



**Space Dynamics**  
LABORATORY  
Utah State University Research Foundation

# Cooperative Mobile Sensing

Daniel Bryce  
USU Dept. of Computer Science



# Summary of Research Objectives

## ► Model Formulation

- Sensor Capabilities
- Mobile Sensor Topology
- Dynamic Route Planning
- Joint Observation Utility
- Decentralized Control



## ► Algorithm Development

- Markov Decision Processes (MDPs)
  - Normative Model for Optimal Sequential Decision Making
- Heuristics for Scale-up
  - Developments in PI's lab provide leverage

## ► Simulation Environment

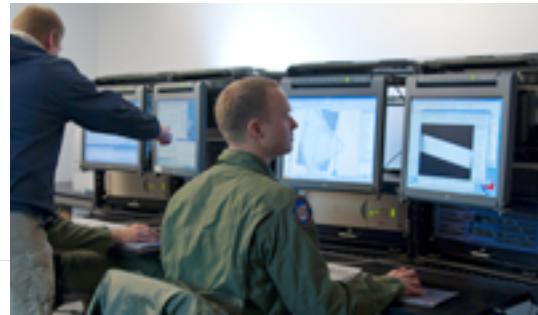
- Based on Commercial product (X-Plane)
- Plug-ins for MDP-based sensor control



# Benefit to SDL Thrust Area

## ► C4ISR Benefits

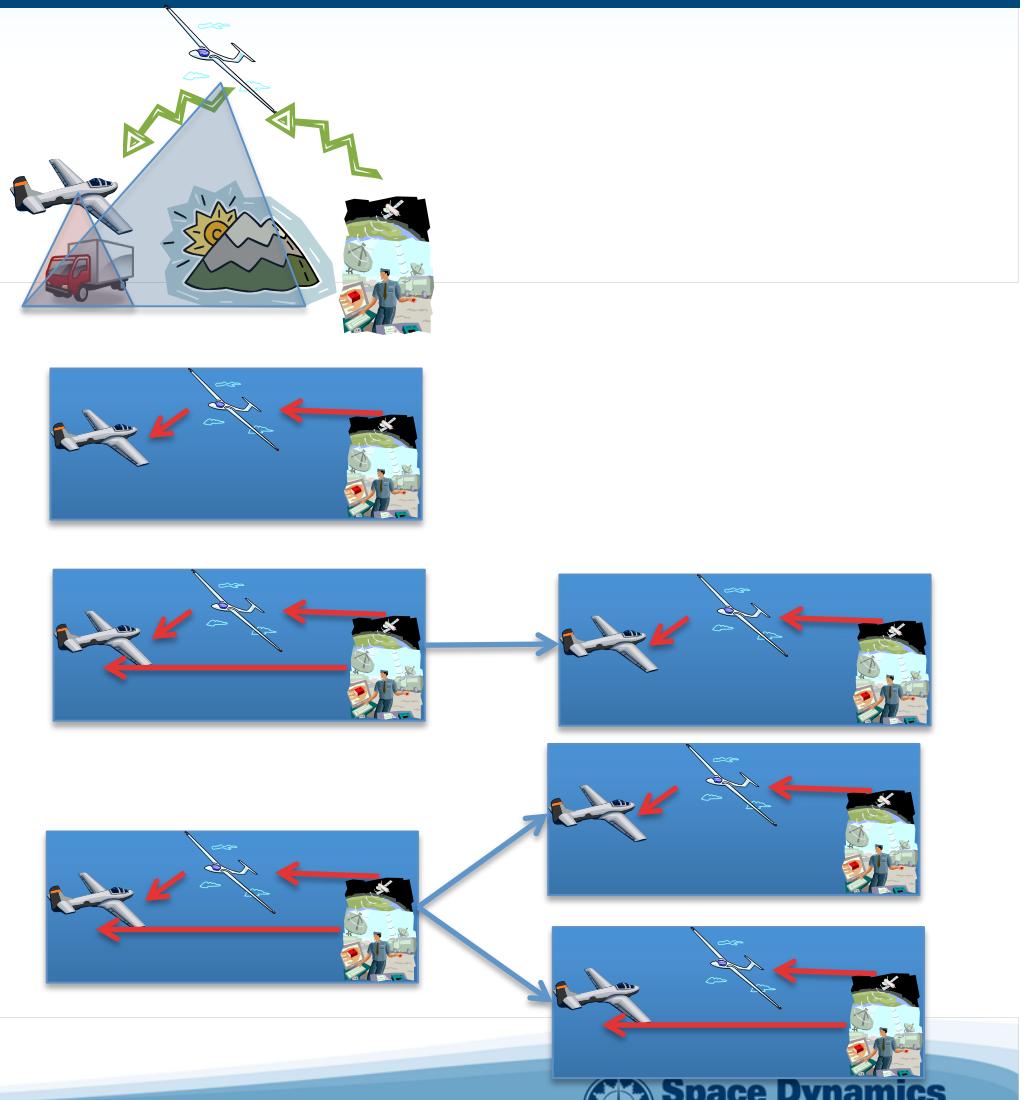
- Sensor to Operator Ratio (Tooth-to-Tail)
  - More sensors per human operator
  - Decreased cognitive load
- Increased Observation Utility
  - Opportunistic Sensing
  - Just-in-time sensor allocation
  - Distributed control



# Description of Research Project

## ► Model Formulation

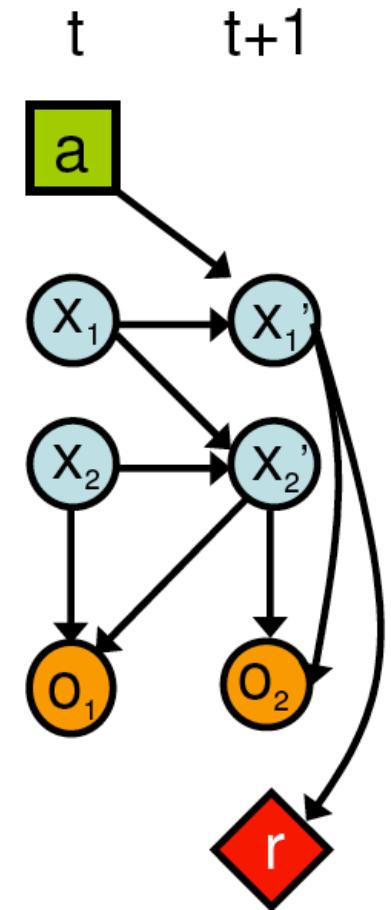
- Common Ingredients
  - Sensor Capabilities, Possible Observation Requests, Environment Map, Routes, Observation Utilities
- Static Topology
  - Sensor Communication Fixed
  - Targets appear Non-Deterministically
- Dynamic Topology
  - Sensor Communication Changes
- Non-Deterministic and Dynamic Topology
  - Sensor Communication Changes in unpredictable manner



# Description of Research Project

## ► Algorithm Development

- Markov Decision Process ( $S, A, T, R, \gamma$ )
  - $S$ : States
  - $A$ : Actions
  - $T$ : Transition Relation
  - $R$ : Reward Function
  - $\gamma$ : Discount
  - Find policy  $\pi$  that Maximizes  $E[\sum_t \gamma^t r_t | s_0, \pi]$
  - Extensions:
    - ◆ Multiple Agents, Partial Observations, Decentralized
- Approach
  - Heuristic search
    - ◆ Construct Policy using expected reward estimates
    - ◆ Led to state-of-the-art approaches
    - ◆ Active research of PI



# Description of Research Project

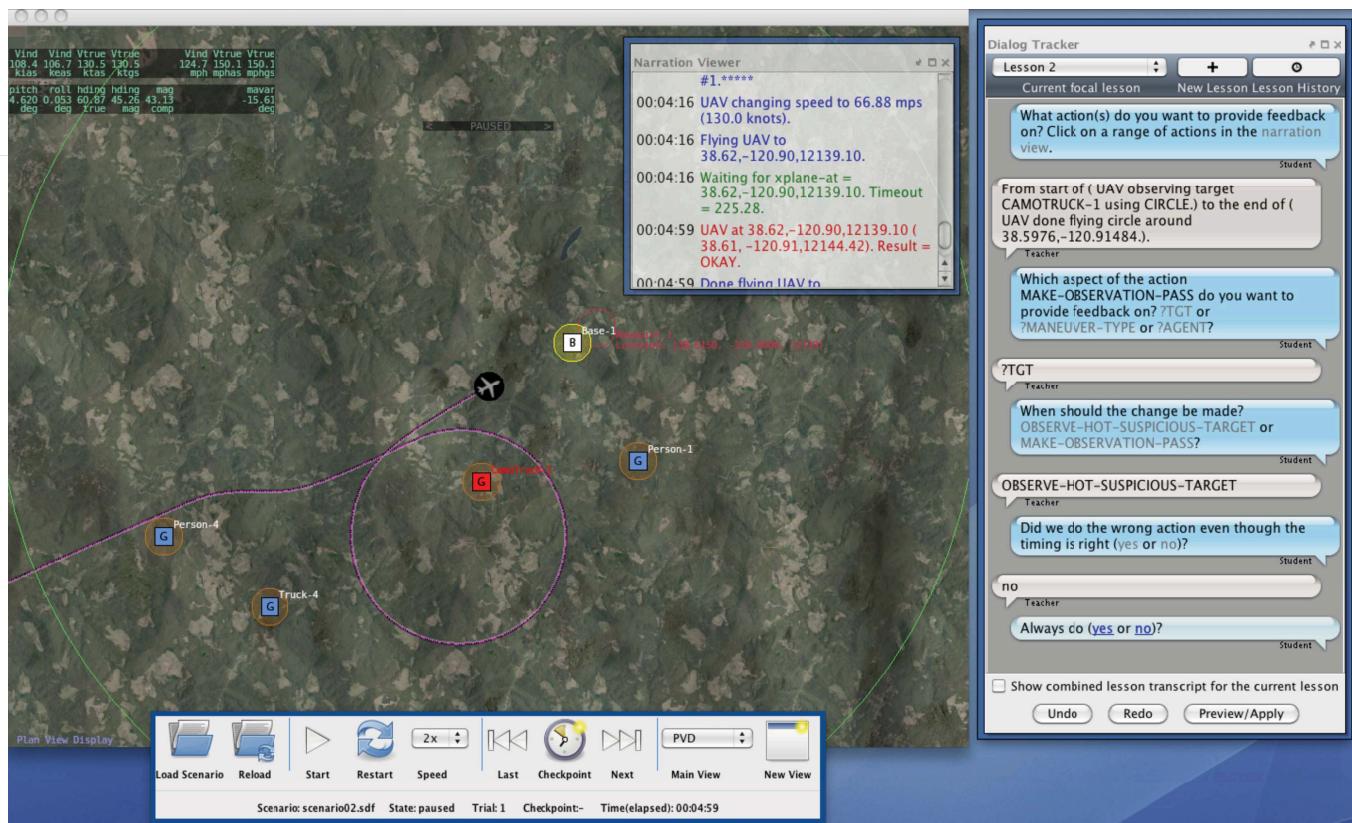
## ► Simulation Environment

### ■ X-Plane

- Robust
- Commercial
- Extensible

### ■ Plugins for CMS Scenarios

- Policy Executor
- Policy Optimizer



# Return on Investment / Intellectual Property

## ► Scenario Development

- Data and Scenario Files for Simulation Environment
- Sensor Models
- Independent, but Illustrative of CMS approach

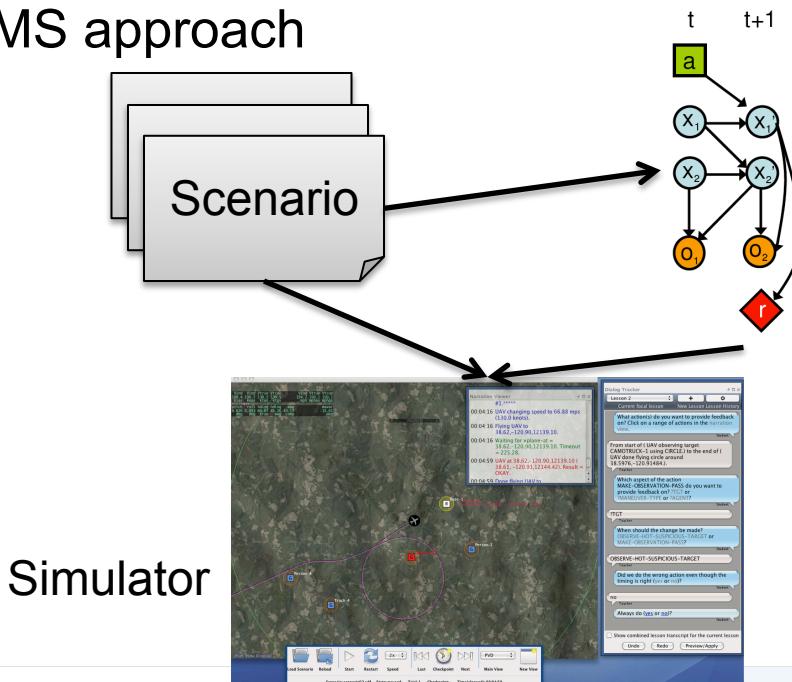
## ► Algorithms

- Source Code
- Documentation
- Re-usable (domain independent)

## ► Simulation Environment

- Source Code
- Re-usable

MDP  
Algorithms



# Schedule and Spending Plan

## ► Schedule

Task	Q3 FY2011	Q4 FY2011	Q1 FY2012	Q2 FY2012
Scenario Model	Static Topology	Dynamic Topology	Non-Deterministic and Dynamic Topology	Non-Deterministic and Dynamic Topology
MDP Algorithms	Apply existing algorithm software	Customize algorithms for cooperative mobile sensing	Enhance Algorithm Scalability	Enhance Algorithm Scalability
Scenario Simulator	Simulator Engine and Entity Representation	Graphical View of Simulation	Sponsor Customization of Simulator	Sponsor Customization of Simulator

## ► Spending

- Students: 2 x 0.5 FTE
- PI: 1mo salary, 1 course teaching release