

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

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**Zheng Tao**

**Ganghuai Wang**

***COE CST Fifth Annual Technical Meeting***

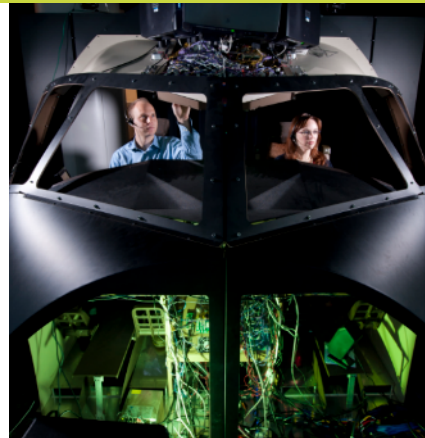
**October 27-28, 2015**

**Arlington, VA**

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➤ **1958**    **Not for Profit**    **Conflict Free Environment**    **Science & Technology**    **Present** ➤



# 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**

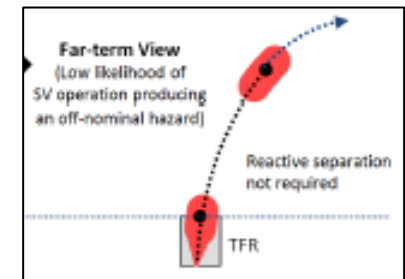
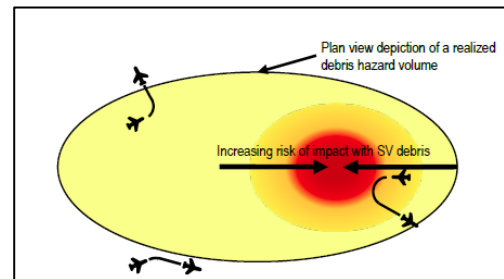


- **Office of Comercial Space Transportation**
  - Nick Demidovich
  - Dr. Paul Wilde

# Research question

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

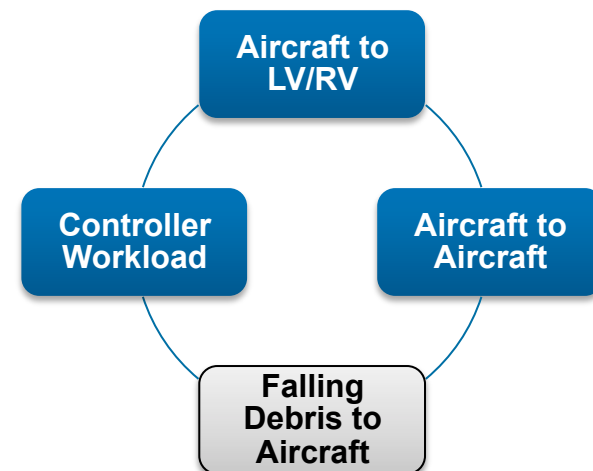
## ■ FAA NextGen Separation Concepts



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

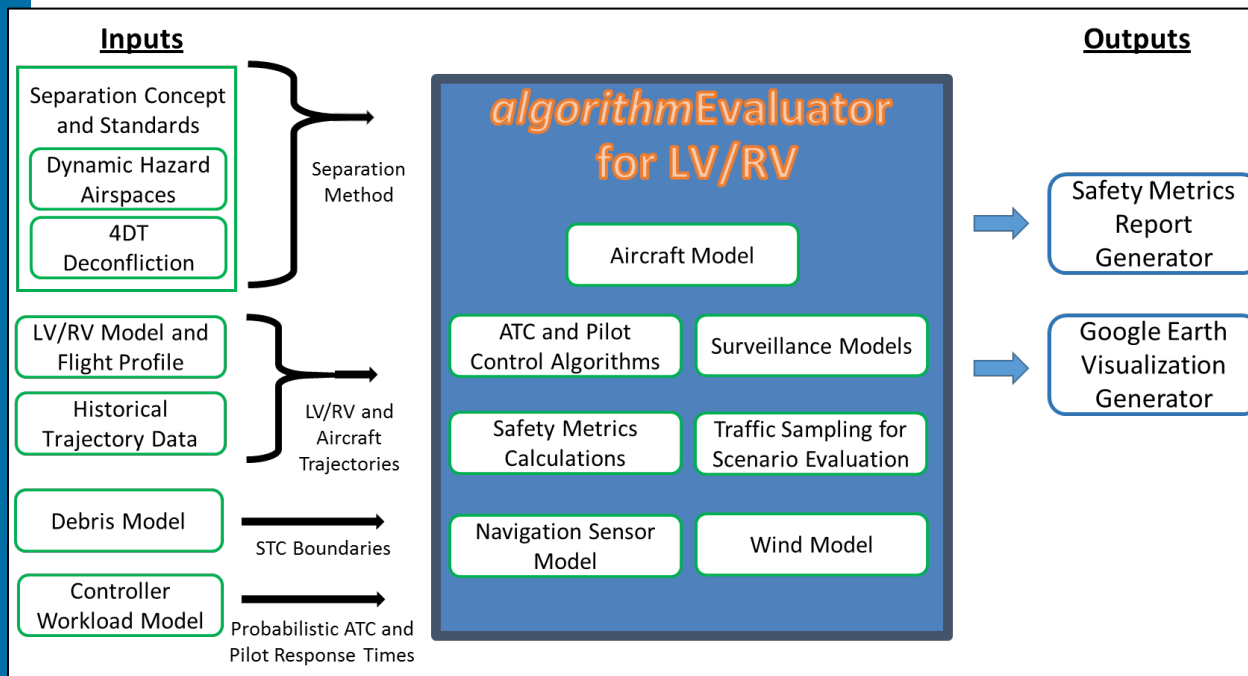
## ■ Separation Standards for:

- Suborbitals
- Flyback ops
- Hybrid vehicles
- Generic hazard areas



# 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**



# 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



# Metrics

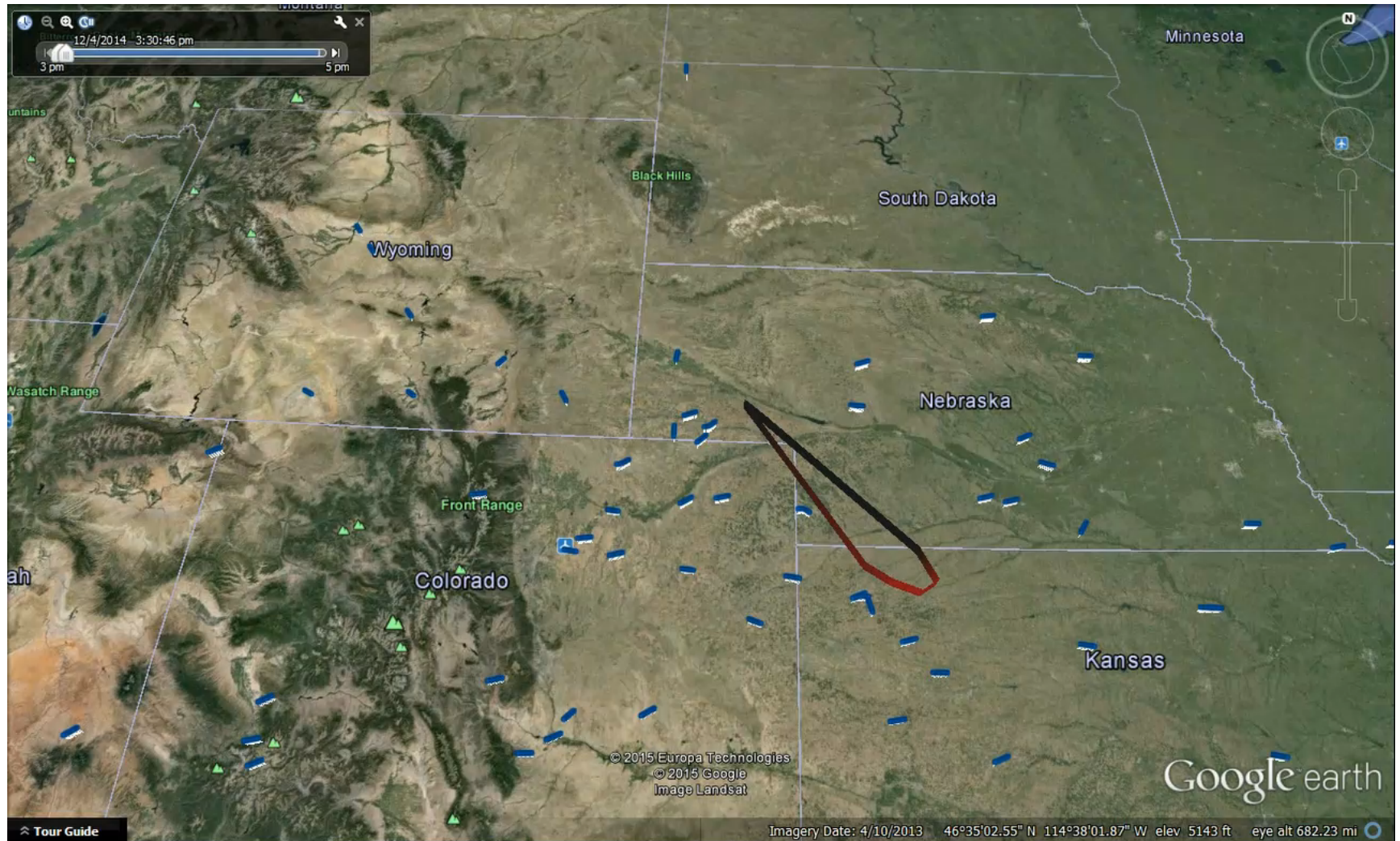
- **Defined 8 operationally focused metrics to measure:**
  - Separation between Aircraft to LV/RV and Aircraft to Aircraft
  - Time and number of aircraft in hazard airspace and debris filed
  - Time to provide and execute commands
- **Qualitative metrics from observing visualizations**
  - 
  - Sector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



# Debris Model Visualization

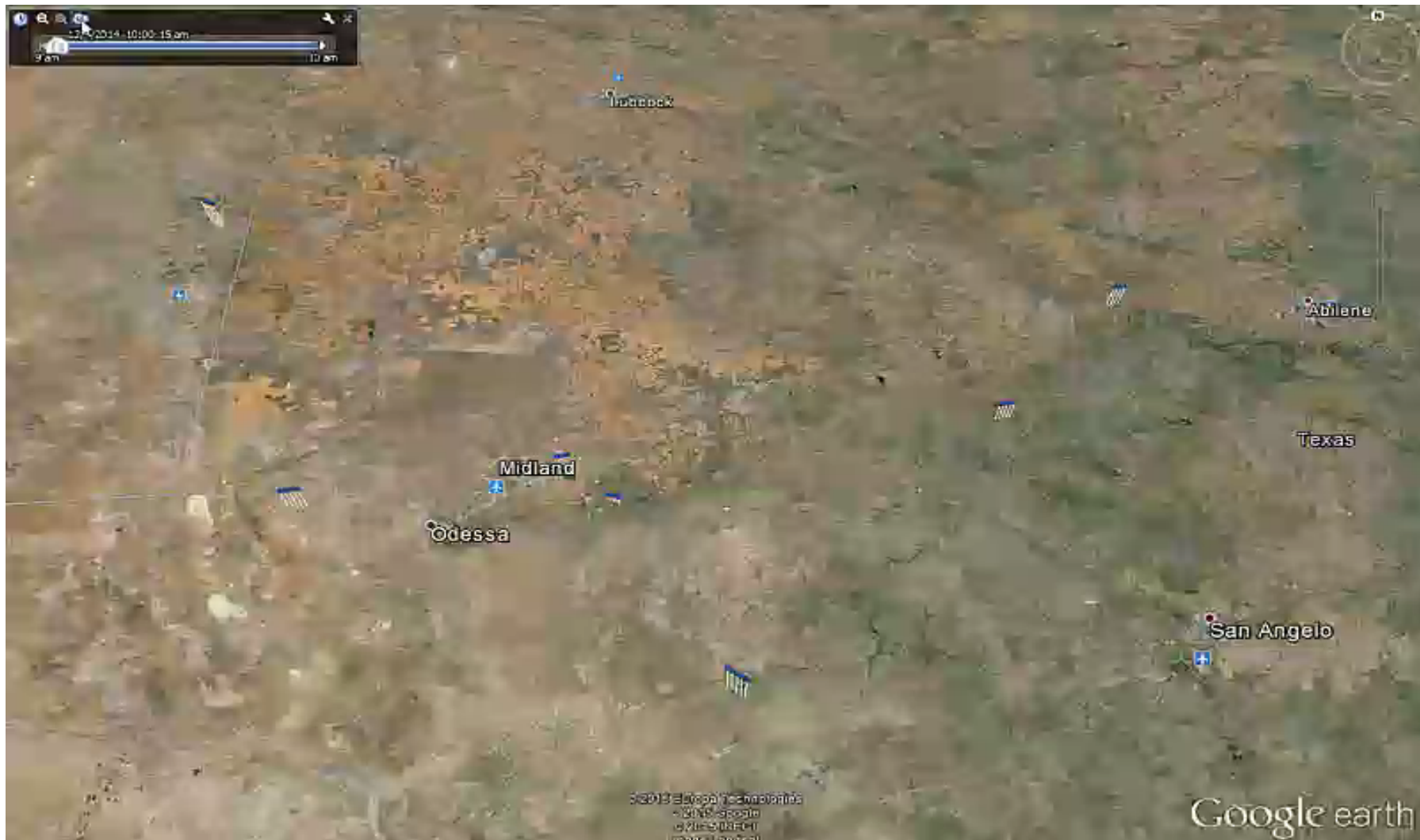


# Capsule Re-entry Scenario Visualization





# Spaceplane Arrival Scenario Visualization



# 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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