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Toward The Development Of A Predictive Computer Model Of Decision Making Under Uncertainty For Use In Simulations Of U.S. Army Command And Control Systems

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Complexity of the Battlefield

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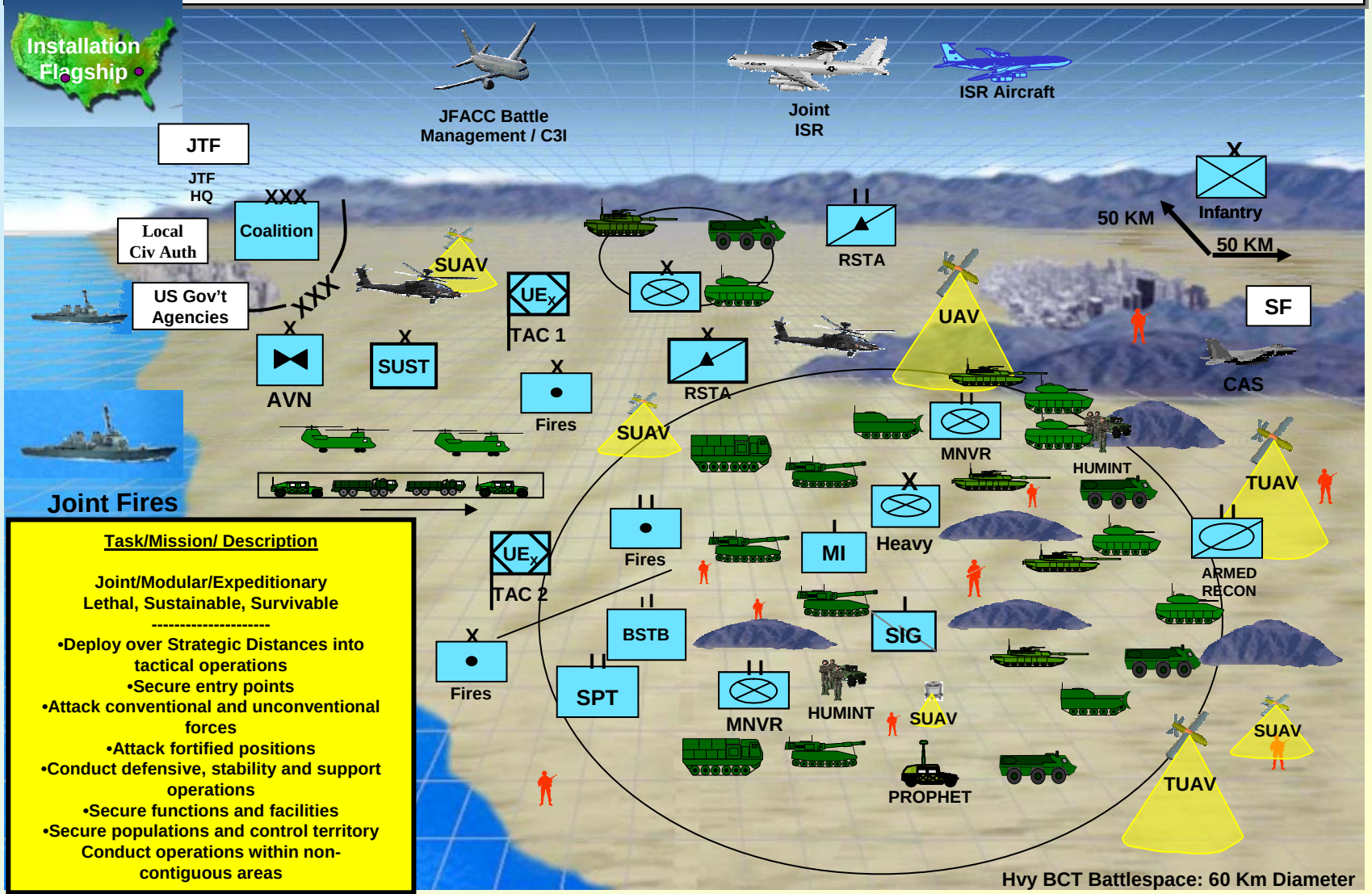
Heavy Brigade Combat Team



Task/Mission/ Description

Joint/Modular/Expeditionary
Lethal, Sustainable, Survivable

- Deploy over Strategic Distances into tactical operations
- Secure entry points
- Attack conventional and unconventional forces
- Attack fortified positions
- Conduct defensive, stability and support operations
- Secure functions and facilities
- Secure populations and control territory

Conduct operations within non-contiguous areas

Modeling Decision Making

Background

- Fundamental Aspect Of Human Cognition Is The Ability To Make Decisions.
- Most Decisions That Are Made Are Not “One Off” Decisions In Which The Decision Is Made And Then The Rewards Reaped Or The Punishment Endured.
- One Challenge Faced By Any Decision Maker Is The Uncertainty That The Decision Maker Has About The **True** State Of The System.
  - Generally The True State Of The System Is Unknown Or Hidden.
  - True State Cannot Be Directly Observed.
- Typical Response Can Be Characterized By The Observe-Orient-Decide-Act (OODA) Cycle.*
  - Observe: Example Is To Send A UAV To Find The Enemy.
  - Orient: Example Is To Update Belief About The Enemy Based On UAV Report.
  - Decide: Example Is To Declare Mission Complete And Take Appropriate Follow-on Actions.
  - Act: Example Is To Take Action To Kill Enemy Such As Firing Artillery At Suspected Location.

* Belknap, M. (1996). Military Decision Making in the Information Age. Unpublished Monograph, Naval War College, Newport, RI. Joint Military Operations Department. Ad-a307-648-6-xab.

Modeling Decision Making

Approach

- Optimal Observer.
  - To evaluate performance in a task that leads to uncertainty and probabilistic actions, it is useful to determine the optimal performance within a task.
  - The optimal performance can be calculated using an extension of Bayesian statistics called *Partially Observable Markov Decision Processes* (POMDP).
  - Optimal performance can then be used as a benchmark by which to compare human performance.

- Belief Updating.
  - Hypotheses can be generated about the current state of the problem following an action and the returned observation.

Modeling Decision Making

Example

- Observe.
  - Can be generalized as an effort to gain information about the nature of the problem. Example: Fly a UAV over a suspected enemy location.
- Orient.
  - Can be generalized as the cognitive evaluation of the information.
- Decide.
  - Can be generalized as the determination to seek additional information or take an action.
- Act.
  - Can be generalized as an effort to achieve a result. Example: Firing artillery to destroy an enemy at a suspected location.

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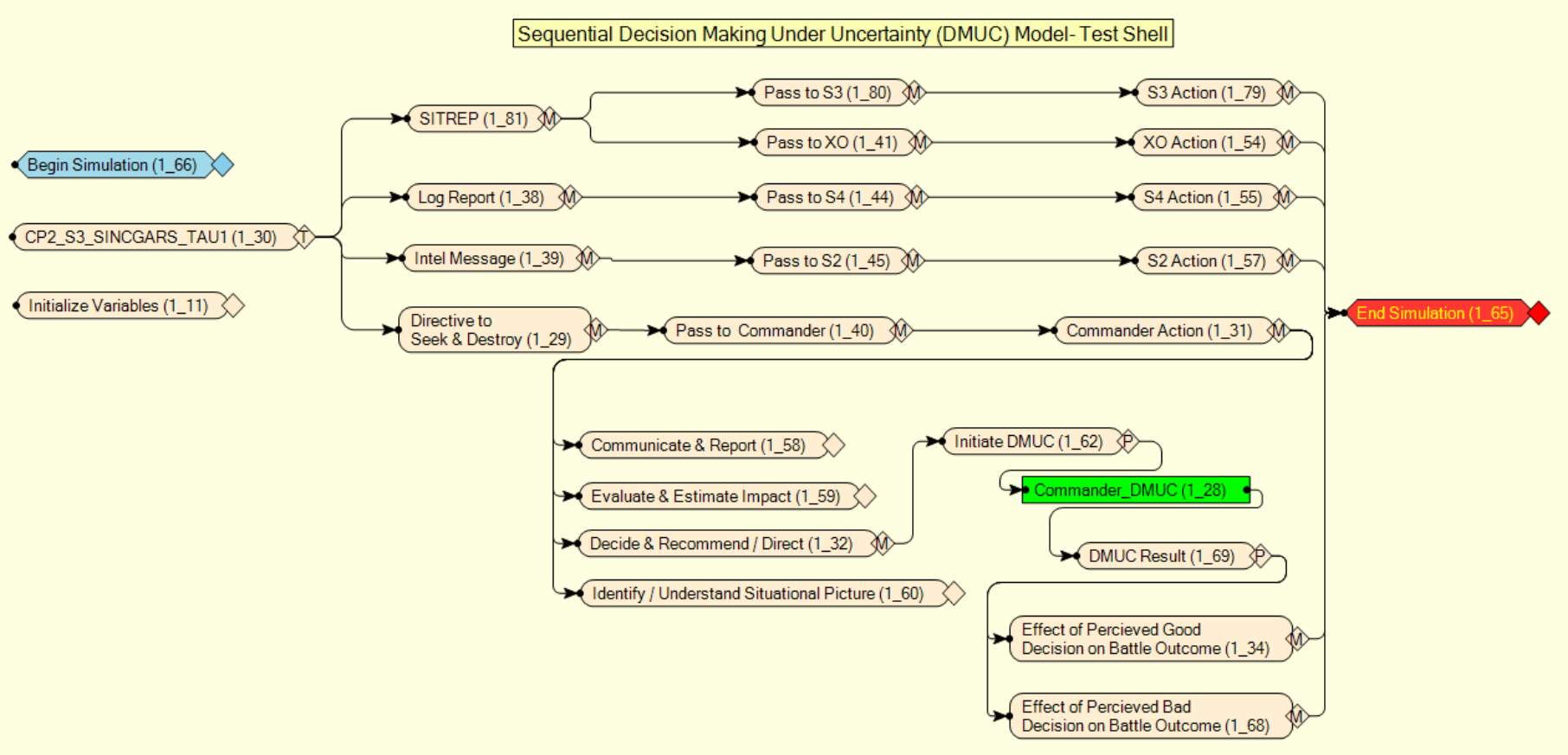
Example: Command and Control Simulation Vignette



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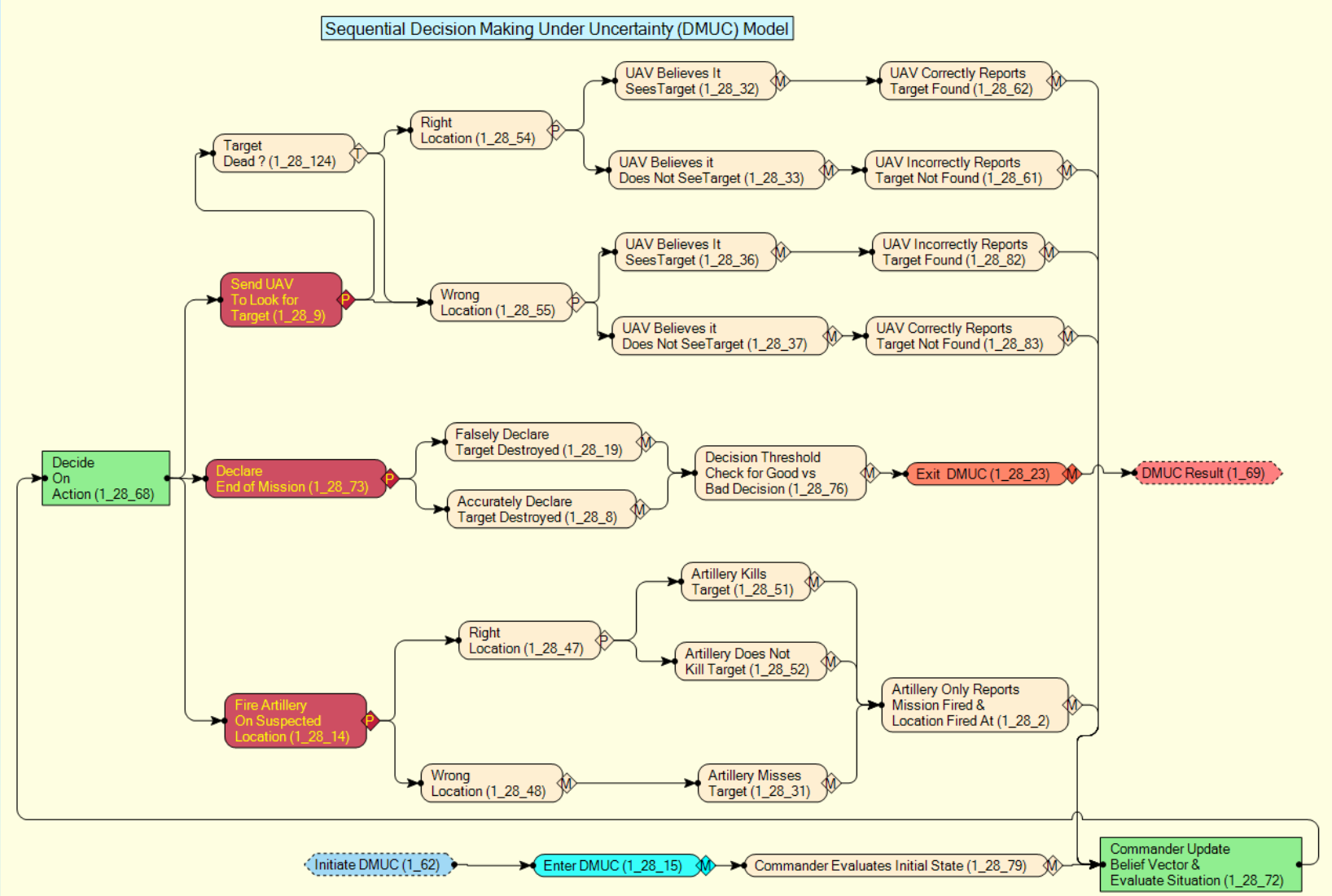
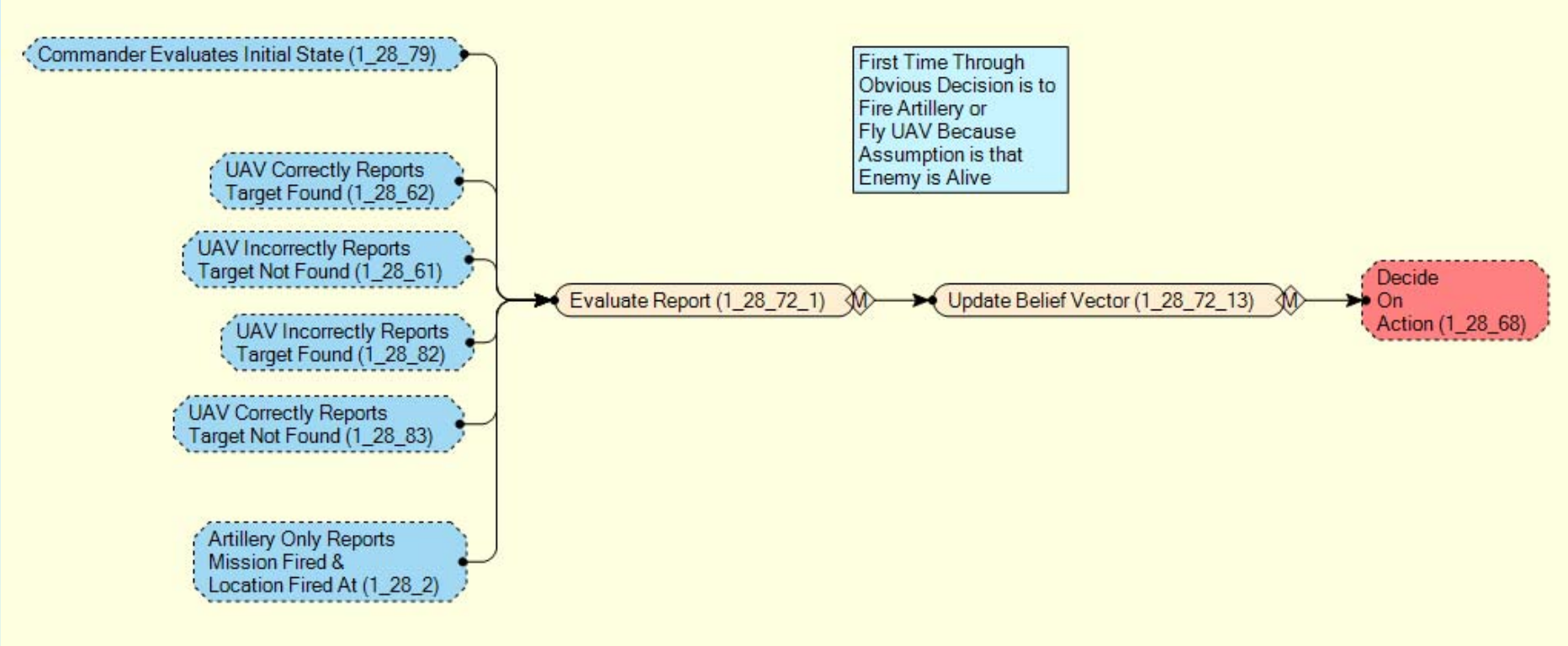
Decision Making Under Uncertainty Model



Modeling Decision Making

Modeling of Belief Updating



Modeling Decision Making

Belief Vector Updating Logic

For UAV Mission Cases:

If (UAV mission ordered) & (Enemy Located at specified location)
- Then, Update Belief Vector with positive information for State Reconed.
- Then, Update Belief Vector with negative information for State Not Reconed.
- Then, Update Belief Vector with negative information for State Dead.

If (UAV mission ordered) & (Enemy Not Located at specified location, or is dead)
- Then, Update Belief Vector with positive information for State Not Reconed.
- Then, Update Belief Vector with negative information for State Reconed.
- Then, Update Belief Vector with negative information for State Dead.

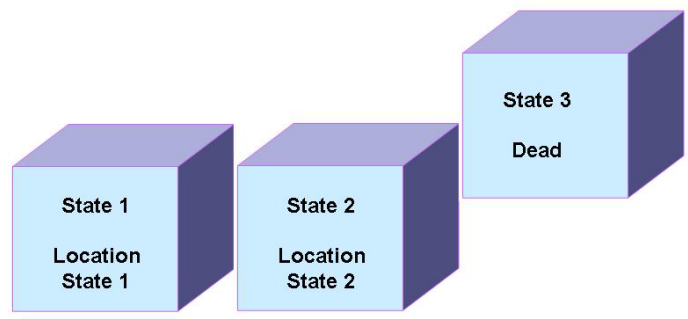
For Arty Mission Cases:

If (Arty mission ordered) & (Enemy Located at specified location)
- Then, Update Belief Vector with positive information for State Fired Upon.
- Then, Update Belief Vector with negative information for State Not Fired Upon.
- Then, Update Belief Vector with positive information for State Dead.

If (Arty mission ordered) & (Enemy Not Located at specified location)
- Then, Update Belief Vector with negative information for State Fired Upon.
- Then, Update Belief Vector with negative information for State Not Fired Upon.
- Then, Update Belief Vector with negative information for State Dead.

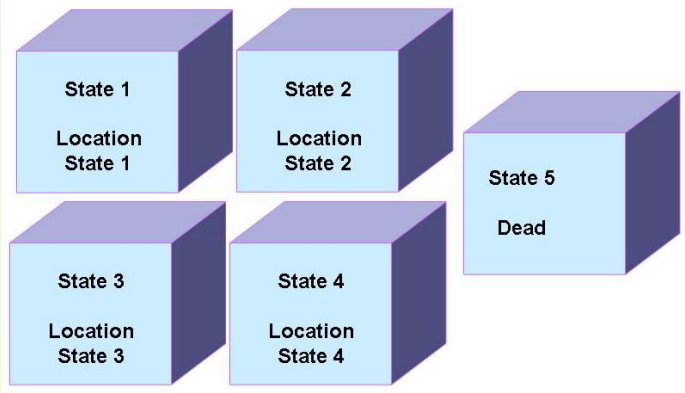
Modeling Decision Making

State Space Development



Initial / Current Work

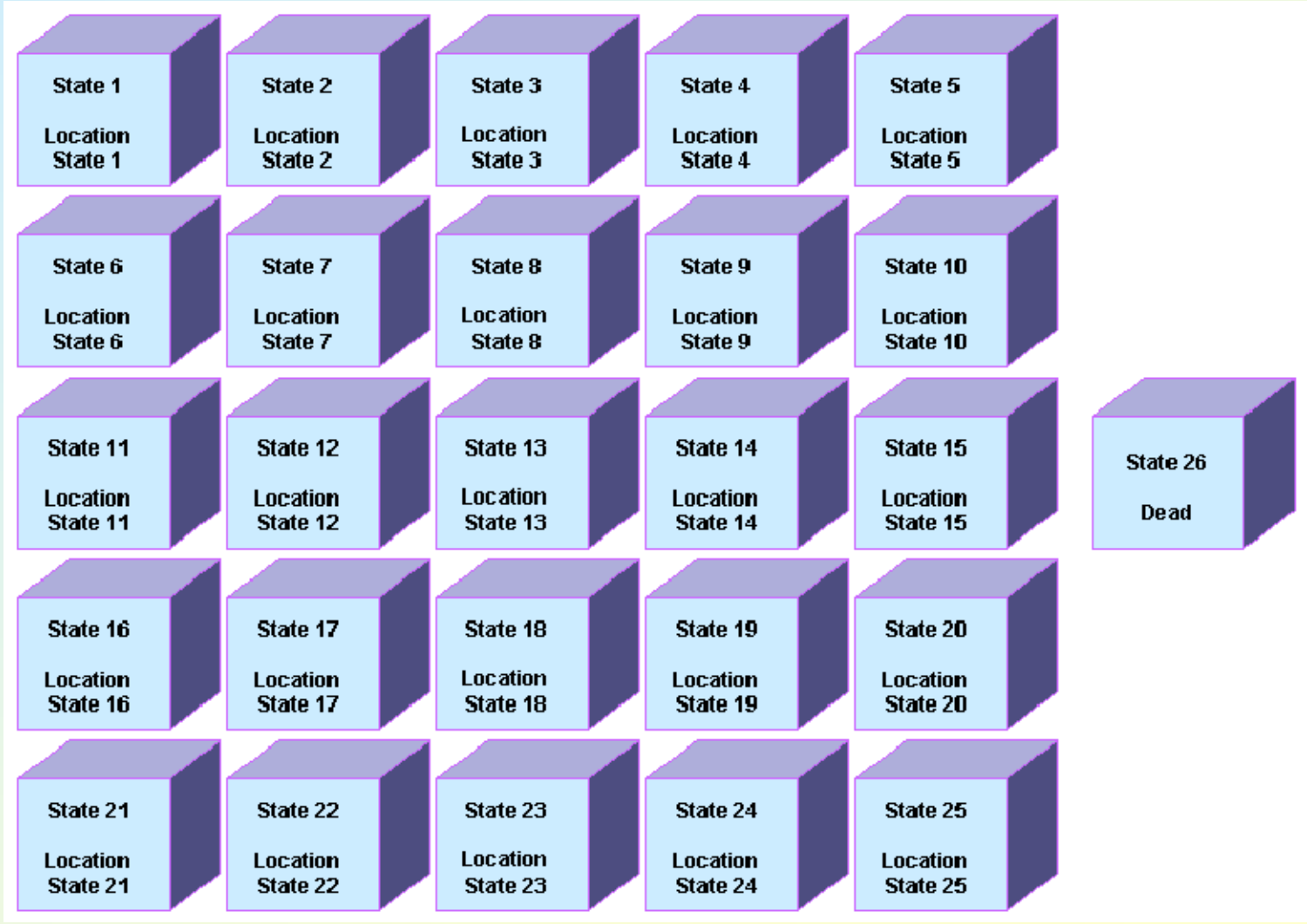
Intermediate Development



Modeling Decision Making

State Space Development

Target State Matrix



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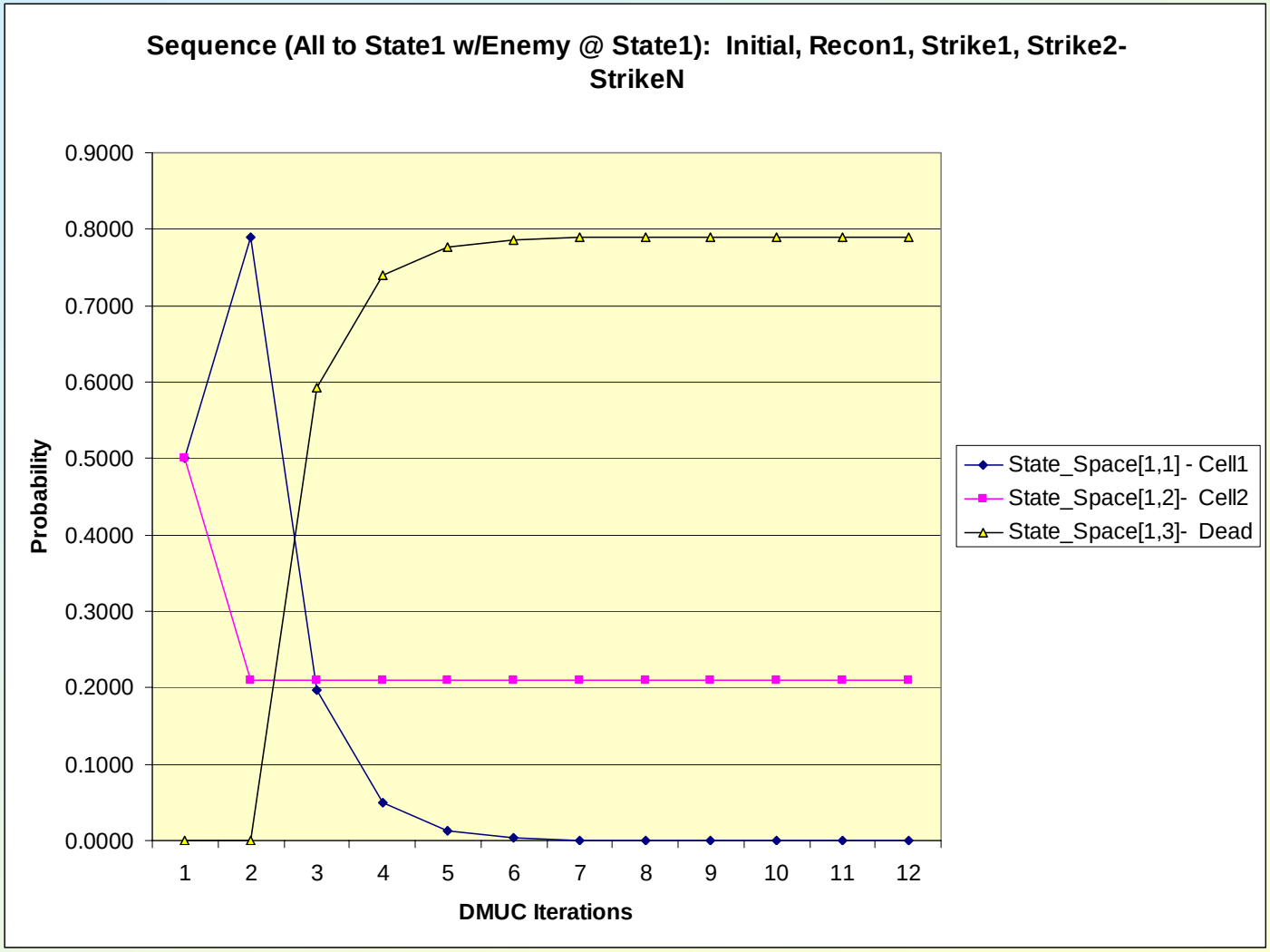
Belief Updating Predictions



Modeling Decision Making

Application

- Evaluation of cognitive performance possible from changes in system components.
  - Predict optimal level of decisions possible from given set of input conditions.
  - Compare actual human performance from laboratory testing to optimal predictions.
  - Estimate the impact that system changes will have on possible human cognitive performance.

Future Work

- Establish the size of the location state space as a metric for the complexity of the problem space the decision is acting upon.
- Expand from static enemy location state to dynamic movement:
  - Random movement.
  - Movement toward an objective location.

Questions?