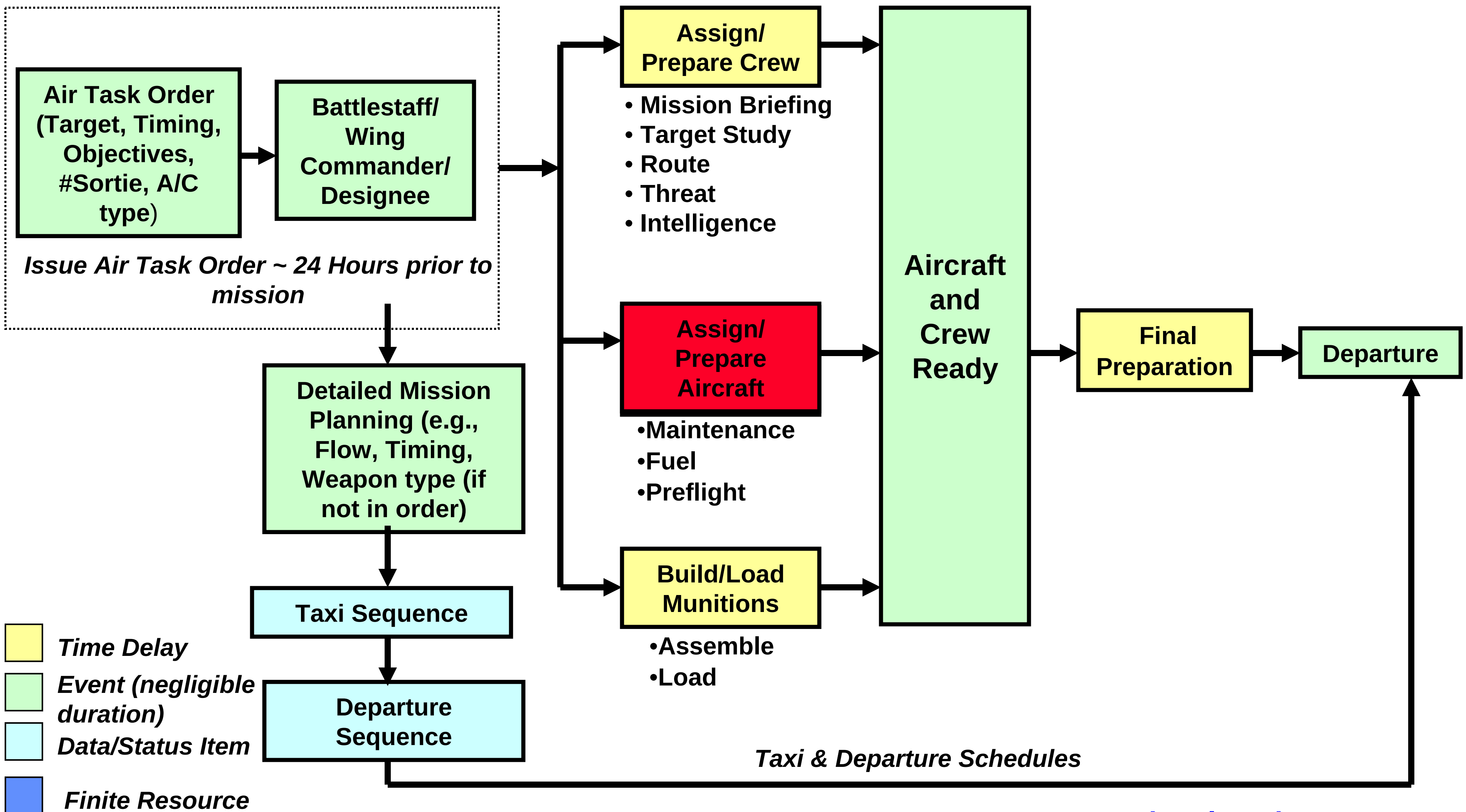
- **Mission definition:**
  - Dispatch 20 fighter aircraft
  - Schedule departures at 1 minute intervals, starting 12 hours after task order
  - Total mission duration 24 hours

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

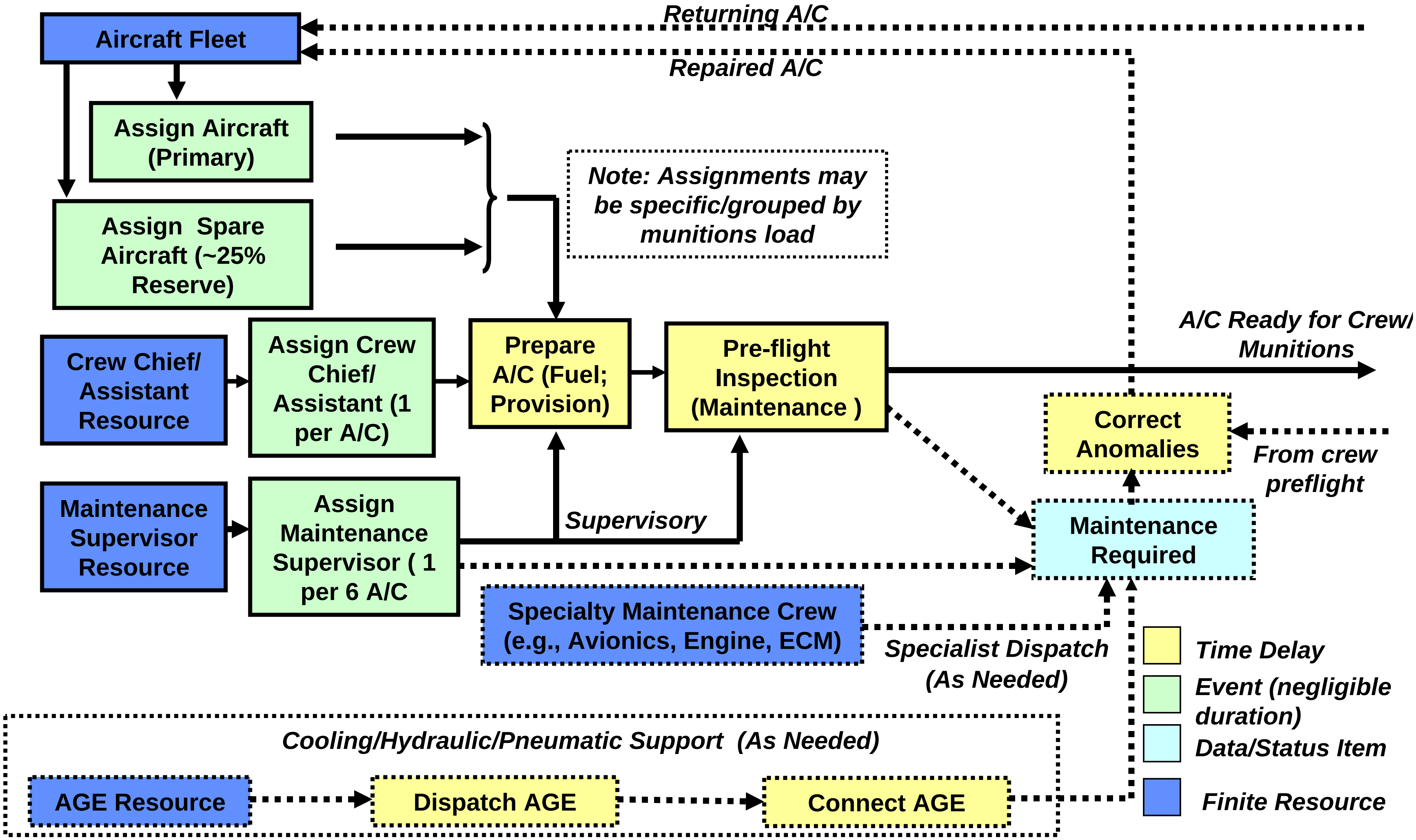
Scenario Concept



Preliminary Mission Structure – Fighter A/C Departure



Preliminary Mission Structure – Aircraft Preparation Detail



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	Environmental Variables	Model Variables
• MOPP Policy –None –Routine • Critical Facility Placement •Size of Security Perimeter	• Attack Type •Attack Location •Agent •Weather	•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

Random sampling of attack space is inefficient

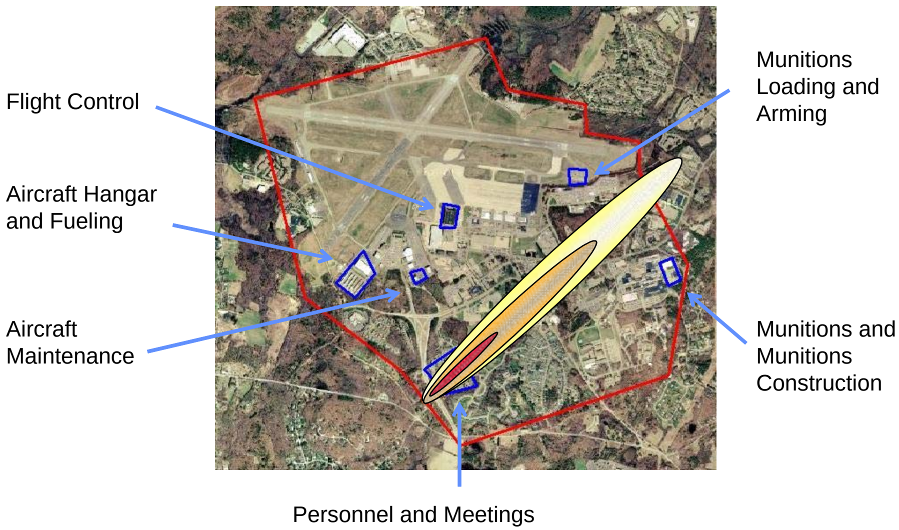
- **Case 1: “Random” (40) attacks, distributed evenly around the security perimeter**
  - **Majority of attacks (97.5 %) affected areas in which no people or critical actions were taking place**
  - **Minimal effect on mission predicted**
  - **Assumes little to no planning/intelligence by attacker**

Intelligent sampling of attack space is more appropriate

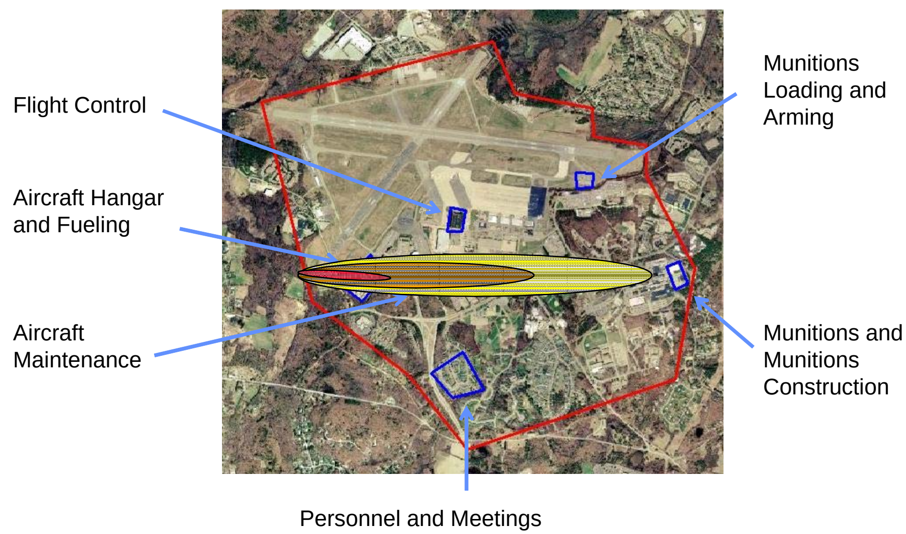
- **Case 2: “Intelligent” attack set, directed at operational and/or populated areas**
  - **All of the attacks affected at least one area important to the mission**
  - **Mission effect much more significant**
  - **Likely more realistic representation of potential attack threat**

Future efforts will examine applicability of statistical techniques to enhance simulation efficiency (i.e., reduce number of scenarios)

Illustrative Attack Plumes (Backpack Sprayer)



Consequence is highly dependent on attack location and wind direction.



Average Predicted MOE (Illustrative Example)

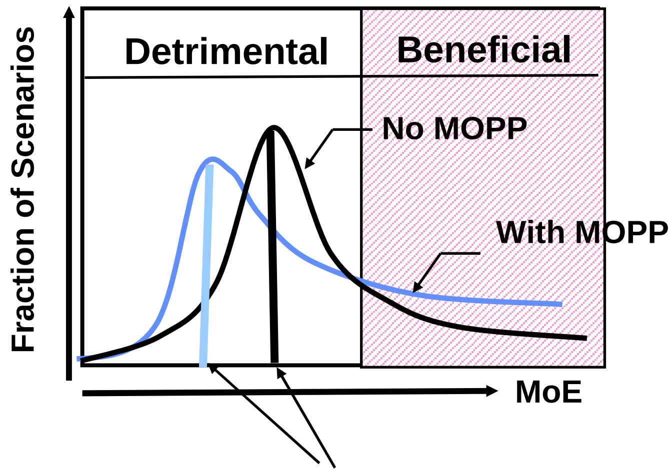
Scenario	Mean Departure Delay (Minutes)	Departures on Schedule (Percent)	Average Flights Departed	Max Sortie Generation Rate** (Sorties/ Minute)
No Attack*	0.1	92.7%	20	0.2
Sprayer* Attack	16.1	87.8%	19.1	0.2
Rocket* Attack	32.3	83.8%	18.2	0.2
Always in MOPP	73.8	0.06%	20	0.08

* 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…

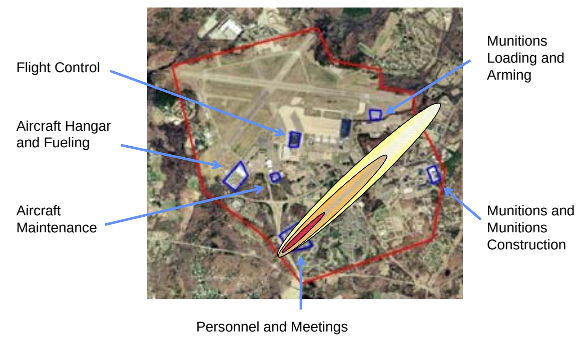
Example Decision Issues (Illustrative Example)



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

- **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



- **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