An Operation-time Simulation Framework for UAV Swarm Configuration and Mission Planning

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Outline

- Project Introduction – Challenges and Motivations (G. Madey)
- Applying DDDAS to UAV Swarm Control
- Simulation Framework
- Conclusion and Future Work

Project Introduction (Begin)
G. Madey

Introduction: Unmanned Airborne Vehicles

- A UAV is an aircraft that does not require on-board pilots.
- Usually controlled remotely or by an autonomous computer.

Applications of UAVs

Precision agriculture

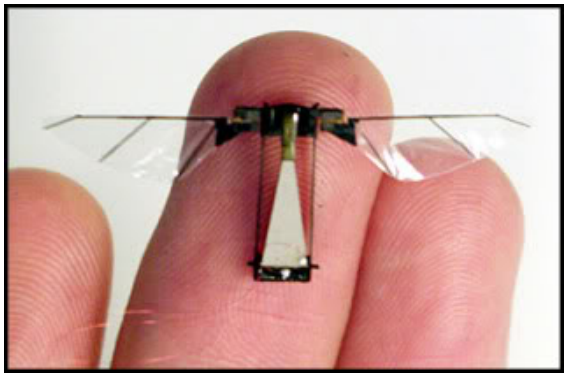
Natural resource monitoring

Public safety

Real estate sales

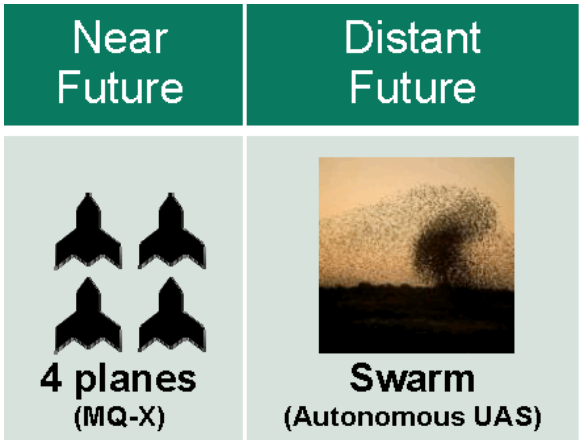
From single UAV to a swarm

- Decreasing cost, decreasing sizes
- Increasing capabilities, increasing numbers
- UAV swarms, rather than individual UAVs
- Current control approaches have limited scalability
- New methods and approaches required to <u>fly the swarm</u>, not individual UAVs

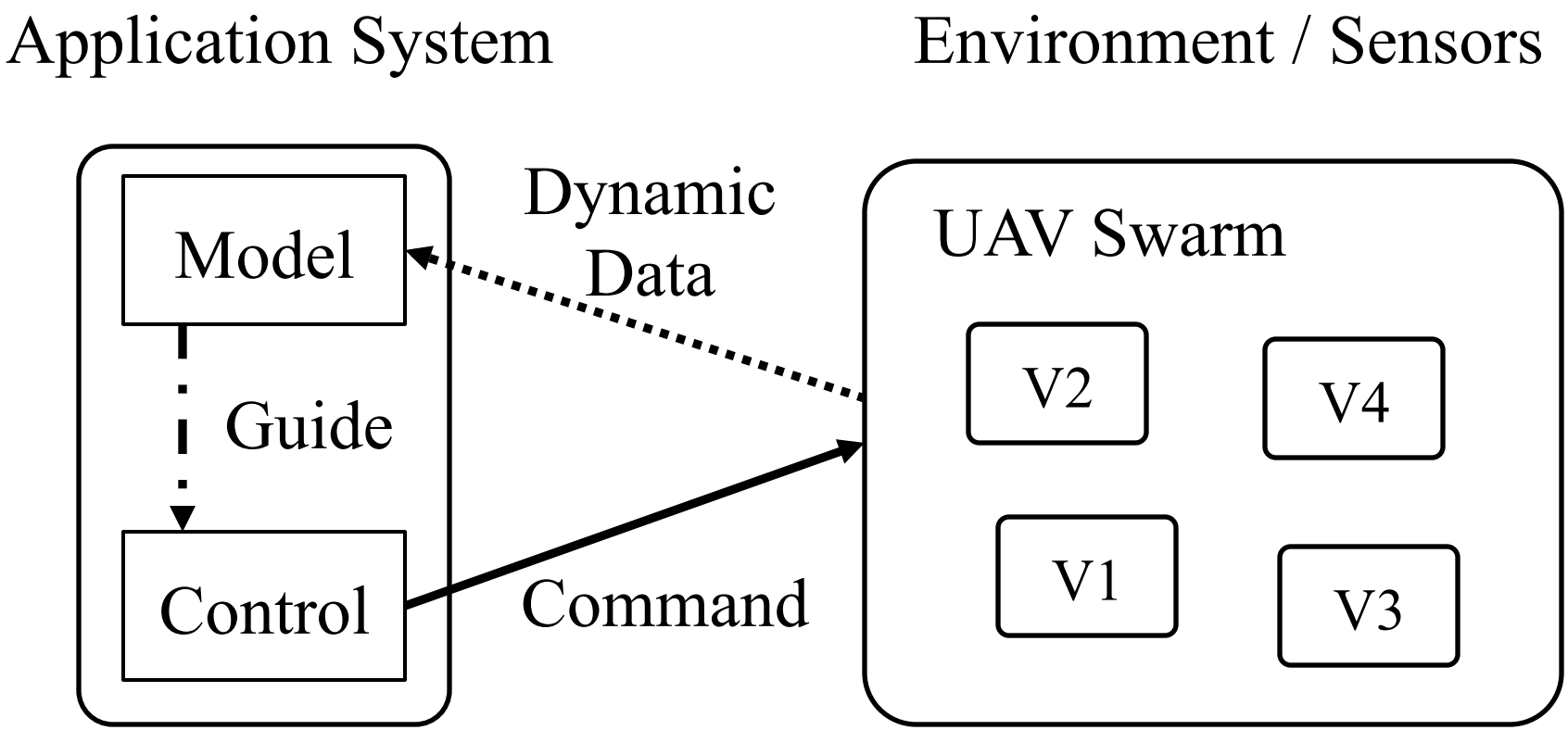


Major Challenges

- Develop autonomous control mechanism for individual UAVs
- High level control of the entire swarm
- Swarm control decision making based on imperfect data



Application of DDDAS Principles



Project Introduction (End)
G. Madey

Introduction and Disclaimer

First Author, Yi Wei (now Dr. Yi Wei), Graduated Last Week and off to the Microsoft Azure Group ☺

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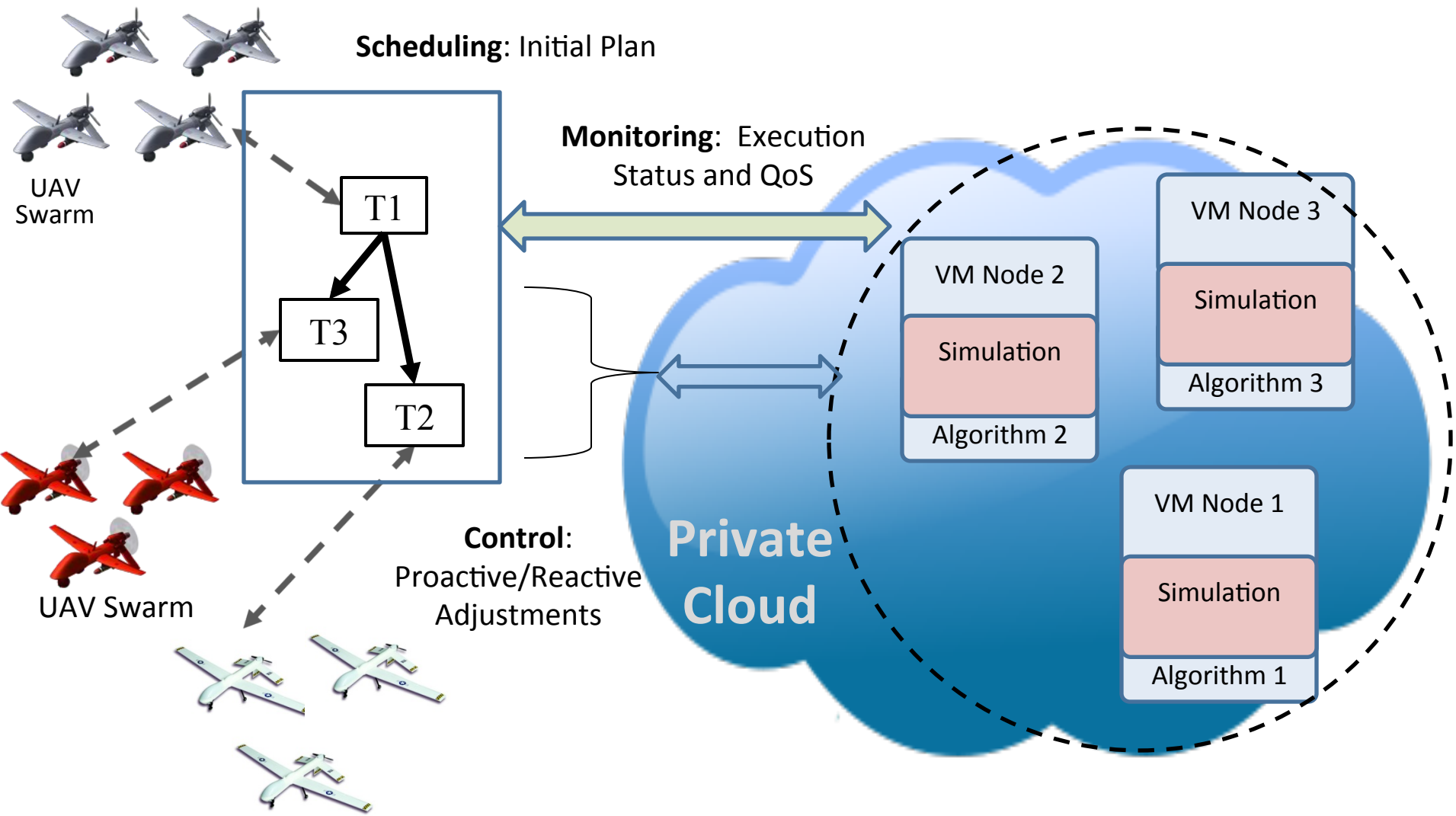
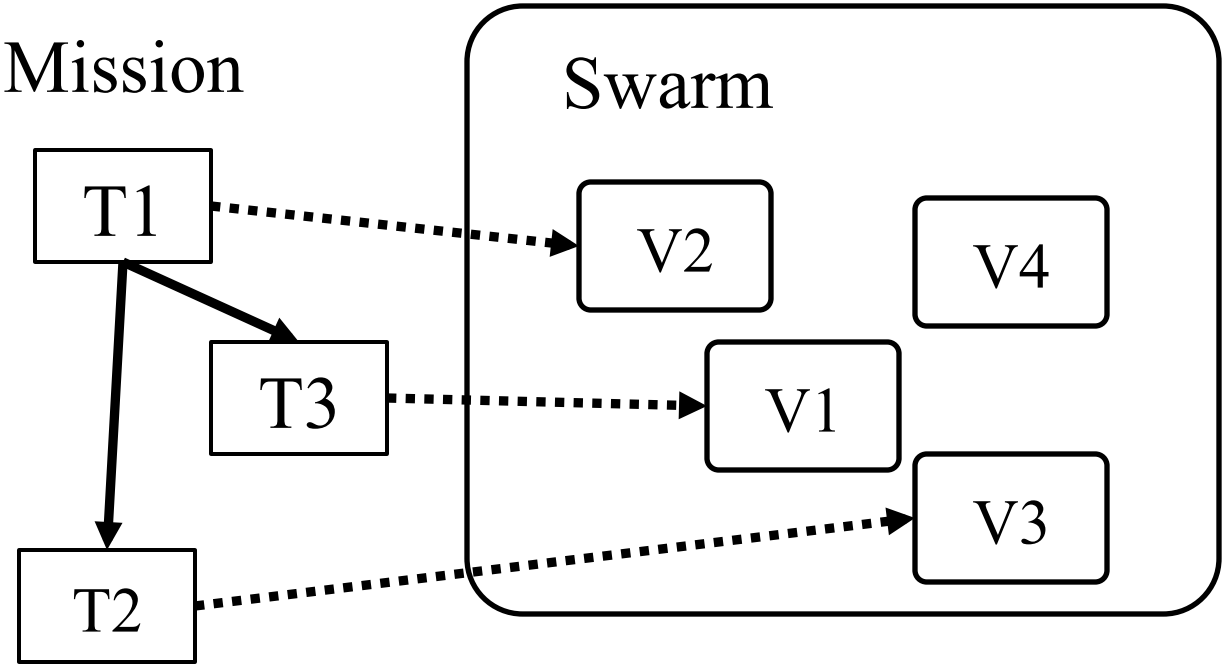
Challenges: Flying the Swarm



Major Research Problem: What frameworks facilitate distributed control?

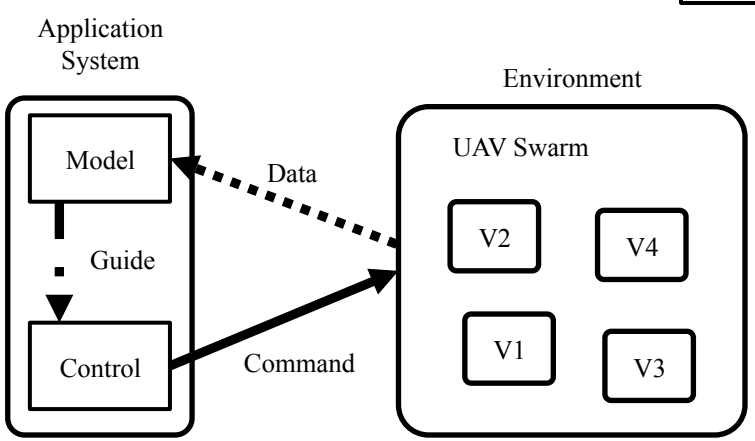
Mission Planning Criteria

Model: Swarm and mission plan and status at the ground control



Control: Schedule new tasks, request UAV status update, or reassign a task to another UAV

Data: Task information and UAV status sent from each UAV



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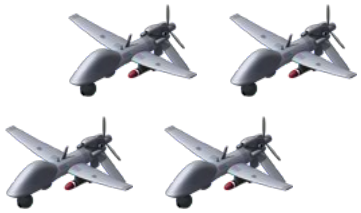
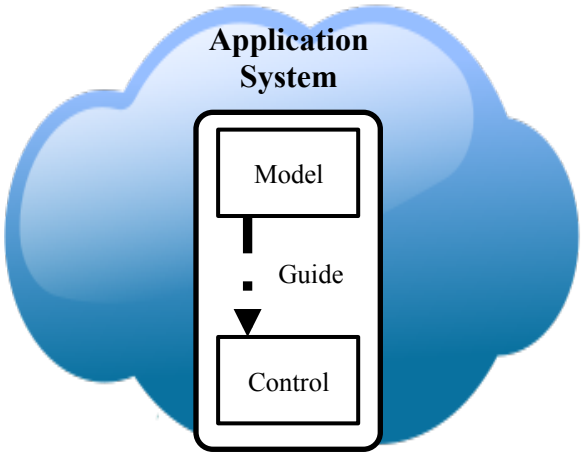
Real-World Challenges: *Imperfect Data*

- Each UAV has a specified maximum fuel capacity
- A randomly changing fuel consumption rate is also associated with each UAV



UAV Swarm

- Ground control has to estimate whether a UAV is capable of completing a new task based on its knowledge about that UAV
- Resources and processing time for application system on the ground (a need for just-in-time processing)

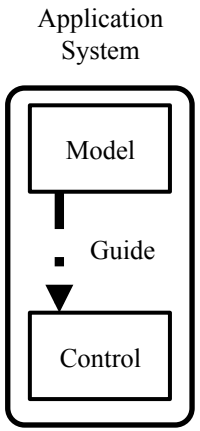


Related Approaches

- **General Purpose Agent Frameworks**- MASON, MultiUAV2, Cougar, JADE, etc.
- **Extended Flight Simulators** – Simulators where primary control is with the human user (Garcia)
- **Predominantly Distributed Simulations** – Control leveraging Agent-SWARM techniques (Gaudiano and Varela) and using multi-objective evolutionary algorithms (Lamont)
  - *Minimal central control, if any*
- **Domain-Specific Simulations** – Cooperative search, detection, and evasion of moving targets (Vincent), target recognition (Dasgupta), and specialized task allocation (Dionne and Dasgupta)

Our Contribution: A framework that allows assessment of hybrid central and distributed control. A defined model, albeit preliminary, for mission communication and control

Facilitating Global-Local Hybrid Planning



- Ground control periodically requests UAVs to send back their latest status to update its knowledge about the swarm and missions
- Ground control assigns tasks to different UAVs based on its model and other constraints.
  - Candidate UAVs for new tasks selected by calculated cost with by optimizing final location and resulting residual fuel

- Each UAV schedules new tasks based on local information in context of current mission status information.
  - Policies include First Come First Serve, Insertion-Based, Traveling Salesman, and Adaptive Selection (via same cost model as the application system)

UAV Swarm

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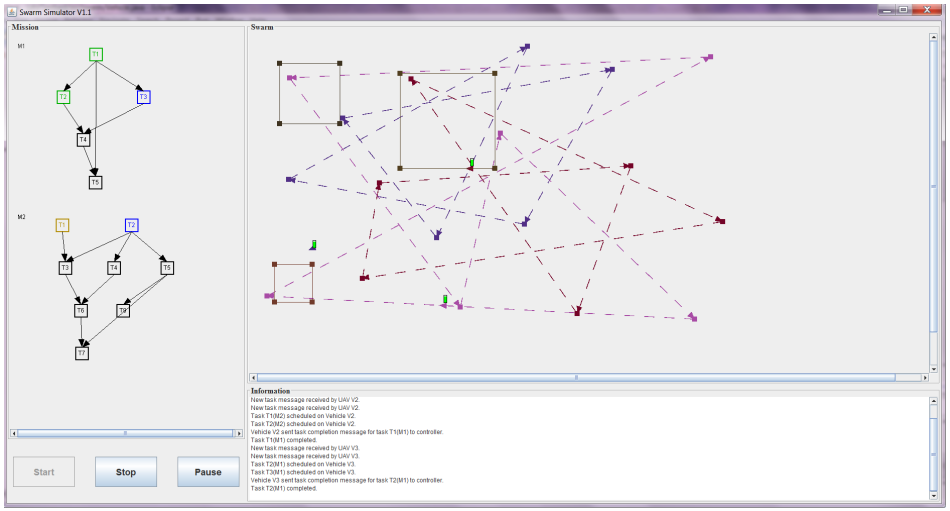
Proof of Concept: Testbed/Sim. Program (1)

- Implemented as a Java multi-threaded application
- The ground control and all UAVs are implemented as threads
- The JFreeChart library is used to generate simulation reports



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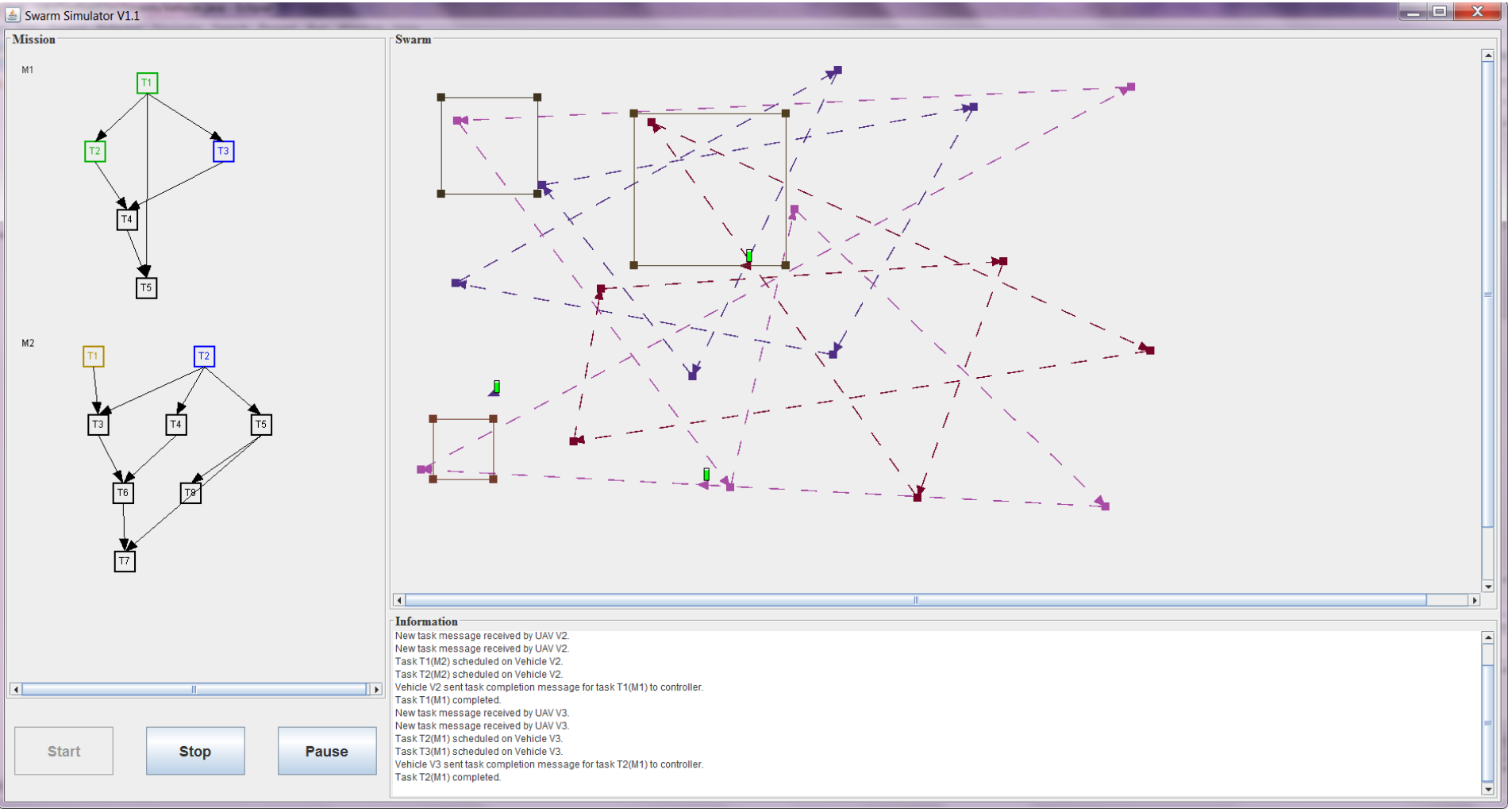
Proof of Concept: Testbed/Sim. Program (2)

Message Types

1. **New mission**: from operator to ground control
2. **New task**: ground control to UAV
3. **Status request/return**: between ground control and a UAV
4. **Task completion**: UAV to ground control
5. **Task reassignment**: UAV to ground control

Models

Mission: Implemented as a directed acyclic graph (DAG)



Demonstration

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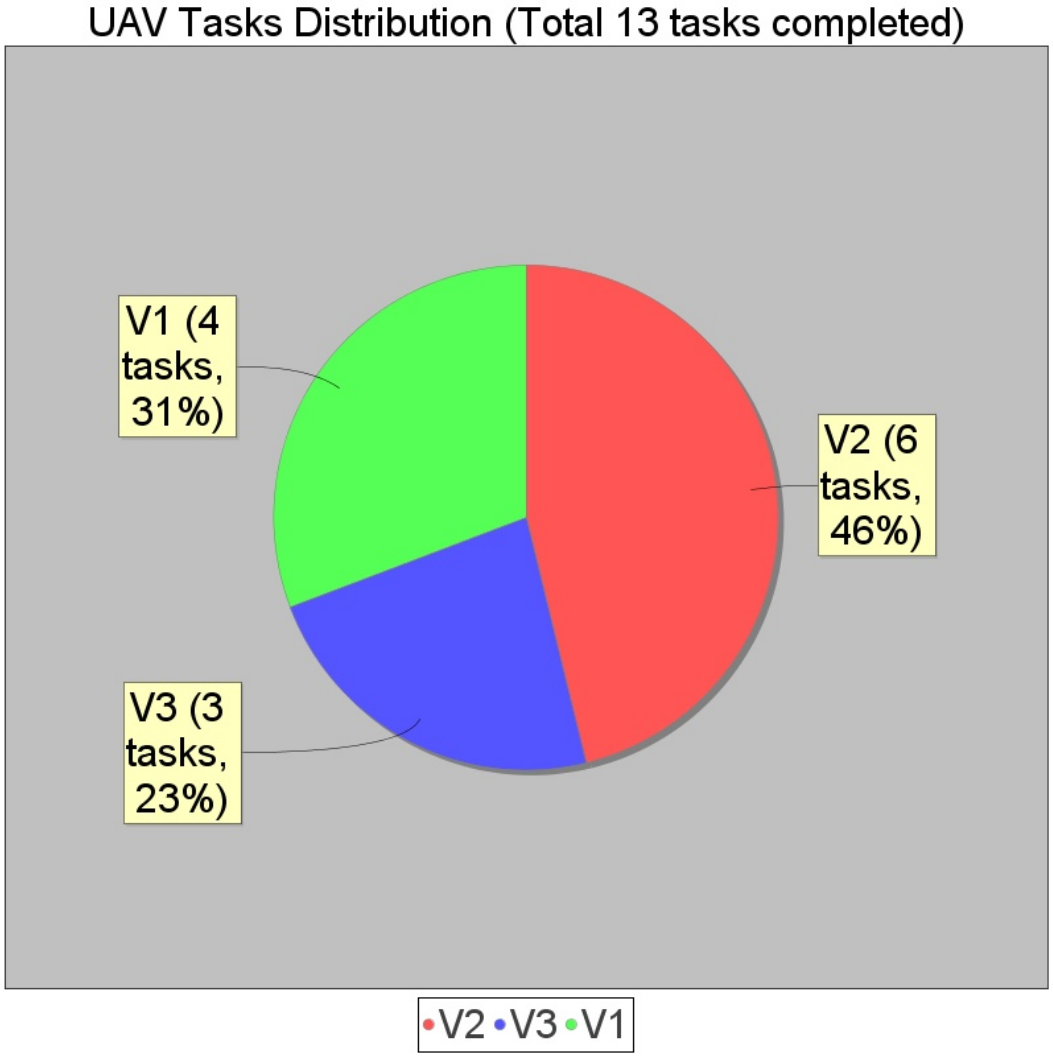
Generated Charts – Number of Tasks Completed



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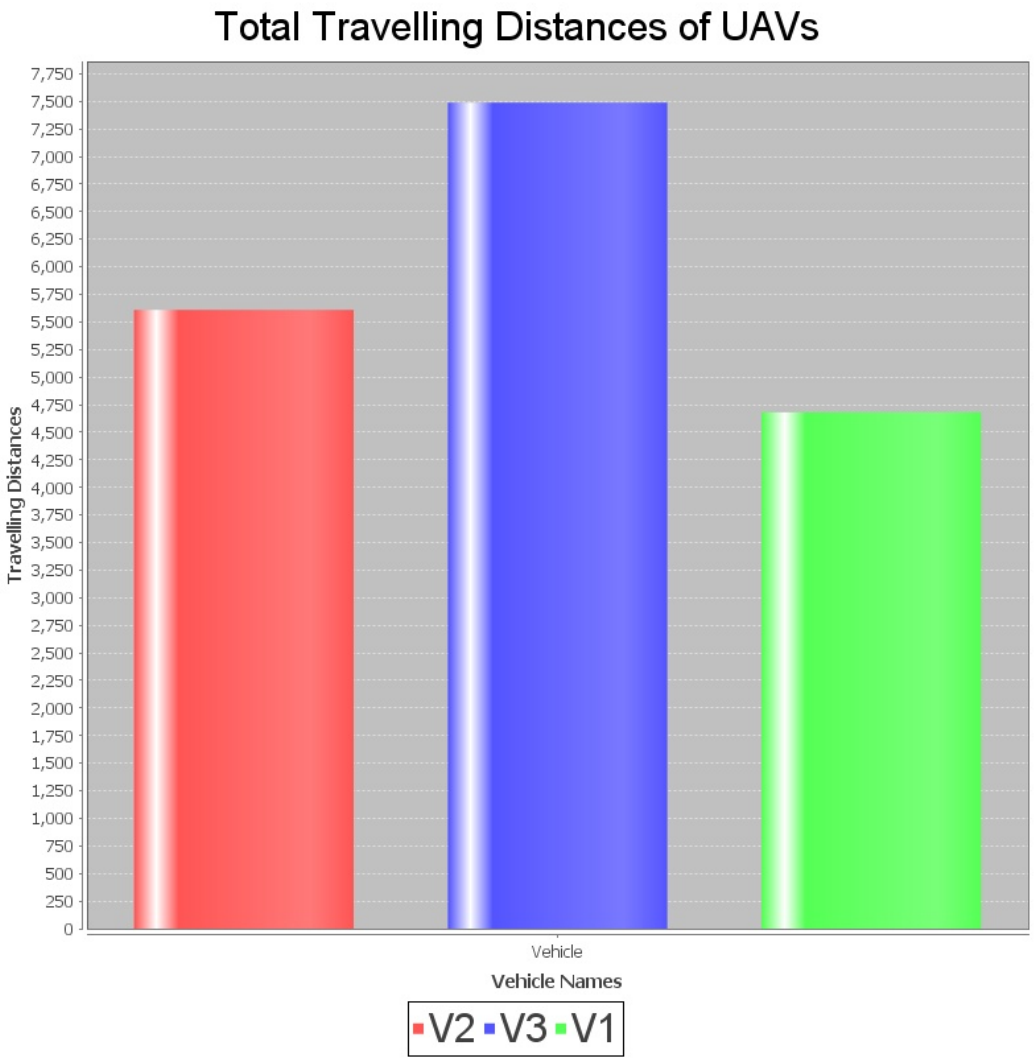
Generated Charts – Total Travelling Distances



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Limitations of Current Approach

- Only one task type and simple DAG mission structure
- Perfect communications are assumed
- Simplified UAV mobility model

Conclusion

- The adoption of swarm based UAV operations require new control models and algorithms
- DDDAS principles can be applied to the swarm mission planning problem
- Global-local hybrid method is employed to facilitate planning process

Future Work

1. Incorporate more realistic scenarios, such as UAV losing contact to the ground station
2. Incorporate more task types and mission structures
3. Development of an expressive mission specification language

Acknowledgements

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- Project members: M. Brian Blake, Greg Madey, Christian Poellabauer, Hongsheng Lu, R. Ryan McCune, and Rachael Purta

Thank You!

Questions?

Background

Native of Savannah, Georgia

Education

Bachelor of Electrical Engineering, *Georgia Tech*

Master of Electrical Engineering, *Mercer University*

PhD, Software Engineering, *George Mason University*

Professional Experience:

Engineer and Defense Contractor (6 yrs)

Professor & Chair, Computer Science, *Georgetown University*

Associate Dean & Professor, *University of Notre Dame*

Vice Provost & Dean of the Graduate School, ***University of Miami***

Family:

Wife, Bridget, BME GA Tech / MBA Johns Hopkins

Brendan (8yrs old), Bryce (1yr old)