Evaluating Space Launch Vehicle / Reentry Vehicle (LV/RV) Separation Concepts and Standards

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October 27-28, 2015

Arlington, VA

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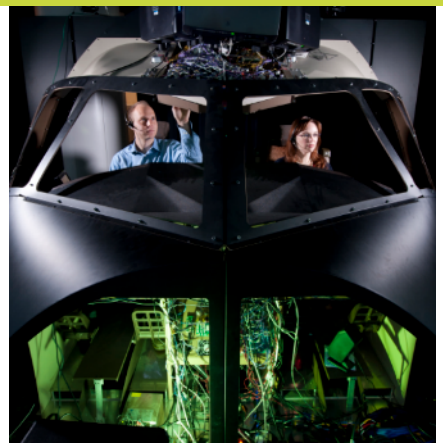

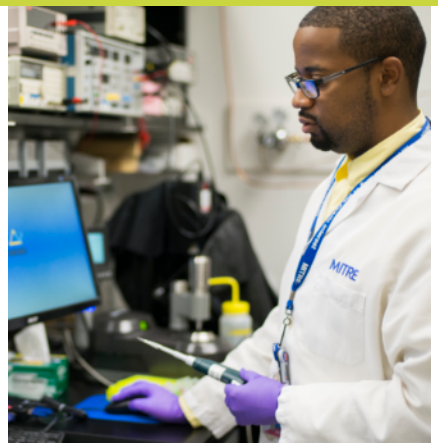

Team Members

Zheng Tao
Principal Investigator

Ganghuai Wang
Algorithms

Tudor Masek
Modeling

Ashley Williams
Developer

Tom St. Clair
ATC SME

Mark Banyai
Space SME

Jonathan Schwartz
Algorithms

Collaboration with COE CST

- **Juan Alonso - PI**
  - Francisco Capristan
  - Tom Colvin

- **Research/Industry Member**
- **Research Roadmap**

- **Office of Comercial Space Transportation**
  - Nick Demidovich
  - Dr. Paul Wilde

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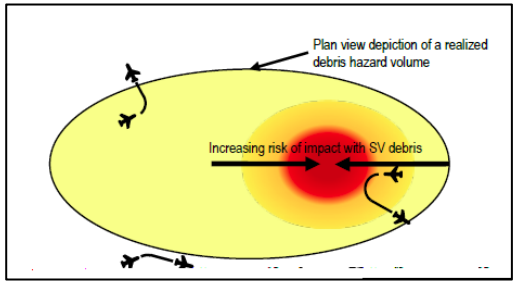
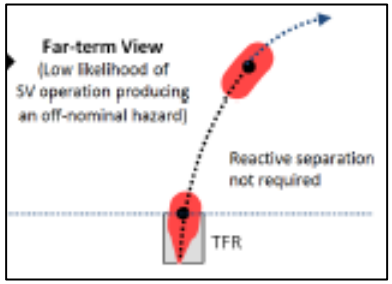
Research question

How to evaluate the safety of Launch Vehicle / Reentry Vehicle (LV/RV) separation concepts and associated standards?

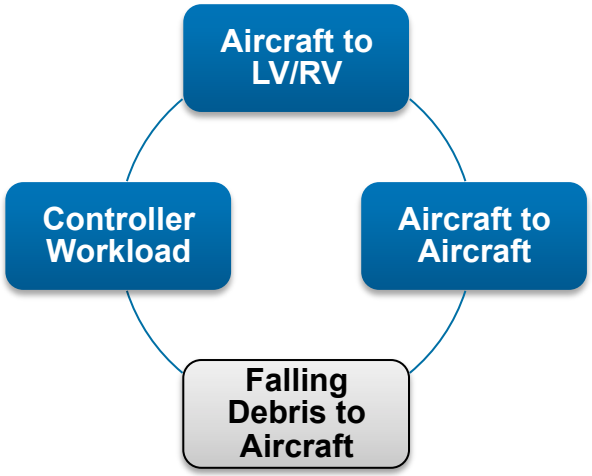
- **FAA NextGen Separation Concepts**





FAA, "Management of Space Vehicle Operations in the National Airspace System Concept of Operations," Version 1.1, August 2014.

- **Separation Standards for:**
  - Suborbitals
  - Flyback ops
  - Hybrid vehicles
  - Generic hazard areas



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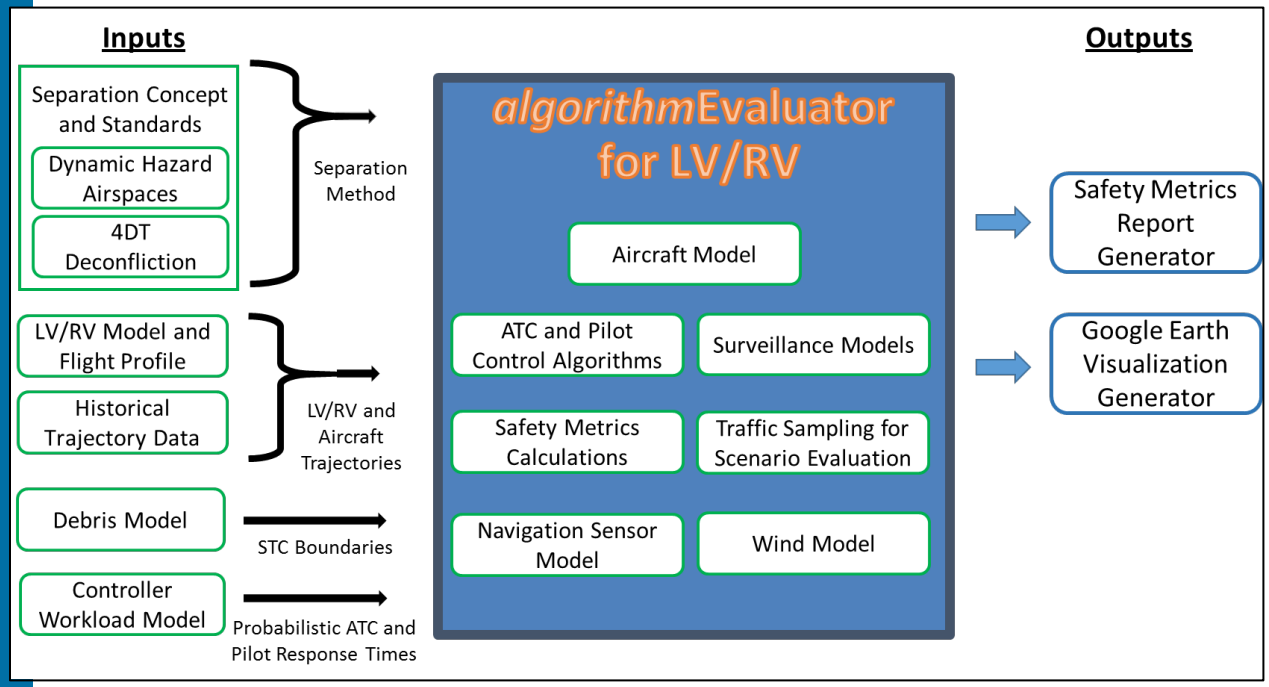
Approach

Develop a flexible, fast-time analysis capability to provide operational measures of safety to evaluate LV/RV separation concepts and standards



- **Insight into requirements for**
  - Surveillance, communications, navigation performance
  - Automation tools
- **Supports FAA's Safety Management System process**
- **Evaluate procedures and traffic flow considerations**

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Debris Modeling

Developed in-house debris trajectory estimator

- Adapted and enhanced from Stanford's debris propagator in their Range Safety Assessment Tool
  - Integrated into MITRE's space vehicle trajectory estimation tool
  - Other enhancements

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Metrics

- **Defined 8 operationally focused metrics to measure:**
  - Separation between Aircraft to LV/RV and Aircraft to Aircraft
  - Time and number of aircraft in hazard airspace and debris filed
  - Time to provide and execute commands
- **Qualitative metrics from observing visualizations**
  -
  - Sector loading
- **Preliminary findings to be published at Space Traffic Management Conference**

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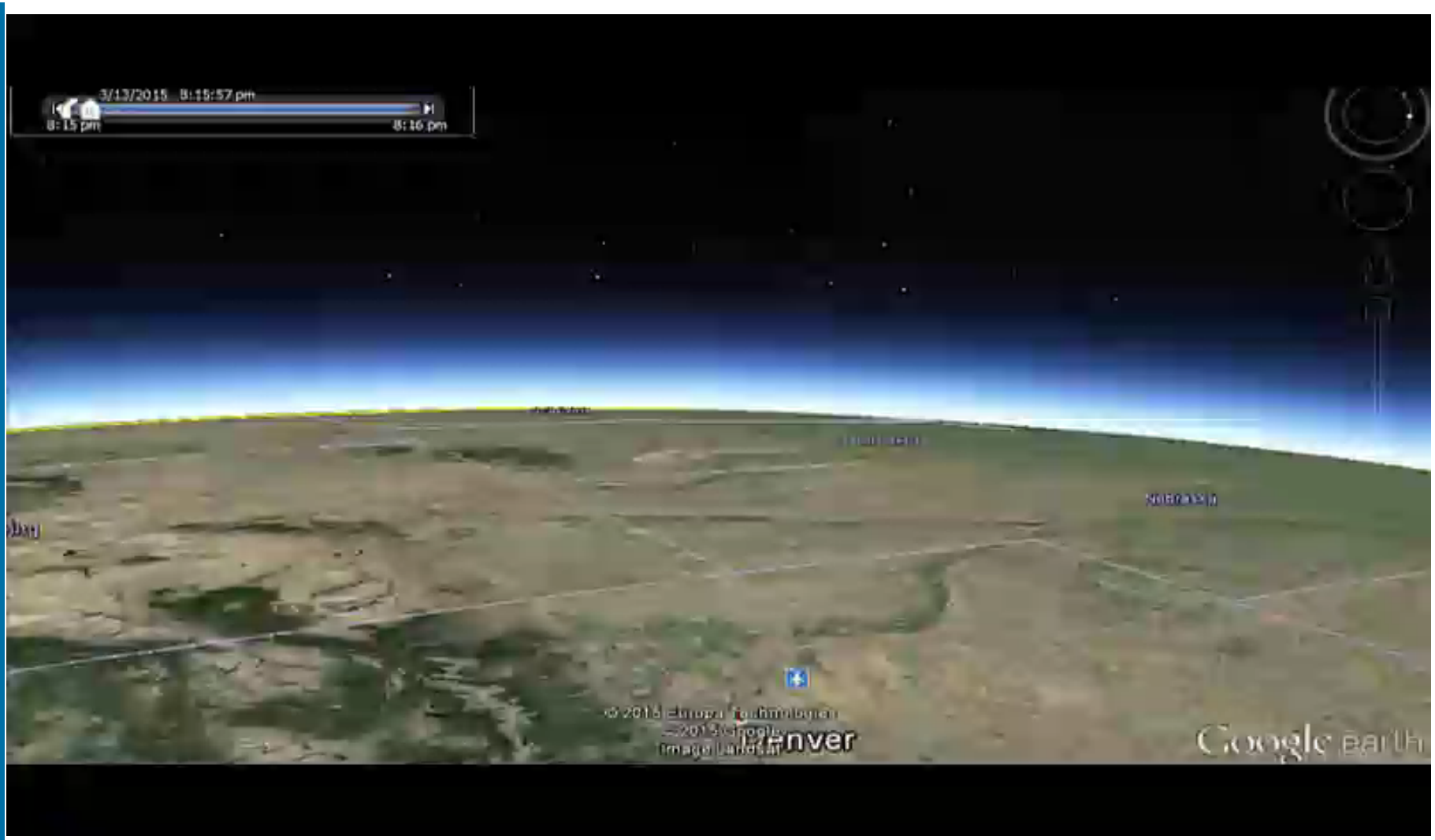
Debris Model Visualization



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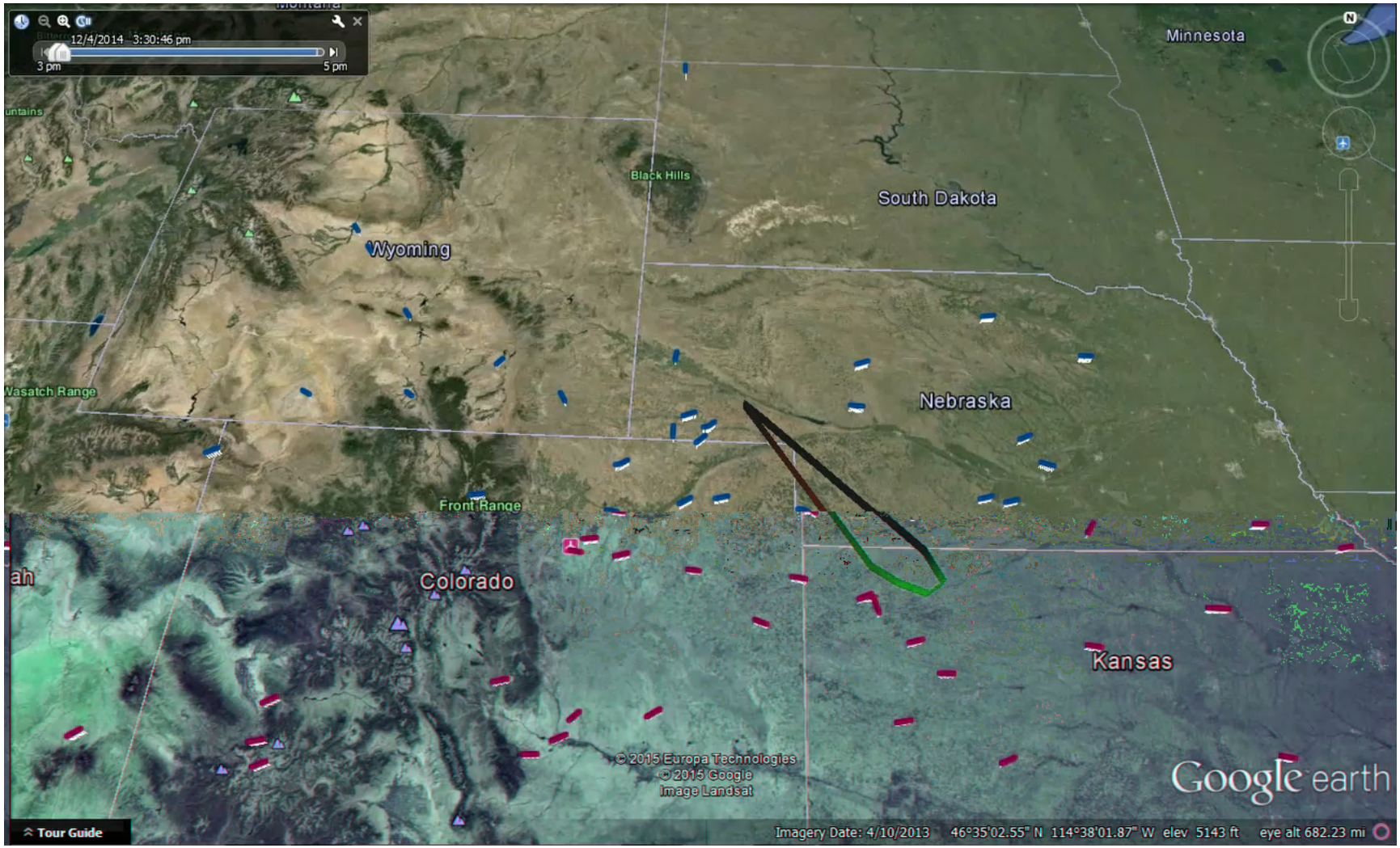
Capsule Re-entry Scenario Visualization



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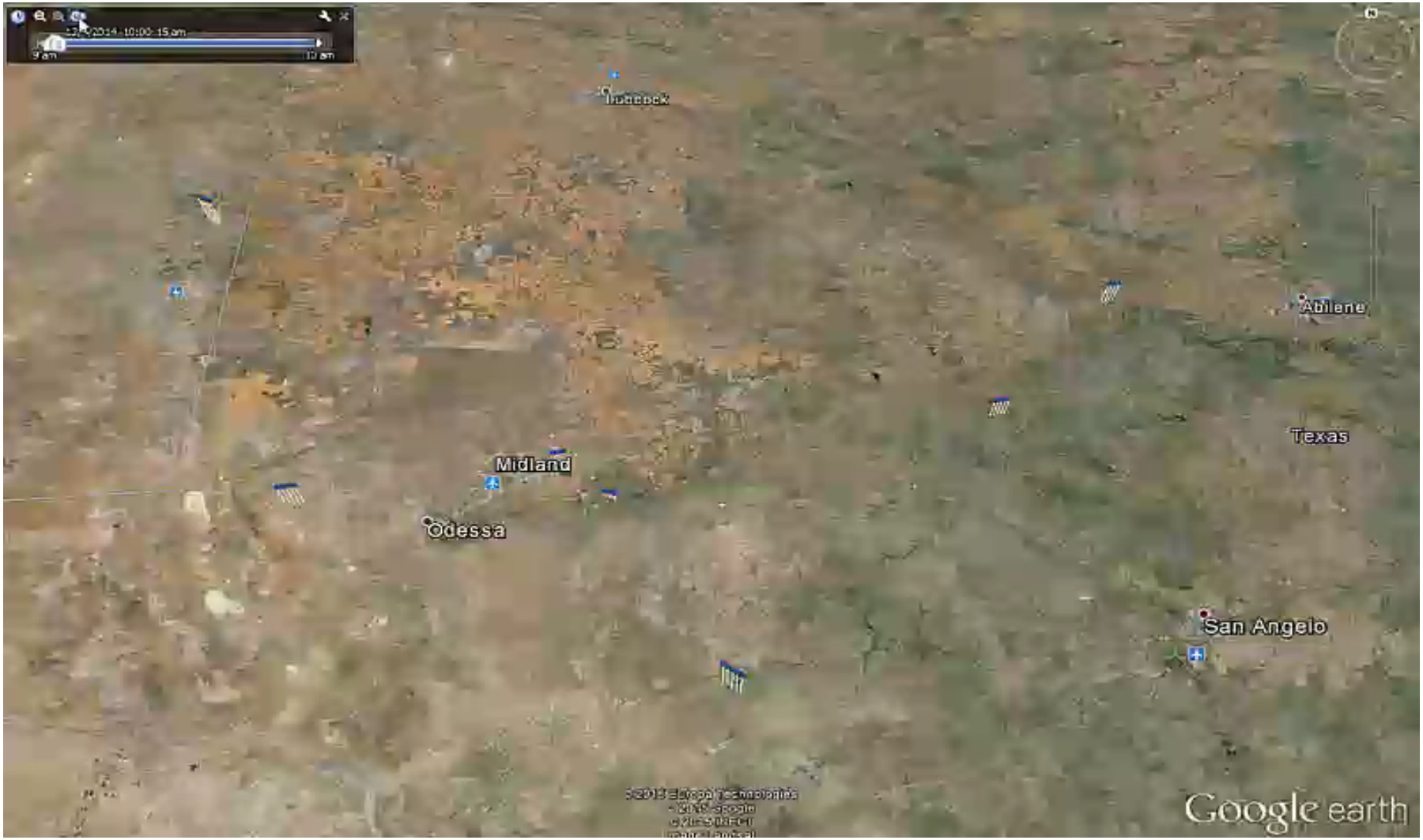
Spaceplane Arrival Scenario Visualization



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Status and Future Work

- **Developed an initial capability that can run and evaluate safety of LV/RV separation concepts and standards**
  - Outputs safety metrics and Google Earth visualizations
  - Preliminary findings to be presented at Space Traffic Management Conference (November 2015)
- **FY16 plan**
  - Confirm and assessing the model's performance
  - Improve trajectory models and algorithms
  - Evaluate potential separation standards for large generic hazard areas, flyback ops, suborbitals, or hybrid vehicles
  - International scenarios

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