

COE CST Seventh Annual Technical Meeting

Task 331. Advanced 4D Special Use Airspace

**Mykel J. Kochenderfer
Rachael E. Tompa**

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Agenda

- Team Members
- Task Description
- Schedule
- Goals
- Results
- Conclusions and Future Work

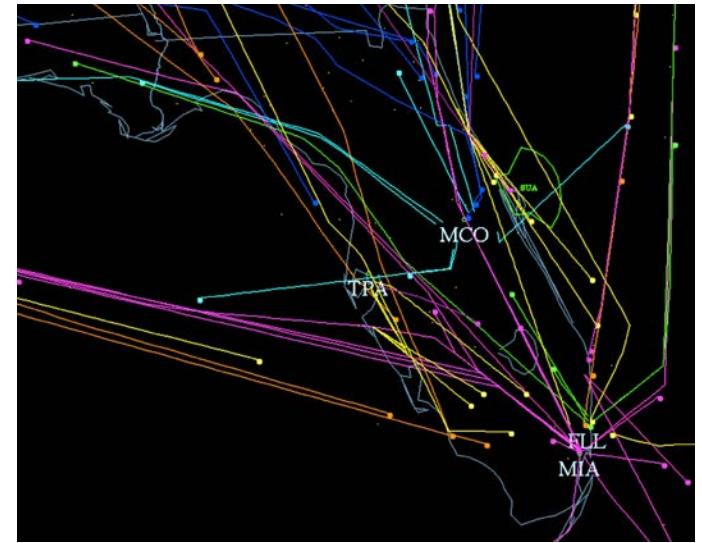
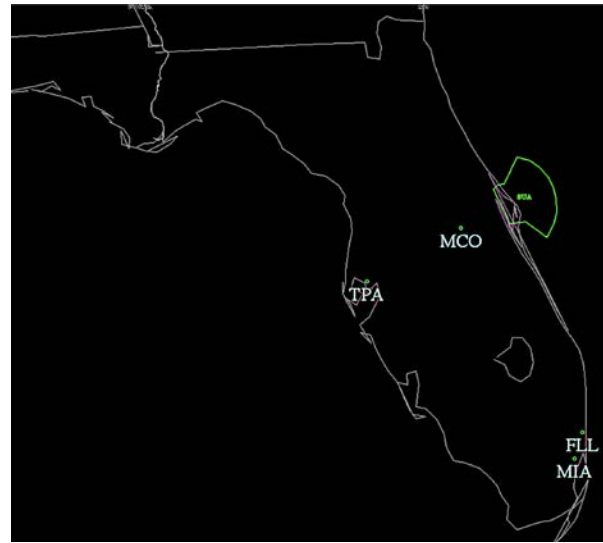
Team Members

- Principal Investigator
 - Mykel J. Kochenderfer
- Students
 - Rachael E. Tompa
 - Apoorva Sharma
 - Jayesh Gupta
- Organizations
 - AGI
 - NASA Ames
 - MIT Lincoln Laboratory



Task Description

Currently the FAA shuts down a large column of airspace during a commercial space launch



Reduce airspace disruptions while maintaining airspace safety

Schedule

Complete:

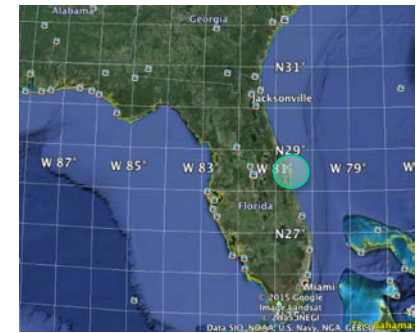
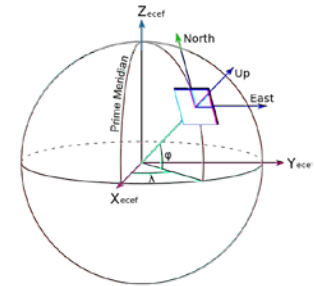
- Discretized Framework
Proof of Concept
- Robust Debris Model

Ongoing:

- Continuous Framework

Future:

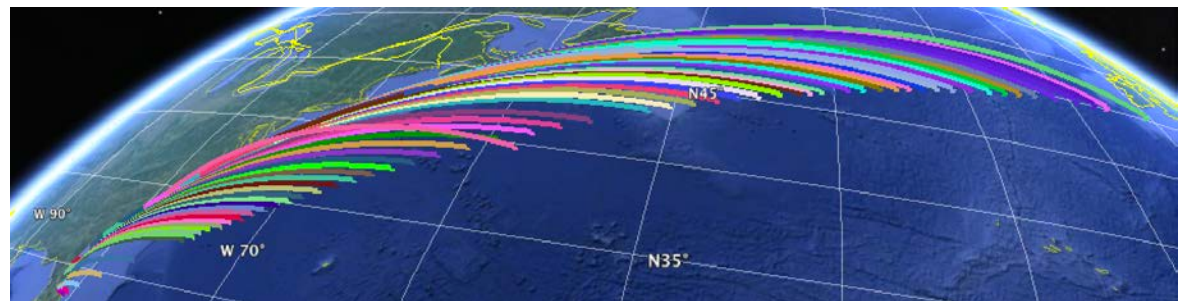
- Action Space Expansion
- Scenario Expansion



Goals

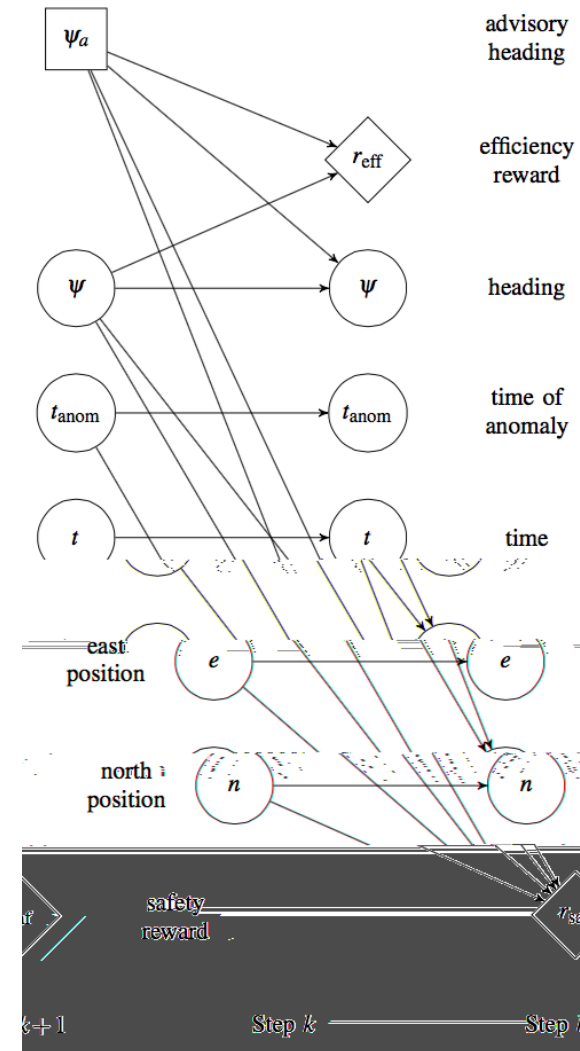
Investigating dynamic restrictions that

- Change throughout launch trajectory and with vehicle health
- Account for uncertainties
- Adapt to anomalies
- Promote efficiency
- Ensure safety

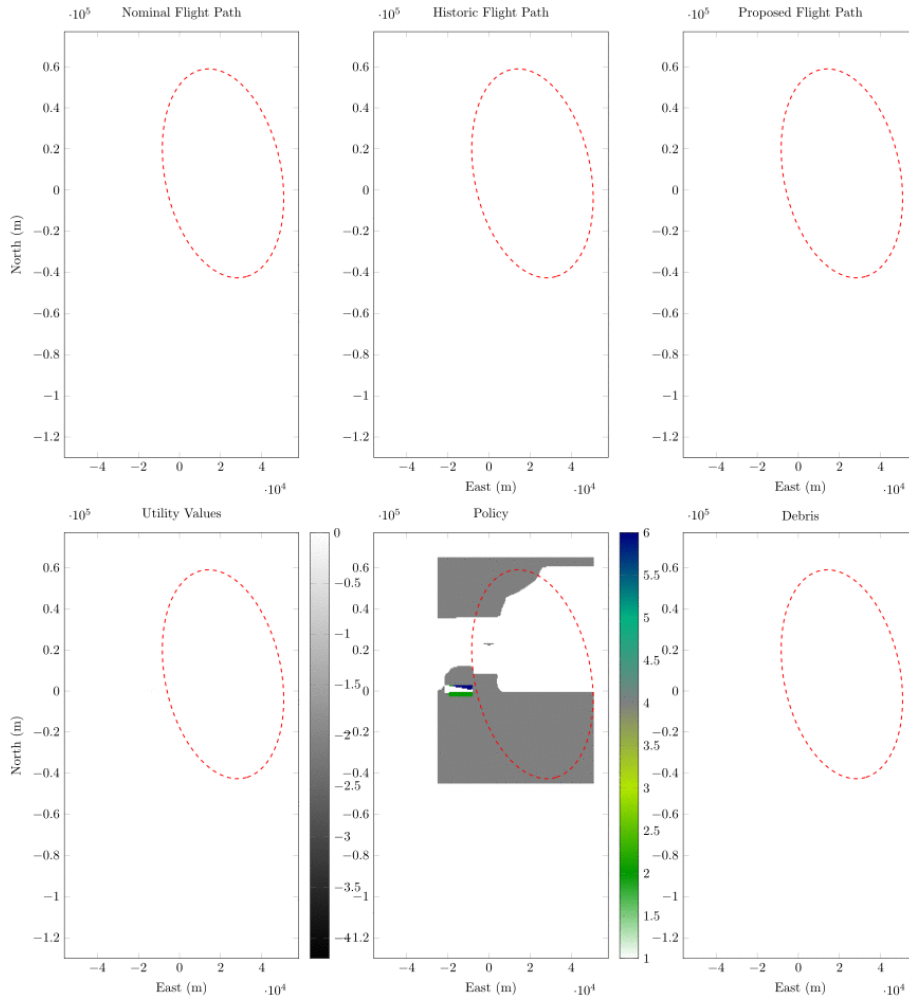


Results – Discretized Framework

- Modeled the problem as a Markov decision process
 - State Space
 - Action Space
 - Reward Function
 - Safety
 - Efficiency
 - Transition Function



Results – Discretized Framework



- Dynamic restrictions are smaller than historic static regions
- Fewer rerouted flights
- Rerouted flights have smaller flight deviations
- Minimal safety degradation

R. E. Tompa, M. J. Kochenderfer, R. Cole and J. K. Kuchar, "Optimal aircraft rerouting during commercial space launches," *2015 IEEE/AIAA 34th Digital Avionics Systems Conference (DASC)*

□ no action ■ turn strong right ■ turn right ■ maintain ■ turn left ■ turn strong left

Progress – Continuous Framework

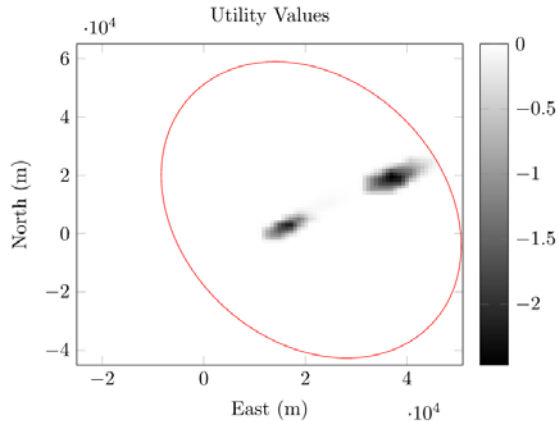
- MDP solution is constrained by exponential growth of the state space needed to correctly expand action space (incorporate metering)
- Solving a continuous problem discretely

Use Deep Reinforcement Learning

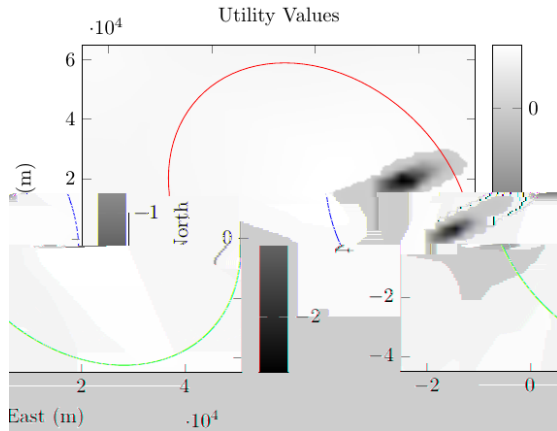
- Can we learn a good policy?
- Can we improve the policy in the continuous domain?

Progress – Continuous Framework

Discrete Policy



Continuous Policy



- Use supervised learning to learn a policy
- Matches current policy
- **Avenue 1:** continuing training on this policy
- **Avenue 2:** instead of learning existing policy use existing policy to steer training

Publication TBD

Conclusions and Future Work

- The proof of concept was successful and work is being conducted to alleviate scalability concerns
- Fully transition from discrete to continuous model
- Tackle oceanic flights including the incorporation of metering actions
- Investigate additional operational and safety metrics
- Broaden modeled scenarios

Thank you

- FAA Center of Excellence for Commercial Space Transportation
- Gunther Smiley, FAA AST
- Juan Alonso, Tom Colvin, and Francisco Capristán

