Florida Institute of Technology

Florida State University

NM State University

New Mexico Tech

Science • Engineering • Research • University

Leland Stanford Junior University

University of Central Florida

UF University of Florida

utmb Health

www.coe-cst.org

COE CST

Federal Aviation Administration Center of Excellence for Commercial Space Transportation

Year 1 Annual Report

Executive Summary

Executive Summary

December 2011

Federal Aviation Administration
Center of Excellence for Commercial Space Transportation
Year 1 Annual Report Executive Summary

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PREFACE

The Federal Aviation Administration (FAA) Office of Commercial Space Transportation (AST) is pleased to release this FAA Center of Excellence for Commercial Space Transportation (COE CST) Year 1 Annual Report Executive Summary.

For more information about the content of this report, please visit the COE CST web site at www.coe-cst.org.

Please address any questions or corrections to COE CST Program Manager, Ken Davidian, 202-267-7214, ken.davidian@faa.gov.

- December 14, 2011

INTRODUCTION

This executive summary accompanies a more detailed annual report of the FAA Center of Excellence (COE) for Commercial Space Transportation (CST) that began operation on August 18, 2010.

This executive summary begins with overviews of the FAA Office of Commercial Space Transportation (the sponsoring organization), the FAA COE Program and the COE CST. The time period covered in this summary includes the first year of COE CST operation, starting on August 18, 2010 and ending on August 17, 2011.

Next, brief introductions to each of the nine member universities are provided, with general descriptions as well as specific strengths the universities bring to the COE CST.

Finally, the scope of COE CST research areas are given and each of the research tasks initiated and conducted under the COE CST during the first year of operation is listed and summary information of each is provided.

OVERVIEWS

FAA OFFICE OF COMMERCIAL SPACE TRANSPORTATION (AST)

As of August 2011, the FAA Office of Commercial Space Transportation (AST) is comprised of approximately 80 full time equivalent (FTE) civil servants and operates with a budget of $15 million. (By contrast, the FAA has 48,000 FTEs and a total budget of $15 billion.) Despite its relatively small size, AST has an important set of responsibilities as described in their mission and defined in the Code of Federal Regulations, Title 51 US Code Subtitle V, Ch. 509. The two main goals of AST are:

- Regulate the commercial space transportation industry, only to the extent necessary, to ensure compliance with international obligations of the United States and to protect the public health and safety, safety of property, and national security and foreign policy interest of the United States.
- Encourage, facilitate, and promote commercial space launches and re-entries by the private sector.

FAA CENTER OF EXCELLENCE (COE) PROGRAM

The FAA Center of Excellence (COE) program was established by the Omnibus Budget Reconciliation Act of 1990, Public Law 101-508, Title IX, Aviation Safety and Capacity Expansion Act.

COEs are intended to be a 10-year partnership of academia, industry, and government to create a world-class consortium that will address current and future challenges for commercial space transportation. The three main goals of every COE include research, training, and outreach.

A unique attribute of the COE program is the one-to-one matching requirement for every federal dollar granted to a COE university. The matching requirement can be satisfied through direct or in-kind contributions from any non-federal funding source, including industry, universities, or state and local government organizations.

Eight other COEs have been established by the FAA that pre-date the COE CST, including:

- The Joint Center for Computational Modeling of Aircraft Structures, 1992 to 1996.
- The Center of Excellence for Airport Technology (CEAT), established 1995.
- The National COE for Aviation Operations Research (NEXTOR), 1996 to 2007.
- The Airworthy Assurance COE (AACE), 1997 to 2007.
- The COE for General Aviation Research (CGAR), established 2001.
- The Partnership for Aircraft Noise & Aviation Emissions Mitigation Research (PARTNER), established 2003.

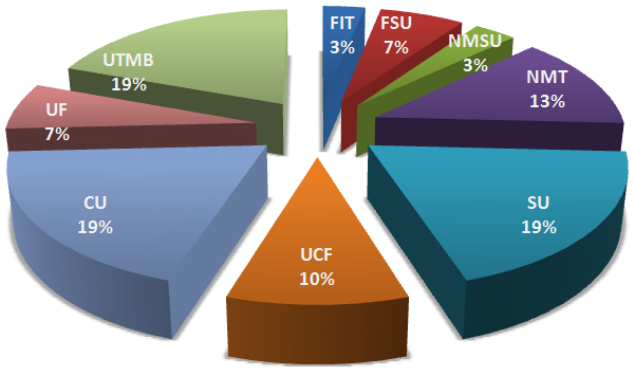
- The Joint Center for Advanced Materials (JAMS), established 2003.
- The Airliner Cabin Environment Research (ACER) Center, also called the COE for Research in the Intermodal Transport Environment (RITE), established 2004.

FAA CENTER OF EXCELLENCE FOR COMMERCIAL SPACE TRANSPORTATION

FUNDING DETAILS

- FAA Funding Year 1 Level: $2M (FY10)

Distribution of COE CST Students by University



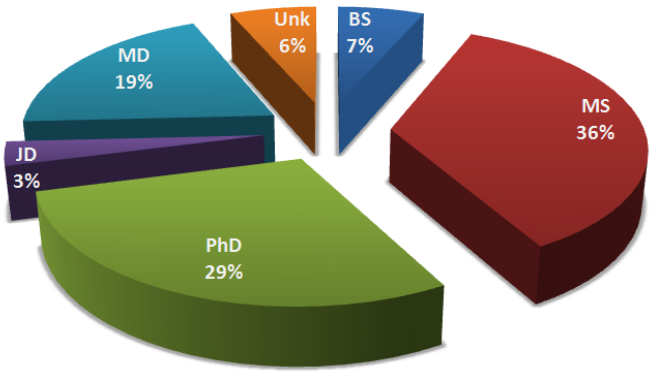
MEMBER UNIVERSITIES

The nine COE CST member universities are:

- Florida Institute of Technology (FIT, or Florida Tech)
- Florida State University (FSU)
- New Mexico Institute of Mining and Technology, (NMT, or New Mexico Tech)
- New Mexico State University (NMSU)
- Stanford University (SU)
- University of Central Florida (UCF)
- University of Colorado at Boulder (CU)
- University of Florida (UF)
- University of Texas Medical Branch at Galveston (UTMB)

The COE CST member universities provide a comprehensive distribution of geographical coverage representing the entire Commercial Space Transportation industry, including the top four civil space states (California, Colorado, Texas and Florida) and New Mexico, the state leading the suborbital industry as well as having a significant level of military space activity. Combined, the nine universities bring over 50 other government, industry and academic organizations as research partners.

Distribution of Degrees Sought by COE CST Students



RESEARCH TASKS

- Number of Research Tasks: 25
- Number of Principal Investigators: 27
- Number of Students: 31

Distribution of students by university and degree are shown in the graphs to the right.

COE CST YEAR 1 HIGHLIGHTS

The following are the major milestones for the FAA COE CST during its first year of operation:

- COE CST Public Announcement Date: August 18, 2010
- Execution Dates of Cooperative Agreements: September 15, 2010.
- Meeting #1: Oct 21, 2010, held in Las Cruces, NM.
- Meeting #2: Nov 9-10, 2010, hosted by UTMB in Galveston, TX.
- Meeting #3: Feb 9, 2011, held in conjunction with the AST Conference in Washington, DC.
- Meeting #4: Nov 8-9, 2011, the First Annual Technical Meeting held in Boulder, CO.

COE CST MEMBER UNIVERSITIES

As a single entity, the nine COE CST member universities bring complementary strengths together for the benefit of the overall COE. FAA finds that each team member provides highly respected and accomplished experiences that directly address the research and study needs of the commercial space industry.

This section provides more detail on each of the nine member universities of the COE CST.

FLORIDA INSTITUTE OF TECHNOLOGY (FIT)

Florida Tech (FIT) offers broad expertise in aerospace and space-related engineering, science, space traffic management and launch operations, vehicle and payload analysis and design, thermal systems and propulsion.

FLORIDA STATE UNIVERSITY (FSU)

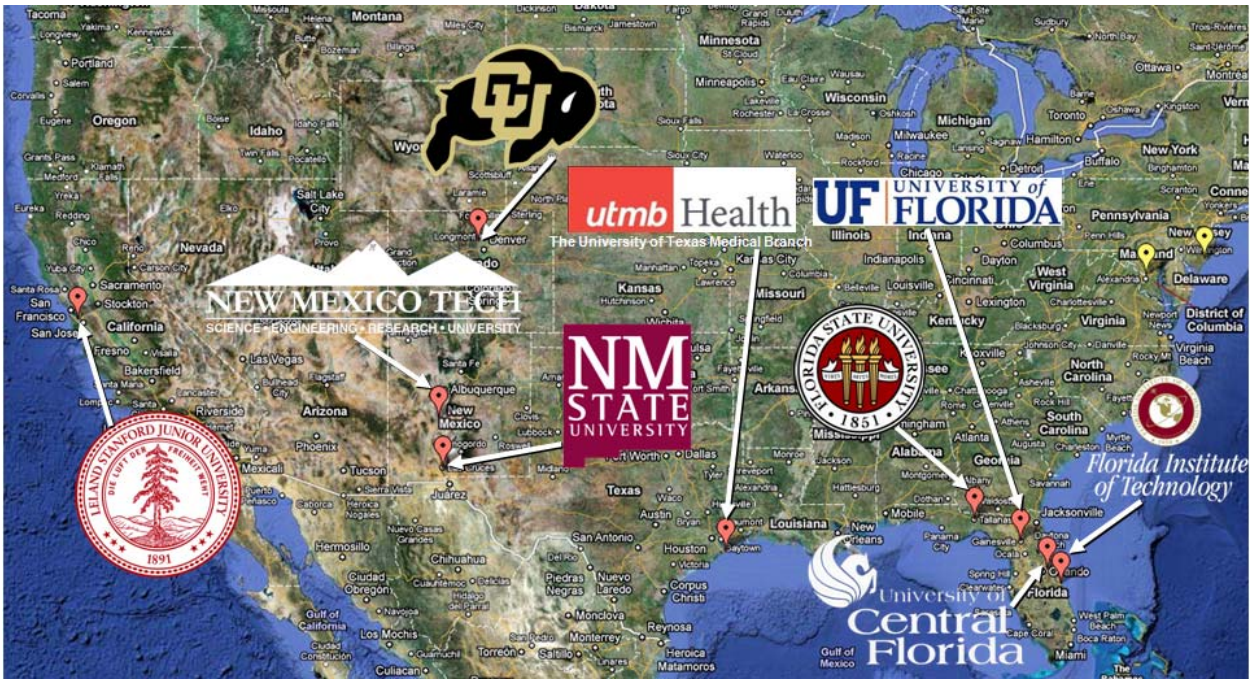
FSU brings a range expertise and unique infrastructure in many areas relevant to the COE CST, including but not limited to: cryogenics, thermal management, vehicle aerodynamics and controls, sensors, actuators and system health monitoring and high performance simulations.

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY (NMT)

NMT is a science, math and engineering university with a focus on applied research. Major research facilities include a rocket engine test fixture at the Energetic Materials Research and Testing Center, and a 2.4M fast tracking telescope at the Magdalena Ridge Observatory dedicated to the study of near earth objects.

NEW MEXICO STATE UNIVERSITY (NMSU)

NMSU and its Physical Sciences Laboratory have led space and aerospace research in areas of suborbital investigations from the time of Werner Von Braun to the current era of commercial sub-orbital space transportation with Virgin Galactic. New Mexico Space Grant Consortium, the 21st Century Space and related aerospace research focuses on annual access to space for student and faculty experiments, unmanned aerial vehicles, scientific ballooning and nano-satellite development.



STANFORD UNIVERSITY (SU)

SU brings a 50 year history of aerospace research excellence and a broad scope of expertise to the COE CST, including the optimization and autonomous operation of complex systems, strategic research planning, organizational integration and distributed administration experience.

UNIVERSITY OF CENTRAL FLORIDA (UCF)

UCF, as partners of Florida Center for Advanced Aero-Propulsion (FCAAP) and the Center for Advanced Turbines & Energy Research (CATER), offers its experience and expertise in thermal protection system, propulsion system components, cryogenic systems and materials, composites, sensors and actuators, and guidance and control.

UNIVERSITY OF COLORADO AT BOULDER (CU)

CU offers the COE CST their experience in spacecraft life support systems and habitat design, human factors engineering analysis, payload experiment integration, and expertise in space environment and orbital mechanics.

UNIVERSITY OF FLORIDA (UF)

UF has been performing aeronautical and aerospace research since 1941, with current emphasis in the Department of Mechanical and Aerospace Engineering on research in space systems, MEMS, computational sciences, structural dynamics, controls, gas dynamics, and propulsion.

UNIVERSITY OF TEXAS MEDICAL BRANCH AT GALVESTON (UTMB)

UTMB has a long history of medical support and human spaceflight physiological research with NASA. This is complemented by more recent involvement in the commercial orbital and suborbital spaceflight industry supporting space flight participant visits to the ISS and preparation of passengers and crew for suborbital space flights.

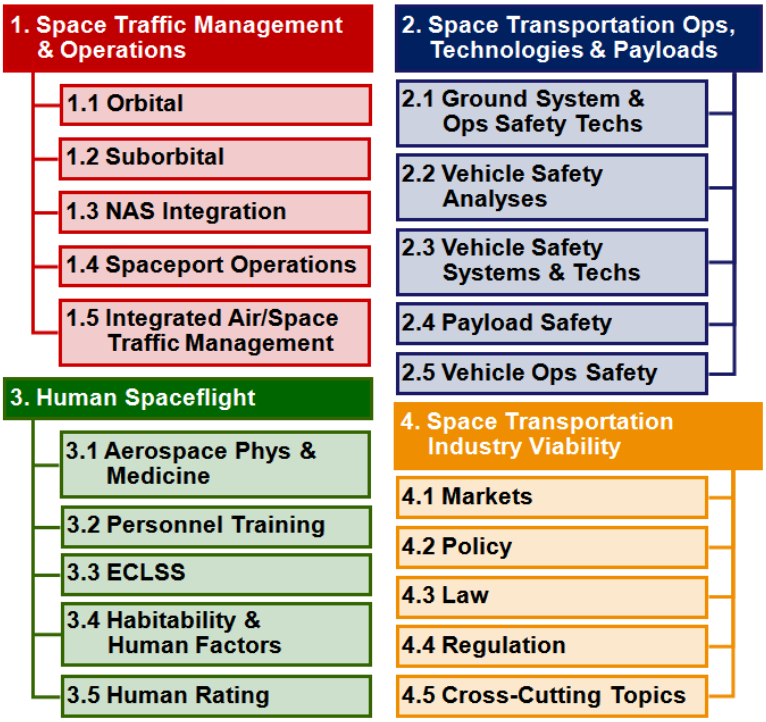
RESEARCH TASKS

The research conducted within FAA AST is broken into four major research areas:

- Space Traffic Management & Operations
- Space Transportation Operations, Technologies & Payloads
- Human Spaceflight
- Space Transportation Industry Viability

Each of these major research areas are divided into sub-areas and these, in turn, are further sub-divided into lower level divisions.

The following pages include a list of the individual COE CST research tasks conducted during the first year of operation followed by summary charts, one for each task.



COE CST Research Tasks

Research Task Name	RA	PI Name (University)
186. Space Environment MOD Modeling & Prediction	1.1	Fuller-Rowell (CU), Close (SU)
187. Space Situational Awareness Improvements	1.1	Scheeres (CU)
185. Unified 4-Dimensional Trajectory Approach for Integrated Traffic Mgt	1.3	Alonso (SU)
220. Develop a Spaceport Operations Framework	1.4	Hynes (NMSU)
247. Air and Space Traffic Considerations for Commercial Space Transportation	1.5	Villaire (FIT)
257. Masters Level Commercial Operations Instruction Criteria	2.1	Born (CU)
258. Analysis Environment For Safety Assessment of Launch & Re-Entry Vehicles	2.2	Alonso (SU)
259. Flight Software Validation & Verification Workshop	2.2	Alonso (SU)
228. Magneto-Elastic Sensing for Structural Health Monitoring	2.3	Zagrai & Ostergren (NMT)
241. High Temperature Pressure Transducers for Hypersonic Vehicles	2.3	Sheplak (UF), Oats (FSU)
253. Ultra High Temperature Composites for Thermal Protection Systems	2.3	Gou & Kapat (UCF)
244. Autonomous Rendezvous and Docking (For Space Debris Mitigation)	2.3	Axelrad (CU), Rock (SU), Fitz-Coy (UF), Collins (FSU)
255. Wearable Biomedical Monitoring Equipment For Human Spaceflight	3.1	Jennings (UTMB)
181. Physiological Database Definition and Design	3.1	Vanderploeg (UTMB)
182. Human System Risk Management Approach	3.1	Vanderploeg (UTMB)
256. Additional NASTAR Centrifuge Testing	3.3	Vanderploeg (UTMB)
184. Human Rating of Commercial Spacecraft	3.4	Klaus (CU)
183. Flight Crew Medical Standards & Participant Acceptance Guidelines	3.5	Jennings (UTMB)
193. Role of COE CST in Encourage, Facilitate & Promote (EFP)	4.5	Hubbard (SU), Born (CU)

TASK 186. SPACE ENVIRONMENT METEORITE AND ORBITAL DEBRIS MODELING & PREDICTION

PROJECT AT-A-GLANCE

- AST RDAB POC: Karen Shelton-Mur
- AST RESEARCH AREA: 1.1 STM & Ops – Orbital STM
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. Tim Fuller-Rowell
- STUDENT RESEARCHER: None
- PERIOD OF PERF: Jan 1, 2011 – Dec 31, 2012
- STATUS: Ongoing

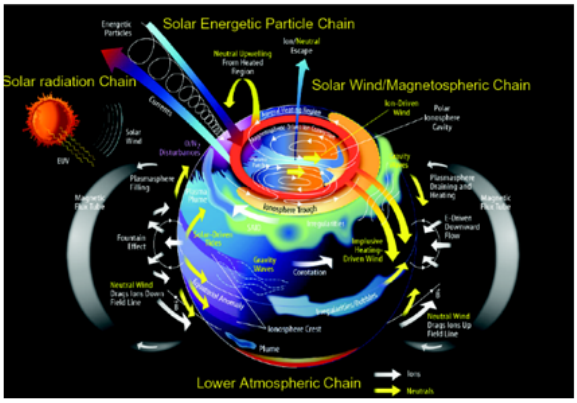
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- An integrated air and space traffic management system requires seamless and real-time access to density predictions for on-orbit collision avoidance and atmospheric re-entry, and near-surface weather prediction.

STATEMENT OF WORK

- Predict the environmental (e.g. gravity waves, tides, planetary waves, midnight density maximum, wave 4 structure, sudden stratospheric warmings, etc.) and space weather (e.g. solar flares, geomagnetic storms, solar proton events) conditions for safe orbital, sub-orbital, re-entry, descent, and landing operations as well as navigation and communications of commercial launch and reentry vehicles.
- Simulate the internal atmospheric sources of variability WAM is designed to forecast the environmental conditions from the ground to 600km. (Previous model was 60km.)

WHOLE ATMOSPHERE MODEL (WAM)



FUTURE WORK

- Extend WAM data assimilation into the lower thermosphere.
- Test higher resolution WAM T382 (35 km resolution) to resolve wave field penetrating to the thermosphere and test semi-annual variation in density.
- Full coupling of the ionosphere to respond to solar and magnetospheric forcing.
- Test assimilation of ionospheric data for density prediction.
- Assimilate hi-res whole atmosphere/ionosphere data.

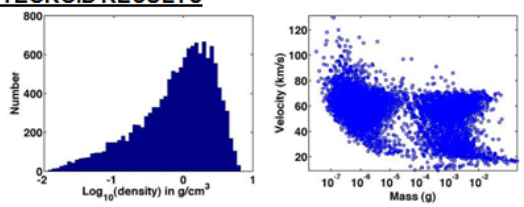
TASK 186. SPACE ENVIRONMENT METEOROID AND ORBITAL DEBRIS MODELING & PREDICTION

PROJECT AT-A-GLANCE
- AST RDAB POC: Karen Shelton-Mur
- AST RESEARCH AREA: 1.1 STM & Ops – Orbital STM
- UNIVERSITY: Stanford University
- PRINCIPAL INVESTIGATOR: Dr. Sigrid Close
- STUDENT RESEARCHER: Mr. Alan Li (MS)
- PERIOD OF PERF: Jan 1, 2011 – Dec 31, 2012
- STATUS: Ongoing

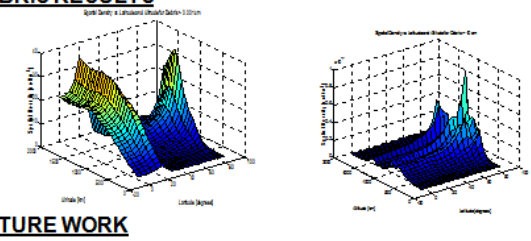
RELEVANCE TO COMMERCIAL SPACE INDUSTRY
- LEO spacecraft are routinely struck by impactors, both man-made (aka space debris, posing a mechanical threat) and natural (aka meteoroids, posing a mechanical and electric threat). Characterizing the impactor population through data analysis and modeling will help predict MOD threat to the launch and operation of commercial LEO spacecraft.

STATEMENT OF WORK
- Provide the first characterization of debris and meteoroid parameters, including density, in order to provide LEO spacecraft and satellite risk assessment.

METEOROID RESULTS



DEBRIS RESULTS



FUTURE WORK
- Meteoroids
  - Compressed sensing techniques for improved detection/analysis
  - Force modeling for improved orbit determination
  - Electromagnetic scattering models for plasma diagnostics
- Debris
  - Characterization of all sources/breakups
  - Comparison between MASTERS/ORDEM
  - Propagation and atmospheric models

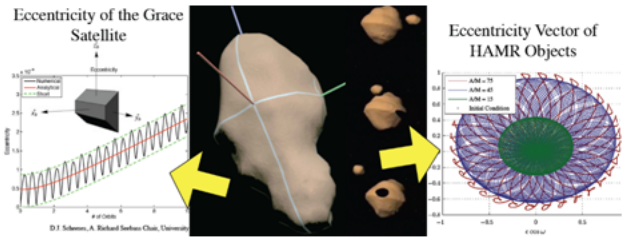
TASK 187. SPACE SITUATIONAL AWARENESS IMPROVEMENTS

PROJECT AT-A-GLANCE
- AST RDAB POC: Julie Price
- AST RESEARCH AREA: 1.1 STM & Ops – Orbital STM
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. Dan Scheeres
- STUDENT RESEARCHER: Mr. Kohei Fujimoto (PhD)
- PERIOD OF PERF: Jan 1, 2011 – Dec 31, 2012
- STATUS: Ongoing

RELEVANCE TO COMMERCIAL SPACE INDUSTRY
- Orbital safety and debris threat mitigation schemes can be improved with the ability to accurately and autonomously predict the current and future location of space objects in near real-time by reducing the associated uncertainties.

STATEMENT OF WORK
- Improve uncertainty modeling and propagation, precision long-term orbit propagation, non-gravitational model prediction and estimation, and orbit estimation techniques.
- Examine the uncertainty associated with resident space objects and the time propagation of these uncertainties through coordinated extensive research of:
  - Next Generation Space Catalog
  - Resident Space Object Characterization
  - Collision Avoidance/Conjunction Analysis
  - Orbital Safety and Debris Removal.

SOLAR RADIATION PRESSURE NON-GRAVITATIONAL MODELS DEVELOPED FOR ASTEROIDS APPLIED TO RESIDENT SPACE OBJECTS



STATUS
- Developing novel semi-analytical solutions for long-term probability density function propagation.
- New approach to initial orbit determination and correlation developed; Won "Best Paper of Conference" in 2010.
- 5 conference papers presented, 2 journal articles in press.

FUTURE WORK
- Mechanisms for matching funds have been identified and taken advantage of.
- Research progressing on all fronts identified.

TASK 185. UNIFIED 4D TRAJECTORY APPROACH FOR INTEGRATED TRAFFIC MANAGEMENT

PROJECT AT-A-GLANCE

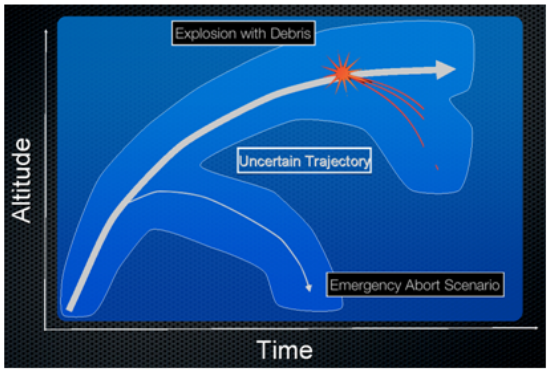
- AST RDAB POC: TBD
- AST RESEARCH AREA: 1.3 STM & Ops - NAS Integration
- UNIVERSITY: Stanford University
- PRINCIPAL INVESTIGATOR: Dr. Juan Alonso
- STUDENT RESEARCHER: Mr. Tom Colvin (MS)
- PERIOD OF PERF: Jan 1, 2011 – Dec 31, 2012
- STATUS: Ongoing

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- The projected growth in demand for the use of the traditional airspace by commercial space transportation entities will make it increasingly hard to accommodate launches on a Special Use Airspace (SUA) basis.

STATEMENT OF WORK

- Development of requirements, architecture and prototype implementations of simultaneous air/space traffic management procedures for commercial space transportation. Leverage projected improvements derived from NextGen.
- Develop plausible architectures for an Integrated Airspace Management System
- Research and develop the foundation of IAMS based on 4D, time-space probabilistic trajectories and safety assessments
- Create a prototype implementation for a proof-of-concept of the IAMS that may be further developed in a follow-on project.



STATUS

- Code accepts arbitrary thrust, weather, and failure profiles for Monte Carlo simulation of uncertain trajectories
- Creates multiple polygonal envelopes around the trajectories (and debris) that represent a no-fly zone
- Demonstrates the possibility of significant volume (area*sec) savings over conventional tube approach

FUTURE WORK

- Full 4-D (Swinging Slab)
- Accurate weather and debris models with uncertainty
- Active control in rocket during ascent and staging
- Integration with NASA's FACET tool for scenarios with various launch sites, frequencies + typical day in the NAS

TASK 220. DEVELOP A SPACEPORT OPERATIONS FRAMEWORK

PROJECT AT-A-GLANCE

- AST RDAB POC: René Rey
- AST RESEARCH AREA: 1.4 STM - Spaceport Operations
- UNIVERSITY: New Mexico State University
- PRINCIPAL INVESTIGATOR: Dr. Patricia Hynes
- STUDENT RESEARCHER: Morgan McPheeters
- PERIOD OF PERF: Jan 1 – Dec 31, 2011
- STATUS: Ongoing

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Establishing a framework to capture a body of knowledge for commercial spaceport practices will help the industry community understand those documents, concepts, terms, and activities that may encompass commercial spaceport operations.

STATEMENT OF WORK

- Develop a framework for spaceport operations and validate by surveying Spaceport Directors and Range Commanders.
- Analyze the framework and evolve it until the results reflect a comprehensive body of knowledge of best practices for commercial spaceport operations.

U.S. SPACEPORTS

STATUS

- Current framework was developed in collaboration with Spaceport Directors.
- Survey conducted to validate framework. Responses included 7 Spaceport Directors and members of the Range Commanders Council.

FUTURE WORK

- Research into existing and applicable practices, documents and other relevant material related to framework classification areas.
- The study will be conducted to capture documents related to existing practices and standards from all sources applicable to commercial spaceports.
- Conduct gap analysis to compare the variables in framework with the existing practices, standards, policies and best practices documentation. Identify extant gaps.

TASK 247. AIR & SPACE TRAFFIC CONSIDERATIONS FOR CST

PROJECT AT-A-GLANCE
- AST RDAB POC: Demidovich, Nick
- AST RESEARCH AREA: 1.5 STM - Integration & Operations
- UNIVERSITY: Florida Institute of Technology
- PRINCIPAL INVESTIGATOR: Dr. Nat Villaire
- STUDENT RESEARCHER: Ms. Nicole Maillet (BS)
- PERIOD OF PERF: Apr 1, 2011 – Mar 31, 2012
- STATUS: Ongoing

RELEVANCE TO COMMERCIAL SPACE INDUSTRY
- In order to facilitate the integration of atmospheric traffic with transitional spacecraft (atmospheric to space and vice versa) concepts and procedures for integration need to be developed. Identifying the information necessary is the necessary first step to developing these concepts and procedures.

STATEMENT OF WORK
- Identify the commercial space vehicle (CSV) operational parameters affecting the NAS.
- Identify the appropriate controlling FAA Orders & Regulations.
- Assist the FAA and CSV operators by identifying specific questions affecting their integration into the NAS.
- Develop top level questions which must be resolved to effect NAS integration for following flight phases: Preflight, Takeoff, Departure, Exiting & Entering NAS, Arrival, Landing.
- Increase the depth of information required for routine CSV operations in the NAS.

STATUS
- 58 Preflight areas of clarification identified (VFR: 29, IFR: 14, General: 15)
- Sample questions for remaining flight phases:
  - Takeoff: Will CSV have a newly defined priority or will they be subject to the current "first come, first served" system?
  - Departure: What aerodynamic/operating parameters of CSVs will define separation requirements?
  - Exit/Enter NAS: What NAVAIDS will be required by ATC for integration of CSVs into the NAS?
  - Arrival: Will Approach Control be able to sequence CSVs in conventional traffic patterns?
  - Landing: Can CSVs be sequenced in a standard arrival pattern?

FUTURE WORK
- Divide the applicable FARs into smaller groupings for fine analysis of their effects on CSV operations.
- Divide the applicable FAA Orders on ATC and Airspace into smaller groupings for fine analysis of their requirements in controlling CSV operations.
- Begin construction of a guide for FAA which will help the organization address the problems presented by integration of CSVs into the NAS.

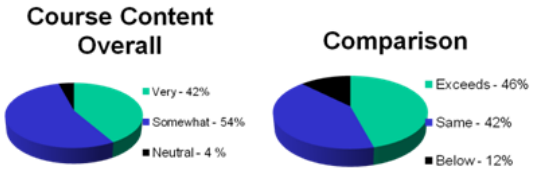
TASK 257. MASTERS LEVEL COMMERCIAL SPACE OPERATIONS INSTRUCTION CRITERIA

PROJECT AT-A-GLANCE
- AST RDAB POC: Rey, René
- AST RESEARCH AREA: 2.1 Ground Systems & Ops Safety
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. George Born
- STUDENT RESEARCHER: Mr. Bradley Cheetham (PhD), Ms. Jules Feldhacker (PhD)
- PERIOD OF PERF: Jan 1, 2011 – Dec 31, 2012
- STATUS: Ongoing

RELEVANCE TO COMMERCIAL SPACE INDUSTRY
- This course provides insight to graduate level aerospace students on both operational and industrial dynamics to ensure the availability a highly-trained workforce required by commercial space transportation operators.

STATEMENT OF WORK
- Develop one-semester course and one-semester lab; refine content based on student and industry feedback; standardize and establish Graduate Certificate.
- Draft academic objectives based on industry discussion; solicit feedback on academic objectives; define curriculum topics and solicit feedback; identify subject matter experts who develop and deliver content.
- Academic objectives include: (a) Comprehension of total mission sequence; (b) Constraints on design and operations including: Technical, Policy/Legal, Business, and Practical; (c) Understanding of and insight into current industry practices: Past to present; (d) Overview of project management and team dynamics; (e) Cross cutting theme of Risk (through all objectives).

STUDENT COURSE SATISFACTION SURVEY RESULTS



STATUS
- 30 Course Lectures in Background (3), Launch (5), Operations (11), End of Mission (3), Mission Planning (4), Misc (1), Conclusion (3).
- Total students enrolled: 28 (19 on-campus, 9 off-campus).
- Assignments: Weekly discussion, 4 Open Ended Assignments, 4 Labs, 1 Research Paper.

FUTURE WORK
- Spring-Summer 2012: Continued development/revision of course; Initiate development of lab portion.
- Fall 2012: Offer lecture for second time.
- Spring 2013: Offer lab for first time; Continue alternating course/lab; Formalize Certificate program.

TASK 258. ANALYSIS ENVIRONMENT FOR SAFETY ASSESSMENT OF LAUNCH AND RE-ENTRY VEHICLES

PROJECT AT-A-GLANCE

- AST RDAB POC: TBD
- AST RESEARCH AREA: 2.2 Vehicle Safety Analyses
- UNIVERSITY: Stanford University
- PRINCIPAL INVESTIGATOR: Dr. Juan Alonso
- STUDENT RESEARCHER: Mr. Francisco Capristan (MS)
- PERIOD OF PERF: Jan 1, 2011 – Dec 31, 2011
- STATUS: Ongoing

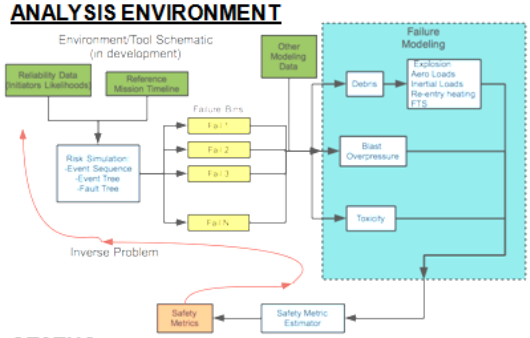
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- The ability to identify acceptable ranges of component design parameters that satisfy final system safety limits will give vehicle designers increased flexibility to minimize costs while maintaining high levels of safety.

STATEMENT OF WORK

- Provide the FAA and the community with an independent multi-disciplinary analysis capability based on tools of the necessary fidelity.
- Develop and establish quantitative safety metrics appropriate for commercial space transportation (launch and re-entry).
- Validate the resulting tool with existing and proposed vehicles so that the resulting tool/environment can be confidently used.
- Increase the transparency of the safety assessment of future vehicles via a common analysis tool that is entirely open source and, thus, streamline the licensing process for a variety of vehicle types.

ANALYSIS ENVIRONMENT



STATUS

- Initial framework architecture developed, modular components being added. Initial focus on damage to the ground on ELV ascent trajectory. Initial trajectory and debris dispersion tools have been implemented, and successfully automated to generate thousands of Monte Carlo evaluations. The current debris dispersion tool captures basic physical effects of falling debris and does acceptably locates risk areas.

FUTURE WORK

- Validate the dispersion tool against other well accepted debris analysis tools. Add malfunction turns to the simulation. Implement other random distributions to calculate casualty expectation. Begin theoretical development for probabilistic inversion of safety requirements.

TASK 259: FLIGHT SOFTWARE VALIDATION & VERIFICATION WORKSHOP

PROJECT AT-A-GLANCE

- AST RDAB POC: TBD
- AST RESEARCH AREA: 2.2 Vehicle Safety Analyses
- UNIVERSITY: Stanford University
- PRINCIPAL INVESTIGATOR: Dr. Juan Alonso
- STUDENT RESEARCHER: None
- PERIOD OF PERF: Jan 1, 2011 – Dec 31, 2011
- STATUS: Ongoing

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Software Independent Validation and Verification is regarded as one of the major issues today and in the future for the timely and cost-effective development and certification of launch and re-entry systems.

STATEMENT OF WORK

- Formulate a coherent plan of research to impact flight software V&V for commercial space transportation systems.
- Produce a research roadmap of activities that may lead to a full project pursued under the umbrella of the COE.
- Develop a white paper for research challenges in flight software V&V for commercial space transportation systems.

STATUS

- Outcome of this effort is meant to be a workshop to outline a plan of research in this area.

FUTURE WORK

- The intent is to hold this workshop during the early Spring of 2012.
- Possibility of adding the output of workshop to road mapping activity sublevels

TASK 228: MAGNETO-ELASTIC SENSING FOR STRUCTURAL HEALTH MONITORING

- **PROJECT AT-A-GLANCE**
- AST RDAB POC: Nick Demidovich
- AST RESEARCH AREA: 2.3 Vehicle Safety Systems & Tech
- UNIVERSITY: New Mexico Tech
- PIs: Drs. Andrei Zagrai & Warren Ostergren
- STUDENT RESEARCHERS: Ms. Jaclene Gutierrez (BS), Mr. Daniel Meisner (MS), Mr. David Conrad (MS), Mr. Walter Kruse (MS-graduated)
- PERIOD OF PERF: Jan 1, 2011 – Dec31, 2012
- STATUS: Ongoing

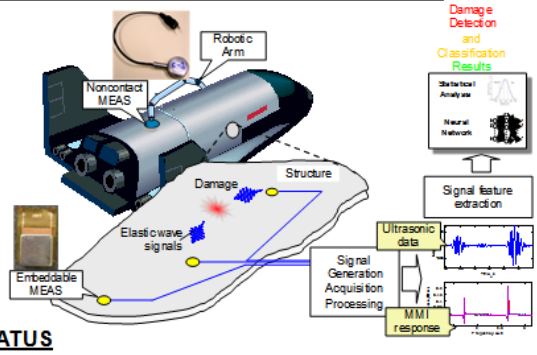
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Structural health monitoring (SHM) is seen as a key technology to reduce cost land improve safety of operation of modern space vehicles. Future spacecraft require sensing technologies that are reliable, multi-purpose, durable, and long-lived. These sensors need to detect and characterize impact damage from space debris, assess structural integrity of the spacecraft, provide information on structural interfaces, explore spacecraft electrical signature, enable reusable component requalification for flight, and possibly conduct non-contact inspection in space

STATEMENT OF WORK

- Develop innovative magneto-elastic sensing technologies for structural diagnosis of space vehicles.
- Conduct theoretical and experimental research on the physical mechanism of sensing, its practical realization in the engineering system, information inference from the magneto-elastic response and automatic data classification / decision support.

MAGNETO-ELASTIC ACTIVE SENSORS (MEAS)



STATUS

- MEAS SHM 1-D analytic theory is in progress.
- MEAS signal manifestation of damage measured.
- Damage in adhesive interfaces and fatigue in material as manifested in MEAS signal measured.
- MEAS pre-crack damage detection capability is confirmed

FUTURE WORK

- Create 1-D model for damaged MEAS interface.
- Conduct experiments with additional samples with interface damage.
- Conduct experiments with fatigues samples.
- Work toward separation of electrical and mechanical responses.
- Conduct analysis of data classification algorithms for MEAS.

TASK 241. HIGH TEMPERATURE PRESSURE SENSORS FOR HYPERSONIC VEHICLES (MANUFACTURING)

- **PROJECT AT-A-GLANCE**
- AST RDAB POC: Nick Demidovich
- AST RESEARCH AREA: 2.3 Vehicle Safety Systems & Technologies
- UNIVERSITY: University of Florida
- PRINCIPAL INVESTIGATOR: Dr. Mark Sheplak
- STUDENT RESEARCHER: Mr. David Mills (MS), Mr. Daniel Blood (MS)
- PERIOD OF PERF: Jan 1, 2011 – Dec 31, 2011
- STATUS: Ongoing

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Orbital commercial space vehicles require high-temperature sensors (>1000°C) or various phases of flight (e.g, hypersonic flight, high speed reentry) or to monitor system and subsystem performance (e.g., for gas turbines or scramjets). Current commercial sensors are only capable of up to ~300°C/600°F.

STATEMENT OF WORK

- Design, fabricate, and characterize a robust, high-bandwidth micro-machined pressure sensor for harsh environments.
- Develop novel processing techniques for the fabrication of high temperature sensors, including laser micro-machining processes for patterning of structures in sapphire and alumina, and thermo-compression bonding process for fabrication of multi-wafer sensors enabling three-dimensional structures.

HIGH-TEMPERATURE SENSOR MANUFACTURED

STATUS

- Low Temperature Prototype Manufactured: Silicon diaphragm; Silica fiber and low temp epoxy.
- High Temperature Sensor Manufactured: Pt-coated sapphire diaphragm; Sapphire fiber w/ zirconia optical ferrule

FUTURE WORK

- Process development: Laser machining parameters for thinning sapphire diaphragms; Bonding; Improve temperature and pressure control; Eliminate substrate cracking.
- Package high temp sensor
- PWT Calibration: Frequency response; Linearity.
- High Temperature Calibration: Temperature drift; Environmental chamber.

TASK 241. HIGH TEMPERATURE PRESSURE SENSORS FOR HYPERSONIC VEHICLES (FRACTURE MECHANICS)

- **PROJECT AT-A-GLANCE**
- AST RDAB POC: Nick Demidovich
- AST RESEARCH AREA: 2.3 Vehicle Safety Systems & Technologies
- UNIVERSITY: Florida State University
- PRINCIPAL INVESTIGATOR: Dr. William Oates
- STUDENT RESEARCHER: Mr. Justin Collins (MS)
- PERIOD OF PERF: Jan 1, 2011 – Dec 31, 2011
- STATUS: Ongoing

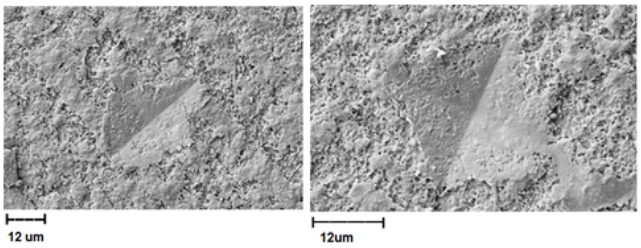
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Orbital commercial space vehicles require high-temperature sensors (~1000°C/1600°F) or various phases of flight (e.g, hypersonic flight, high speed reentry) or to monitor system and subsystem performance (e.g., for gas turbines or scramjets). Current commercial sensors are only capable of up to ~300°C/600°F.

STATEMENT OF WORK

- Characterize virgin vs. laser machining fracture and quantify crack opening: measure Intrinsic crack tip toughness using SEM.
- Analyze and measure fracture toughness.
  - Preliminary Vicker's indentation characterization
  - No visible cracks
  - Laser machining parameters

TOUGHNESS INDUCED LASER MACHINING



STATUS

- SEM Characterization: Crystal structure has been correlated with anisotropic elastic properties.
- Fracture Analysis
  - Crack tip toughness quantified in virgin sapphire specimens. Good correlation with data in literature.
  - Laser machining effects on fracture. Unusual toughness enhancement.

FUTURE WORK

- Hypothesis: Laser induced dislocations. TEM characterization and dislocation/fracture modeling currently underway.

TASK 253. ULTRA HIGH TEMPERATURE COMPOSITES FOR THERMAL PROTECTION SYSTEMS (TPS)

- **PROJECT AT-A-GLANCE**
- AST RDAB POC: Demidovich, Nick
- AST RESEARCH AREA: 2.3 Vehicle Safety Systems & Technologies
- UNIVERSITY: University of Central Florida
- PRINCIPAL INVESTIGATOR: Dr. Jan Gou, Dr. Jay Kapat, Dr. Linan An, Dr. Ali Gordon
- STUDENT RESEARCHER: Mr. Jeremey Lawrence, Mr. James DeMarco, Mr. Jinfeng Zhuge
- PERIOD OF PERF: Jan 1, 2011 – Dec 31, 2011.
- STATUS: Ongoing

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Ultra-high temperature, light weight and cost effective thermal protection systems (TPS) are enabling technologies for viable commercial space transportation vehicles and their high-temperature systems.

STATEMENT OF WORK

- Develop ceramic and other nanocomposites with embedded health monitoring for inherent safety and real-time assessment of hypersonic TPS applications.
- Develop light weight and cost effective ablative materials against solid rocket exhaust plumes with Al2O3 at very high velocity.
- Provide an analysis tool for the thermal degradation modeling of new ablative materials.
- Provide ablation sensing to monitor the structural health of the ablative thermal protection system.

CERAMIC NANOCOMPOSITES & TEST SAMPLES

STATUS

- Investigated 3 approaches: Phenolic Impregnated Carbon Ablator (PICA), Silicone Impregnated Carbon Ablator (SICA); Carbon/Carbon Composites.
- Manufactured carbon nanopaper/PDC composites: process scalable; experimentally optimizing heat release rates; measured temperature profiles.

FUTURE WORK

- Ablation Testing: Simulated Solid Rocket Motor (SSRM) is a small scale, liquid-fueled rocket burning kerosene and oxygen at Dynetics, Huntsville.
- Thermal Degradation Modeling and Ablation Sensing: Damage modeling and life prediction under thermal- and pressure-loading conditions; Integrated health monitoring with embedded sensors for real-time assessment

TASK 244: AUTONOMOUS RENDEZVOUS AND DOCKING (BASIS OF REQUIREMENTS AND METHODS)

PROJECT AT-A-GLANCE

- AST RDAB POC: Nick Demidovich
- AST RESEARCH AREA: 2.3 Vehicle Safety Systems & Technologies
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. Penina Axelrad
- STUDENT RESEARCHER: Ms. Holly Borowski (PhD)
- PERIOD OF PERF: Jun 1, 2011 – Dec 31, 2011
- STATUS: Ongoing

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Commercial missions require flexible and efficient methods for rendezvous and docking. This task develops a framework to enable autonomous rendezvous and docking in LEO a routine and safe activity by developing a framework to enable licensing of multiple vehicle systems.

STATEMENT OF WORK

- Construct a draft basis for standards for AR&D of vehicles in LEO encompassing approach trajectories, sensing, estimation, guidance and control, human interaction, and reliability.
- Identify stages, requirements & risks for commercial LEO AR&D; Evaluate the maturity of key technologies; Develop requirements flow down (technology pull); Look at promising technologies that can enhance performance, safety, robustness, reliability (technology push); Identify connections to other FAA activities including aircraft collision avoidance, UAV flight rules, mid-air refueling, and space situational awareness; Draft plan for bringing the pieces together over a 5 year period to form the basis for standards development.

STATUS

- Initial literature search completed, summary of existing AR&D approaches compiled.
- Commercial LEO AR&D Considerations
  - Manned or unmanned
  - Automated or autonomous
  - Target geometry known or unknown
  - Target cooperative or non-cooperative
  - Target attitude controlled or uncontrolled
  - Number of vehicles - two or more
  - Duration – long (multi-orbit) or short
- Key mission phases defined and relevant technology elements and some risks for each identified.
- Met with potential industrial collaborators from Ball Aerospace who provided information on sensor development and experiments.

FUTURE WORK

- Identify discrete mission phases and their particular requirements, the interfaces or transitions between phases.
- Integrate the findings of the partner schools and provide them with draft requirements for the mission phases and technologies they are already addressing.
- Collaboratively identify other significant technology gaps that should be addressed.

TASK 244: AUTONOMOUS RENDEZVOUS AND DOCKING (FOR SPACE DEBRIS MITIGATION - TARGET POSE & SHAPE SENSING)

PROJECT AT-A-GLANCE

- AST RDAB POC: Nick Demidovich
- AST RESEARCH AREA: 2.3 Vehicle Safety Systems & Technologies
- UNIVERSITY: Stanford University
- PRINCIPAL INVESTIGATOR: Dr. Steve Rock
- STUDENT RESEARCHER: Mr. Jose Padial (PhD), Mr. Marcus Hammond (PhD)
- PERIOD OF PERF: Jan 1, 2011 – Dec 31, 2011
- STATUS: Ongoing

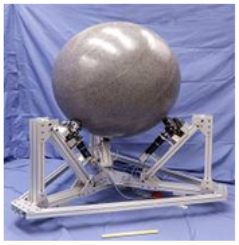
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

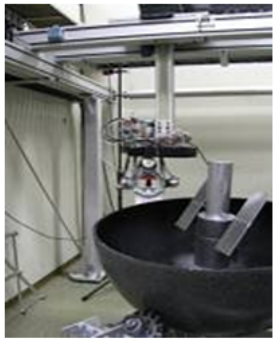
- Safe approach and successful capture of uncooperative space debris will require the ability to autonomously identify the object of interest and its motion vectors.

STATEMENT OF WORK

- Develop and demonstrate robust autonomous rendezvous and docking (AR&D) sensing technology for
  - Targets undergoing complex, potentially tumbling motion
  - Damaged and/or uncommunicative spacecraft
  - Orbital debris.
- Develop new technology to enable safe, autonomous rendezvous and docking with disabled spacecraft or capture of debris

6 DEGREE OF FREEDOM GANTRY ► ROTATING BASE MOTION SIMULATOR ▼





STATUS

- Camera-LIDAR simulation environment has simulated LIDAR range scanning of 3D target models and generated simulated images.
- Demonstrate rendezvous and docking using a baseline SLAM algorithm. Develop a plan to accommodate lighting anomalies. Develop a plan to port the SLAM algorithms to low power processors.

FUTURE WORK

- Modify and extend algorithms to account for lighting anomalies. Modify and implement algorithms for low-power computer processors. Demonstrate extended algorithms using ground-based simulator. Begin development of a small-satellite demonstration.

TASK 244: AUTONOMOUS RENDEZVOUS AND DOCKING (FOR SPACE DEBRIS MITIGATION - NON-COOPERATIVE PRE/POST-CAPTURE OPS)

PROJECT AT-A-GLANCE

- AST RDAB POC: Nick Demidovich
- AST RESEARCH AREA: 2.3 Vehicle Safety Systems & Technologies
- UNIVERSITY: University of Florida
- PRINCIPAL INVESTIGATOR: Dr. Norm Fitz-Coy
- STUDENT RESEARCHER: Mr. Takashi Hiramatsu (?)
- PERIOD OF PERF: Jan 1, 2011 – Dec 31, 2011
- STATUS: Ongoing

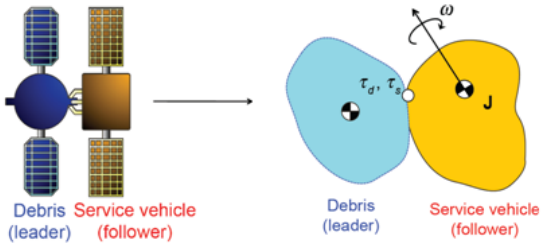
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Small form factor satellites experience high failure rates (caused by malfunctioning actuators, communications, etc.) and their proliferation leads to an increase in debris. Pre- and post-docking methods of non-cooperative debris that minimize interaction "forces" between vehicles when docked will help minimize debris threat to other LEO spacecraft during active space debris removal.

STATEMENT OF WORK

- Assess 3 phases: (a) trajectory planning, (b) proximity operations and (c) post-docking.
- Characterize non-cooperative post-docking with "disabled spacecraft" (i.e., debris). Develop necessary control strategy to counteract debris's motion and maintain a safe docked state.
- Make an intelligent estimate of the debris's behavior to compute the reacting control strategy of the service vehicle.
- Use Stackelberg Game Theory Approach (multiple player system with non-cooperative spacecraft as leader).

TOWING NON-COOPERATIVE DEBRIS



STATUS

- Preliminary analysis shows promise for removal of non-cooperative debris.
- Game theory with Stackelberg strategy addresses the post-dock interactions and lowers interactions between service vehicle and debris.
- Developed solution preserves nonlinearity of system dynamics (linearity in the error model).

FUTURE WORK

- Add constraints to the control effort.
- Extend the controller design to a multiplicative error model.
- Year 2: Assessment of hardware implementation issues in APFG collision avoidance and SBMPC; APFG collision avoidance strategies; Continued assessment of post-dock scenarios.

TASK 244: AUTONOMOUS RENDEZVOUS AND DOCKING (FOR SPACE DEBRIS MITIGATION FAST TRAJECTORY GENERATION)

PROJECT AT-A-GLANCE

- AST RDAB POC: Nick Demidovich
- AST RESEARCH AREA: 2.3 Vehicle Safety Systems & Technologies
- UNIVERSITY: Florida State University
- PRINCIPAL INVESTIGATOR: Dr. Emmanuel Collins
- STUDENT RESEARCHER: Mr. Griffin Francis (PhD)
- PERIOD OF PERF: Jan 1, 2011 – Dec 31, 2011
- STATUS: Ongoing

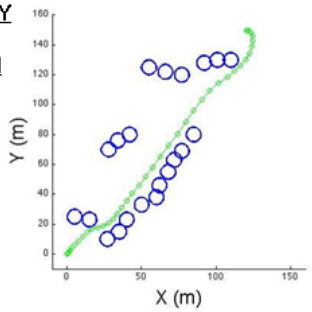
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- According to a recent NASA study, there is an immediate need to develop space debris mitigation technology and the development of "Space Tow Truck" capability is a promising approach toward direct debris removal. This approach requires automated guidance to approach target debris. This task develops 'an onboard ability to quickly generate (within a few seconds) dynamically feasible trajectories that enable a space tow truck to approach debris for docking.

STATEMENT OF WORK

- Develop space tow truck dynamic model to account for actuator characteristics and vehicle momentum.
- Effectively plan position, orientation, and velocity with respect to target debris.
- Optimize relevant trajectory metrics (distance, time, energy).
- Avoid moving debris.
- Quickly replan using prior trajectory plan.
- Develop a graph search method called Sampling Based Model Predictive Optimization (SBMPO).

2D TRAJECTORY GENERATION RESULTS (WITH OBSTACLES)



STATUS

- 50-250x faster computation of 3D trajectories demonstrated.
- 2D trajectory generation with obstacles and distance optimization computed.

FUTURE WORK

- Apply collision avoidance to 3D planning environment with orientation goal.
- Consider moving obstacles.
- Demonstrate minimum time trajectories.
- Develop and demo minimum energy consumption model.
- Demonstrate rapid replanning to accommodate newly sensed obstacles.
- Implement trajectory constraints based on CU research.
- Determine final pose constrainst using SU and UF research.

TASK 255. WEARABLE BIOMEDICAL MONITORING EQUIPMENT FOR HUMAN SPACEFLIGHT

- **PROJECT AT-A-GLANCE**
- AST RDAB POC: Doug Graham
- AST RESEARCH AREA: 3.1 Human Spaceflight – Aerospace Physiology & Medicine
- UNIVERSITY: University of Texas Medical Branch
- PRINCIPAL INVESTIGATOR: Dr. Richard Jennings, MD
- STUDENT RESEARCHER: Dr. Anil Menon, MD, Dr. Jennifer Law, MD
- PERIOD OF PERFORMANCE: Jan 1, 2011 – Dec 31, 2012
- STATUS: Ongoing. Year 2 of 2.

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Collection of biomedical data from the diverse population of commercial spaceflight participants (SFPs) will greatly enable the FAA in developing relevant regulations for SFPs.

STATEMENT OF WORK

- Comprehensively review existing wearable biomedical monitoring equipment to determine COTS availability.
- Determine physiological parameters and data to be collected. Survey experts to identify equipment req'ts.
- Compare existing hardware and software with the needs of the operational and research community to identify gaps.
- Identify new technologies needed to fill identified gaps, exploring repackaging of existing technologies to be incorporated into the wearable system.
- Identify/set design requirements. Procure prototype biomedical monitoring equipment.
- Test the prototype hardware configurations under expected G profiles in various operator's launch/landing systems.

BIOMEDICAL DATA COLLECTED DURING CENTRIFUGE TRAINING

STATUS

- Review of existing equipment and alternative concepts.

FUTURE WORK

- Survey of needs and requirements / perform gap analysis.
- Procure / develop prototype hardware.
- Equipment testing and verification in centrifuge.

TASK 181. PHYSIOLOGICAL DATABASE DEFINITION & DESIGN

- **PROJECT AT-A-GLANCE**
- AST RDAB POC: Doug Graham
- AST RESEARCH AREA: 3.1 Human Spaceflight – Aerospace Physiology & Medicine
- UNIVERSITY: University of Texas Medical Branch
- PRINCIPAL INVESTIGATOR: Dr. Jim Vanderploeg, MD
- STUDENT RESEARCHER: Ms. Jennifer Law, MD and Mr. Charles Mathers, MD
- PERIOD OF PERFORMANCE: Jan 1, 2011 – Dec 31, 2012
- STATUS: Ongoing. Year 2 of 2

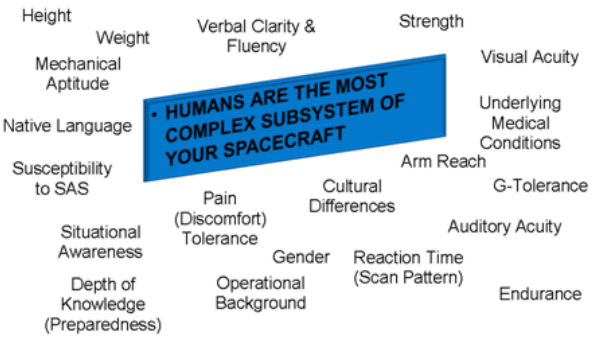
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- The emerging commercial space transportation industry of will soon involve hundreds to thousands of individuals covering a wide range of ages and medical conditions about which very limited information has been collected. Improve pre-flight medical screening criteria on which operators can make informed decision about the suitability of prospective customers by including a wide range of individuals with a variety of existing medical problems. Collection and management of this information will also better inform the development of regulations for commercial human spaceflight.

STATEMENT OF WORK

- Identify appropriate data elements about the health and physiologic status of commercial space flight participants. Recommend a scalable design for a database system.
- Identify and document the infrastructure and processes for capturing data from pre-flight, in-flight, and postflight assessments and from research studies performed during suborbital and orbital flights.

UNDERSTANDING HUMAN COMPLEXITY



STATUS

- Identify stakeholders (operators, flight surgeons, government, individuals, researchers, trainers).
- Initial draft of data elements (in progress)

FUTURE WORK

- Identify hosting options and resources
- Initial draft of security, confidentiality, and access requirements
- Conduct workshop in Spring 2012
- Draft report – mid 2012
- Final report and recommendations – Dec. 2012.

TASK 182. HUMAN SYSTEM RISK MANAGEMENT APPROACH

- **PROJECT AT-A-GLANCE**
- AST RDAB POC: Doug Graham
- AST RESEARCH AREA: 3.1 Human Spaceflight – Aerospace Physiology & Medicine
- UNIVERSITY: University of Texas Medical Branch
- PRINCIPAL INVESTIGATOR: Dr. Jim Vanderploeg, MD
- STUDENT RESEARCHER: Ms. Jennifer Law, MD and Mr. Charles Mathers, MD
- PERIOD OF PERFORMANCE: Jan 1 – Dec 31, 2011
- STATUS: Near completion

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Investigate the feasibility of applying the JSC Human System Risk Management approach for long-duration spaceflight to commercial suborbital and short duration orbital spaceflight.

STATEMENT OF WORK

- Select subset of risks appropriate for commercial spaceflight.
- Quantify the health and performance risk.
- Define mitigation strategies.
- Sources of Information:
  - NASA Human Research Roadmap (HRR)
  - Historical Human Spaceflight Data
  - Integrated Medical Model
- Thirty-one operationally focused risks defined in HRR Program Requirements Document.
- Integrated Research Plan and Evidence Book (IRD) details activities to fill the knowledge and mitigation gaps.

ASSIGN LEVEL OF CONCERN FOR EACH APPLICABLE COMMERCIAL SPACEFLIGHT PARTICIPANT RISK

Concern Level	Crew	Passengers
Definite	3	4
Possible	21	21
Least	7	6

STATUS

- Thirty-one risks have been identified and categorized.
- Twenty-four risks for crew members and 25 for passengers are being evaluated for mitigation strategies.
- Draft report is under review.

FUTURE WORK

- Complete the final report for submission to the FAA Office of Commercial Space Transportation.
- Consider publication in peer-reviewed medical journal.
- Follow-on project to create software system to identify and categorize risks and define mitigation strategies.

TASK 256. ADDITIONAL NASTAR CENTRIFUGE TRAINING

- **PROJECT AT-A-GLANCE**
- AST RDAB POC: René Rey
- AST RESEARCH AREA: 3.2 Human Spaceflight – Training
- UNIVERSITY: University of Texas Medical Branch
- PRINCIPAL INVESTIGATOR: Dr. Jim Vanderploeg, MD
- STUDENT RESEARCHER: Dr. Becky Blue, MD and Dr. James Pattarini, MD
- PERIOD OF PERFORMANCE: Jan 1, 2011 – Dec 31, 2012
- STATUS: Ongoing. Year 2 of 2.

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Commercial space flight will enable the participation of the general public with a variety of disease states that have not been studied to date. This study will permit research into the physiological implications on the new cross-section of the flying public.

STATEMENT OF WORK

- Conduct training and evaluation of flight crew members in various G profiles to verify the environment does not adversely impact their ability to control the vehicle.
- Use centrifuge-induced G-force to evaluate subjects with defined disease states under the G-loads expected during commercial space flights. Defined Disease States: controlled hypertension, diabetes, cardiovascular/coronary disease, respiratory disease, and spinal disease or injury.
- Develop optimal and effective training protocols for passengers for G-force countermeasures.
- Evaluate biomedical monitoring equipment under G profiles of commercial space flights to ascertain the suitability and verify the data quality captured provides the info required.

NASTAR CENTER CENTRIFUGE

STATUS

- Independent Review Board (IRD) reviews and approvals in process.
- Agreements with NASTAR in process of being executed.

FUTURE WORK

- Finalize IRB approval.
- Finalize NASTAR arrangements.
- Recruit subjects.
- Conduct training and evaluation in centrifuge.
- Evaluate biomedical monitoring equipment.

TASK 184. HUMAN RATING OF COMMERCIAL SPACECRAFT

- **PROJECT AT-A-GLANCE**
- AST RDAB POC: Ken Davidian
- AST RESEARCH AREA: 3.5 Human Spaceflight - Human Rating
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. David Klaus
- STUDENT RESEARCHER: Ms. Christine Fangchiang (PhD)
- PERIOD OF PERFORMANCE: Jun 1, 2011 – May 31, 2012
- STATUS: Ongoing. Year 1 of 3.

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- The commercial space industry has no clear definition for the criteria for human rating of an integrated commercial spacecraft and launch vehicle system. This information would support the FAA's regulatory responsibilities.

STATEMENT OF WORK

- Review and summarize human rating literature and practice
- Compile database of guidelines for commercial spaceflight
- Identify and seek collaboration with individuals to participate in a Working Group to identify and address implementation needs
- Extend study from initial needs and capabilities of crew and space flight participants toward era of passenger carrying space vehicles.

LIST OF NASA'S HUMAN RATING DOCS & # OF REQ'TS

Governing Documents	*Requirements*
NASA NPR 8705.2B *Human-Rating Requirements for Space Systems*	131
ESMD-CCTSCR-12.10 *CCTS Certification Requirements for NASA LEO Missions*	31
NASA CCT-REQ-1130 *ISS Crew Transportation and Services Requirements Document*	258
NASA SSP-50808 *ISS to COTS Interface Requirements Document*	724
AFSPCMAN-91-710 *Range Safety User Requirements*	4692
	5721

STATUS

- Task 1 – Literature review, ~160 papers compiled and categorized to date, government / industry practice surveys in work.
- Task 2 – Attended COE Roadmap Workshop Wash. DC (August 2011) and assimilated outcome into research objectives.

FUTURE WORK

- Task 3 – Collaboration with stakeholders initiated, other commercial partners are being contacted. Goals identified during the Washington DC Roadmap Workshop to be further reviewed with industry and government partners.
- Task 4 – COE research objectives for Human Rating task being aligned with academic plans for the PhD student working on this project.

TASK 183. FLIGHT CREW MEDICAL STANDARDS AND PARTICIPANT ACCEPTANCE GUIDELINES

- **PROJECT AT-A-GLANCE**
- AST RDAB POC: Doug Graham
- AST RESEARCH AREA: 3.1 Human Spaceflight – Aerospace Physiology & Medicine
- UNIVERSITY: University of Texas Medical Branch
- PRINCIPAL INVESTIGATOR: Dr. Richard Jennings, MD
- STUDENT RESEARCHER: Dr. Leigh Lewis, MD, Dr. Chuck Mathers, MD
- PERIOD OF PERFORMANCE: Jan 1, 2011 – Dec 31, 2012
- STATUS: Ongoing. Year 2 of 2.

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Commercial space flight will enable the participation of the general public with a variety of disease states that have not been studied to date. This study can guide FAA regulations regarding standards for spaceflight participants.

STATEMENT OF WORK

- Collect and review the existing documents addressing space flight crew member medical certification, passenger medical evaluation guidelines, and recommendations about testing and training for both crew and passengers.
- Prepare a document incorporating the various standards and recommendations and review/comment by commercial space flight industry members and organizations.
- Convene a working group of experts to recommend the medical certification of crew members, medical clearance of passengers, and recommended training procedures.
- Develop a passenger 'Informed Consent' document to convey risks related to personal medical status.

COMMERCIAL SPACEFLIGHT PARTICIPANTS HAVE A VARIETY OF MEDICAL CONDITIONS

STATUS

- Phase I document completed and distributed for review
- Updated document to be distributed by end of 2011

FUTURE WORK

- Phase 2 meeting of players in Feb-March 2012
- Final Document to FAA by June 30, 2012
- Informed Consent Dec 31, 2012.

TASK 193. ROLE OF COE CST IN ENCOURAGE, FACILITATE AND PROMOTE (R&D ROAD MAPPING)

- **PROJECT AT-A-GLANCE**
- AST RDAB POC: Ken Davidian
- AST RESEARCH AREA: 4.5 Industry Viability–Crosscutting
- UNIVERSITY: Stanford University
- PRINCIPAL INVESTIGATOR: Prof. Scott Hubbard
- STUDENT RESEARCHER: Mr. Jonah Zimmerman (MS)
- PERIOD OF PERFORMANCE: Jan 1, 2011 – Dec 31, 2011
- STATUS: Ongoing. Year 1 of 5.

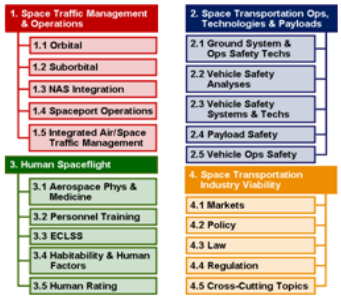
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- The structure of FAA AST R&D activities was set at the highest level in August 2009 but lacked detail of scope and input from other sources government, industry and academia. To better organize and manage the overall R&D activity, a research road map could ensure consistency and efficacy of AST's R&D efforts.

STATEMENT OF WORK

- Phase I - Preliminary Foundation: Identify Scope; Find leadership and acquire sponsorship; Demonstrate problem being solved.
- Phase II - Development Phase: Designate "product" that is the focus; Identify the critical requirements and technology/research areas; Study research alternatives and create needs timeline; Write roadmap report.
- Phase III - Building Consensus and Follow-up: Explain roadmap to larger community; Obtain independent critique and validation; Update as needed.

STRUCTURE OF FAA AST'S FOUR RESEARCH AREAS



STATUS

- Workshop #1 @ Stanford University: April 6-7, 2011, 51 representatives of industry, academia, government. Defined initial theme objectives and structure.
- Workshop #2 @ Washington DC, Lockheed Martin Global Vision Center, August 15-17, 2011, 73 representatives in attendance, Refined theme structure and research prioritization.
- Report status: - First draft completed; Major revisions based on Ken Davidian's comments underway.

FUTURE WORK

- Disseminate results to the community; Improve based on resulting comments and critiques; Update periodically.
- Implement roadmap into COE's research planning and decision making.

TASK 193. ROLE OF COE CST IN ENCOURAGE, FACILITATE AND PROMOTE (GRADUATE WORKSHOPS)

- **PROJECT AT-A-GLANCE**
- AST RDAB POC: Ken Davidian
- AST RESEARCH AREA: 4.5 Industry Viability–Crosscutting
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. George Born
- STUDENT RESEARCHER: Mr. Bradley Cheetham (PhD), Ms. Juliana Feldhacker (PhD)
- PERIOD OF PERFORMANCE: Jan 1, 2011 – Dec 31, 2011
- STATUS: Ongoing. Year 1 of 5.

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- The FAA COE program has three primary goals: research, training and outreach. This activity emphasizes COE CST's outreach goal by engaging students in graduate seminar activities, conference attendance that emphasizes commercial space topics, and the execution of specific research work for presentation at professional space conferences in commercial space paper sessions.

STATEMENT OF WORK

- Identify key industry characteristics to facilitate EFP efforts.
- Support on-going FAA COE CST road mapping efforts.
- Hosted workshops for student and young professionals.
- Support conferences to educate students and young professionals.
- Incorporate young professional perspectives in ongoing efforts.

ESIL-01 WORKSHOP ATTRACTED 26 ATTENDEES

STATUS

- Wrote and presented 2011 IAC paper "Strategic Evaluation of Commercial Crew to Orbit Transportation Industry Structure and Status" which was a second iteration of Michael Porter's Industry Structural Analysis on the on-orbit spacecraft commercial market segment.
- Conducted the first Emerging Space Industry Leaders (ESIL-01) Workshop on October 26-27 in Boulder, CO.
- Partnered with SEDS SpaceVision to support dissemination of industry information to broad diverse student population by partnering with CU SEDS chapter, speaker advising and assistance, and recording/dissemination of programming.

FUTURE WORK

- Future iterations of Industry Structural Analysis work.
- ESIL-02 and beyond: discussing options in Spring 2012; Future workshops hosted around the country in collaboration with other industries.
- SpaceVision 2012

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