Multi-vehicle Collaborative Autonomous Control Under Difficult Communications Conditions

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The Swarming Autonomy “Theme Bug”

Our MVC Vision

Unmanned Vehicles as a Ubiquitous Service for the Warfighter

Underwater MVC Challenges

- UUVs need Collaborative MVC that is
  - » Effective under Poor Communications Environments
  - » Effective in Dynamic and/or Intractably Complex Conditions
  - » Rapid in Response to Perturbations in the Environment or the Objectives
  - » Robust and Survivable

Bottom Line

We Have Achieved Robust Militarily Useful Behaviors Reactively and Emergently

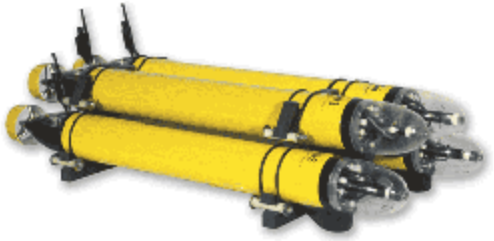
Generated Behaviors

	Fields Generated by		
	Targets	Peers	Area Effects
Patrol		✓	✓
Track & Trail	✓	✓	✓
Survey & Map	✓	✓	✓
Path Finding	✓	✓	✓
Formation Flying		✓	
Recruitment	✓	✓	✓
Comm Link		✓	
Resource Allocation ‣ Vehicle Damage ‣ Objective Change ‣ Environmental Change	✓	✓	✓

Emergent Swarming

Emergent Swarming IS…

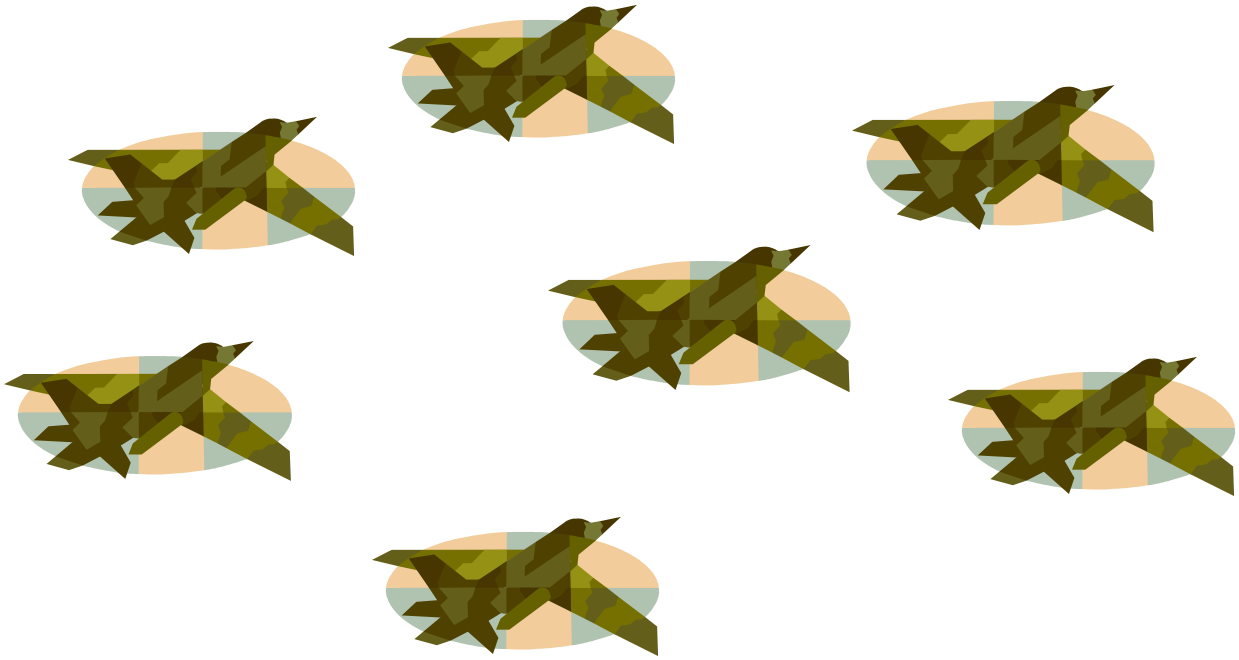
Locally-Executed Control Algorithms That Provide Globally Self-Organizing Behavior Amongst Cooperating Vehicles



Emergent Swarming IS…

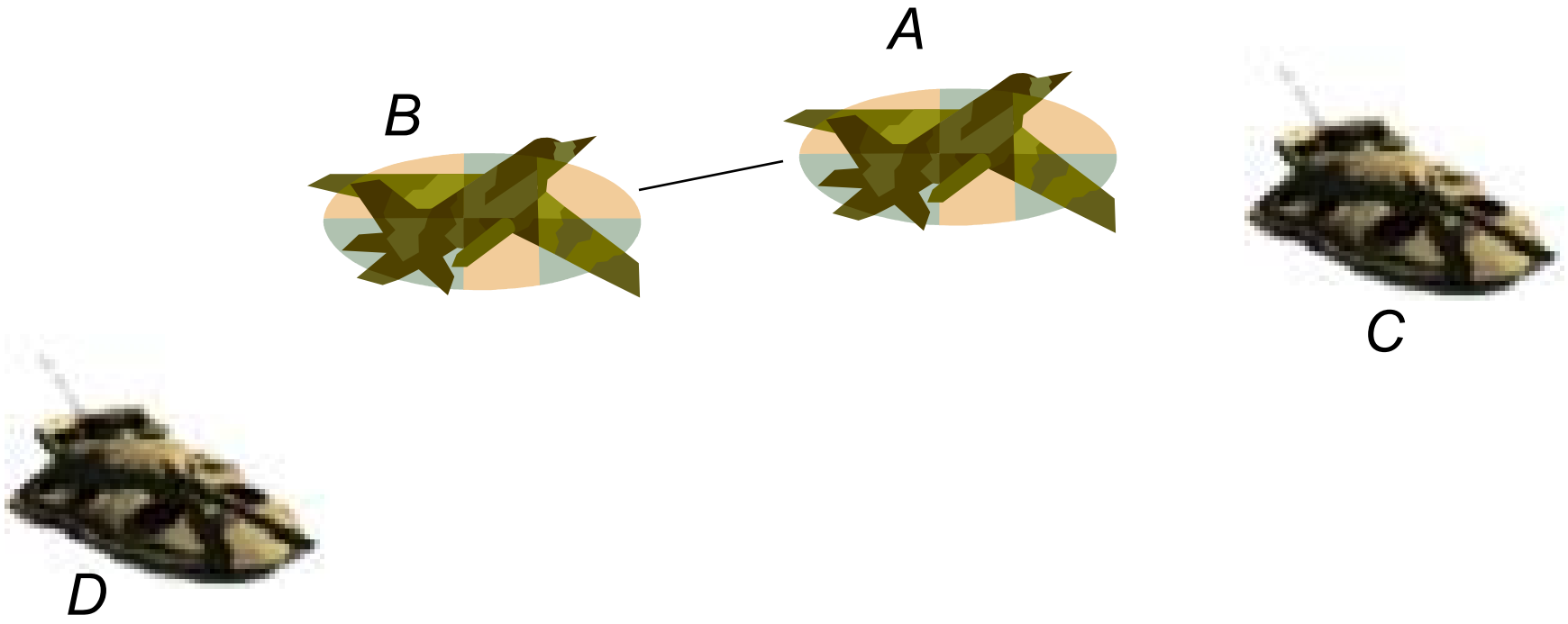
Locally Controlled:

Individual Decision Makers (Agents) on Each Platform



Emergent Swarming IS…

NOT Deliberative:



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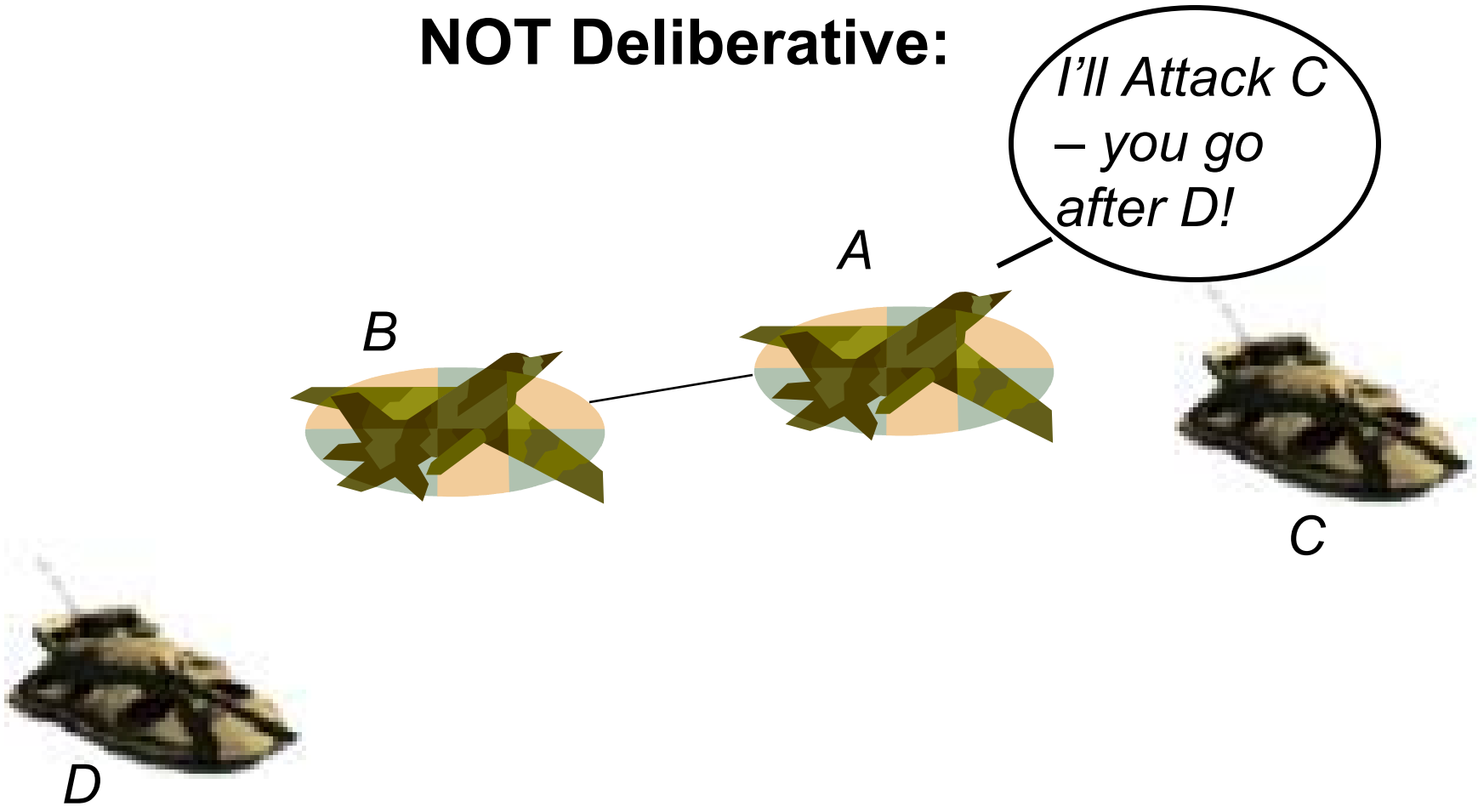

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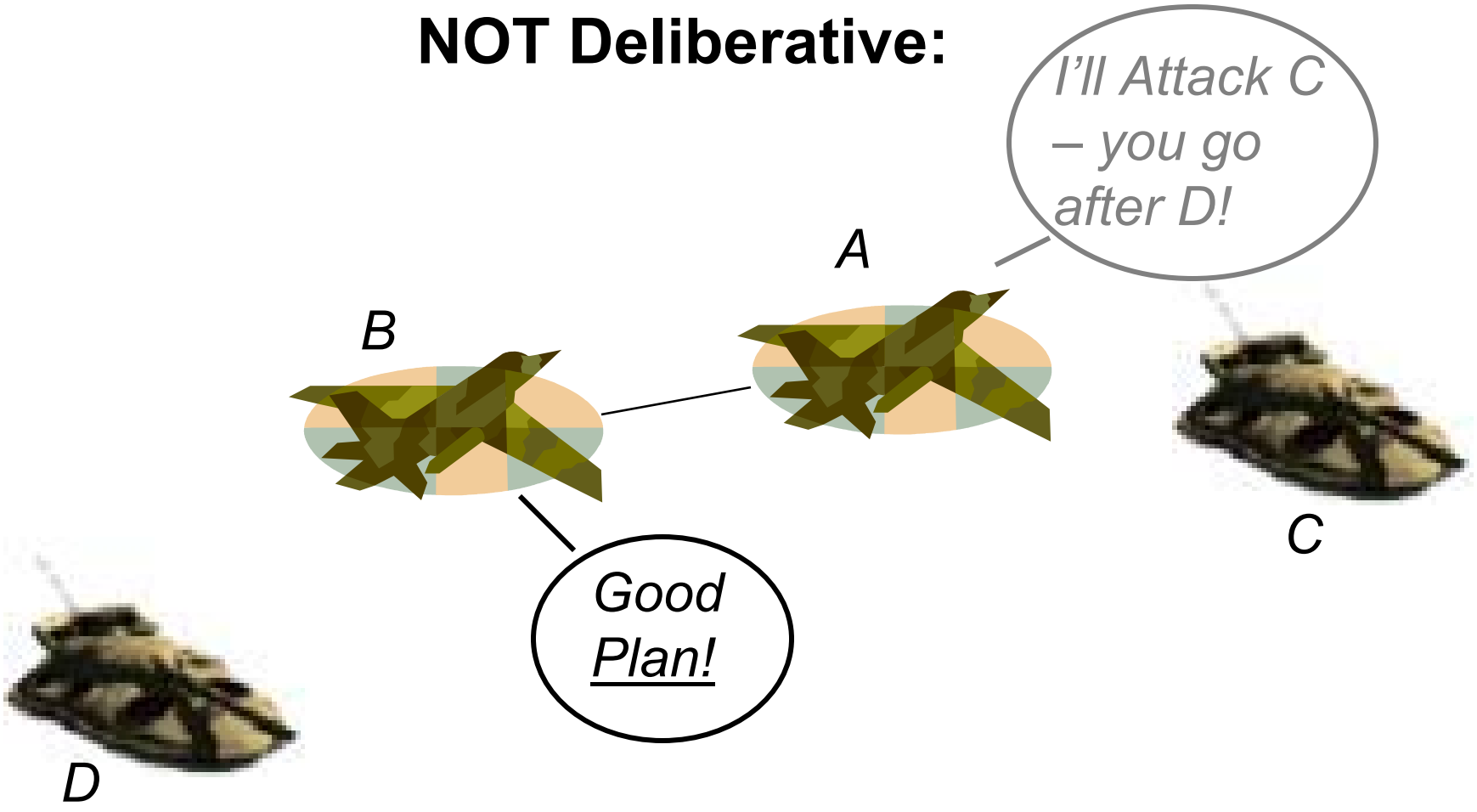

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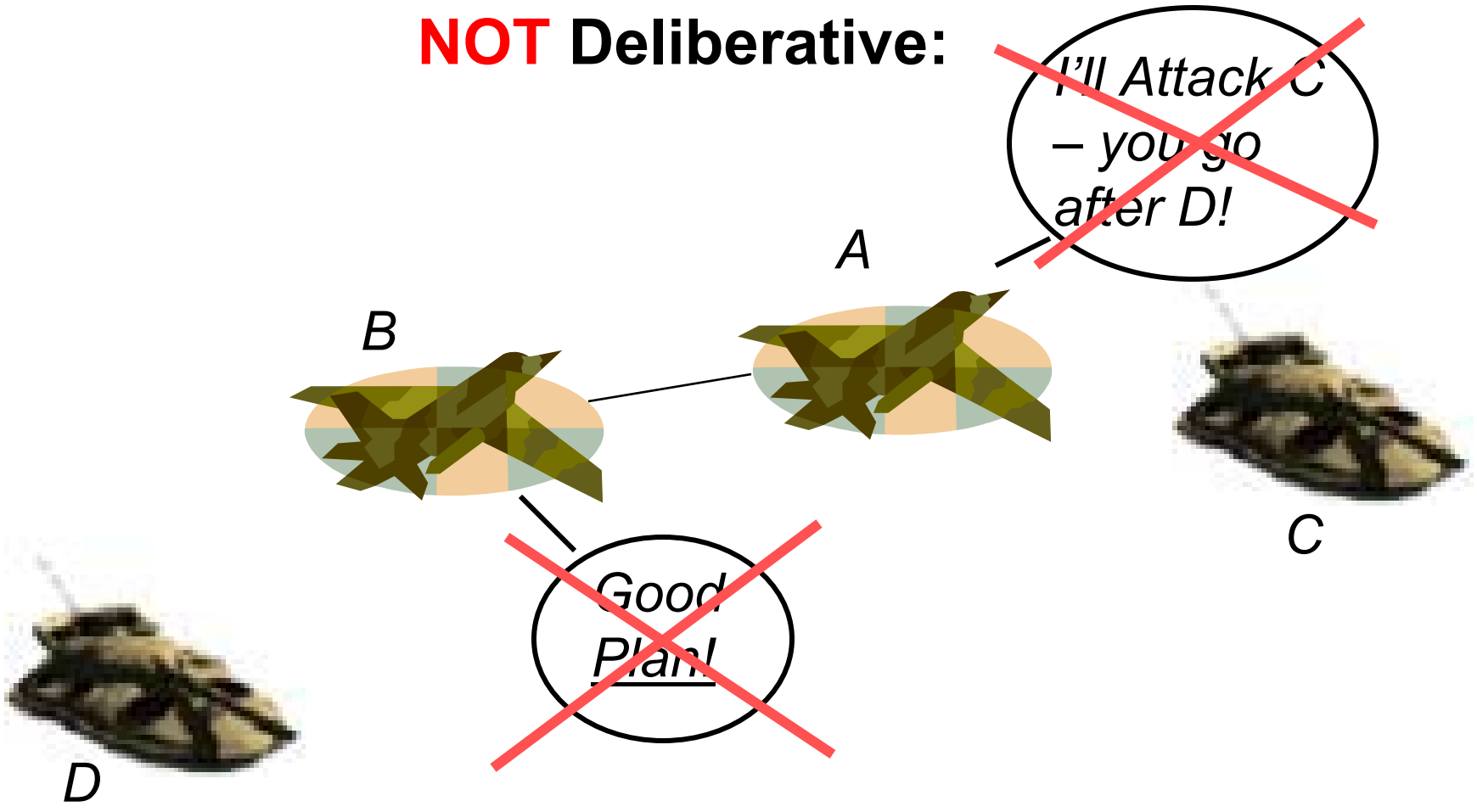

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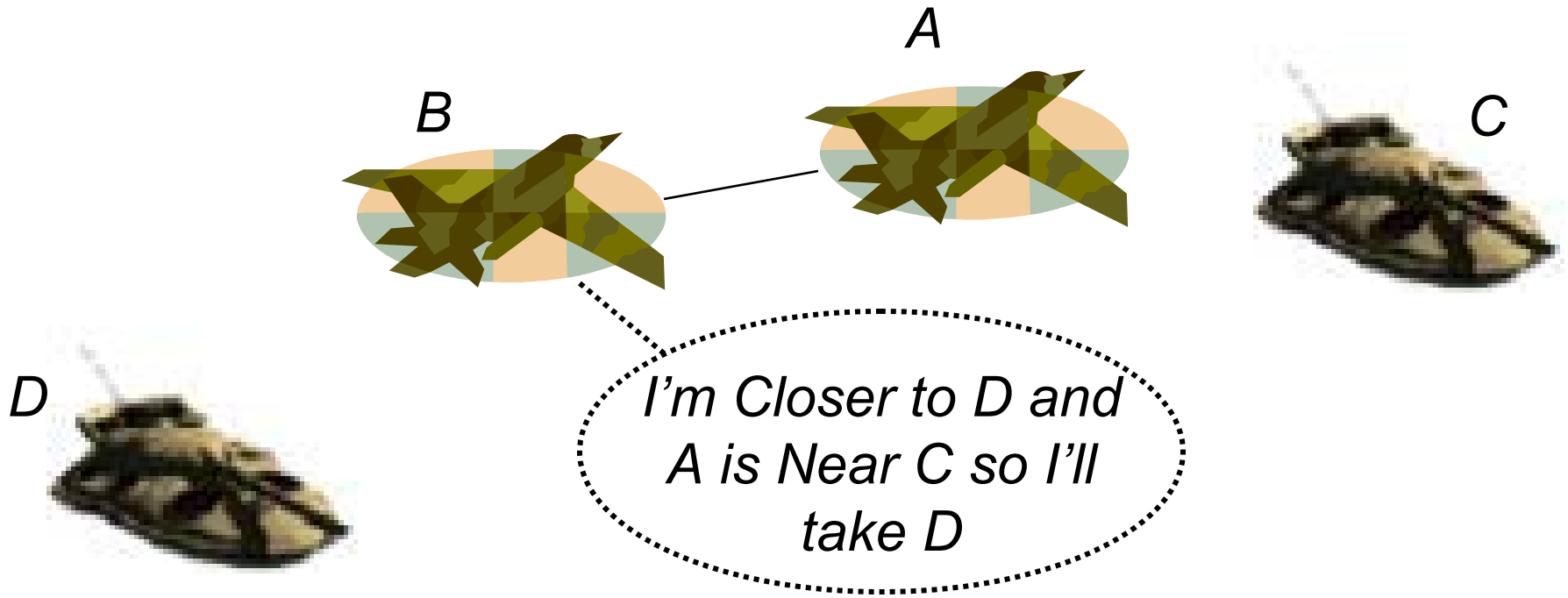


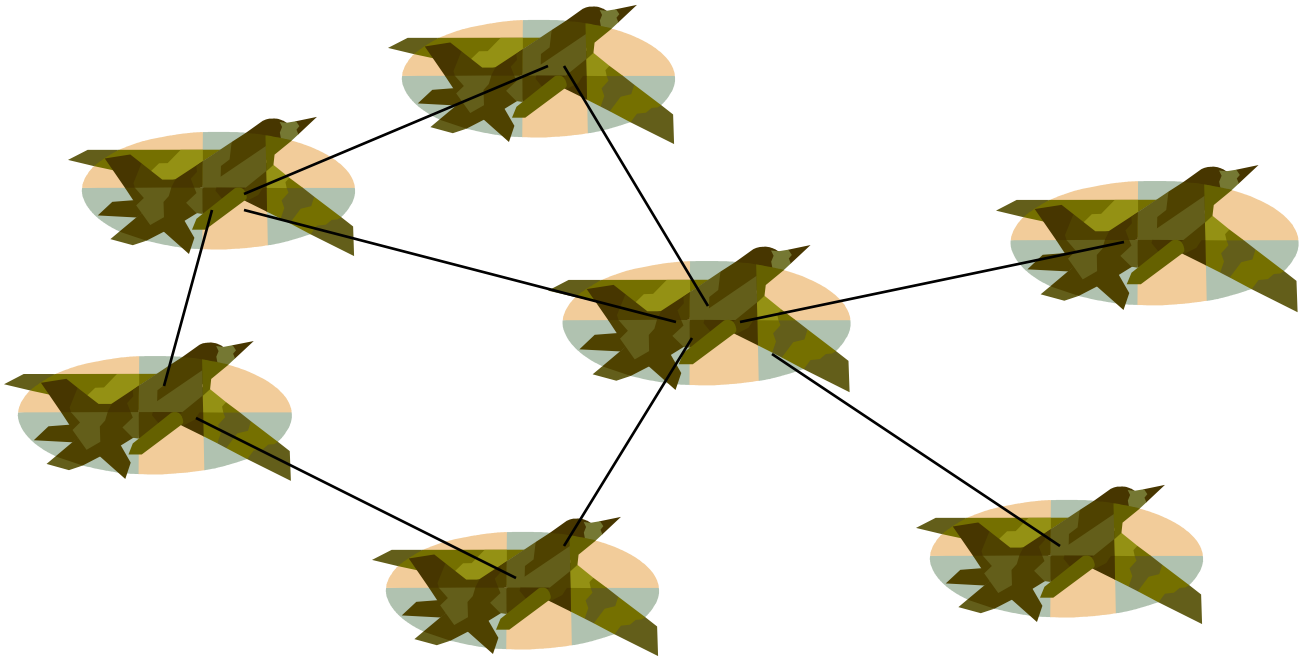
Coordination *Emerges* from Sympathetic Decision Processes and Shared Knowledge

Emergent Swarming IS…

Heterarchical:

An Unstructured Network of Cooperating Peers

No dedicated leaders* ever!



(*single points of vulnerability)

With a Flat Communications Topology any one Swarming Element can be Sufficient to Communicate any End User/Decision Maker

There's no single point of vulnerability, and no particular pre-determined critical path to get information back to the operator.

The nature of the swarming system is such that it can adapt and reshape itself until the requirements are met. This isn't commander Cicada – just the Cicada that was handy and happened to be close enough to relay the relevant information.

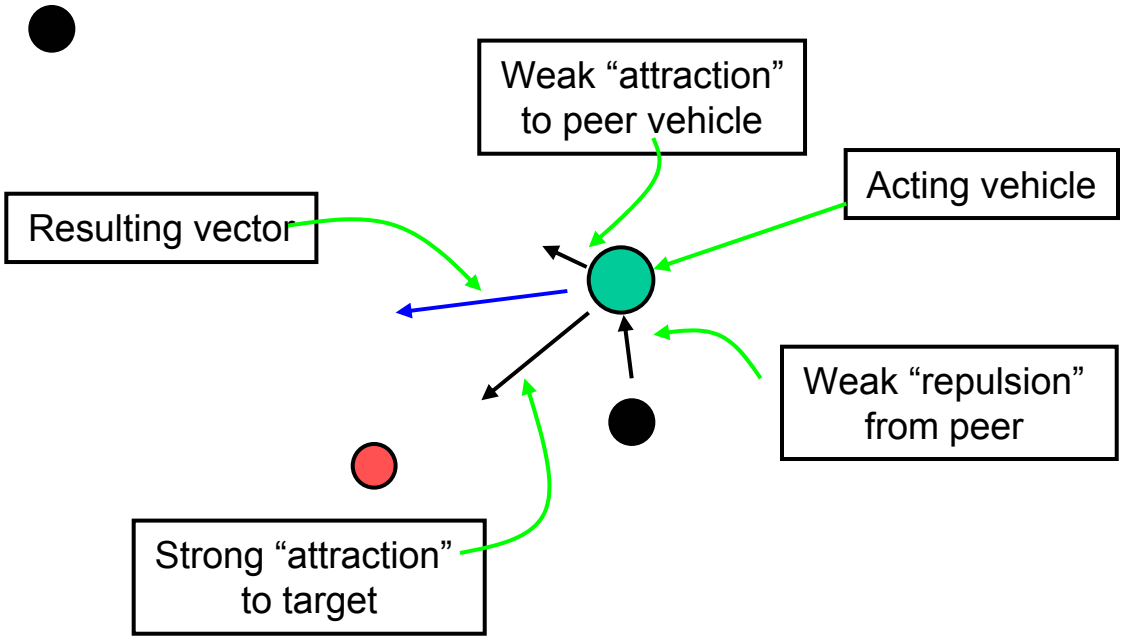
Swarming Models

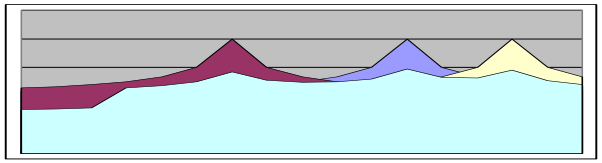
Many Exist, mostly patterned off of natural systems, major themes are:

- Physicomimetic – Pattered after sub-atomic particle interactions
- Biomimetic – patterned after social animals
  - Flocking Behavior
  - Ant Colony Behavior
  - Termite/Wasp Nest Building
  - Wolf-Pack Hunting
  - Mold Growth

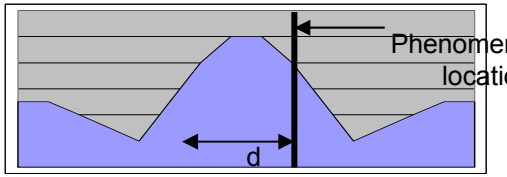
CO-FIELDS BEHAVIORS

Generating Behavior by associating fields with a movement vector.





An Influence Co-field (light blue) Derived from Three Influence Fields



Co-fields Generated by a Single Phenomena may be Used to Keep a Distance “d” from the Phenomena.

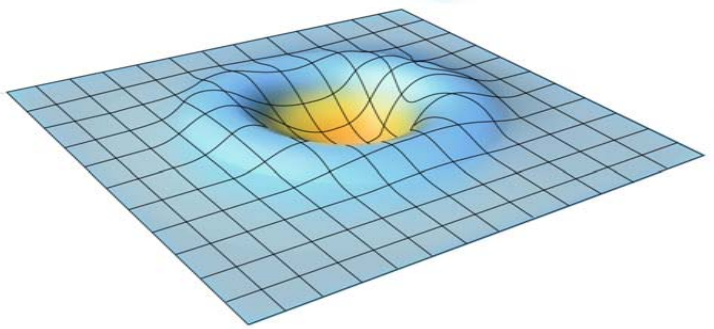
Co-Fields: Towards a Unifying Model for Swarm Intelligence Letizia Leonardi, Marco Mamei, Franco Zambonelli

JHUAPL Innovation: Dynamic Co-Fields

Dynamic Co-Fields Extends Co-Fields by Allowing Individual Fields to Change as a Function of Time

Dynamic Influences May be Generated by:

- Historical Observations
- Introducing Temporal Decay To Knowledge
- Using Observations as an Impetus for Formula Modifications
- Using Field Strengths as an Impetus for Formula Modifications
- **Generating One's Own Field**



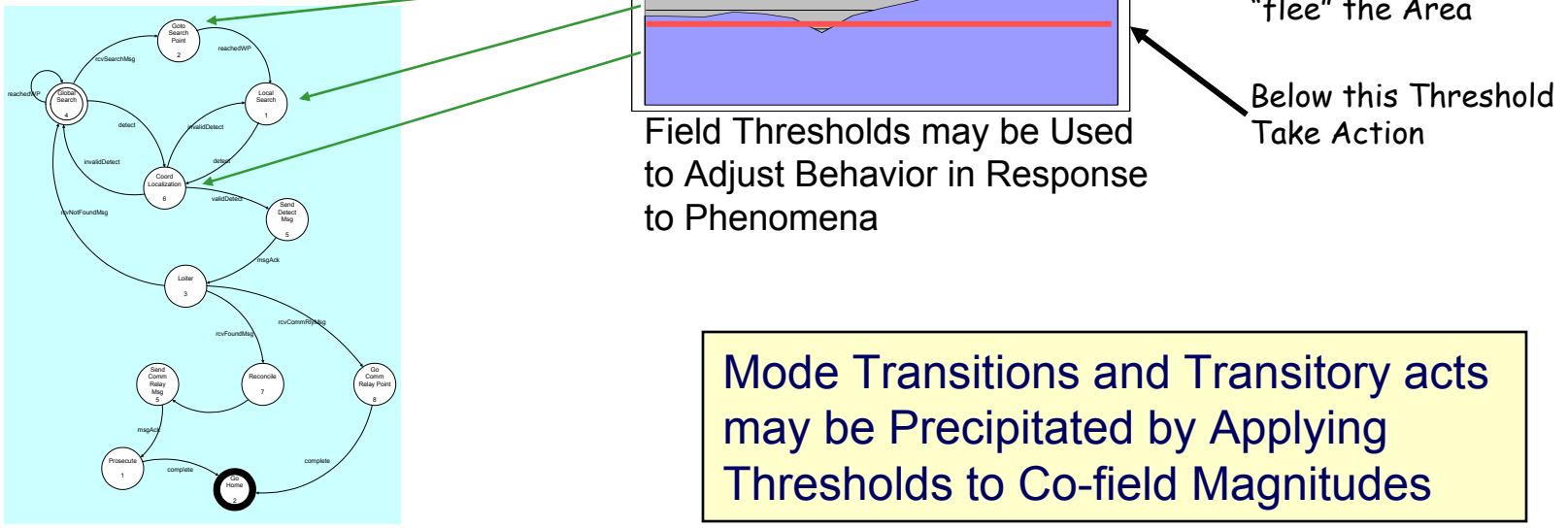
This Allows Vehicles to:

- Patrol
- **Avoid Local Minima**
- Limit Oscillatory Behavior
- Adapt by Learning
- Manage Uncertainty (Intermittent Contacts or Communications)

Vehicle Actions and Modal Behavior

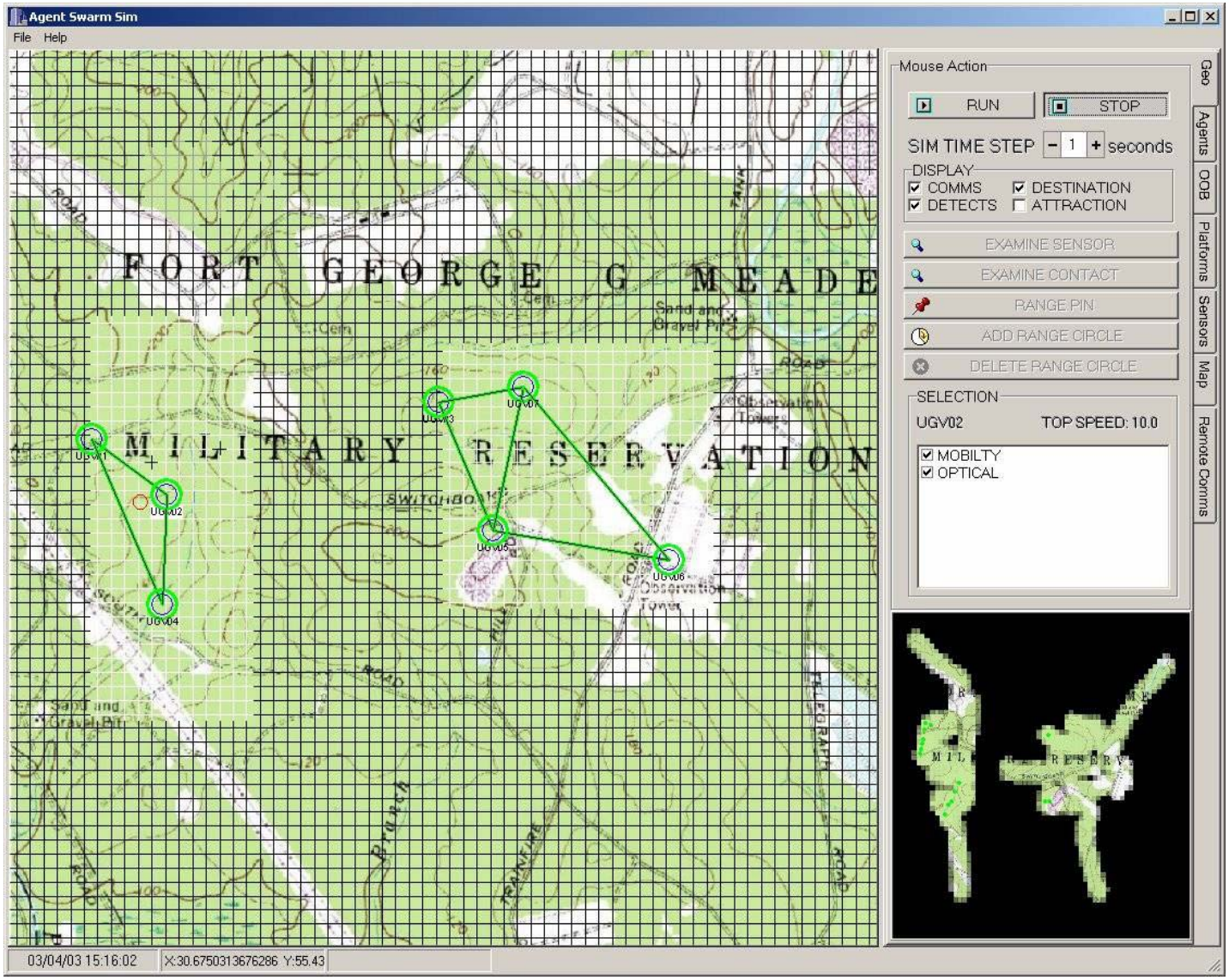
Movement is Not Enough…

Vehicles need to be able to take actions and change from one behavior to another. For example, shifting from patrolling to tracking when a target is detected.

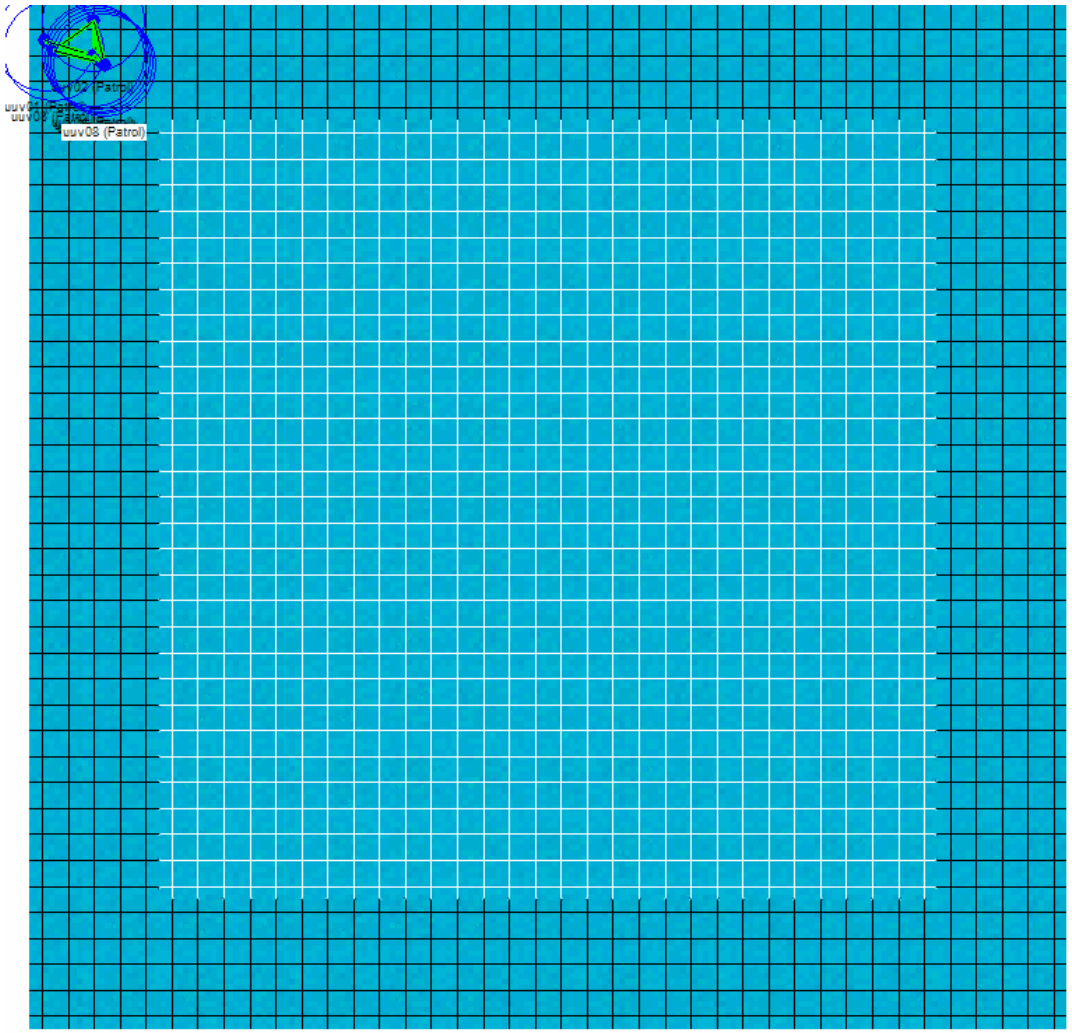


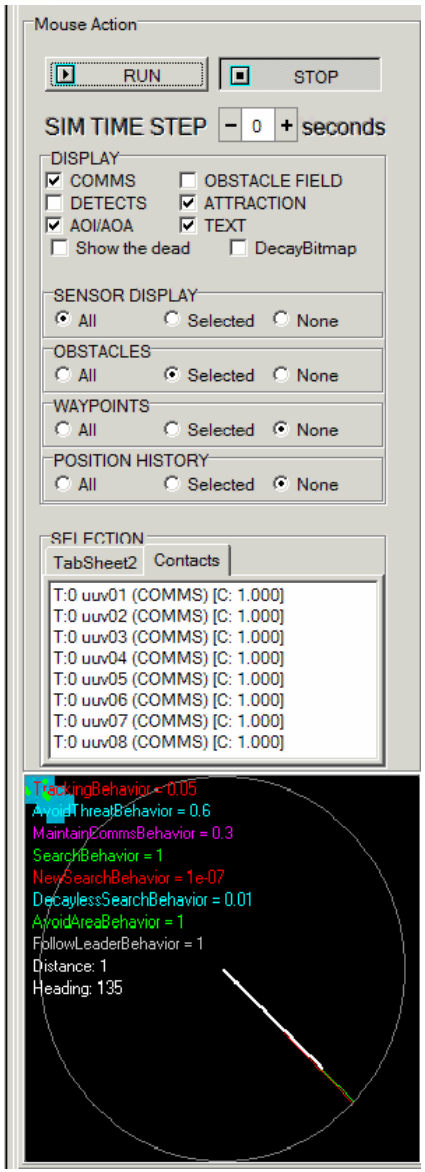
Mode Transitions and Transitory acts may be Precipitated by Applying Thresholds to Co-field Magnitudes

Simulator for Autonomous Agents

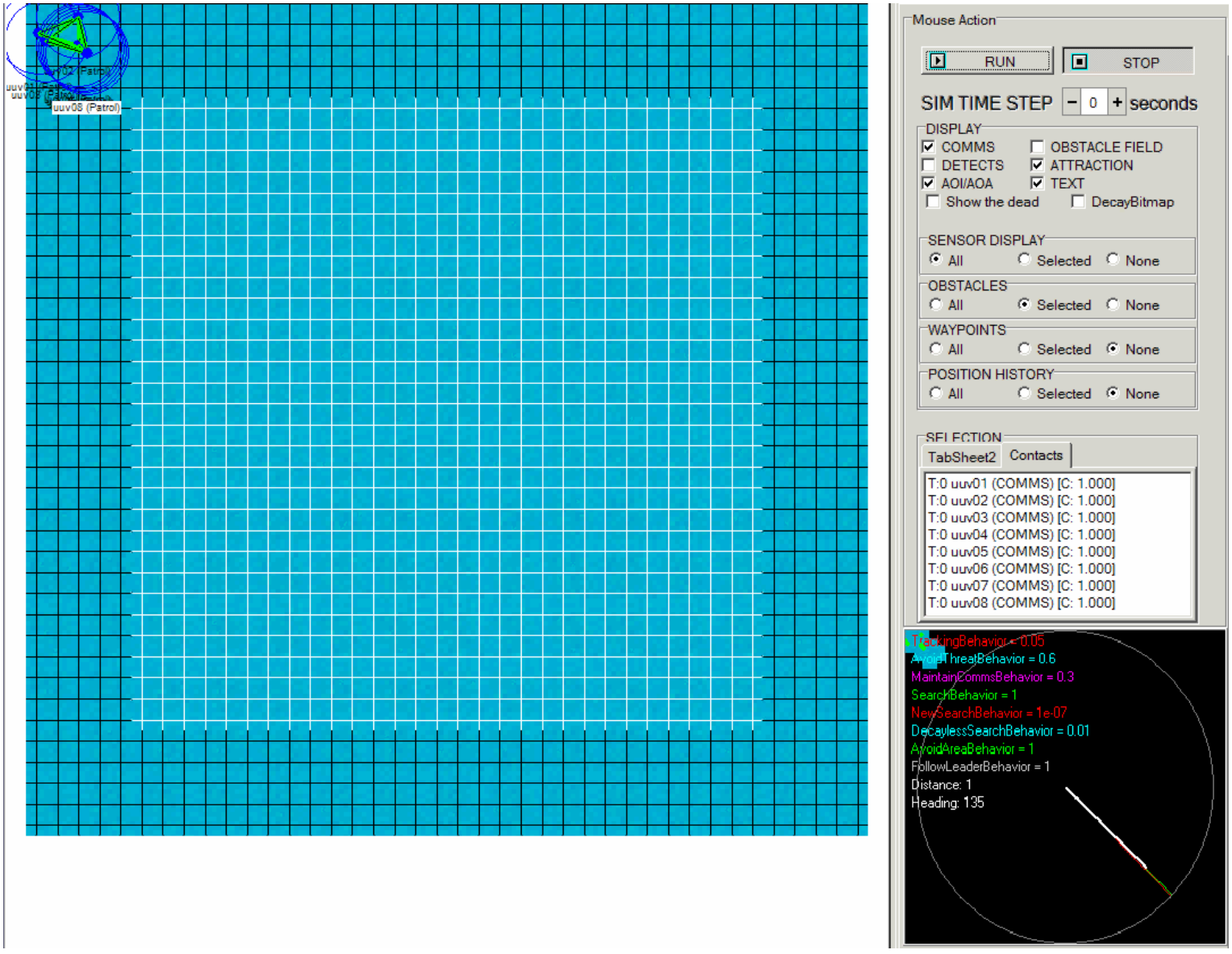


Cooperative Search (weak comms)

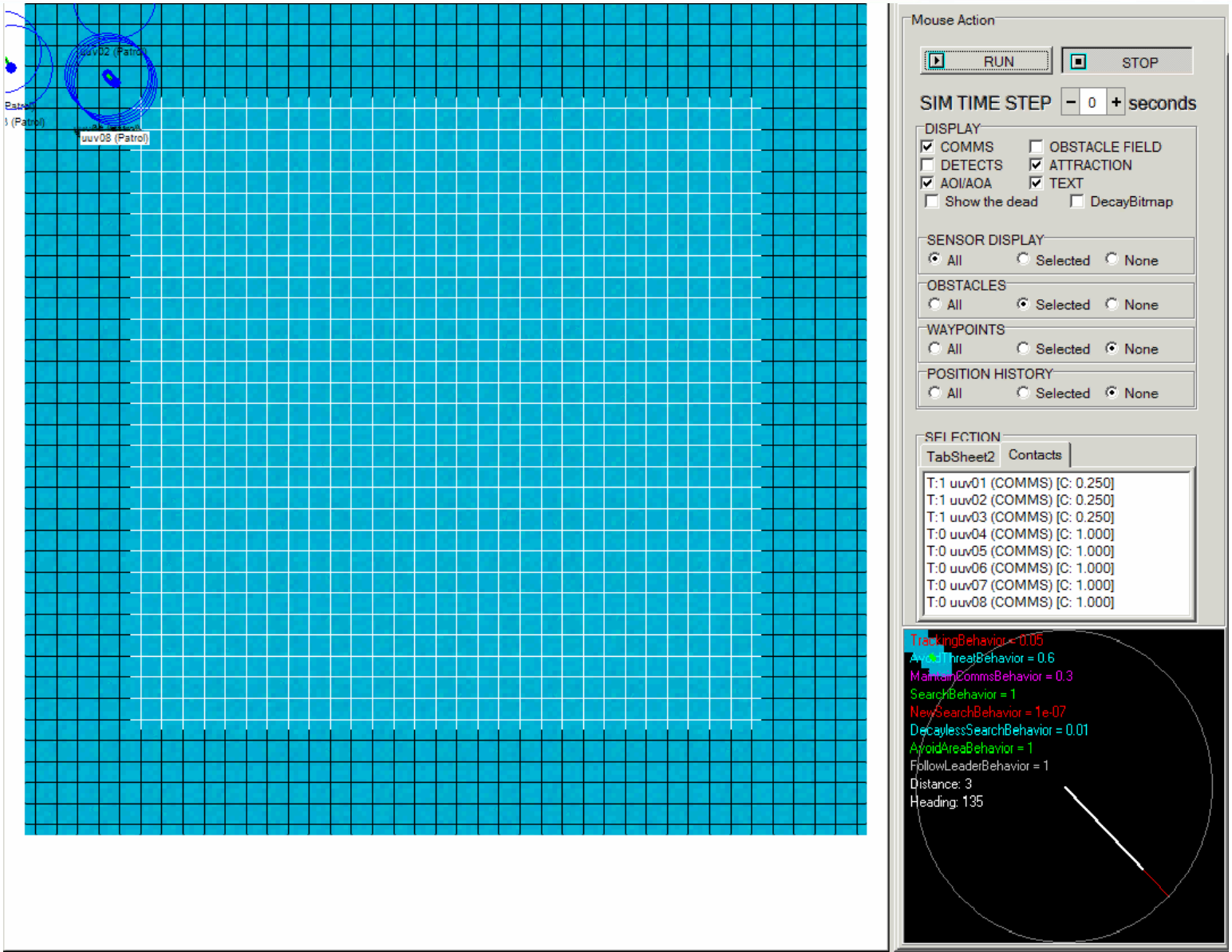




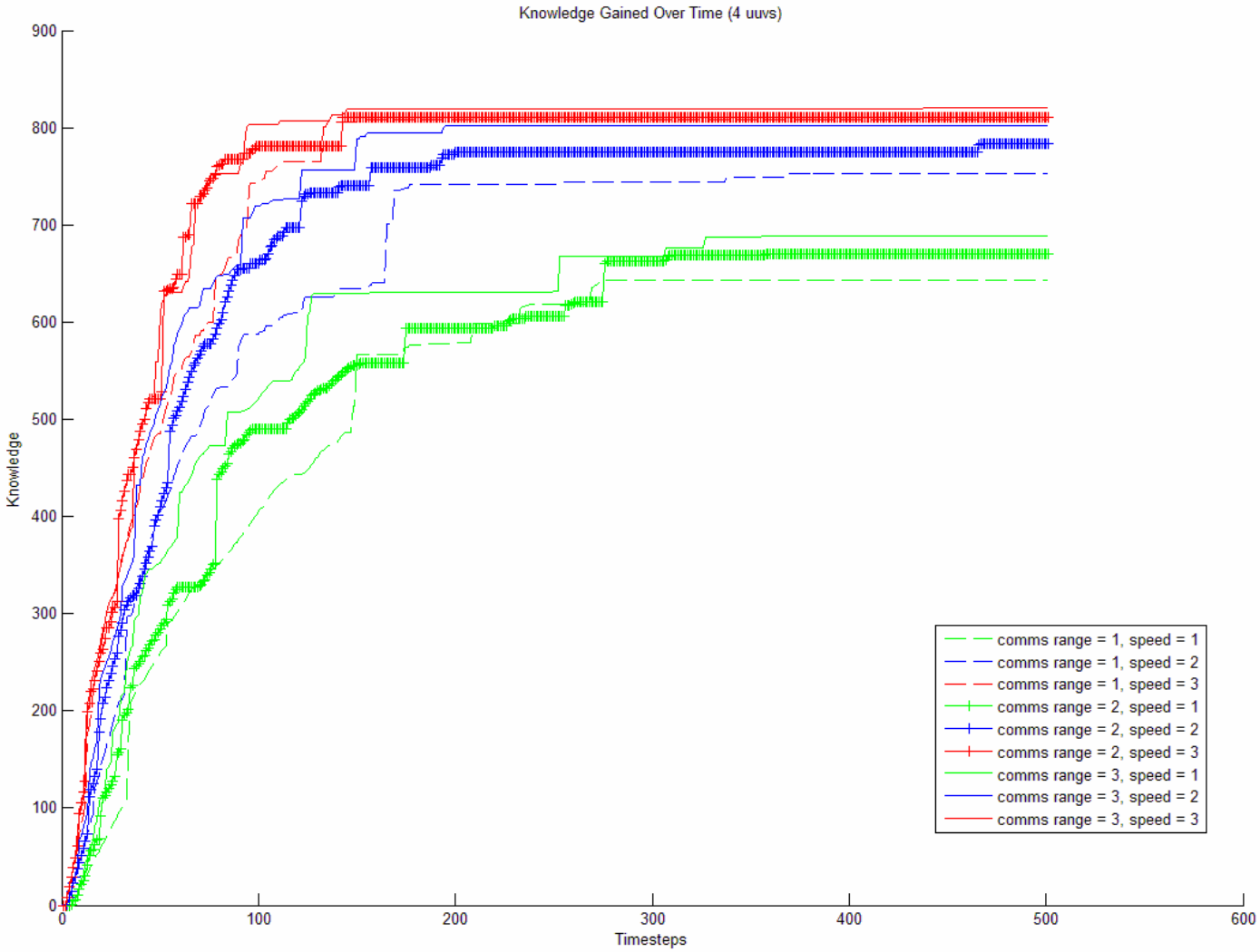
Cooperative Search (longer comms range)



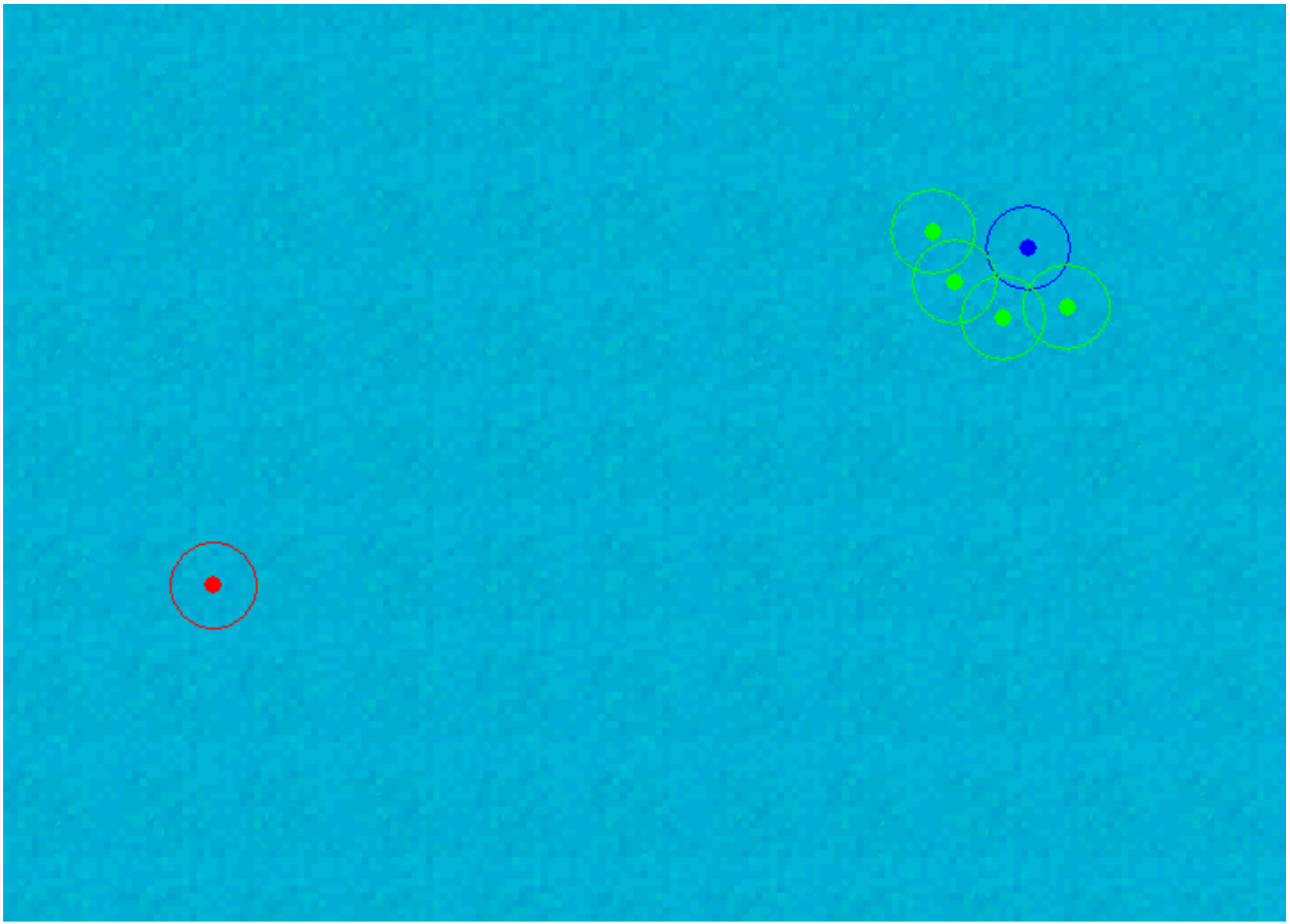
Cooperative Search (faster UUV)



Comms vs. Speed Results



Mode Transition to Comms Chain



Swarming Autonomy Benefits

1,000,000,000,000 Cicadas Can’t Be Wrong!

Thank you!

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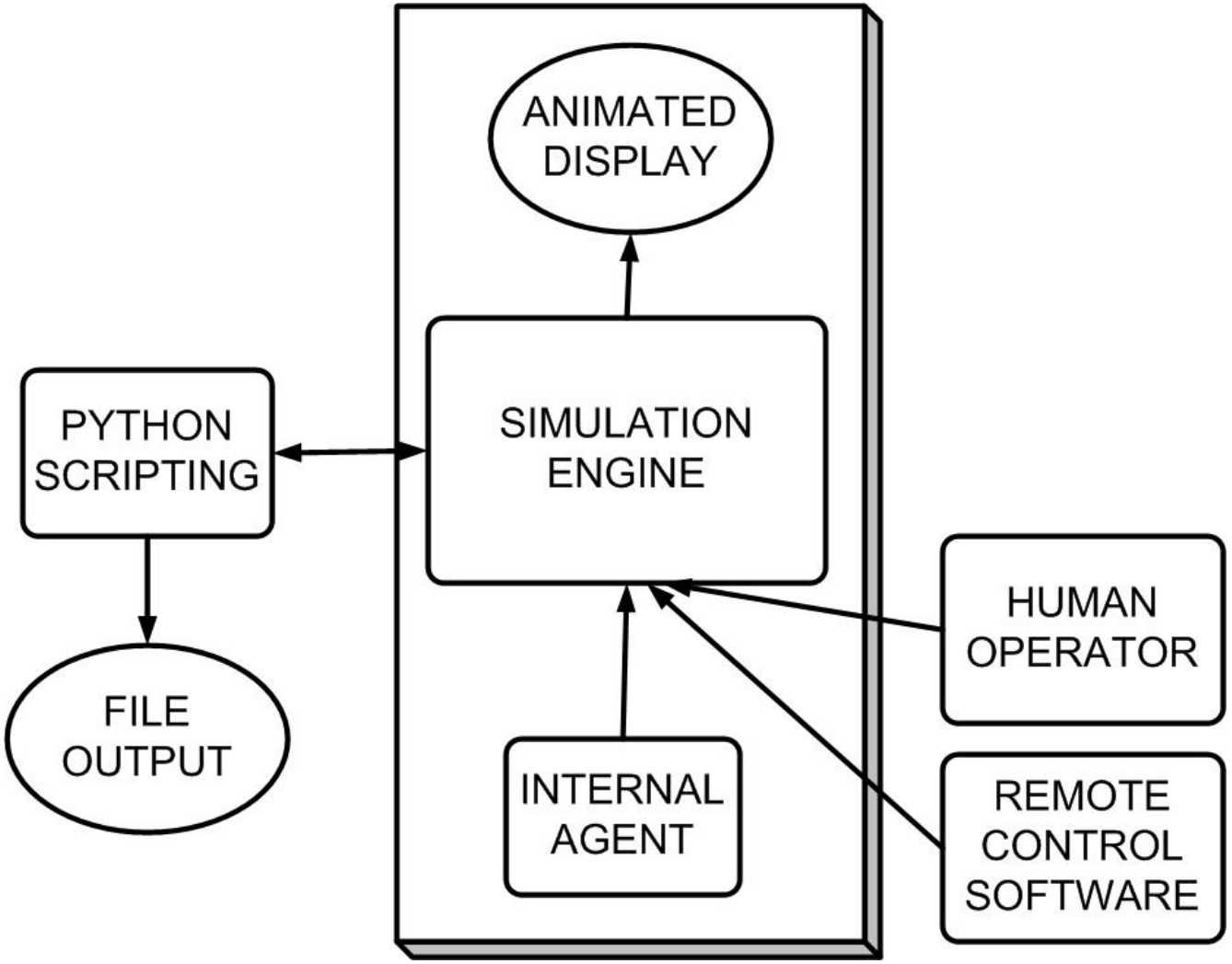
(and David H. Scheidt)

BACKUP SLIDES

Swarming Engagement Simulator Input/Output



Agent Architecture