SmartSwarms: Distributed UAVs That Think

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The Problem

- **How to make automatic real-time decisions for unmanned vehicles?**
- **Examples:**
  - **Unmanned Ground Vehicles (UGVs):** how to get a UGV to its destination fastest?
  - **Unmanned Aerial Vehicles (UAVs):** how to avoid accidents in the air and complete the mission in the least amount of time.

?

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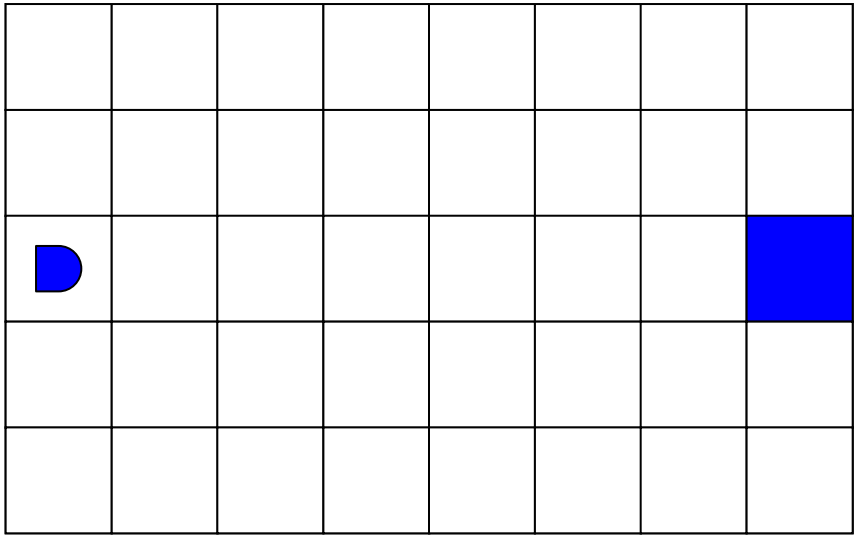
The Current Approach

- **Rule-based**: use a *fixed rule*
- **Examples**:
  - Route UGV along shortest path to destination
  - Route UGV along the least congested route



Shortest path routing rule

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The Current Approach: All Rule-Based

- **Production Rules:** if-then rules (e.g. Soar)
- **Finite State Machines:** rules with states
- **Agent-Based:** distributed rules
- **Logic-Based:** theorem-proving rules
- **Neural Networks:** non-linear rules
- **Genetic Algorithms:** tunes rules

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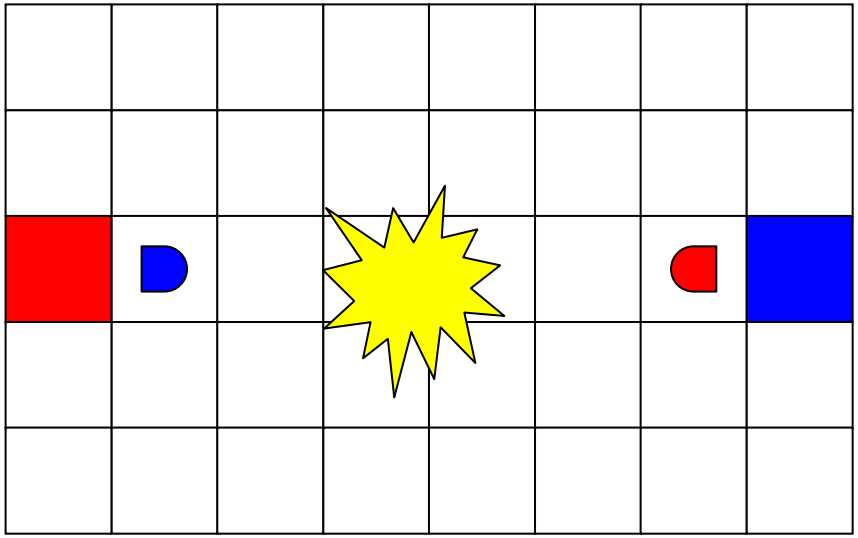
Problems with Fixed Rules

- **Myopic**: fail to take into account long-term ramifications
- **Far-from-Optimal:** because they are myopic
- **Limited expressibility**: difficult to specify uncertainty or complexity
- **Costly to develop**: requires deep knowledge of the application
- **Costly to maintain:**
  - New rule for each new situation
  - Results in patchwork, spaghetti code
- **Clog-ridden:** this is how clogs build with multiple UGVs



Shortest path rule is myopic

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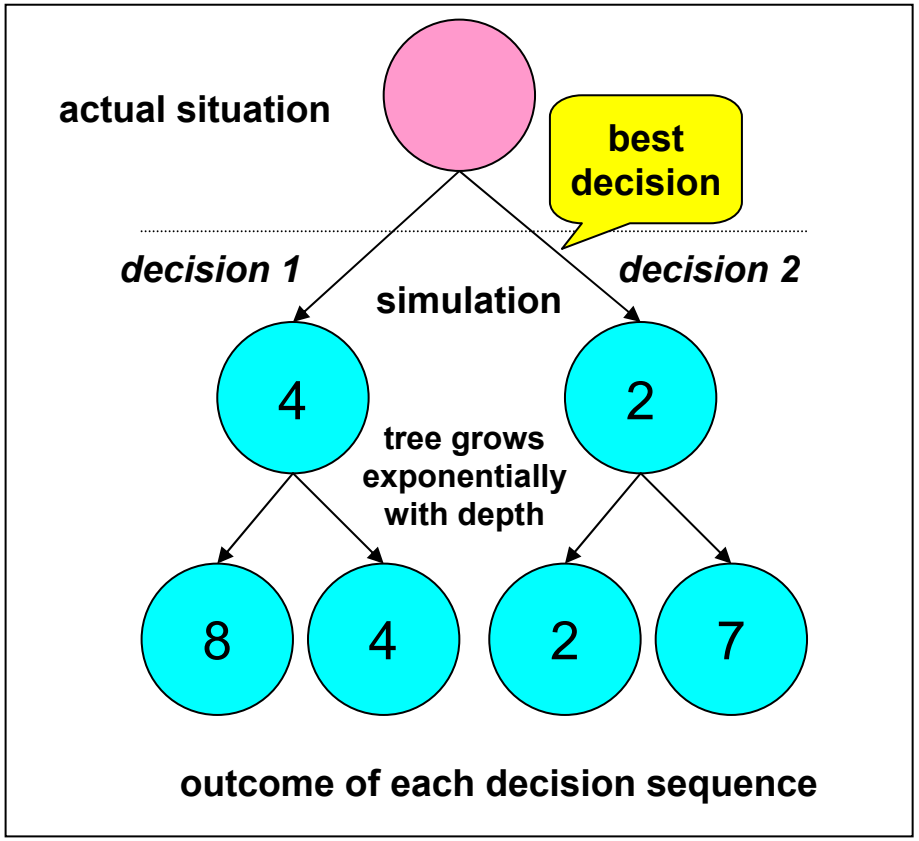
LDI's Innovation: Model-Based Decision-Making

1. **Simulate**: effects of each decision forward in time by building a lookahead tree
2. **Evaluate**: expected outcome of each decision sequence in that tree
3. **Choose**: decision that results in the best expected outcome



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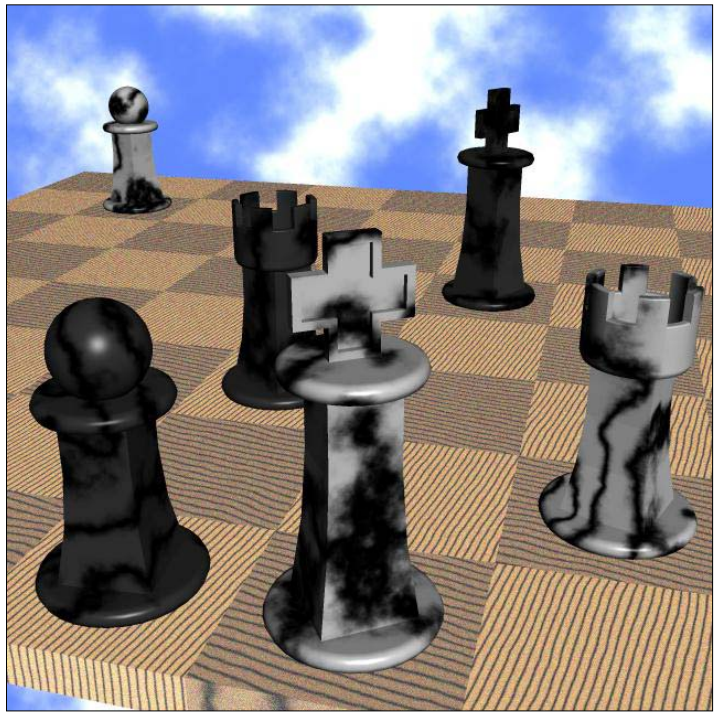
Oasys Works Like World-Champion Chess Programs



- **Oasys:**
  - Searches decision tree more efficiently
  - Takes into account uncertainty, time, parallelism
  - Scales in performance with more PCs
  - Learns to improve

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Advantages of Our Approach

- Telescopic
- Expressively Powerful
- Real-Time
- Anytime
- Principled
- Easily Deployable
- Flexible and Easily Maintainable
- Optimal

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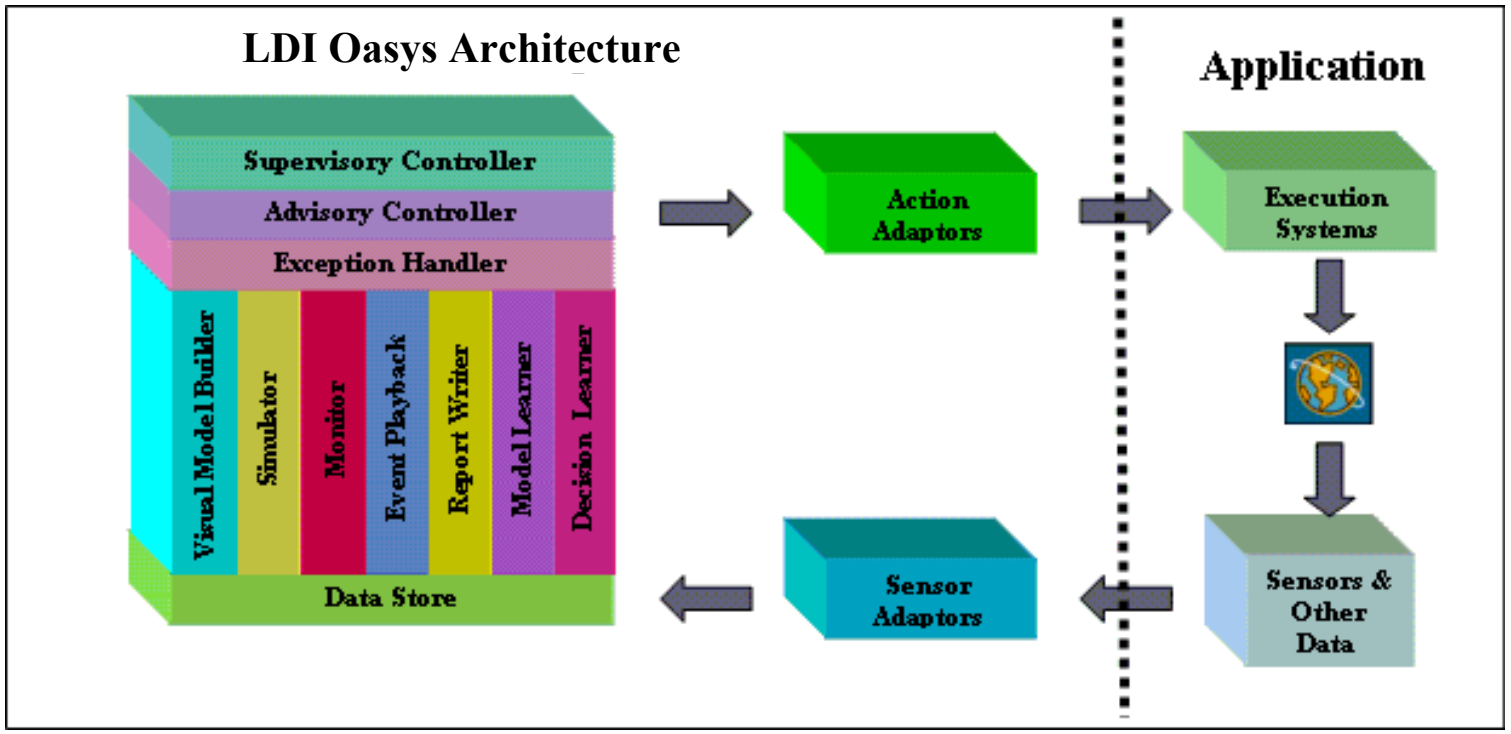
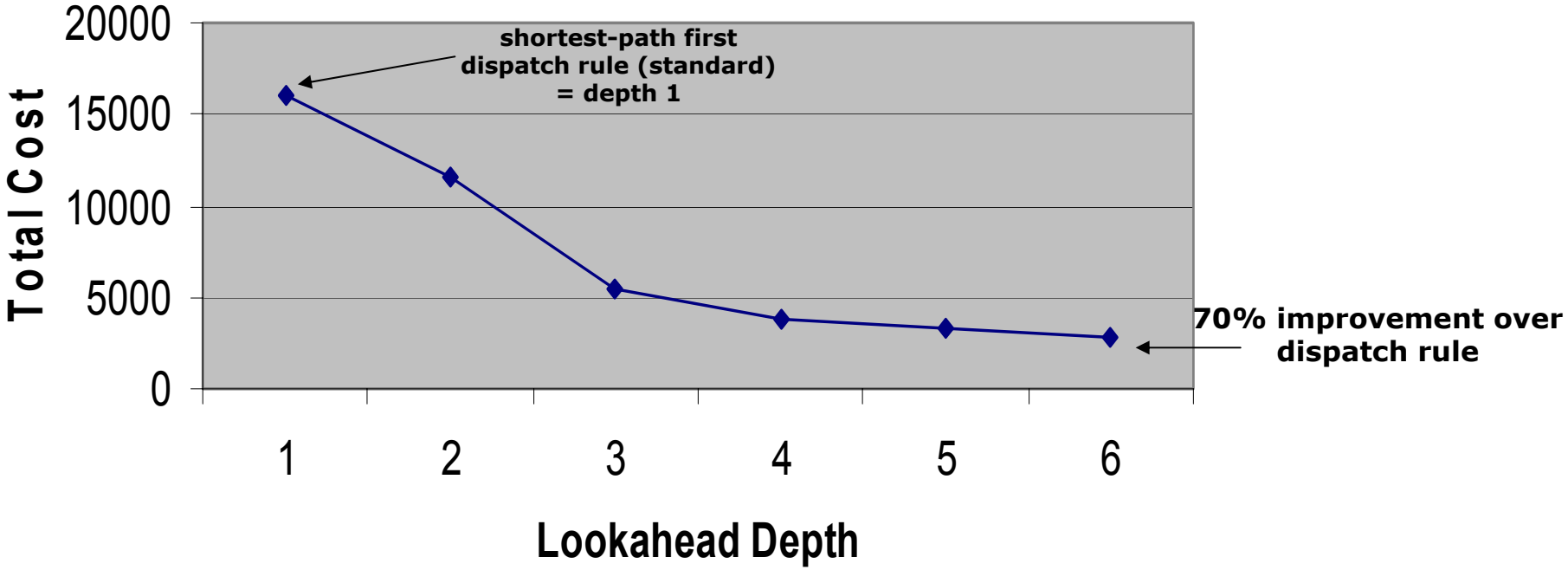
LDI's Oasys Conceptual Architecture: XML-Based



Current Results: UGVs

6x6 MESH with 28 UGVS



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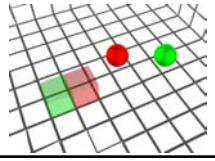
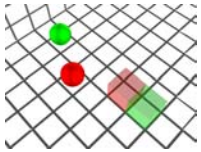
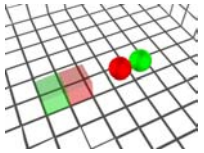
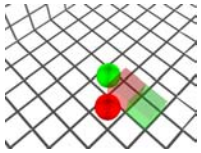
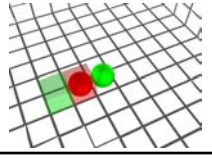
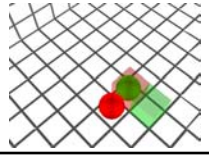
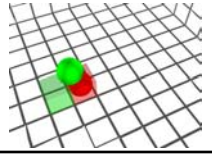
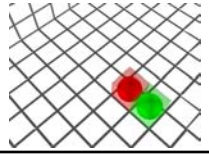
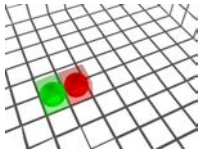
Current Results: Rules vs. Oasys for UAVs

Shortest Path	Oasys
	
	
	
	
	

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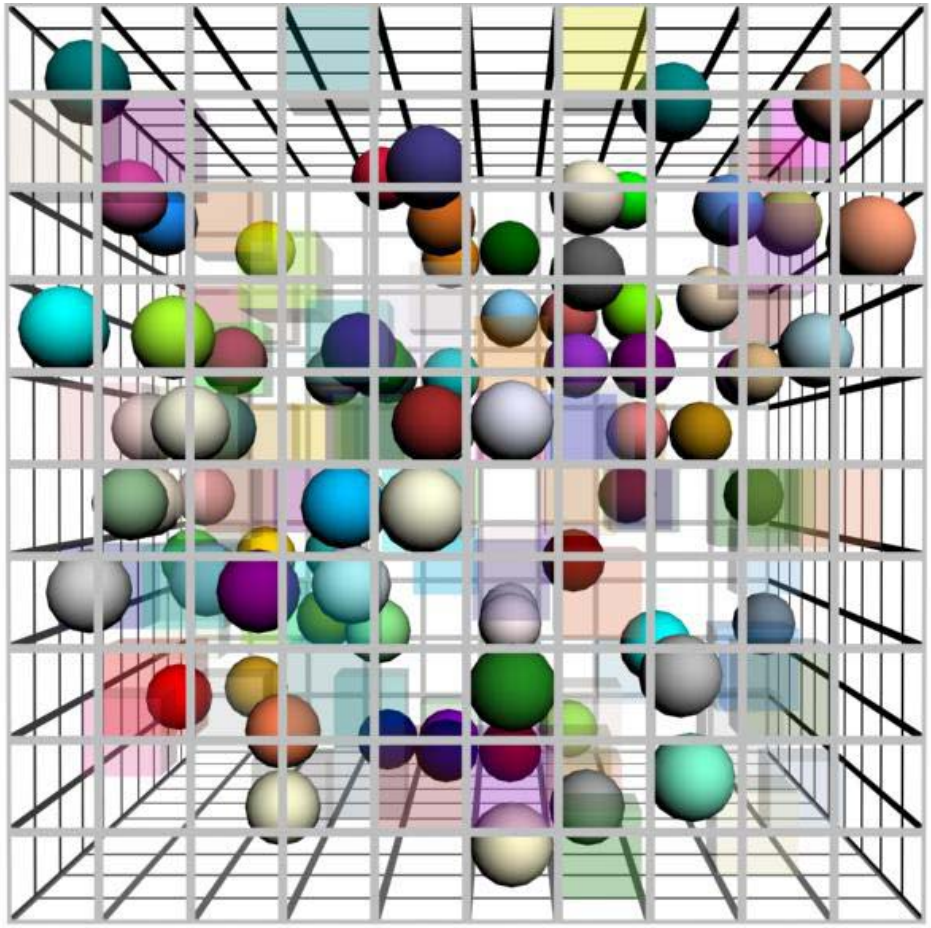
Current Results: UAVs



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Quantitative Results for UAVs

- 10 x 10 x 10 Grid Size
- 80 UAVs
- 61.1% Improvement over Shortest Path

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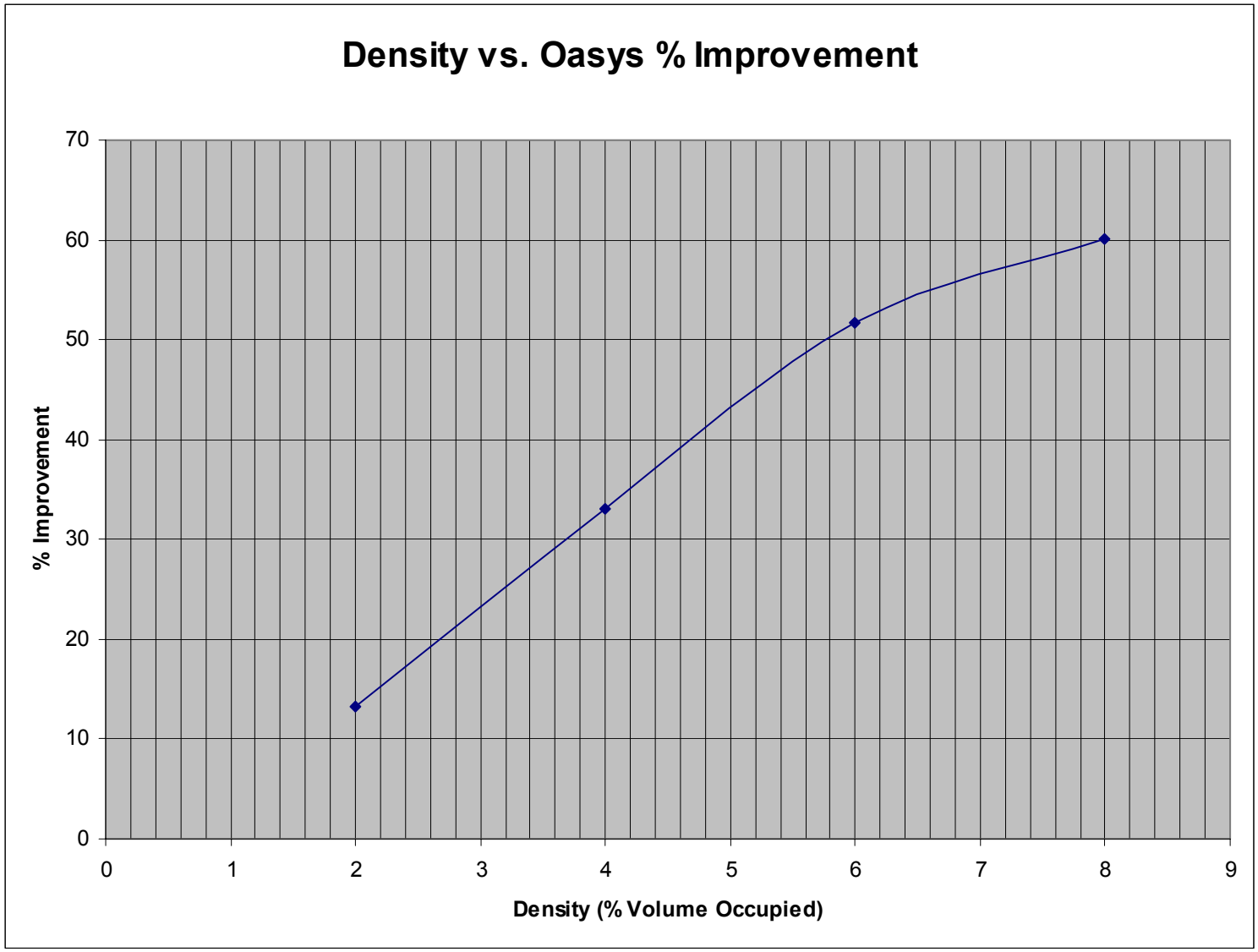
Oasys Does Better with Greater Complexity



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Conclusions and Future Work

- **Model-Based Decision-Making:**
  - Reduces Cost of Deployment
  - Improves Performance
  - Reduces Cost of Maintenance
  - Can Integrate with Higher-Level Goals
- **Future Work:**
  - Multi-level UAV Control System
  - Goals of greater complexity (e.g. different mission types)

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About LDI

- **Focus**: real-time decision-making
- **Products**: Oasys 3.0, a real-time decision-making system
- **Services**:
  - Simulation
  - Workflow
  - Scheduling
- **Verticals:**
  - Healthcare
  - Manufacturing
  - Material Handling
  - Unmanned Vehicles