Deconflicting Travel of Aircraft and Spacecraft Through the US National Airspace System

Lessons Learned from Academic Research

Center of Excellence for Commercial Space Transportation

James Vanderploeg, MD, MPH
Executive Director (ret.)
Center of Excellence for Commercial Space Transportation

Research Conducted Under FAA COE

4D Compact Envelopes

Virtual Elimination of Air-Space Traffic Conflicts

Juan J. Alonso and Thomas J. Colvin

Department of Aeronautics & Astronautics

Stanford University

Assessing the Time to Clear Aircraft Hazard Areas (AHAs)

The MITRE Corporation

4D Compact Envelopes

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CENTER OF EXCELLENCE · COMMERCIAL SPACE TRANSPORTATION

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4D Compact Envelopes

Virtual Elimination of Air-Space Traffic Conflicts

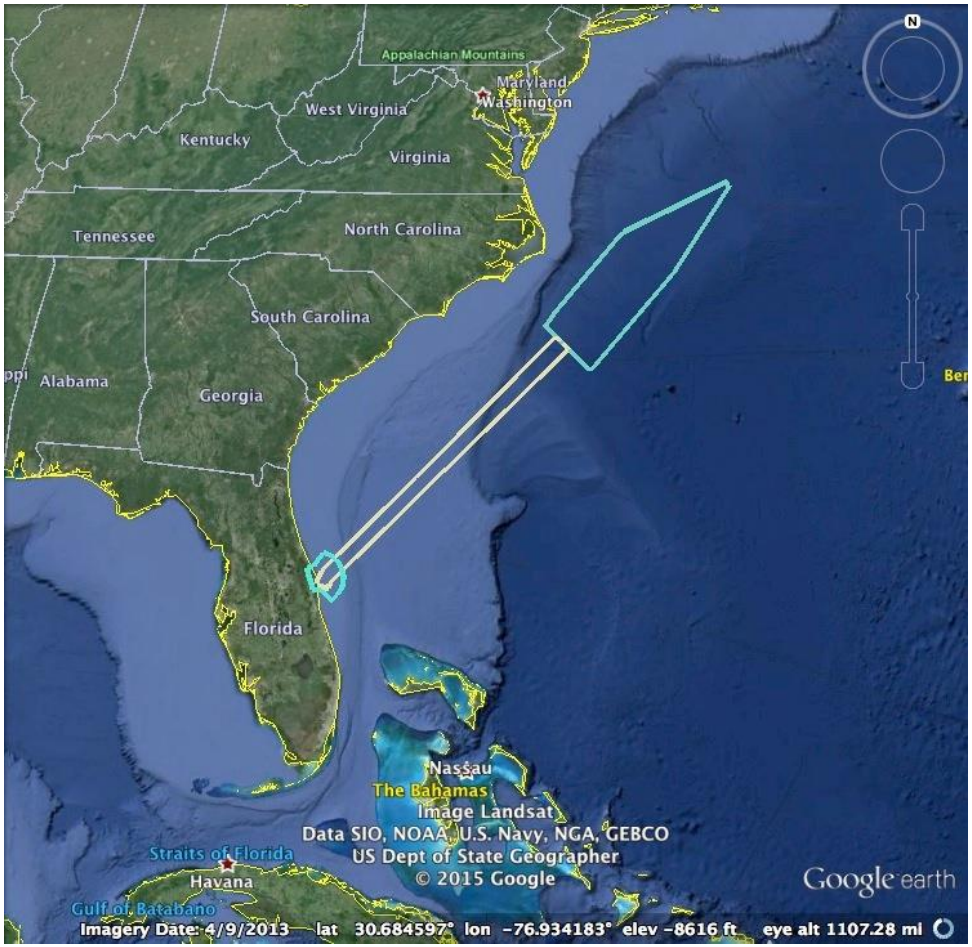
20TH ANNUAL
COMMERCIAL SPACE TRANSPORTATION CONFERENCE
FEBRUARY 8, 2017

Juan J. Alonso and Thomas J. Colvin
Department of Aeronautics & Astronautics
Stanford University

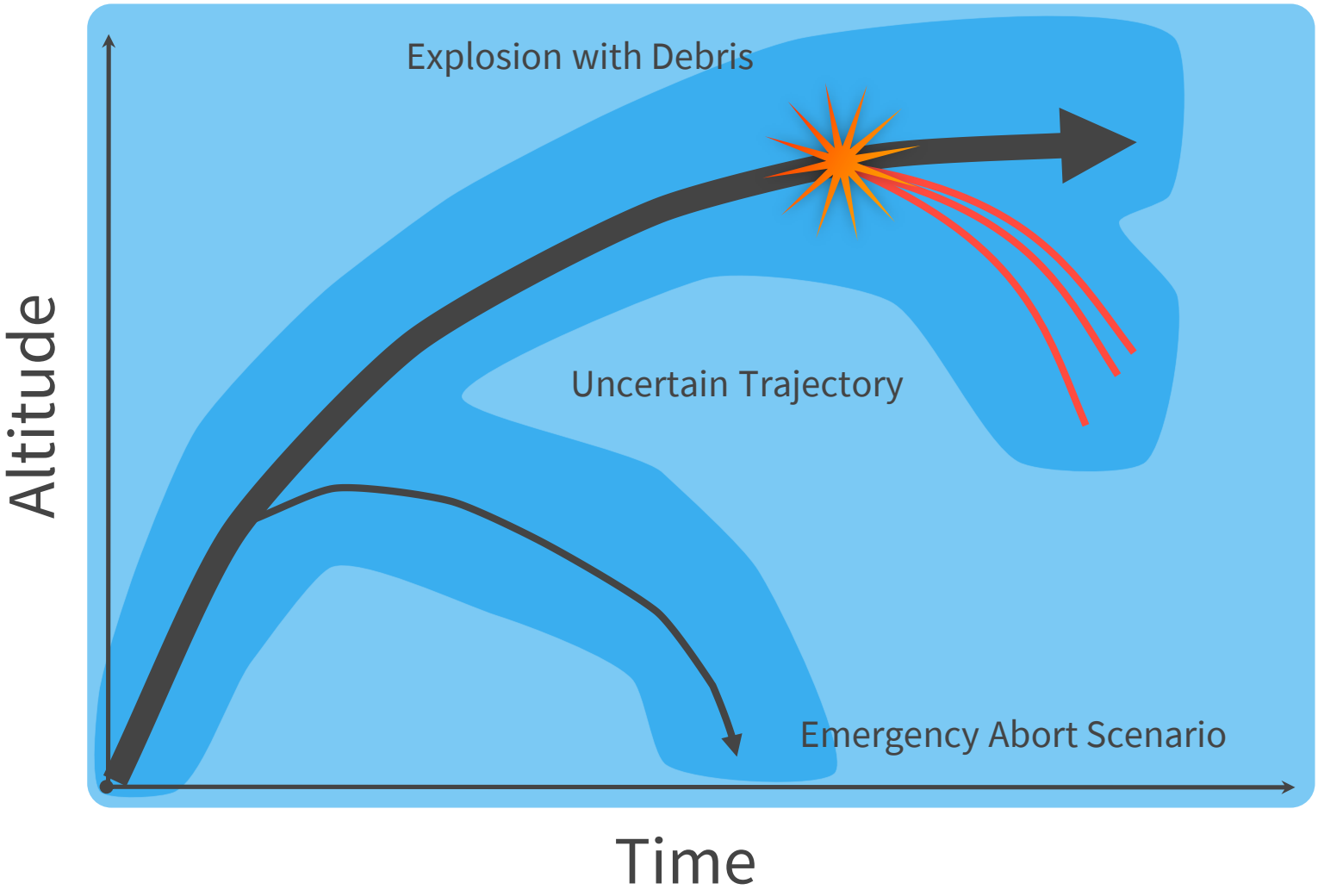
Current Space Operations Disrupt the NAS

- Main objective: safety / separation of air and space traffic / debris
- Launch and re-entries require Special Use Airspaces (SUAs)
- Aircraft are either re-routed (adding time, distance traveled, fuel burn) or held at departure location
- Hazard areas are too large and stay active for too long
  - "…huge swaths of airspace…need to know when to release hold", M. Huerta, FAA
- **This launch: 200 aircraft affected, 25 nm added distance / flight**

March 1st 2013
Three Hazard Areas
Launch to ISS from Cape Canaveral

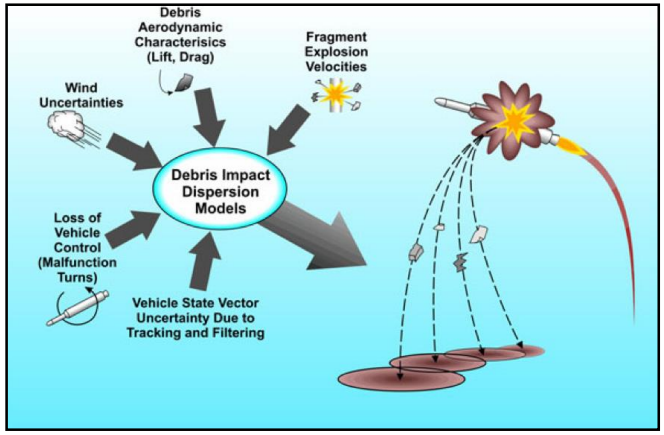


4D Compact Envelope Concept

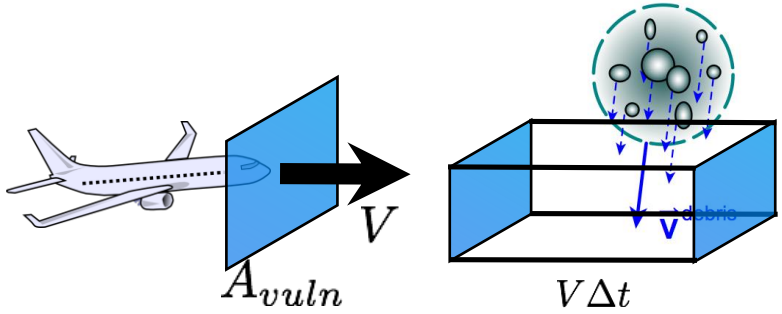


The Solution: Key Elements

Probabilistic Safety Analysis



Source: FAA Flight Safety Analysis Handbook



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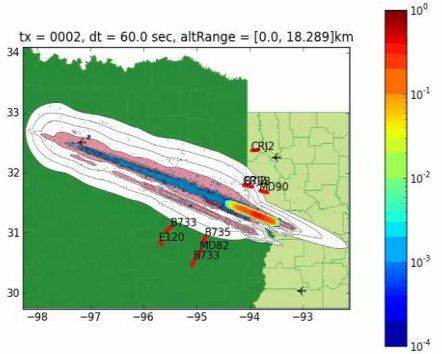
Dynamic Response

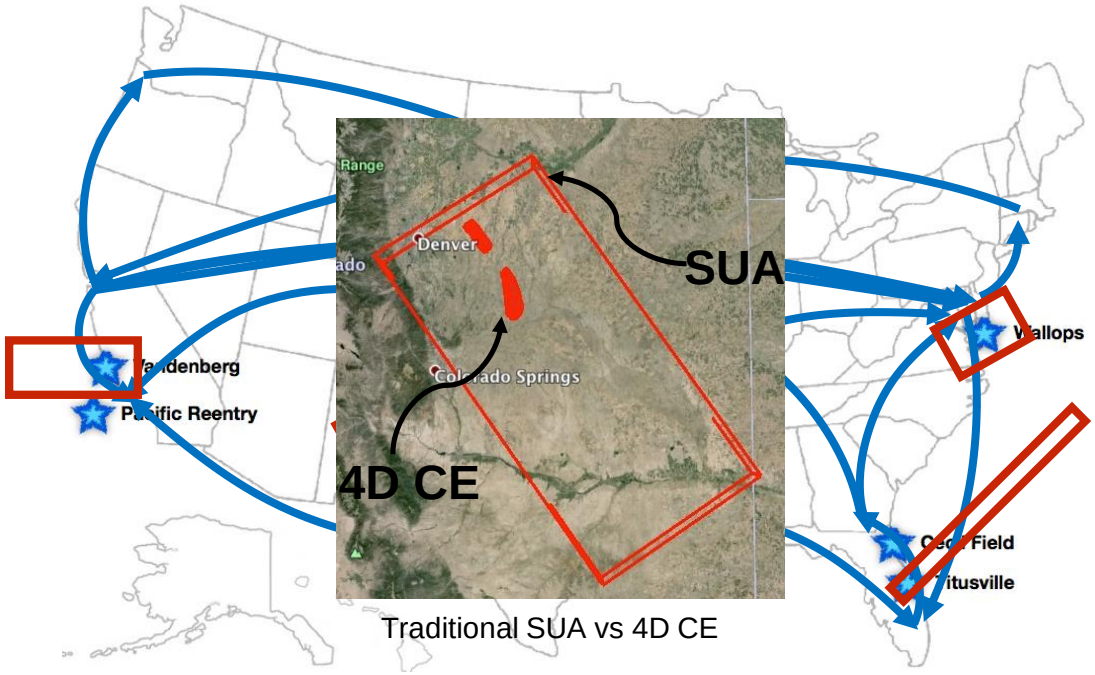


= { **Integrated Airspace**

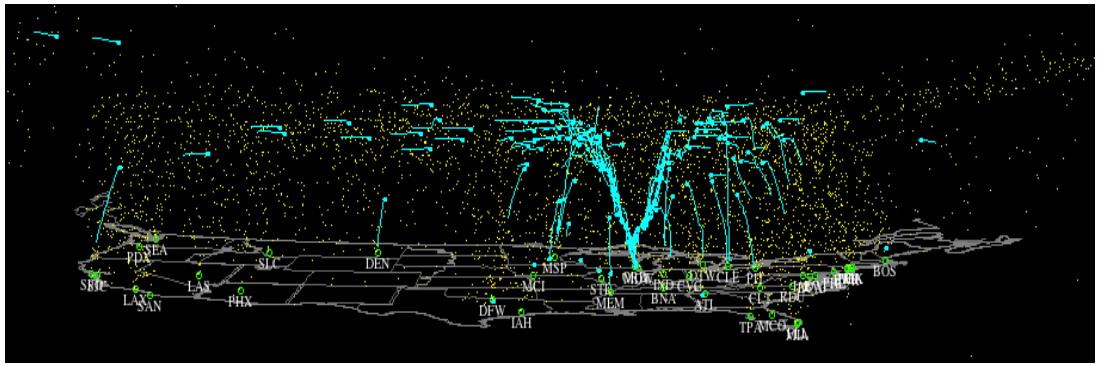
Virtual Conflict Elimination

Case Study: Airspace Disruption

- Full NAS simulations
- 8 vehicles, 10 locations, 14 missions
- Traditional hazard area vs 4D compact envelopes, assuming:
  - Five minute reaction time
  - 90 days of simulations
- 2018 / 2025 traffic forecasts
  - Collaboration with FAA NextGen, FAA Tech Center, and AST
  - Low/medium/high
- Compare disruptions



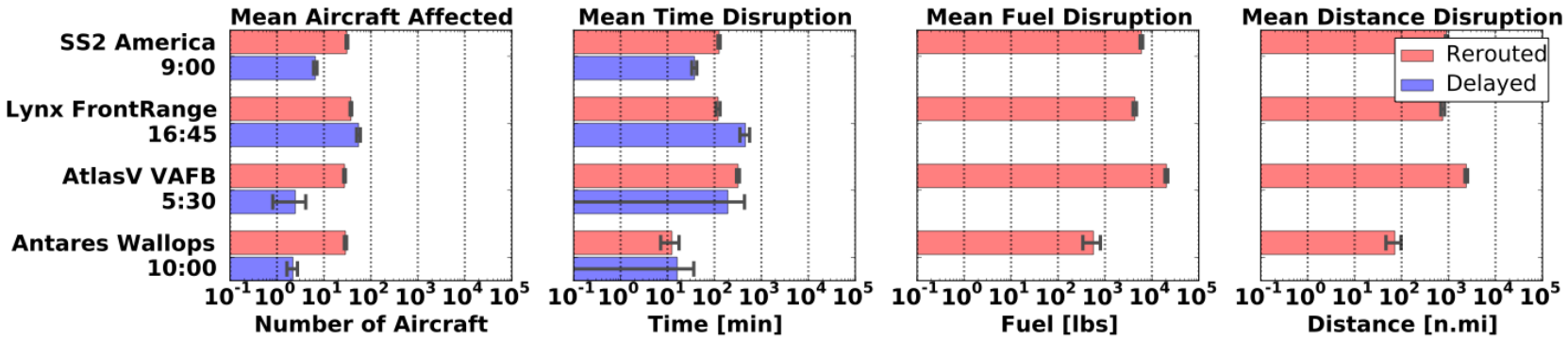
Traditional SUA vs 4D CE



NASA Ames Future ATM Concepts Evaluation Tool (FACET)

Airspace Disruption: Standard

Traditional: Mean Values of Aggregate Impact (N=90)

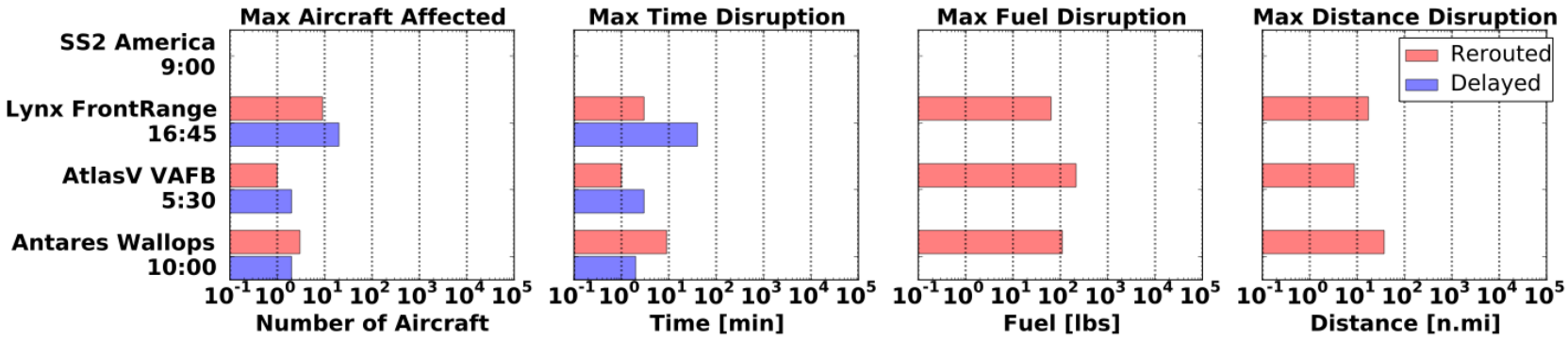


Mission	Rerouted	Delayed	Flight Delay	Ground Delay	Added Fuel	Added Distance
SS2 America	30.86	6.56	125.79	37.52	5989.59	904.73
Lynx FrontRange	37.53	54.64	119.78	454.16	4324.11	754.88
AtlasV VAFB	27.46	2.46	318.03	193.29	20387.36	2390.38
Antares Wallops	28.76	2.18	12.39	16.14	568.16	71.93
Units	Aircraft	Aircraft	Minutes	Minutes	Pounds	Nautical Miles

Colvin, T. J., Alonso, J. J., "Near-elimination of airspace disruption from commercial space traffic using compact envelopes," AIAA SPACE 2015 Conference & Exposition, AIAA Paper 2015-4492, 10.2514/6.2015-4492, Pasadena, CA, Sept. 2015

Airspace Disruption: 4D Compact Envelopes

Envelopes: Maximum Values of Aggregate Impact (N=90)



Mission	Rerouted	Delayed	Flight Delay	Ground Delay	Added Fuel	Added Distance
SS2 America	0.00	0.00	0.00	0.00	0.00	0.00
Lynx FrontRange	9.00	20.00	3.00	40.00	63.67	17.32
AtlasV VAFB	1.00	2.00	1.00	3.00	214.36	8.77
Antares Wallops	3.00	2.00	9.00	2.00	110.06	37.18
Units	Aircraft	Aircraft	Minutes	Minutes	Pounds	Nautical Miles

Note: Maximum values. Mean values nearly zero.

Colvin, T. J., Alonso, J. J., "Near-elimination of airspace disruption from commercial space traffic using compact envelopes," AIAA SPACE 2015 Conference & Exposition, AIAA Paper 2015-4492, 10.2514/6.2015-4492, Pasadena, CA, Sept. 2015

Assessing the Time to Clear Aircraft Hazard Areas (AHAs)

MITRE

August 15, 2017

MITRE

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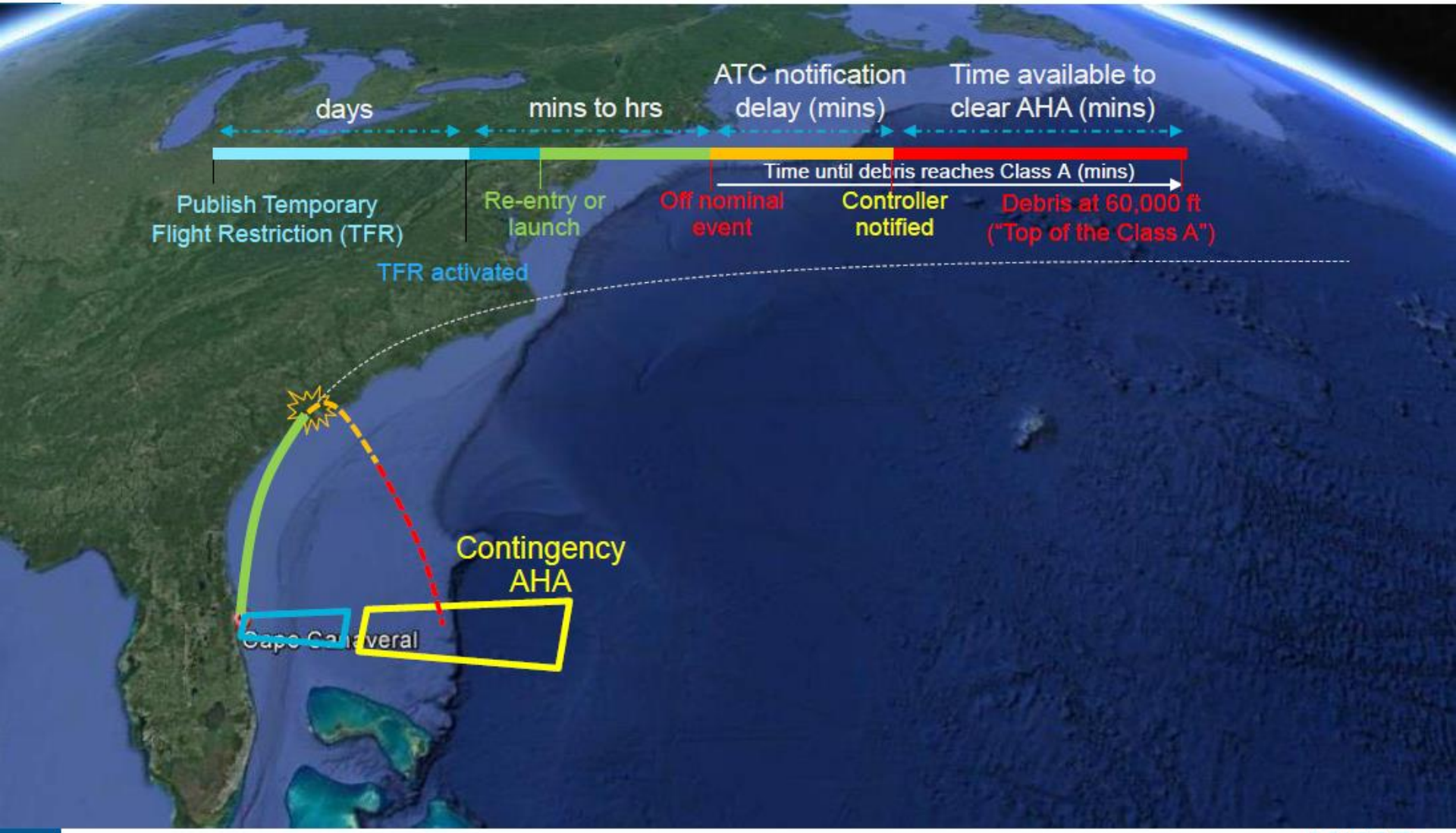
Work conducted under FAA-funded independent research and development, Outcome 8 (Mission-Oriented Investigation and Experimentation)

AHA Event Timeline



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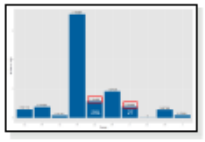
An Objective Method for Mitigating the Airborne Risk of AHAs During Space Flight Operations

A

Pr {Vehicular Failure at time t }

Historical Vehicle Performance Data (Range Risk Analysis Tool)



B

Pr{Aircraft in AHA at t | Event A}

Historical Traffic Data Through AHA at time t

B Mitigating Strategy: *Minimizing aircraft in AHA region at time t*

C

Pr{Unsuccessful Evacuation at t + allowable time buffer | Event B}

Simulation of Ad-Hoc Evacuation Procedures

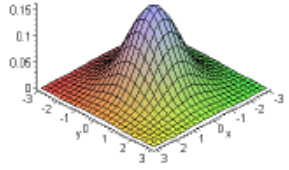
C Mitigating Strategy: *CONOPS to evacuate aircraft from AHA*

MITRE

D

Pr{AC Collides Debris |Event C}

Debris Models (Range Risk Analysis Tool)



Probability of Catastrophic Event = A x B x C x D ≤ Target Level of Safety

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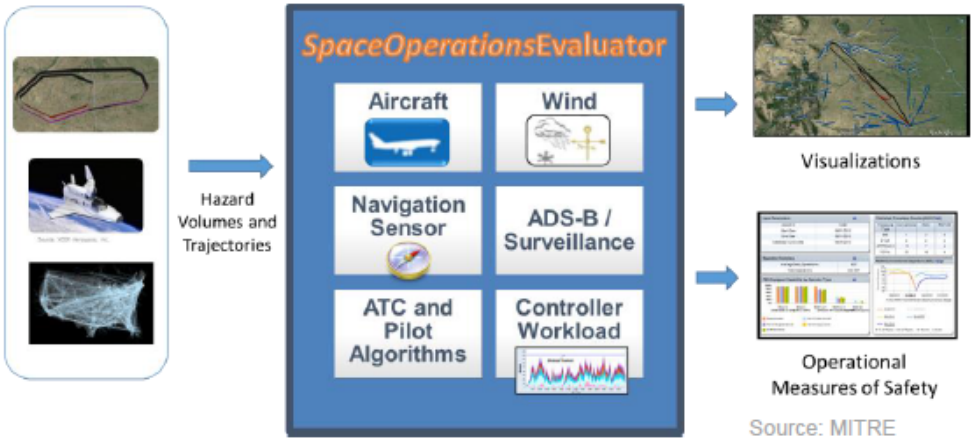
Analyses to Support Change and Enable More Space Traffic in the NAS

- **Research questions for ensuring safety**
  - How much time is needed for ATC to evacuate aircraft hazard areas (AHA)?
  - What are the appropriate ATC strategies and priorities for evacuating/avoiding them?
- **Goals of this research**
  - Provide quantitative data to evaluate procedures, standards, concepts, and tools
  - Identify emerging safety and risk issues
- **Approach**
  - Build on available models to create a fast-time simulation capability to evaluate the safety of launch and re-entry operations



Source: MITRE

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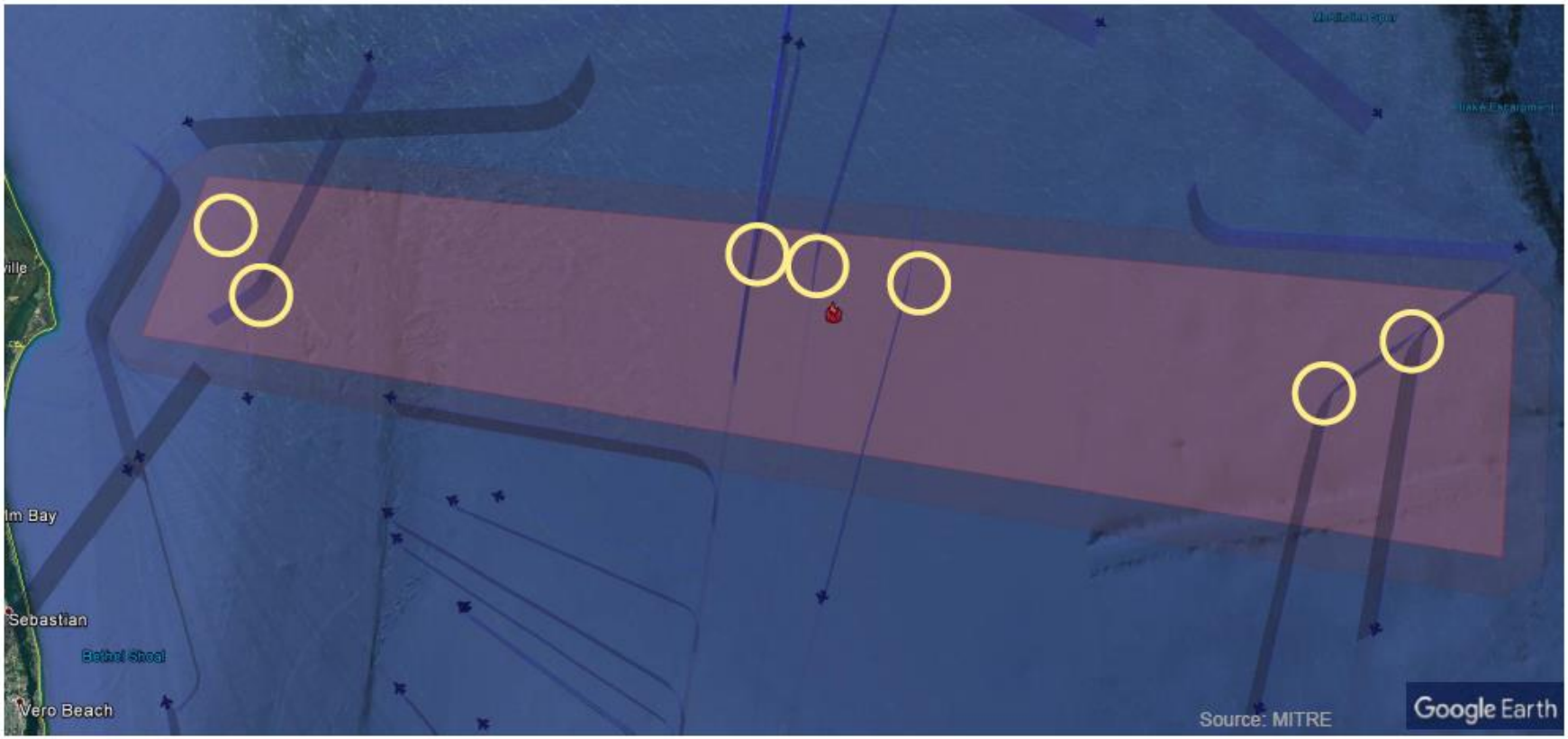
Visualization of Proposed Concept

- **Flights that could interact with a contingent (dynamic) AHA in red**



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Envisioned Stakeholder Usage

- Develop and assess ATC procedures during launch and reentry operations
- Bound performance requirements for potential solutions (e.g., surveillance, safety nets, and decision support tools)
- Evaluate scenarios for Human-in-the-loop simulations

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Collaboration

Stanford University

– Debris modeling

FAA Center of Excellence for Commercial Space Transportation

– Research/Industry Member

FAA AST & ATO

– Scenario development and trajectories

NASA

– Trajectory modeling

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Conclusions

Research conducted under the FAA Center of Excellence for Commercial Space Transportation has demonstrated:

1. Approaches that almost entirely eliminate the need for prolonged closure of extensive segments of the US NAS
2. There is sufficient time to evacuate transiting aircraft from Aircraft Hazard Areas and still meet target level of safety