



Southwest Research Institute®

Cameron Mott

AnyLogic Conference 2016

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# AGENT-BASED EXPLORATION OF SYSTEM NEGOTIATION AND REDISTRIBUTION OF GOALS

# Roadmap

- ⦿ Intro
  - Southwest Research Institute
- ⦿ Research Topic
- ⦿ AnyLogic to the rescue
- ⦿ Application and Model
- ⦿ Conclusion
  - Q&A

# About Southwest Research Institute®



## 10 Operating Technical Divisions

- ❖ Applied Physics
- ❖ Applied Power
- ❖ Mechanical Engineering
- ❖ Engines, Emissions, and Vehicle Research
- ❖ Fluids and Lubricants Research
- ❖ Defense and Intelligence Services
- ❖ Intelligent Systems
- ❖ Space Science and Engineering
- ❖ Geosciences and Engineering
- ❖ Chemistry and Chemical Engineering

## SwRI Statistics

- ❖ ESTABLISHED: 1947
- ❖ STAFF: >2700
- ❖ GROSS REVENUE FY2015: >\$592M
- ❖ FY15 Projects: >6,300
- ❖ CAMPUS: ~4.86 km<sup>2</sup> (1200 Acres)  
in San Antonio, TX
- ❖ LABS/OFFICES: > 204,400 m<sup>2</sup> (2.2M ft<sup>2</sup>)
- ❖ Over 1,235 Patents; 41 R&D 100 Awards
- ❖ FY15 IR&D: \$7.2M, 194 projects

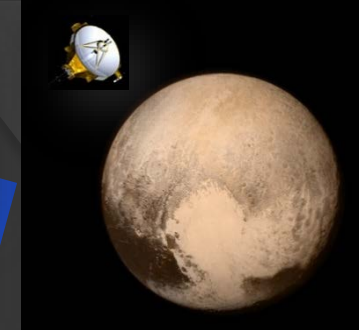
## Organizational Characteristics

- ❖ Independent and nonprofit [501(c)(3)]
- ❖ Revenue provided by R&D contracts
- ❖ Broad technological and scientific capabilities
- ❖ Decentralized organization
- ❖ Internal research encouraged
- ❖ Unique Client-Oriented intellectual property policy

Deep Sea to Deep Space

# And Everything Between

Spacecraft &  
Planetary Sciences



Deep Space -  
New Horizons

Energy



Regenerative  
Medicine

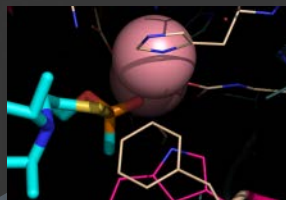
Robotics,  
Automation, and  
Simulations



Lubricants  
Testing



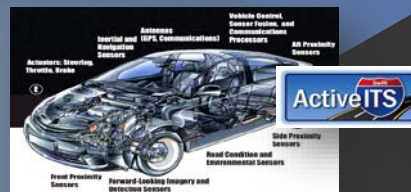
Pharmaceuticals  
& Bioengineering



Deep Sea –  
Alvin



Engine Design  
and Optimization



Infrastructure  
Communications



Materials &  
Engineering



Water and  
Geological  
Engineering

# Autonomous Vehicles at the Institute



**Big Red**  
**Class VIII Freightliner**



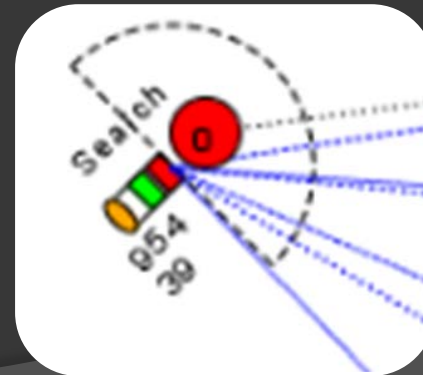
**MARTI Ford Explorer**



**1165 Military HMMWV**



**UAVs: Tri, Quad and Hex rotors**



**Simulated Vehicles**

# Executive Summary of Research Topic

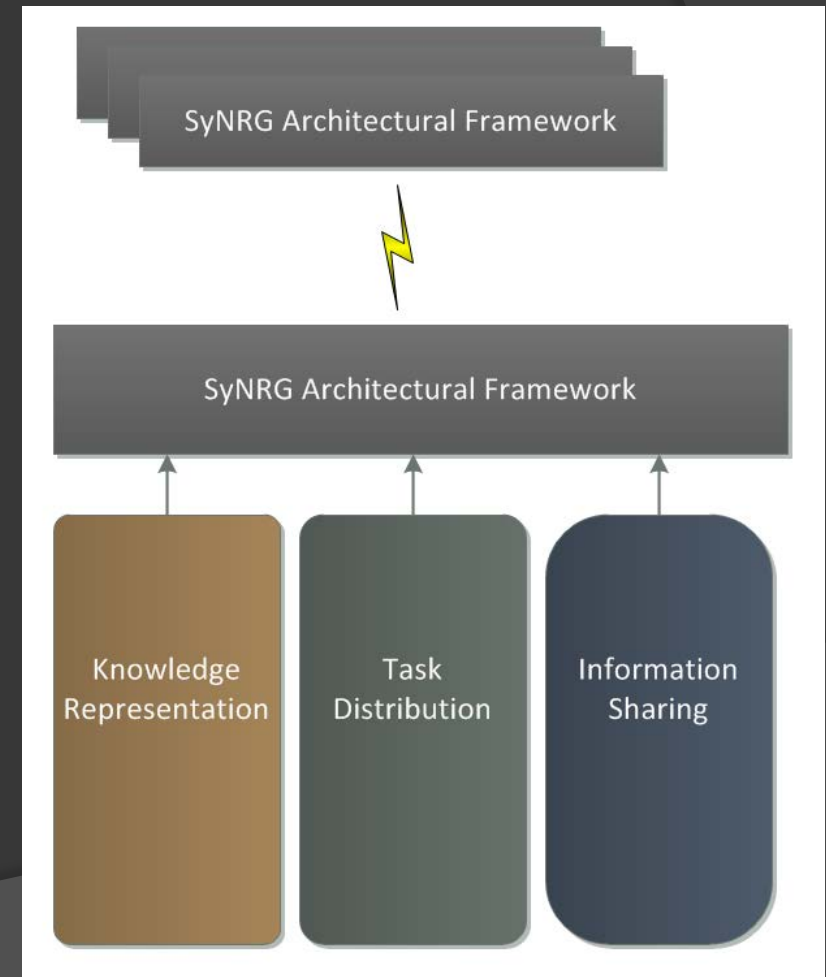
## “Making awesome things more awesome!”

- Each autonomous vehicle is different, with unique characteristics that fit their purpose.
- Working together, there are advantages that each could bring that would further a purpose beyond the limited capability of one vehicle or one type of vehicle (synergy).
- Challenge - Create a team of autonomous vehicles that communicate with each other in a decentralized manner and solve a large system goal through dynamically allocating tasks to each vehicle according to their capabilities and location.

# SyNRG – System Negotiation and Redistribution of Goals

## ● Software Architectural Framework

- Allows intelligent agents to represent and share knowledge
- Form teams based on capabilities that contribute to the system goal
- Coordinates task completion dynamically
- Distributed amongst teamed agents











# Example

- Example Mission: Blended Search & Rescue with Refueling
- Includes autonomous ground, air and simulated vehicles with a variety of capabilities
- Environment includes an unknown number of capsules that are in unknown locations and may need refueling. The vehicles have a variety of capabilities and speeds, not all vehicles can refuel the capsules and not all can identify the fuel level of known capsules.
- Goal: Find all of the capsules and refuel them



# Capabilities





				
1 Sense Objects	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
2 Observe Change	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3 Travel Off-Road	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
4 Refuel	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
5 Identify Objects	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

				
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Capabilities

Goal – Search, Observe, Identify and Refuel							
Tasks	Capabilities					Priority	Trigger
	1	2	3	4	5		
<input checked="" type="checkbox"/> Search	<input checked="" type="checkbox"/>					36	A
<input type="checkbox"/> Observe		<input checked="" type="checkbox"/>				29	B
<input type="checkbox"/> Identify				<input checked="" type="checkbox"/>		67	C
<input type="checkbox"/> Refuel			<input checked="" type="checkbox"/>			82	D

Goal Definition

				
Search	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Observe	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Identify	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
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Establish a Team

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Establish a Team

# Establish a Team

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Observe

Identify

Refuel

Search

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Refuel

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Refuel

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Goal Definition

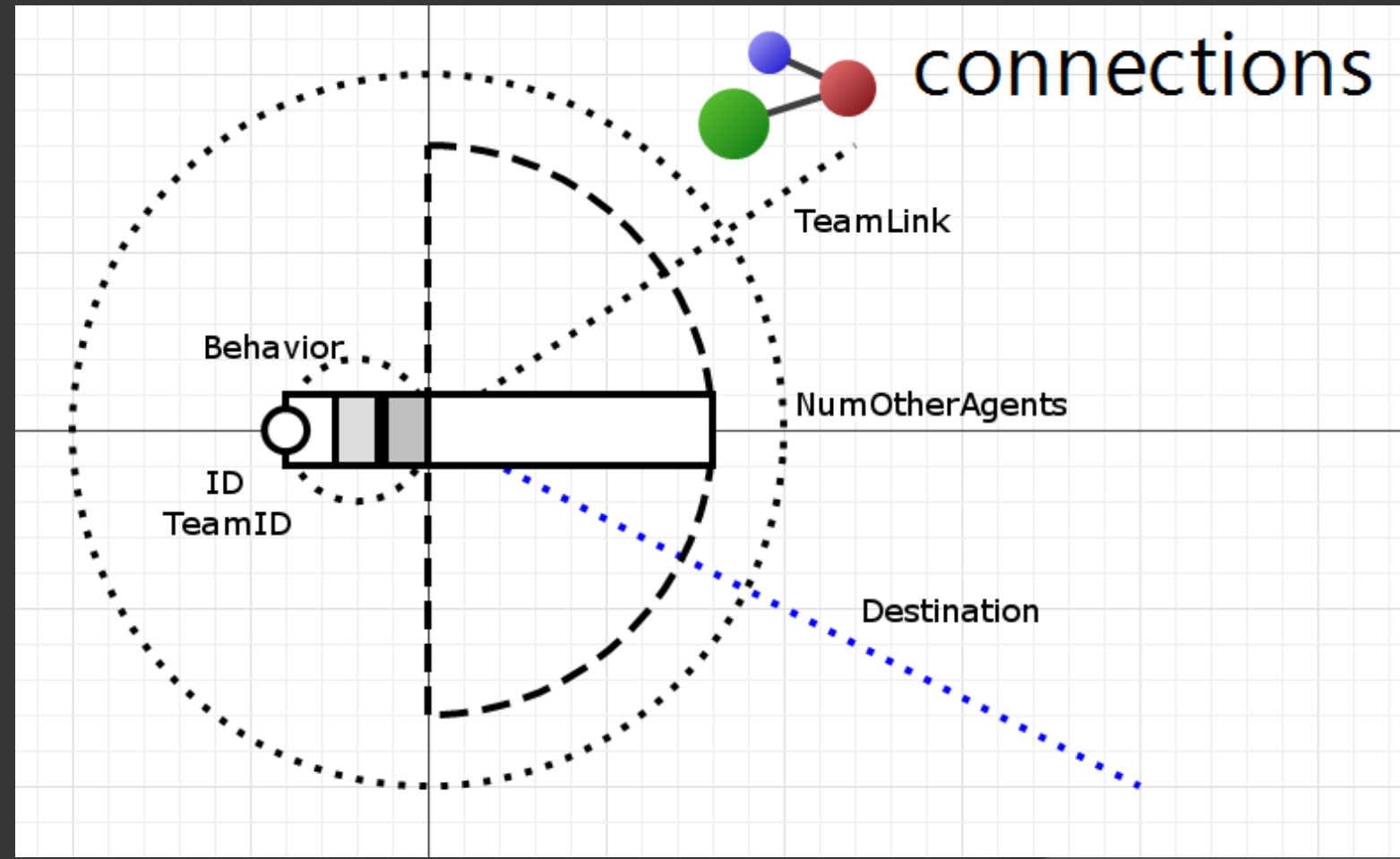
Search	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Observe	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Identify	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Refuel	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

Establish a Team

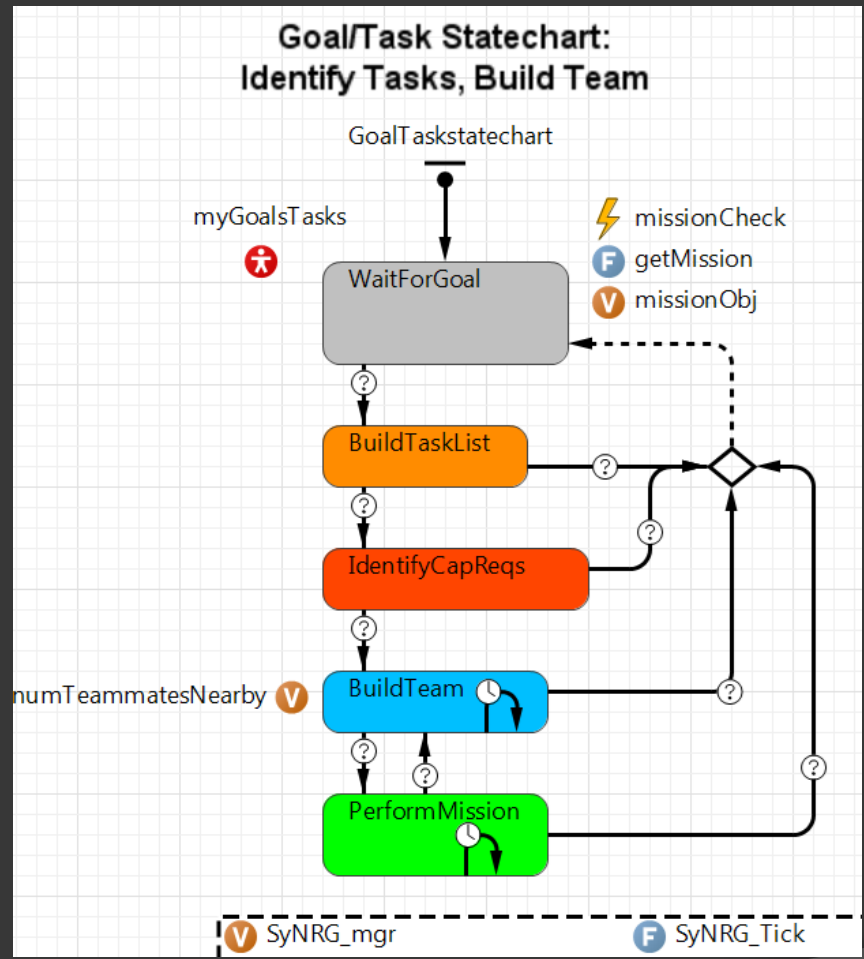
# AnyLogic to the rescue

- ⦿ Expensive to execute on physical vehicles
  - Simulation environment needed
  - Traffic simulation software would not be appropriate
  - Physics simulations are incredibly feature-rich but complicated
- ⦿ Investigated AnyLogic, quickly able to provide proof-of-concept
- ⦿ Intelligent agents were modeled in AnyLogic representing various capabilities
- ⦿ World environment where the agents can interact
- ⦿ Logic and interactions between agents could be simulated and quantified

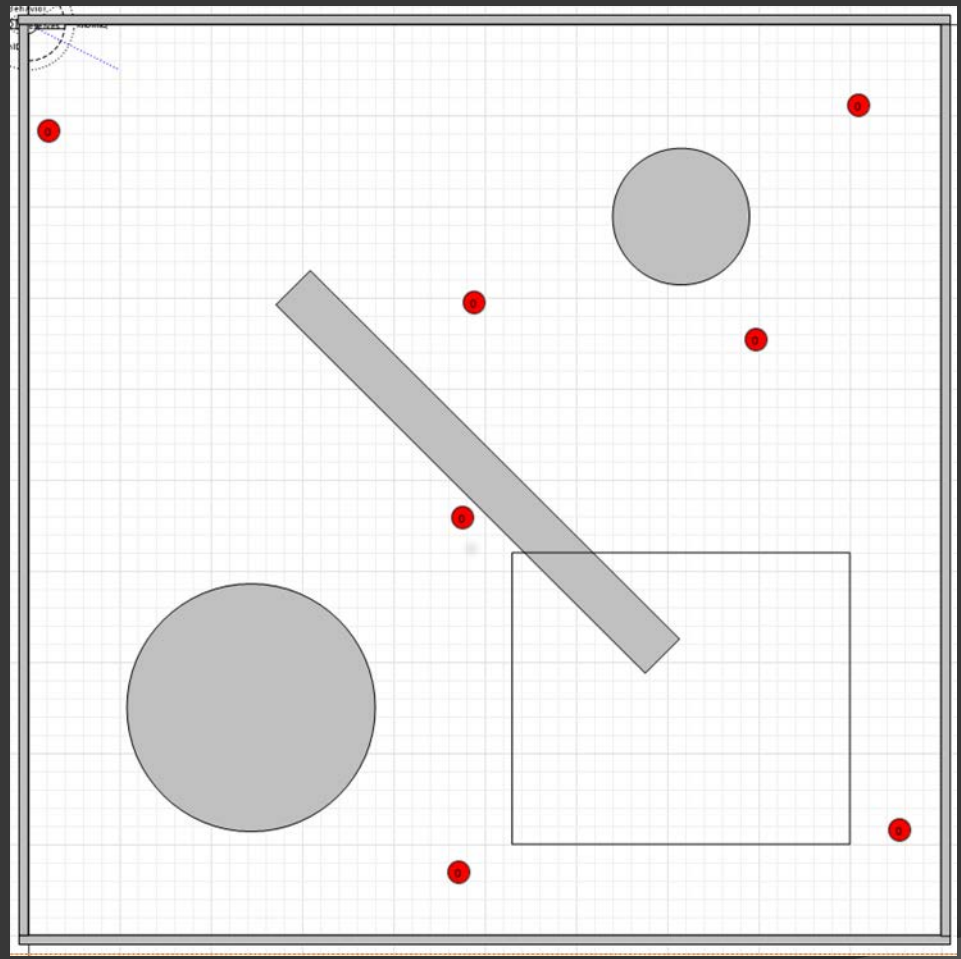
# Agent Model



# Statemachine

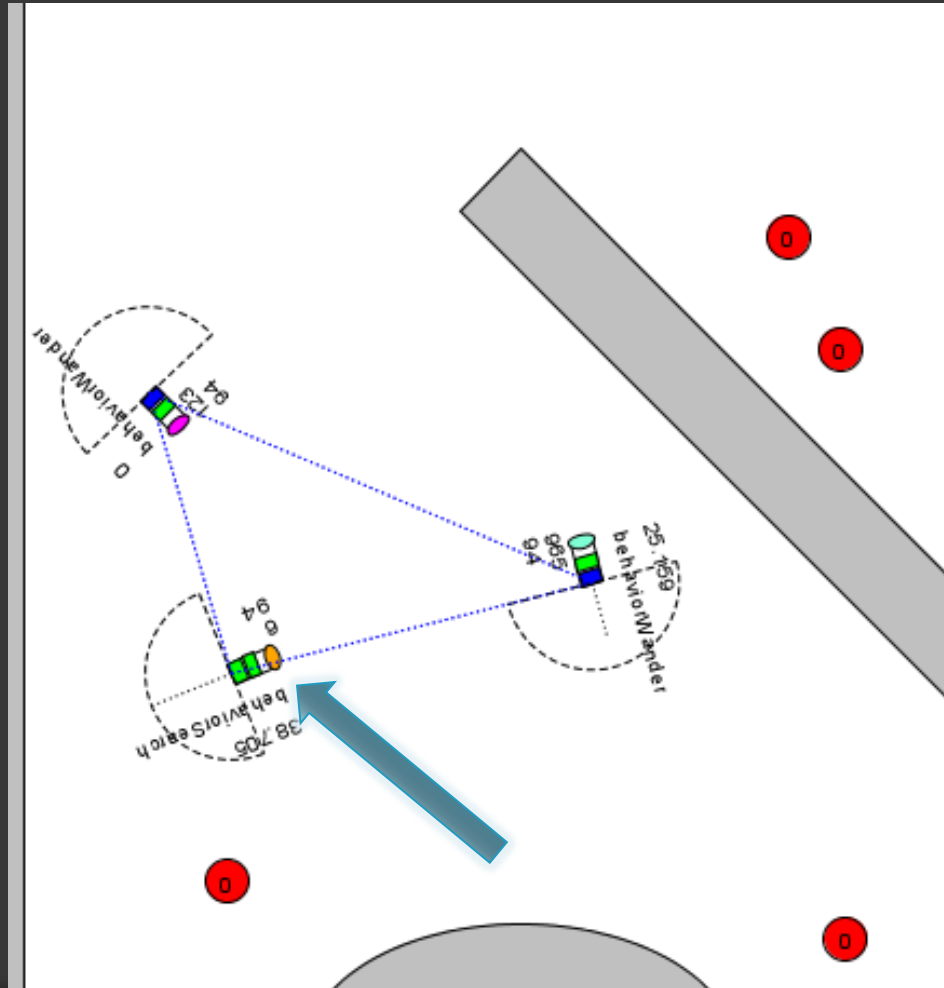


# Environment



# Executing Tasks

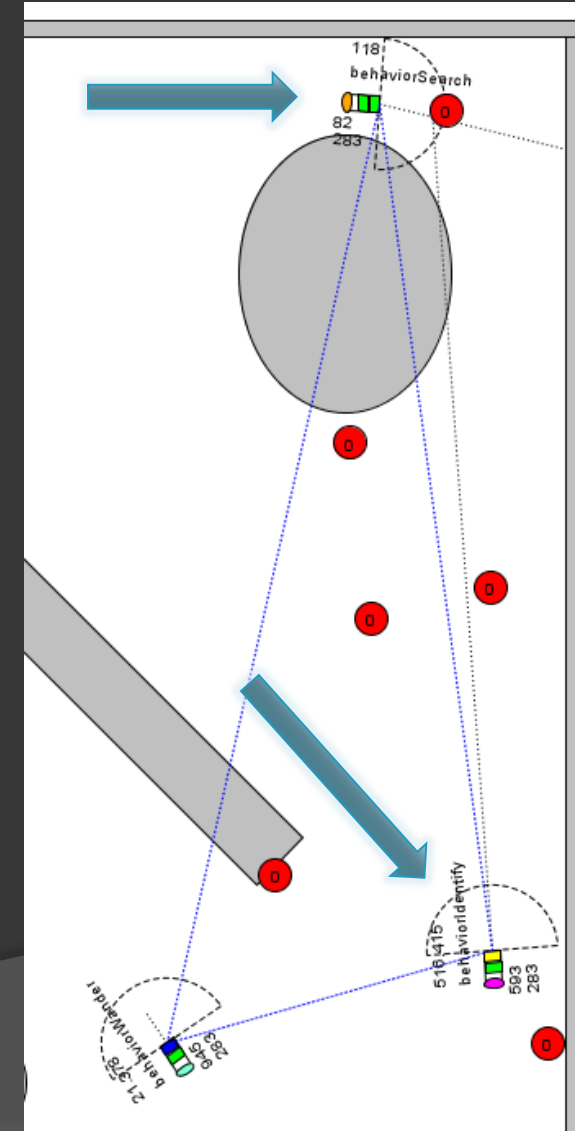
- Searcher is exploring
- Sharing knowledge of encountered objects
- Other vehicles are waiting for a task trigger





# Example of Task Distribution

- ◎ Task trigger occurs
  - Object of interest has been found
  - Trigger sent to teammates – Needs Identification
  
- ◎ Vehicle with Identify capability responds by planning a path to the object

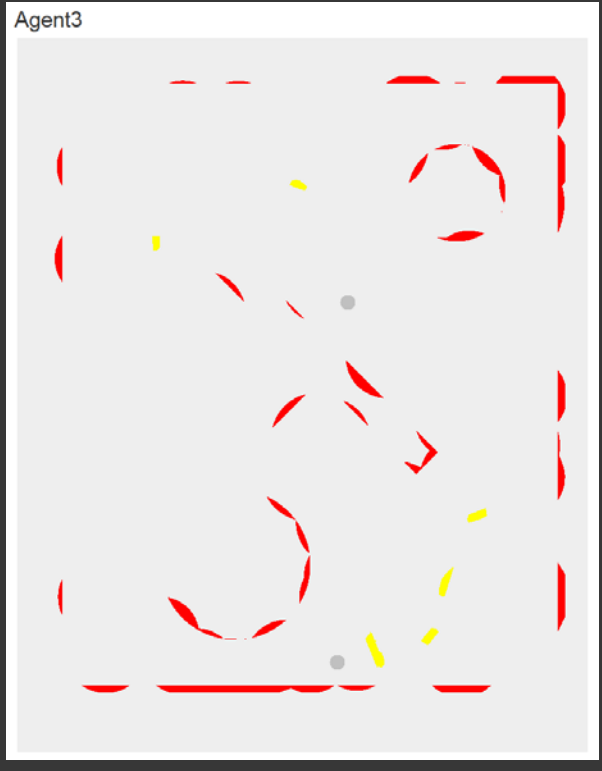


# Model in operation

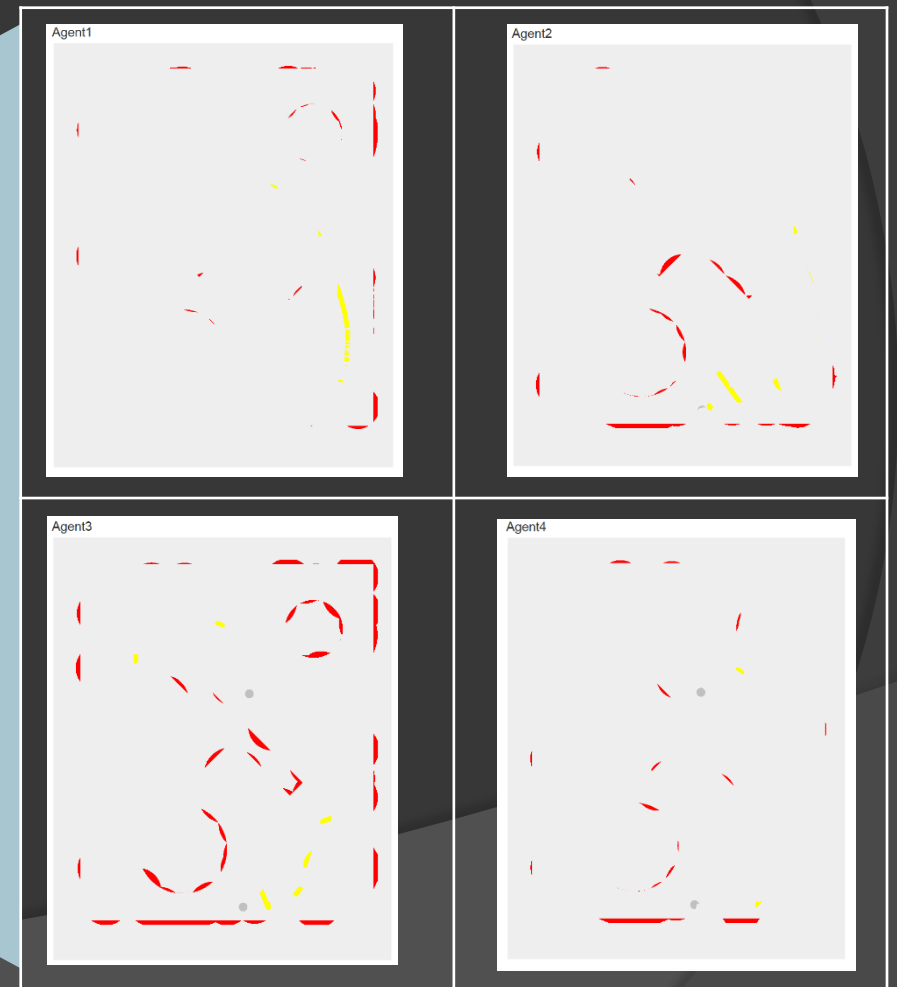
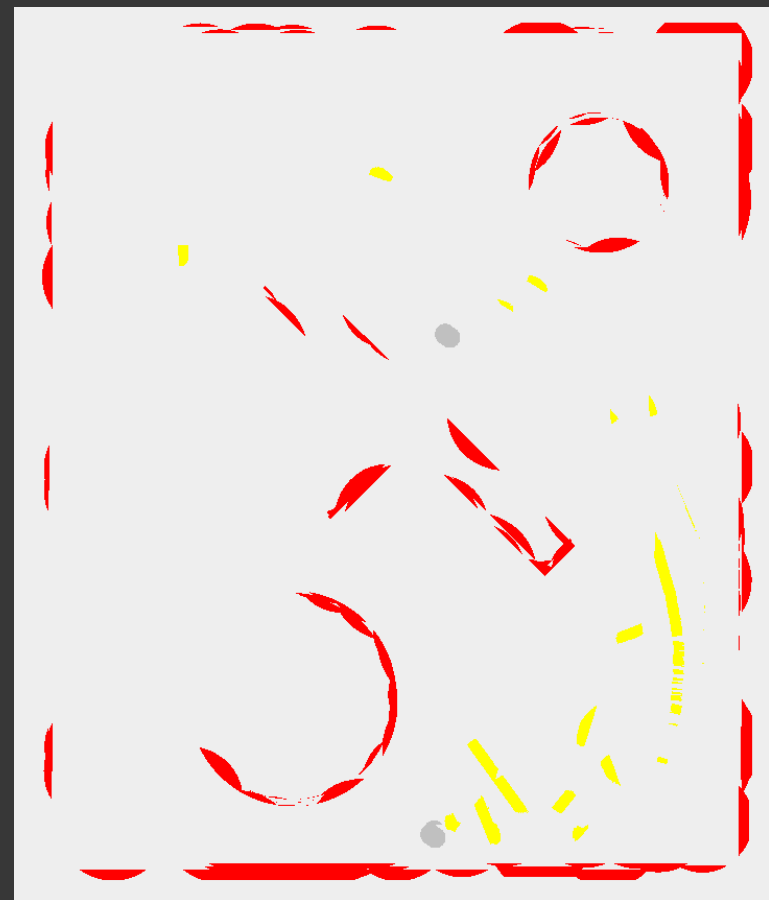
The screenshot displays the AnyLogic simulation environment for a model named 'SynNRG\_1'. The interface is divided into several key sections:

- Control Panel (Top Left):** Contains a 'Print' button and a list of model components including 'MobileAgents [3]', 'target Target [4]', 'environment agents', 'isInsideBoundary', 'envBoundary', 'missionSys', 'missionObjSys', 'timerPopulateWAT', 'populateWorldAreaTypes', 'worldAreaTypes', and 'synrgFunction'.
- Parameter Settings (Top Center):** A configuration area with the following values:
  - targetPopulation: 0.9
  - agentPopulation: 1.5
  - agentsNum: 8
  - targetsNum: 4A button labeled 'Activate All Targets' is also present.
- Simulation Environment (Center):** A large rectangular workspace containing a circular area with internal structures and several small circular markers labeled with IDs: 334, 295, 758, 615, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820.
- Data Graph (Right):** A line graph with a grid. The y-axis ranges from 0 to 3, and the x-axis ranges from 0 to 100. The legend indicates five data series:
  - Wandering (grey line)
  - Searching (green line)
  - Found Target (red line)
  - Responding (yellow line)
  - Max Agent Density (black line)The graph shows a sharp initial spike for 'Max Agent Density' at time 0, reaching a value of approximately 2.0, followed by a drop to 0. A smaller spike for 'Responding' is visible at time 0, reaching a value of 1.0. All other series remain at 0.
- Status Bar (Bottom):** Displays simulation metrics: 'Run: 0', 'Paused', 'Time: 4.10', 'Experiment: No explicit limit', 'Simulation: Stop time not set', and 'Memory: 334K of 254K'.

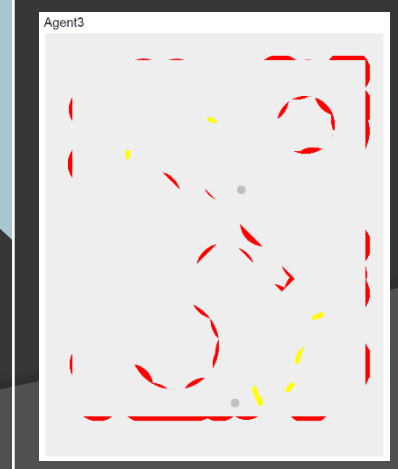
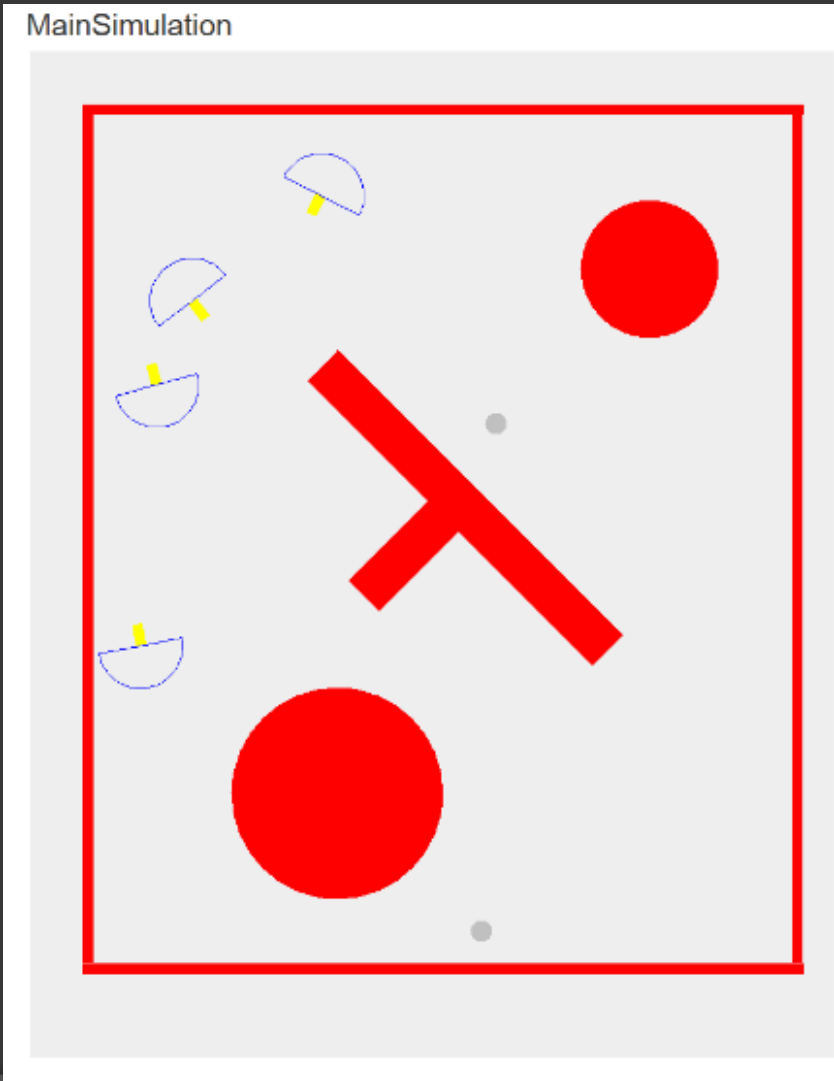
# Discovering the world one agent at a time



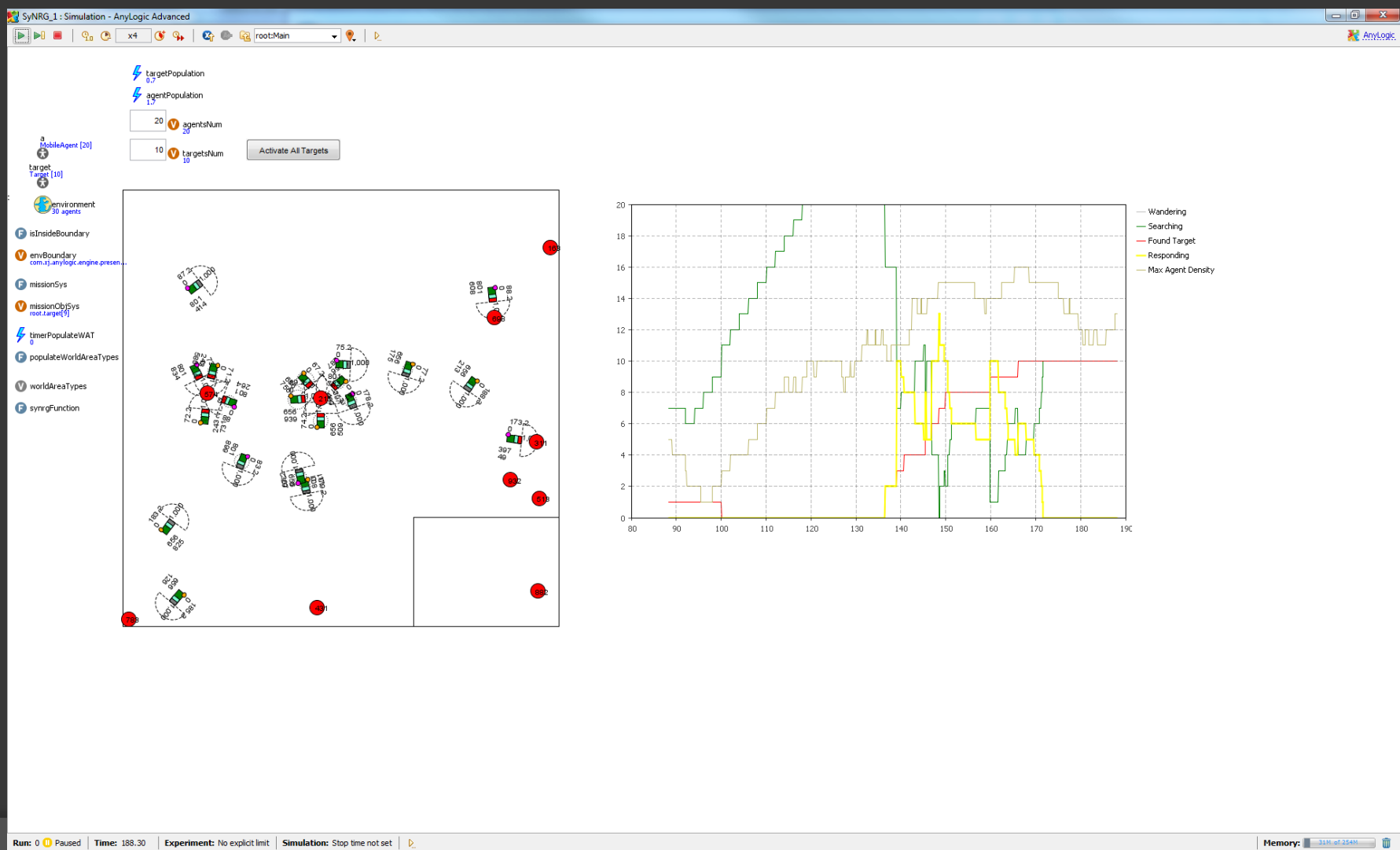
# Sharing knowledge of the world



# Collaborative view



# Running multiple agents and graphing progress



# Results

- Multiple (up to 45) agents running simultaneously in an AnyLogic model
- Enabled algorithm execution and development
  - Optimization of task distribution
  - Goal achievement with given resources
- Capability to address many limitations
- Years (3 likely) ahead of implementation

# Conclusion

- Successful demonstration of team negotiation and dynamic task allocation
- Enabled through AnyLogic agent-based modeling



Questions?