AST Commercial Space Transportation

Overview of the Commercial Space Transportation RE&D Program

To: REDAC NAS Ops Subcommittee
By: Dr. Paul Wilde, Deputy Chief Scientist
FAA Office of Commercial Space Transportation
Date: March 27, 2018

Federal Aviation Administration

Agenda

- Overview
  - AST Mission
- AST R&D Portfolio Overview
  - Example Tasks and Select Highlights in 4 Research Areas
  - Major Milestones
  - BLI Budget Summary
  - REDAC Recommendations – AST Responses
- Summary

Commercial Space Transportation

Federal Aviation Administration

3 sectors of U.S. space program: Civil, Military & Commercial

The FAA's Office of Commercial Space Transportation (AST) **regulates** the commercial sector

Dual Statutory Mission: (51 U.S.C. § 50901)

1. ***Ensure the protection of the public, property, and the national security and foreign policy interests of the United States during commercial launch and reentry.***
2. ***Encourage, facilitate, and promote U.S. commercial space transportation.***

The Dynamic Commercial Space Arena

- **National Space Council** – New and Evolving
- **DOT Strategic Plan** – Recently Released
- **FAA NARP** – Undergoing Metamorphosis
- **Industry Actors** – New entrant firms daily
- **Industry Activities** – New forms of operation and increasingly rapid paced ops

LEVELS OF R&D GOALS

ORGANIZATIONAL GOALS

R&D GOALS

National Space Council

White House & Congress

DOT Strategic Goals
- Safety
- Infrastructure
- Innovation
- Accountability

DOT

- Human Spaceflight Safety
- Increased Economic Competitiveness, PPP
- Innovation Development and Deployment
- Reduced Regulatory Burden, Streamlining

FAA Strategic Initiatives
- Enhance global leadership
- Make aerospace safer & smarter
- Deliver benefits through technology and infrastructure
- Empower & innovate with FAA's people

FAA

FAA NARP
- Improve Air-Space Safety
- Reduce Environmental Impact
- Improve Operational Effectiveness

AST 2018 Priorities
- Keep pace with industry
- Safely integrate CST into the NAS
- Continuously improve HSF safety
- Enable new and non-traditional CST
- **Streamline regulatory framework**
- Improve launch collision risk analyses

AST

AST R&D Goals
- Regulation Streamlining
- Innovation Development and Deployment
- Safely Reduce Airspace Closed to Other Stakeholders
- Spaceport Operations and Innovation
- Systemic Safety

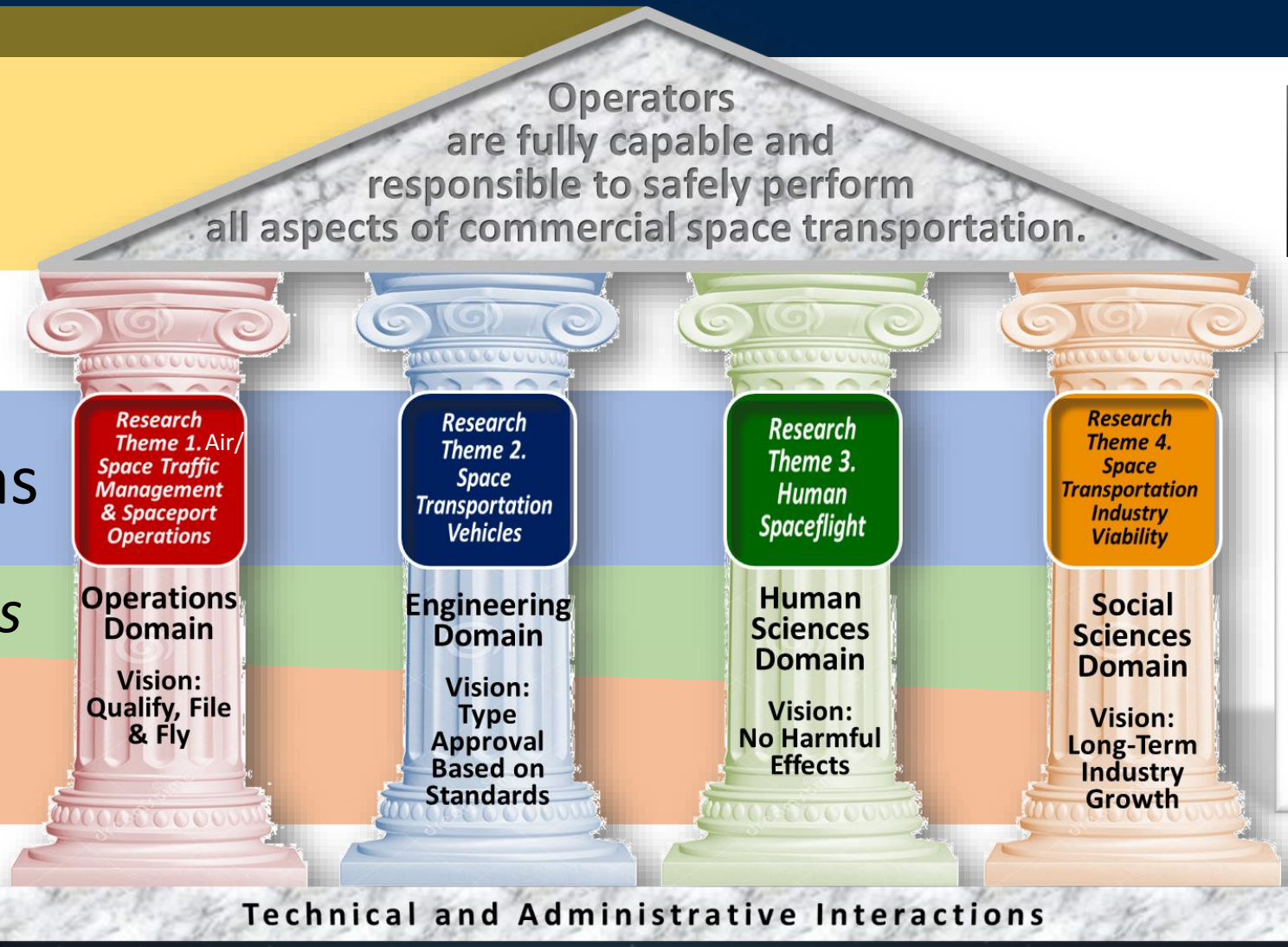
AST R&D Portfolio Overview

Program Goal

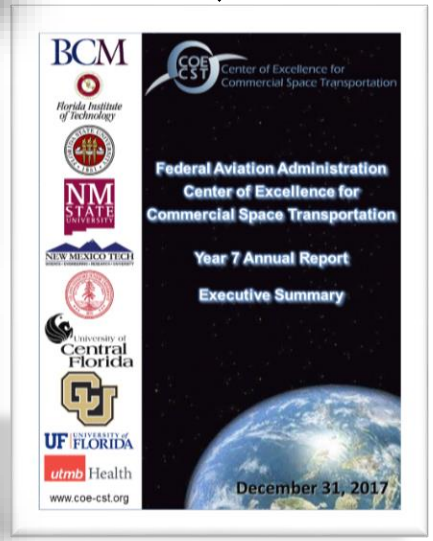
4 Research Areas

Academic Domains

Long-term Vision



For more details, refer to the COE CST Year 7 Exec Summary



COE CST Research Goals

Research Area	Research Goals Applicable to AST's Public Safety Mission	Research Goals Applicable to AST's Industry Promotion Mission
1. Air/Space Traffic Management and Spaceport Operations	• 1S1. Improved analytical and computational methods to evaluate safety of uninvolved public and property. • 1S2. Situational awareness and understanding of risk posed by resident space objects.	• 1P1. Safe and equitable sharing of the NAS by air and space transportation operators, with minimal disruption caused by commercial space traffic (outbound and inbound). • 1P2. Improved spaceport interoperability and development of necessary spaceport industry infrastructure resources.
2. Space Transportation Vehicles	• 2S1. Improve vehicle safety and risk analyses and management, including knowledge of all safety-critical components and systems of the space vehicles and their operations.	• 2P1. Improve the operational capabilities and efficiencies of space transportation vehicles, systems, and subsystems.
3. Human Spaceflight	• 3S1. Identification and reduction of avoidable risks of human spaceflight.	• 3P1. Facilitate the continuous improvement of the safety and efficiency of human-carrying vehicle operations both launch and reentry flight and ground operations.
4. Industry Viability	• 4S1. Develop improved criteria for evaluating public safety, such as performance based requirements for the protection of the public, property, and critical assets.	• 4P1. Encourage the growth of evolving space industry sectors through relevant economic, legal, legislative, regulatory, and market analyses & modeling. • 4P2. Support effective policy decision-making to achieve the dual regulatory and promotional missions of FAA AST. • 4P3. Provide a better understanding of the relationship of governmental policy, innovation adoption, and industry growth.

Commercial Space Safety Research Area 1 Strategy

Problems to be Solved

- Public Safety
- Airspace Integration
- Spaceport Interoperability

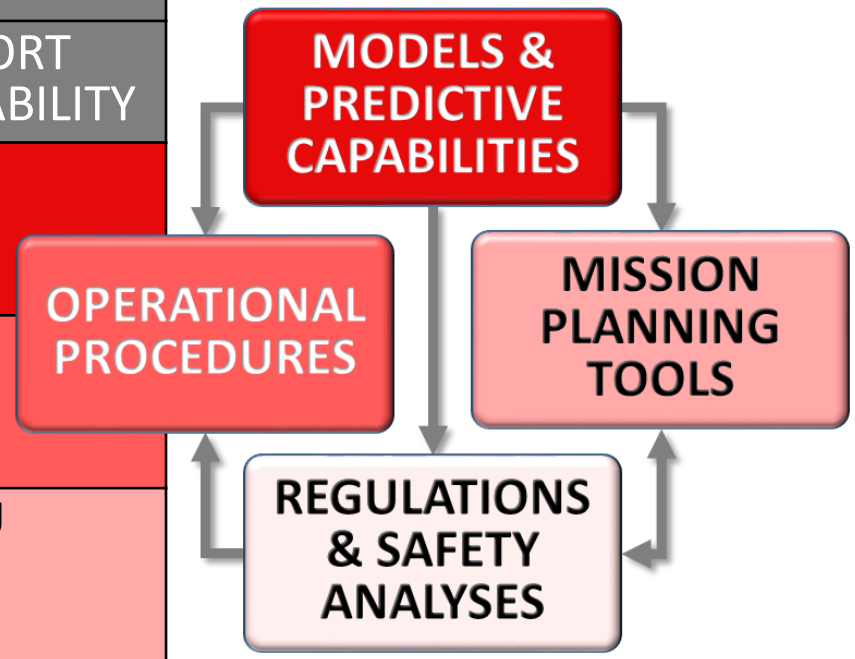
Approaches to Problem Solution

The creation, improvement, and validation of…

- Models & Predictive Capabilities
- Operational Procedures
- Mission Planning Tools
- Regulations & Safety Analyses

Commercial Space Safety Research Area 1 Sample Tasks

	The creation, improvement, and validation of...	PROBLEMS TO BE SOLVED: PUBLIC SAFETY	AIR/SPACE INTEGRATION	SPACEPORT INEROPERABILITY
APPROACHES TO PROBLEM SOLUTION	MODELS & PREDICTIVE CAPABILITIES	• 342-ACTA • 343A-ACTA • 343B-NASA	• 186-CU • 186-SU • 187-CU	• None
	OPERATIONAL PROCEDURES	• None	• 331-SU • 335-CSSI • 336B-Aerospace	• None
	MISSION PLANNING TOOLS	• 334-TBD	• 360-MITRE	• 220-NMSU
	REGULATIONS & SAFETY ANALYSES	• 340-ACTA	• None	• None



RA #1 Sample Task #s and Titles

Task #	FY16	FY17	Title
186-CU	X	X	Space Environment Modeling/Prediction
186-SU	X		Probabilistic Debris Model Development
187-CU	X		Orbital Object Location Prediction
306-NMSU/ERAU	X		ADS-B Research and Demonstration
307-NMSU/Satwest	X		Test of COTS Satellite Communications Systems
319-UF	X		Space Vehicle Fragmentation Characterization
331-SU	X		Advanced 4D Special Use Airspace Research
334-TBD		X	Spaceport Siting Analyses
335-CSSI	X		Separation Standards
336B-TBD	X		Monitoring of Launch/Re-Entry Vehicles
339A-TBD	X		DB History, Taxonomy, Requirements
340-ACTA	X		Dynamic Population Risk Analyses
342-ACTA	X		Launch/Reentry Vehicle Probability of Failure
343A-ACTA	X		Use of Vehicle Breakup Database
343B-NASA/ARC	X	X	Collect Launch and Reentry Breakup Data
360-MITRE	X	X	Safety of Launch and Reentry Operations in the NAS
367-CU		X	CubeSat Deployment Tracking
371-NMSU/UTAustin		X	Space Object Database
372-CU		X	Resident Space Object (RSO) System Mechanics
375-DLR		X	Interoperable Air and Space Traffic Management

TASK 186. CU: MITIGATING THREATS THROUGH SPACE ENVIRONMENT MODELING & PREDICTION

University of Colorado Boulder

PROJECT AT-A-GLANCE

- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. Tim Fuller-Rowell
- AST RDAB POC: Karen Shelton-Mur

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

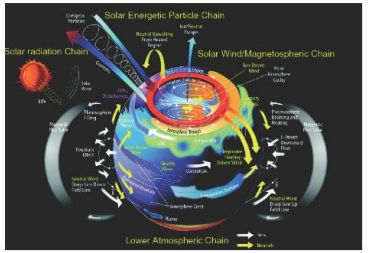
- An integrated air and space traffic management system requires real-time knowledge of environmental conditions and their impact on flight conditions from the ground to 600 km altitude, including:

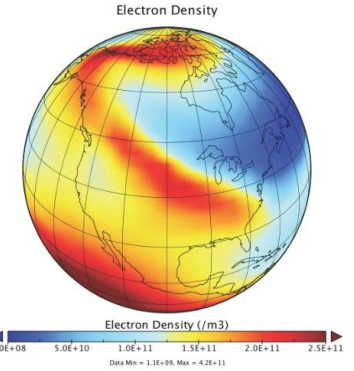
1. Neutral density variability and structure for on-orbit collision avoidance, spacecraft drag, and atmospheric re-entry, and forecast of near-surface and space weather conditions
2. Plasma density, D-region absorption, total electron content, ionospheric structure and irregularities, for impact on communications, navigation, and safety in flight

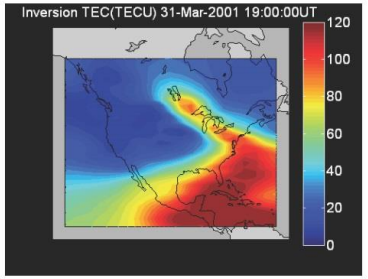
STATEMENT OF WORK

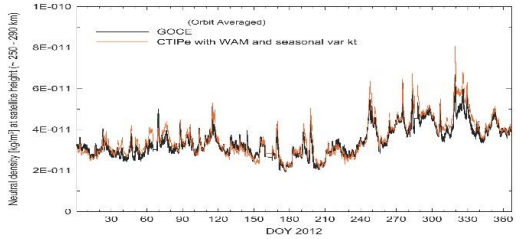
- Develop a seamless atmosphere-space model from the ground to 600 km altitude to fill gap between conventional weather and space weather conditions
- Develop terrestrial and space weather products tailored to suborbital and commercial space transportation needs
- Integrate terrestrial and space weather forecasts from one coordinated source

The Physical System (image courtesy of Joe Grebowsky)









STATUS

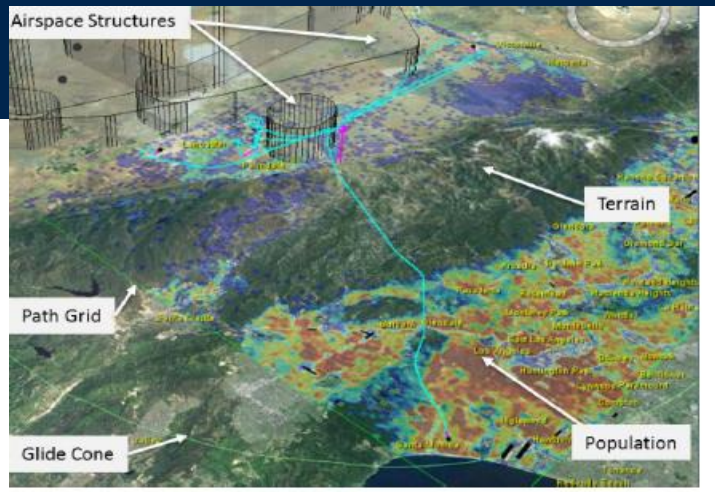
- Real-time NEMS-WAM with lower atmosphere data assimilation has been running in development mode for one year
- WAM has been coupled 1-way to a plasma model IPE

FUTURE WORK

- Compare WAM tidal and wind fields in the 100 to 150 km suborbital and re-entry region with satellite wind and temperature observations from SABER and WINDII.
- Compare WAM temperature structure with available ground-based LIDAR observations.
- Examine impact of WAM dynamic variability on the ionosphere.
- Begin to investigate how WAM/IPE fields can support CST.

- Benefits include hazard mitigation, facilitation of mission planning to ensure communication and data links, to better predict where debris would impact due to a reentry malfunction, etc.
- Aligns with DOT goals of Safety and Infrastructure.

Mission Planning & Spaceport Tool



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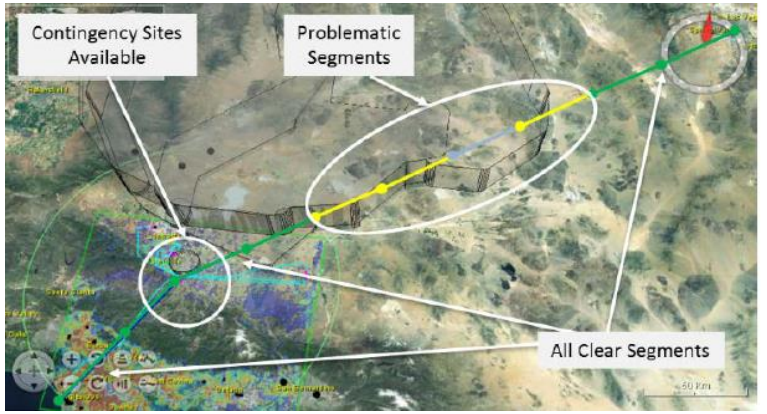
Project Goal:

Develop and implement a tool to assess risk and integration factors at established or prospective launch sites

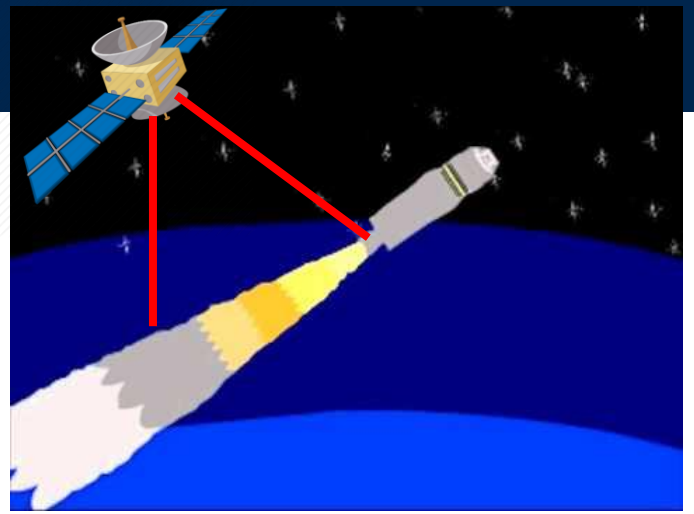
Project Objectives:

Develop a system to gather, organize, distribute data and analyze selected launch sites or proposed launch sites:

- Classes of Launch vehicles (Horizontal or Vertical takeoff)
- Aircraft keep out zones/Aircraft Hazard Areas (AHAs)
- Ground population (public safety)
- Ground critical infrastructure (modes of transportation)
- NAS integration and airports
- NEPA environmental impacts (e.g. sonic boom, noise, wildlife)
- Weather patterns



336B-Aerospace: Launch Vehicle Overhead Tracking Technical Support



PROJECT AT-A-GLANCE

- CONTRACTOR: Aerospace Corp.
- PRINCIPAL INVESTIGATOR(S): Bob Seibold, Greg Fruth
- TECHNICAL MANAGER: Nick Demidovich

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Potential to improve public safety for government and commercial space transportation programs by supplementing telemetry during ascent and reentry.
- Enables real time minimization of airspace closure and potentially warning of debris outside AHAs.
- Useful in post flight anomaly resolution also.

STATEMENT OF WORK

- Investigate feasibility of using existing overhead sensor assets to track launch and reentry vehicles and compare the results both to actual flight path data derived from telemetry and data from ground-based sensors.

STATUS

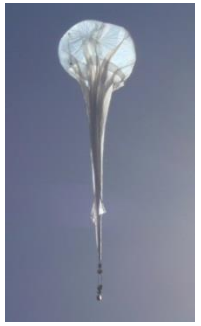
- Initial phase of task complete (ascent focus)
- Report due in early April will describe how launch vehicle tracking information from the overhead sensors could be disseminated for an actual launch.

FUTURE WORK

- Investigate feasibility of reentry tracking.
- Strategy to further develop capability and integrate with SDI or otherwise improve real-time response.
- Fusion of IR with radars and or telemetry is optimal.

Select Highlights/Accomplishments for RA #1

- Demonstrated advanced ADS-B tracking capabilities
  - Hosted on a variety of rocket powered vehicles, stratospheric balloons, and an RV prototype with various trajectories
  - Advanced prototype ADS-B does function at> 4G, 60Kft, 1000kts (unlike aircraft ADS-B); flew to 70+ miles altitude
  - Showed ADS-B meets most applicable requirements for tracking sources used by range safety (RCC-324-01, Appendix A)

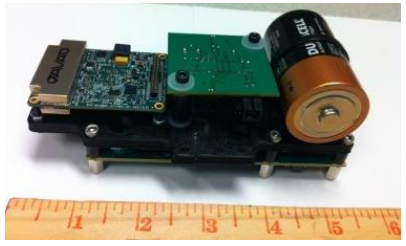


Near Space Corp. Balloon

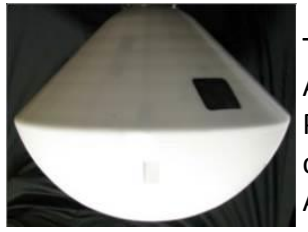
Masten Space Systems Xombie RLV

UpAerospace SpaceLoft "Sounding Rocket" like RLV

Near Space Corp High Altitude Shuttle System (HASS) -Winged RLV surrogate



UBR-ERAU Advanced ADS-B Transmitter

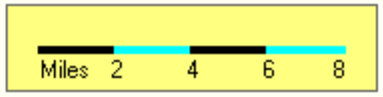


Terminal Velocity Aerospace Prototype commercial RV And REBR

Select Highlights/Accomplishments for RA #2

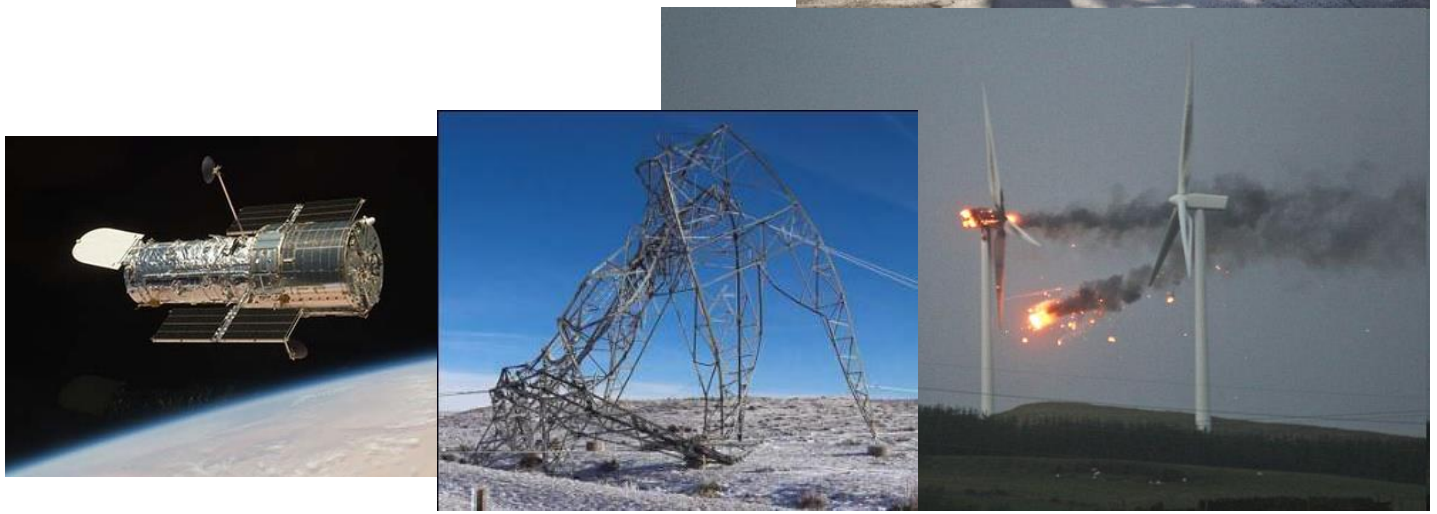
- NARP milestone
  - Compared debris predictions to empirical evidence from recent mishaps to identify potential areas for improvement in public safety assessments
  - Showed small adjustments to SS2 debris list (for high beta frags) produces model results that match PF04 actual debris impacts

Computed debris footprint using RRAT (95% confidence ellipses) and best available input data matches well with recorded debris impact locations



Select Highlights/Accomplishments for RA #4

- Drafted property protection criteria
  - Six types of property accounted for
    - Utility infrastructure
    - Transportation & other infrastructure
    - Emergency response facilities
    - Hazardous facilities (i.e. potential secondary effects)
    - Range critical assets
    - Significant cultural, historical, environmental site
    - Satellites



Outputs for 2019 - 2020

2019 – Report of recommended criteria by which operators can assess their compliance with specific FAA regulations related to human factors of suborbital winged commercial spaceflight vehicle design, mission design, restraint and stowage, and vehicle operations.

2019 – Gap analysis between applicable commercial space regulations, vehicle profiles and performance characteristics and current airport design guidance, standards, regulations.

2019 - Identify improved methods for assessing a proposed launch or reentry site location for its impact on the public, to include airspace and airport operations, other transportation modes, population centers, and critical national assets

2020 - Develop and assess separation standards for improved airspace management of launch/reentry vehicles, such as hybrids and manned stratospheric balloons, during non-explosive phases of flight

2020 – Terrestrial and space weather model that will permit improved prediction of environmental conditions for safe and efficient launch and re-entry operations tailored to CST industry needs.

2020 - Identify draft recommended practices for autonomous flight safety systems

2020 - Develop refined approaches to estimate failure probabilities for RLVs

BLI A11.n Commercial Space R&D Summary

- FY2016 President's request included Commercial Space Transportation Safety RE&D budget line for the first time
- Budget is far too low to address all CST research needs:
  - AST has repeated requested substantial increases
  - For FY19, lack of major cut in the PBR showed priority on CST R&D

FY	16	17	18	19	20	21	22
Status	Approp	Approp	PBR	Est	Est	Est	Est
Funding ($K)	2,000	2,453	1,796	2,500	2,433	2,393	2,352

BLI Budget Summary

A11.n Program	FY16	FY17	FY18	FY19
A11.n Appropriation/Estimated	**2,000**	**2,453**	**2,780**	**2,500**
1. Air/Space Traffic Mgt & Spaceport Ops	**673**	**595**	**1,030**	**930**
1.1 Air/Space Traffic Integration	434	221	510	555
1.2 Risk-based Launch & Reentry Collision Safety	189	344	300	275
1.3 Spaceport Operations	50	30	220	100
2. Space Vehicle Safety Systems and Technologies	**742**	**537**	**695**	**515**
3. Human Spaceflight Safety Research	**187**	**319**	**300**	**255**
4. Regulation and Policy Innovation Research	**153**	**350**	**445**	**450**
5. Administration	**250**	**284**	**310**	**350**

all table entries K$

REDAC NAS Ops Subcommittee Recommendations

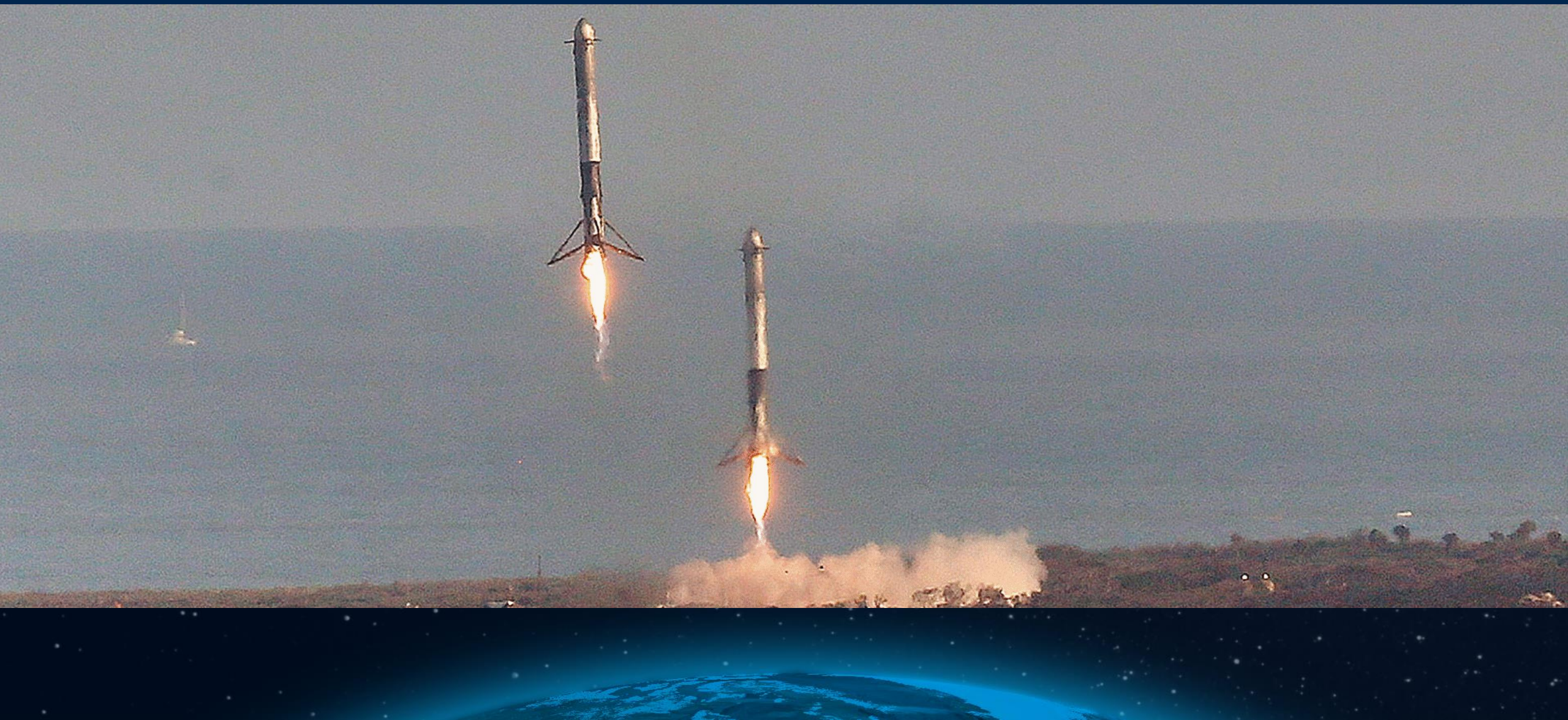
Recommendation (R1)

- The Subcommittee recommends that the Commercial Space R&D be prioritized and limited to those activities that directly support early integration of Commercial Space into the NAS.
- Lower-priority activities, such as those in pillar 4, should be stopped completely.

R1 Response

- By law, AST is responsible for ensuring public safety AND promoting, encouraging and facilitating the industry.
- Research pillar 4 directly addresses the responsibility to encourage, facilitate and promote and includes critical activities such as regulatory reform.
- AST has a full range of responsibilities for licensing commercial space launches that are well beyond airspace integration.

AST welcomes the opportunity to engage REDAC NAS Ops Subcommittee in discussions to address all topics of mutual interest.



Back-Up

“Commercial Space” is …

- Commercial space is comprised of various sectors (and segments), with different characteristics and needs.

- Heavy cargo to orbit: *mature-evolving, production*
- Light cargo to orbit: *emerging, pre-production*
- Humans to orbit: *mature-evolving, pre-production*
- Small payload suborbital: *mature-evolving, production*
- Human suborbital: *emerging, pre-production*
- High-altitude balloons: *emerging, pre-production*
- Spaceports: *emerging, production*

- Earth Observation
- Satellite Communications
- Space Science
- Launch Services
- Security
- Satellite Navigation
- Human Spaceflight
- Space Manufacturing
- Debris Removal

Commercial Space Research R&D – Select Criteria

- **Criteria 1. Ensure programs are based on sound science:** The use of COE CST and highly qualified contractors ensures that the CST research (BLI A11.n) adheres to the highest quality of research. Researchers (both contractor and university) are encouraged to publish their non-proprietary findings in peer-reviewed journals to ensure rigorous academic review, and maximum diffusion of research results.
- **Criteria 3. Ensure research has the potential to contribute to the public good:** All Commercial Space Transportation research (BLI A11.n) contributes to the public good through dual goals of ensuring the safety of uninvolved public, and encouraging the long-term viability of CST industry segments.
- **Criteria 4. To the extent possible, develop and utilize quantitative metrics to evaluate R&D outcomes and effectiveness of STEM programs:** Quantitative metrics of R&D inputs and outputs are maintained to the greatest extent possible, but meaningful qualitative metrics are also collected to measure the effectiveness R&D.
- **Criteria 5. Utilize partnerships to innovate and create new aviation products/services for the American people:** The use of COE CST universities ensures that the CST research (BLI A11.n) is conducted in a partnership environment of academia, industry, and government. Partnerships are imperative for the execution of COE CST research.
- **Criteria 7. Consider modification or elimination of R&D programs where Federal involvement is no longer needed or appropriate:** Federal research is justified for specific CST industry segments that are evolving, emerging, and/or pre-production states.
- **Criteria 8. Give priority to funding basic and early-stage applied research...:** The CST research program mixes research with different foci, including diffusion-oriented (most akin to “basic” research) and mission-oriented (most akin to “applied” research, regardless of stage).
- **Criteria 12. Incorporate STEM education and workforce training opportunities into programs:** See response to Criteria 13.
- **Criteria 13. Give priority to policies and actions that place an emphasis on expanding the STEM workforce:** As in the case of Criteria 12, university research, conducted by PhD students, is inherently an educational process, expanding and developing a workforce with highly specialized and advanced skills.
- **Criteria 16. Manage long-term, multi-year investments, so that resources are not wasted at the end of the fiscal year:** Long-term, multi-year research budgeting planning, integrated with annual technical performance review, is implemented to ensure year-to-year continuity of research activities.