Florida Institute of Technology

Florida State University

NM State University

New Mexico Tech

Leland Stanford Junior University

University of Colorado

University of Central Florida

UF University of Florida

utmb Health

www.coe-cst.org

COE CST Center of Excellence for Commercial Space Transportation

Federal Aviation Administration Center of Excellence for Commercial Space Transportation

Year 2 Annual Report

Executive Summary

December 31, 2012

Federal Aviation Administration
Center of Excellence for Commercial Space Transportation
Year 2 Annual Report Executive Summary
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Pictured below: Participants of the COE CST Emerging Space Industry Leaders Workshop #2, held in Washington, D.C. on April 26-27, 2012.

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 2 Annual Report Executive Summary.

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

All efforts have been made to ensure the accuracy of information included in this report but it is possible that errors may have crept in. Please address any questions or corrections to COE CST Program Manager, Ken Davidian, 202-267-7214, ken.davidian@faa.gov.

- December 31, 2012

Pictured right: COE CST plaques were presented to each of the member universities in 2012. Left column from top to bottom: University of Florida, Florida Tech, University of Colorado Boulder, and University of Texas Medical Branch Galveston. Right column from top to bottom: Florida State University New Mexico Tech, Stanford University, University of Central Florida, and New Mexico State University.

INTRODUCTION

This document accompanies a more detailed Year 2 Annual Report of the FAA Center of Excellence for Commercial Space Transportation (COE CST) that began operation on August 18, 2010. The period of the COE CST second year is January 1 through December 31, 2012.

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.

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.

Quad charts are next given and each of the research tasks initiated, conducted and concluded by the COE CST during the second year of operation[1] is listed and summary information of each is provided.

Finally, a comprehensive list of research partners, students and publications that contributed to the COE CST second year of operation are given.

OVERVIEWS

FAA OFFICE OF COMMERCIAL SPACE TRANSPORTATION

As of December 2012, 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 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.

[1] The first “year” of COE CST operation began on August 18, 2010 and ended December 31, 2011. The second year of COE CST operation covered in this document includes all of calendar year 2012.

- The National COE for Aviation Operations Research (NEXTOR), operated from 1996 to 2007.
- The Airworthy Assurance COE (AACE) operated from 1997 to 2007.
- The COE for General Aviation Research (CGAR), in operation from 2001 to 2013.
- The Partnership for Aircraft Noise & Aviation Emissions Mitigation Research (PARTNER), in operation from 2003 to 2013.
- The Joint Center for Advanced Materials (JAMS), in operation from 2003 to 2015.
- The Airliner Cabin Environment Research (ACER) Center, also called the COE for Research in the Intermodal Transport Environment (RITE), in operation from 2004 to 2014.

Since the creation of the COE CST in August 2010 and as of December 2012, one new COE has been created and another two COEs been announced. They are:

- The Center of Excellence for General Aviation Safety Research (named PEGASAS, Partnership to Enhance General Aviation Safety, Accessibility and Sustainability), established in 2012.
- The Center of Excellence for Alternative Jet Fuel and Environment, announced in 2012.

FAA CENTER OF EXCELLENCE FOR COMMERCIAL SPACE TRANSPORTATION

COE CST YEAR 2 HIGHLIGHTS

The following are the major milestones for the FAA COE CST during its second year:

At-A-Glance Metrics	Year 1	Year 2
# Research Tasks	34	43
# New / # In Process / # Ended	*34 / 0 / 0*	*9 / 24 / 10*
# Tasks per Research Area	*7 / 10 / 6 / 2 / 9*	*7 / 13 / 8 / 4 / 11*
# Principal Investigators	27	28
# Students	31	37
# Reports	0	38
# Research Partners	NA	17
# Industry Partners	NA	28
# Affiliate Members	0	1
Funding	$2M (FY10)	$0.5M (FY11) $1.9M (FY12)

- Second Annual Administrative Meeting held at FSU in Tallahassee, Florida on April 25-26, 2012.
- Creation of the Executive Committee, consolidating the Coordinating and Planning Committees into a single entity, and creation of 3 Subcommittees: Self-Governance, Strategic Planning, and Collaboration.
- First Full Year of operation for the COE CST Industry Advisory Committee (CESTAC)
- Induction of the first Affiliate Member, McGill University of Montréal, Canada, also the first international member.
- Second Annual Technical Meeting held at NMT in Socorro, New Mexico on October 31-November 1, 2012.

In the second year of COE CST operation, there were 9 new tasks started, 24 ongoing from the previous year and 10 tasks completed. The complete list of all tasks is given in the second half of this executive summary.

FAA FUNDING DETAILS

During the 2012 funding cycle, all funded COE CST research tasks were synchronized to a period of performance that starts on June 1 of the funding year and ends on May 31 of the next. During the one-year period between June 1, 2012 and May 31, 2013 tasks are using some combinations of FY10, FY11 and FY12 funds.

COE CST STUDENTS, PARTNERS AND PUBLICATIONS

In the second year of operation, the COE CST benefited from the services of 37 students, 17 research partners and 28 industry partners. The combined effort resulted in 38 technical or programmatic papers published in journals or presented at conferences. A complete list of students, partners (both industry and research organization) and publications are given after the research task summary charts in this report.

COE CST 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) and 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.

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.

In 2012, McGill University of Montréal, Canada, joined the COE CST as the first Affiliate University. The remainder of this section provides more detail on each of the nine member universities and one affiliate university of the COE CST.

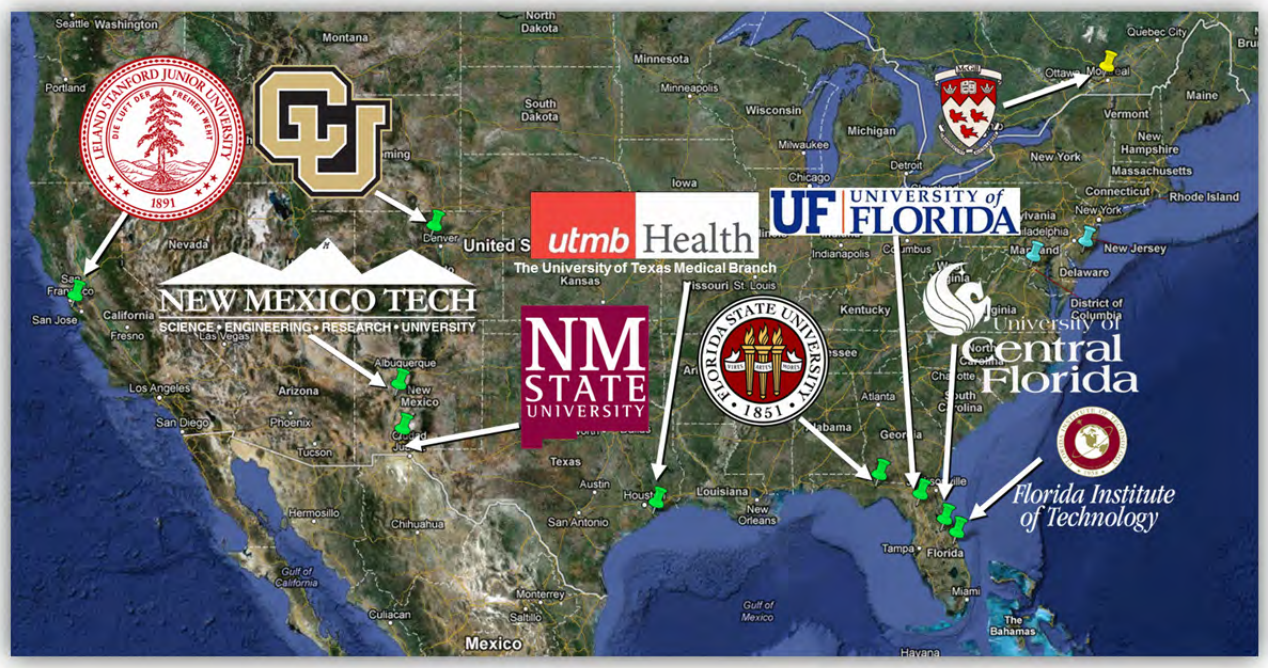
FLORIDA INSTITUTE OF TECHNOLOGY (FIT)

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.

COE CST Member and Affiliate University Geographic Distribution



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.

AFFILIATE MEMBER: MCGILL UNIVERSITY (MU)

McGill University's Institute of Air and Space Law (IASL) offers the most comprehensive and advanced graduate level space law program in the world covering General Principles of Space Law, Law of Space Applications and Government Regulation of Space Activities.

COE CST RESEARCH TASKS

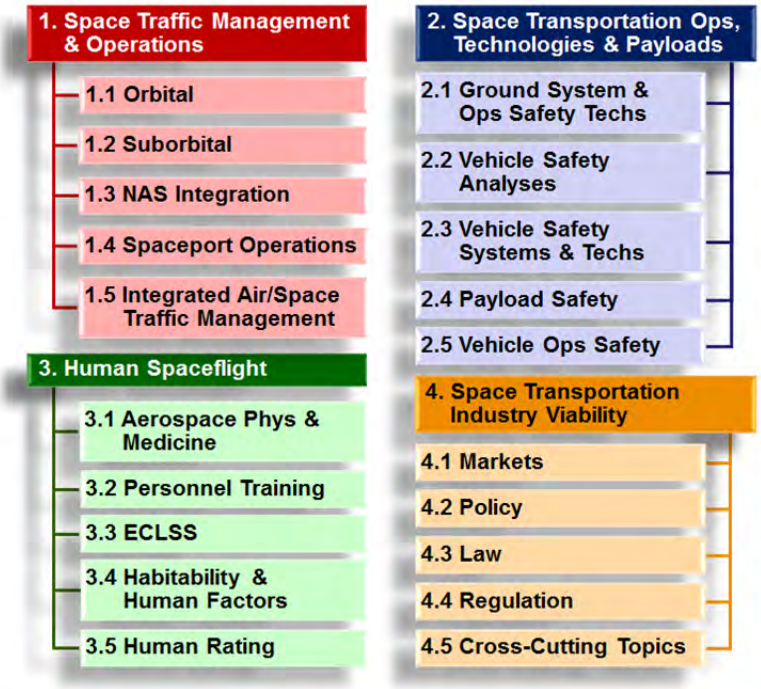
The research conducted within FAA AST is broken into four major research areas:

- 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 second year of operation followed by summary charts for each task.

The presentation order of the summary charts follows the list of tasks given in the table below.



Task # Name / PI Name (Univ) - AST TM		Task # Name / PI Name (Univ) - AST TM	
185 Unified 4-Dimensional Trajectory Analysis Alonso (SU) - Wilde	IP	**181 Physiological DB Definition and Design** Vanderploeg (UTMB) - Lampazzi	IP
186 Space Environment MMOD Modeling and Prediction Close(SU),Fuller-Rowell(CU)-Shelton-Mur	2xIP	**182 Human System Risk Management Approach** Vanderploeg (UTMB) - Lampazzi	END
187 Space Situational Awareness Scheeres (CU) - Earle	IP	**183 Crew and HSP Medical Standards** Jennings (UTMB) - Lampazzi	END
220 Space Operational Framework Hynes (NMSU) - Rey	IP	**184 Human Rating of Commercial Spacecraft** Klaus (CU) - Lampazzi	IP
247 Air and Space Traffic Considerations for CST Villaire (FIT) - Murray	IP	**255 Wearable Biomedical Monitoring Equipment** Jennings (UTMB) - Lampazzi	IP
257 Master's Launch and On-Orbit Operations Laboratory Born (CU) - Rey	IP	**256 Additional NASTAR Centrifuge Testing** Vanderploeg (UTMB) - Lampazzi	IP
228 Magneto-Elastic Sensing for Structural Health Monitoring Zagrai,Ostergren (NMT) -Demidovich	IP	**294 Minor Injury Severity Scale** Jennings (UTMB) - Gerlach	NEW
241 High Temperature Pressure Transducers Sheplak (UF), Oats (FSU) - Demidovich	2xIP	**295 EMF Effects on Implantable Devices** Vanderploeg (UTMB) - Lampazzi	NEW
244 Autonomous Rendezvous and Docking Fitz-Coy (UF), Collins (FSU), Rock (SU), Axelrad (CU) -Earle	4xIP	**193 Role of COE CST in EFP** Hubbard (SU), Born (CU) - Davidian	2xIP
253 Ultra High Temperature Composites Gou & Kapat (UCF) - Demidovich	IP	**301 Spaceport Regulation in a Post-modern Pluralistic World** Jakhu (MU) - Sloan	NEW
258 Multi-Disciplinary Analysis of Safety Metrics Alonso (SU) - Wilde	IP	**302 International Commercial Space Regulations** Jakhu (MU) - Touré	NEW
259 Flight Software Validation & Verification for Safety Alonso (SU) - Wilde	IP	**281-284, 286-289 Technical Oversight** (CU, FIT, FSU, NMSU, SU, UCF, UF, UTMB) - Davidian	8xEND
293 Reduced Order Non-Linear Structural Modeling Miller (NMT) - Demidovich	NEW	**296 CESTAC Support and Outreach** Fiedler (FIT) - Davidian	NEW
298 Integration Evaluation of ADS-B Payloads Hynes (NMSU) - Demidovich	NEW	**297 Technical Oversight & OMIS** Alvi (FSU) - Davidian	IP
299 Nitrous Oxide Composite Tank Testing Ostergren (NMT) - Tran	NEW	**300 Collaborative Activities** Fiedler (FIT) - Davidian	NEW

Note: Among the 43 COE CST tasks active in Year 2, 9 are new (NEW), 24 are in process (IP) and 10 ended (END).
Abbreviations: CU-University of Colorado Boulder, FIT-Florida Tech, FSU-Florida State University, NMSU-New Mexico State University, NMT-New Mexico Tech, SU-Stanford University, UCF-University of Central Florida, UF-University of Florida, UTMB-University of Texas Medical Branch at Galveston

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

PROJECT AT-A-GLANCE

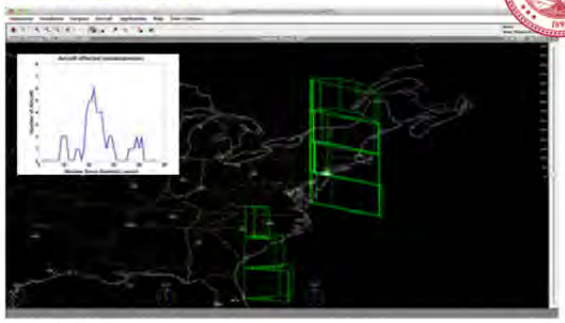
- AST TECH MONITOR: Paul Wilde
- UNIVERSITY: Stanford University
- PRINCIPAL INVESTIGATOR: Dr. Juan J. Alonso
- STUDENT RESEARCHER: Mr. Tom Colvin (Ph.D.)
- STATUS: Ongoing

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 (IAMS)
- Research and develop the foundation of IAMS based on 4D, time-space probabilistic trajectories and safety assessments



STATUS

- Existing models accept arbitrary thrust, weather, and failure profiles for Monte Carlo simulation of trajectories in 4D
- Creates multiple 4D polygonal envelopes around the trajectories (and debris) that represent a no-fly zone
- Automated interface with FACET to count aircraft piercings of compact envelopes (surrogate for time delays)
- Ready to begin analyzing launch profiles / architectures

FUTURE WORK

- Generate realistic mission profiles for analysis
- Develop FACET to reroute aircraft around compact envelopes and calculate added distance / time for aircraft
- Run trade studies and optimize architectures for probabilistic rocket trajectories to minimize impact on NAS

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

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Karen Shelton-Mur
- UNIVERSITY: Stanford University
- PRINCIPAL INVESTIGATOR: Sigrid Close
- STUDENT RESEARCHER: Alan Li (MS), Steven Pifko (NSF), Ryan Volz (NSF)
- STATUS: Ongoing

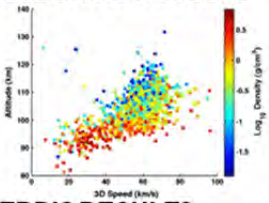
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

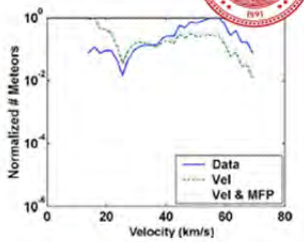
- An integrated air and space traffic management system requires knowledge of the threat to objects in and entering Low Earth Orbit (LEO). LEO spacecraft are routinely struck by impactors, both human-made (space debris, posing a mechanical threat) and natural (meteoroids, posing a mechanical and electrical threat). Characterizing the impactor population through data analysis and modeling will help predict meteoroid and orbital debris (MOD) threat to the launch and operation of commercial LEO spacecraft.

STATEMENT OF WORK

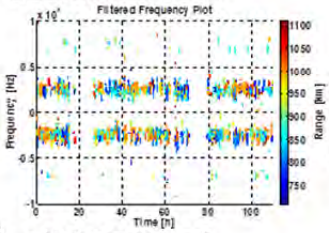
- Provide the first characterization of debris and meteoroid parameters, including e.g. energy flux, orbit, and bulk density, in order to assess MOD threat to LEO spacecraft.

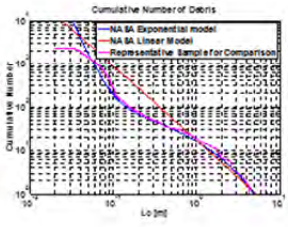
METEOROID RESULTS





DEBRIS RESULTS





FUTURE WORK

- Meteoroids
  - Energy flux model incorporating sporadic sources
  - Effect of spacecraft charging on electrical impact failure
- Debris
  - Analysis of radar (i.e. EISCAT) debris data
  - Comparison of radar data with MASTERS/ORDEM
  - Initial threat assessment model

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

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Karen Shelton-Mur
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. Tim Fuller-Rowell
- STUDENT RESEARCHER: None
- STATUS: Ongoing

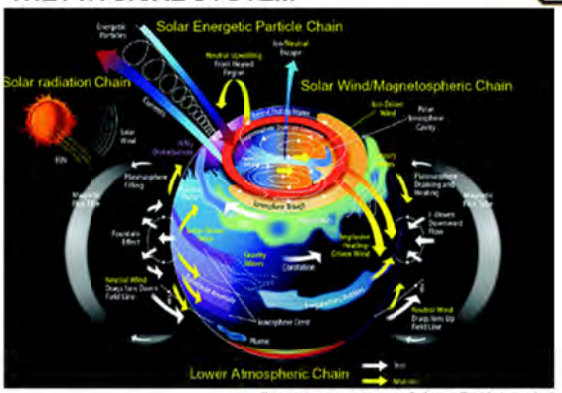
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- 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 warnings, 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.)

THE PHYSICAL SYSTEM



(image courtesy of Joe Grebowsky)

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 187. SPACE SITUATIONAL AWARENESS IMPROVEMENTS

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Steph Earle
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. Dan Scheeres
- STUDENT RESEARCHER: Mr. Kohei Fujimoto (PhD)
- STATUS: Ongoing

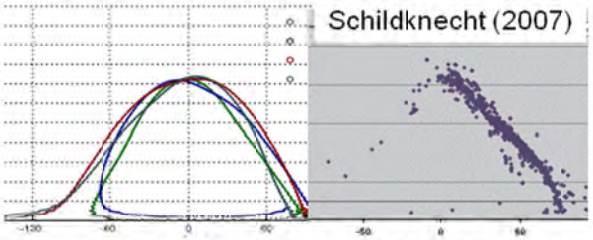
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- 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.
- Long-term policy planning is enabled by development of an improved ability to make long-term predictions of object orbits and rotation states.

STATEMENT OF WORK

- Improve uncertainty modeling and propagation, including non-gravitational modes and orbit estimation techniques.
- Examine the uncertainty associated with resident space objects and the time propagation of these uncertainties through extensive research relevant to a range of topics.
- Improve and develop new methods for long-term orbit propagation and for the rotational physics of uncontrolled objects.

RAPID, LONG-TERM REALISTIC ORBIT PROPAGATION IN GEO



Comparison of GEO observed debris and predicted 50+ year orbit evolutions in inclination/longitude of node space

STATUS

- Developing novel semi-analytical solutions for long-term probability density function propagation.
- Developing novel semi-analytical long-term orbit and rotation state propagation capability for debris
- 14 conference papers to be presented as of 2/2013
- 2 journal articles published, 7 additional to be submitted by May
- Leveraging Fellowship students for key results

FUTURE WORK

- Continue pursuing research on all fronts identified.

TASK 220. DEVELOP A SPACEPORT OPERATIONS FRAMEWORK

NM STATE UNIVERSITY

PROJECT AT-A-GLANCE

- AST TECH MONITOR: René Rey
- UNIVERSITY: New Mexico State University
- PRINCIPAL INVESTIGATOR: Dr. Patricia Hynes
- STUDENT RESEARCHER: Jacob Deavin, Hank Strevel
- STATUS: Ongoing

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Establishing a framework to capture a body of knowledge for commercial spaceport best practices will help current and future spaceport operation personnel by providing commercial and government documents that encompass commercial spaceport operations.

STATEMENT OF WORK

- Develop a framework for spaceport operations. Validate by surveying Spaceport Directors and Range Commanders.
- Analyze the framework and evolve it until it reflects a comprehensive body of knowledge of best practices for commercial spaceport operations through 2012.

U.S. SPACEPORTS

STATUS

- Integrate into the Spaceport Operations Framework applicable documents & relevant materials; enable documents to be found by title, subject, or keyword; assure copyright protections.
- Implementation of a Document Management System (DMS) including development & implementation of DMS parameters & data fields
- Add documents to the body of knowledge DMS

FUTURE WORK

- Gap Analysis

TASK 247. AIR AND SPACE TRAFFIC CONSIDERATIONS FOR COMMERCIAL SPACE TRANSPORTATION

Florida Institute of Technology

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Dan Murray
- UNIVERSITY: Florida Institute of Technology
- PRINCIPAL INVESTIGATOR: Dr. Nathaniel Villaire, Dr. Dan Kirk, Dr. Sam Durrance
- STUDENT RESEARCHER: Mr. Sebastian Rainer
- STATUS: Ongoing

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Current NAS closures due to space vehicle launch and reentry is very expensive for commercial atmospheric traffic. While costs were absorbed in the past by commercial airlines, the advent of commercial space travel has raised issues with prioritizing traffic in the NAS.

STATEMENT OF WORK

- Develop proof of concept software that suggests alternate routes around closed airspace based on cost.
- Provide information for alternate flight paths which may be selected based on meteorological, time and monetary data.

STATUS

- Acquiring and screening sample flight data
- Acquired NOTAM information for Cape Canaveral
- Basic program structure has been outlined
- Database structure has been determined
- Some initial trial data plots generated

FUTURE WORK

- Continue software development
- Integrate time, weather, and cost analysis
- Begin trial runs of software
- Examine ARTCC/RANGE procedures
- Examine specific procedures with Cape Range Officer

TASK 257. MASTERS LEVEL COMMERCIAL SPACE OPERATIONS INSTRUCTION CRITERIA

PROJECT AT-A-GLANCE

- AST TECH MONITOR: René Rey
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. George Born
- STUDENT RESEARCHER: Mr. Bradley Cheetham (PhD), Ms. Jules Feldhacker (PhD), Jon Herman (PhD)
- STATUS: Ongoing

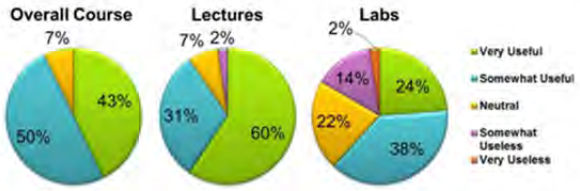
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- 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, 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 to 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, insight into current industry practices: Past to present; (d) Overview of project management and team dynamics; (e) Cross cutting theme of Risk.

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: 48 (34 on-campus, 14 off-campus).
- Assignments: Weekly discussion, 4 Open Ended Assignments, 4 Labs, 1 Research Paper.

FUTURE WORK

- Fall 2012: Second lecture offering, lab development
- Spring 2013: First lab offering
- Summer 2013: Continued refinement of lecture/lab, begin formalizing certificate

TASK 228. MAGNETO-ELASTIC SENSING FOR STRUCTURAL HEALTH MONITORING

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Nick Demidovich
- 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)
- STATUS: Ongoing

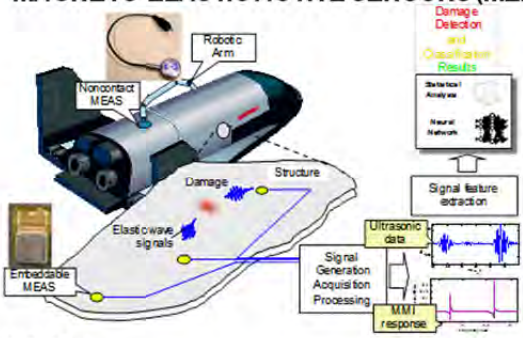
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- 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)

UF UNIVERSITY of FLORIDA

PROJECT AT-A-GLANCE

- AST RDAB POC: Nick Demidovich
- UNIVERSITY: University of Florida
- PRINCIPAL INVESTIGATOR: Dr. Mark Sheplak
- STUDENT RESEARCHER: Mr. David Mills (MS), Mr. Daniel Blood (MS)
- 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 operation 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

- High-Temperature Prototype Sensor Manufactured: Pt-coated sapphire diaphragm; Laser micro-machined alumina housing; Sapphire fiber w/ zirconia optical ferrule; Stainless steel package; Operates to 600°C
- Thermocompression Bonding Process Development: Addition of pressure relief ring; Bond strength >12 MPa; Substrate cracking eliminated

FUTURE WORK

- Process development: Laser machining parameters for thinning sapphire diaphragms; Bond strength evaluation using chevron notched test specimens
- Fabricate and package thermocompression bonded sensor
- PWT Calibration: Frequency response; Linearity.
- High Temperature Calibration: Temperature drift; Environmental chamber.

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

FLORIDA STATE UNIVERSITY 1851

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Nick Demidovich
- UNIVERSITY: Florida State University
- PRINCIPAL INVESTIGATOR: Dr. William Oates
- STUDENT RESEARCHER: Mr. Justin Collins (MS)
- STATUS: Ongoing

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

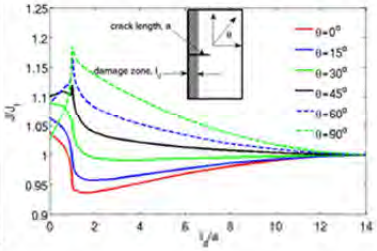
- Orbital commercial space vehicles require high-temperature sensors (~1000°C/1600°F) or various phases of flight (e.g, hypersonic flight, high speed reentry) or to monitor system and subsystem performance (e.g., for gas turbines or scramjets). Current commercial sensors are only capable of up to ~300°C/600°F.

STATEMENT OF WORK

- Implement sapphire based pressure transducer that can operate in high temperature environments (~1000°C to 1200°C)
- Sapphire cannot be manufactured using conventional silicon based chemical etching
- Sapphire based transducer requires a strong understanding of mechanical property changes due to laser micromachining
- Combined studies of fracture mechanics theory and experimental testing focused on sensor reliability

TEM LASER CHARACTERIZATION

LASER EFFECTS ON FRACTURE



STATUS

- Quantified microstructure after laser machining using Transmission Electron Microscopy
- Confirmed formation of dislocations from laser machining based on prior hypothesis (from Year 1 analysis)
- Damage zone influences the driving force for crack propagation
- Crack propagation depends on amount of damage and crystal anisotropy

FUTURE WORK

- TEM characterization after high temperature annealing of laser machined specimens
- Pressure transducer testing

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

PROJECT AT-A-GLANCE

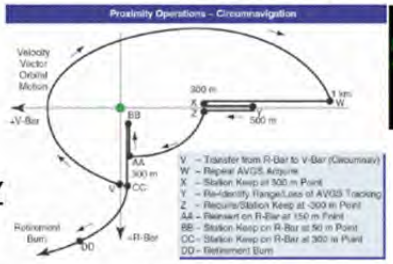
- AST TECH MONITOR: Steph Earle
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. Penina Axelrad
- STUDENT RESEARCHER: Mr. H. Stephen Phillips (PhD)
- STATUS: Ongoing

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Commercial missions require flexible and efficient methods for rendezvous and docking. This task develops a framework for autonomous rendezvous and docking in LEO that enables multiple vehicles to perform AR&D functions safely and without unnecessarily constraining vehicle design.

STATEMENT OF WORK

- Define framework for AR&D profile for cooperative & non-cooperative, unmanned & manned chaser & target objects.
- Identify technologies and risks – for each mission phase analyze the key safety and success risks and candidate technologies (sensing, guidance, control, capture, software).
- Construct compatible requirements – establish draft requirements for each phase that ensure safe operation and maximize likelihood of mission success. Assess whether technologies exist to support these requirements.



Courtesy D. Zimpfer

Scan of ISS with TriDAR on Shuttle

XSS-11 Sensors

STATUS

- Project restarted in October – new student identified, who is coming up to speed on the project.
- Met with Draper Lab expert (Doug Zimpfer) to discuss overall project approach.

FUTURE WORK

- Identify discrete mission phases and specific requirements, describe interfaces or transitions between phases, and AR&D profile.
- Evaluate maturity/risk of technologies and applicability to various mission classes – non/cooperative, un/manned, etc
- Draft framework for requirements for unmanned cooperative targets, then expand to non-cooperative and manned.

TASK 244. AUTONOMOUS RENDEZVOUS AND DOCKING (TARGET POSE & SHAPE SENSING)

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Steph Earle
- UNIVERSITY: Stanford University
- PRINCIPAL INVESTIGATOR: Dr. Steve Rock
- STUDENT RESEARCHER: Jose Padial (PhD), Marcus Hammond (PhD), Andrew Smith (PhD)
- STATUS: Ongoing

IMPROVED 6DOF GROUND-BASED HARDWARE EXPERIMENT

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

STATUS

- Camera-LIDAR simulation environment completed
- Fused vision-LIDAR algorithm validated in simulation
- Validation in ground-based experiment

FUTURE WORK

- Complete validation of fused algorithm in ground-based experiemnt
- Modify /extend algorithms for small-sat compatible processors
- Identify and prepare for flight experiment

TASK 244. AUTONOMOUS RENDEZVOUS AND DOCKING (FAST TRAJECTORY GENERATION)

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Steph Earle
- UNIVERSITY: Florida State University
- PRINCIPAL INVESTIGATOR: Dr. Emmanuel Collins
- STUDENT RESEARCHER: Mr. Griffin Francis (PhD)
- STATUS: Ongoing

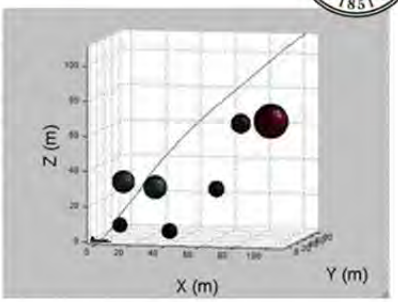
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- 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).

3D TRAJECTORY GENERATION RESULTS (WITH OBSTACLES)



STATUS

- Demonstrated 25x faster computation of 3D trajectories demonstrated than previous methods.
- Planning takes into account both final position and orientation.
- Time optimal trajectories ending in zero velocity generated for a spacecraft with 6 inputs (thrusters and rotation wheels).

FUTURE WORK

- Better visualization tool using MATLAB's Virtual Reality Toolbox.
- "Anytime" version of SBMPO.
- Configuration of lab equipment for hardware implementation.
- Formulation of power consumption model and calculation of minimum energy trajectories.
- Implement trajectory constraints based on CU research.
- Determine final pose constraints using SU and UF research.

TASK 244. AUTONOMOUS RENDEZVOUS AND DOCKING (NON-COOPERATIVE PRE/POST CAPTURE OPS)

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Steph Earle
- UNIVERSITY: University of Florida
- PRINCIPAL INVESTIGATOR: Dr. Norman Fitz-Coy
- STUDENT RESEARCHER: Mr. Windroff Marseille; Takashi Hiramatsu (graduated May 2012)
- STATUS: Ongoing

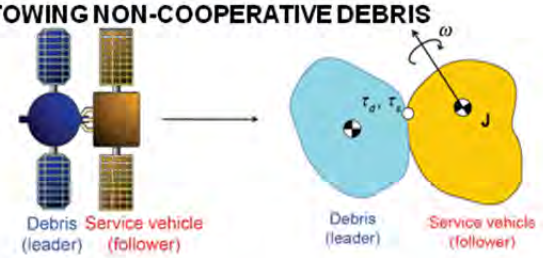
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

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.
- Post-docking: (i) Characterize non-cooperative post-docking with "disabled spacecraft" (i.e., debris). Develop control strategy to counteract debris' motion and maintain a safe docked state. (ii) Make an intelligent estimate of the debris' behavior to compute the reacting control strategy of the service vehicle. (iii) Use Stackelberg Game Theory Approach (multiple player system with non-cooperative spacecraft as leader).

TOWING NON-COOPERATIVE DEBRIS



STATUS

- Demonstrated promise for removal of non-cooperative debris through game theoretic analysis.
- Stackelberg strategy used to address post-dock interactions between service vehicle and debris: demonstrated lower interactions; developed solution preserves nonlinearity of system dynamics (linearity in the error model); however, real-time implementation may be challenging (more work needed)
- Began analysis of vision-based augmented APFG

FUTURE WORK

- Year 3: Continue assessment of APFG collision avoidance and synthesize with SBMPC; Continue assessment of post-dock scenarios (i.e., address real-time implementation issues).

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

University of Central Florida

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Nick Demidovich
- UNIVERSITY: University of Central Florida
- PRINCIPAL INVESTIGATOR: Dr. Jan Gou, Dr. Jay Kapat, Dr. Ali Gordon
- STUDENT RESEARCHER: Mr. Donovan Lui, Ms. Cassandra Carpenter, Mr. Steven Craft
- STATUS: Ongoing

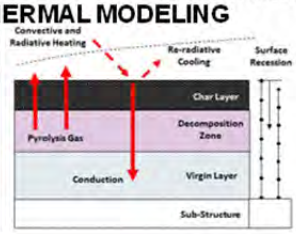
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Ultra-high temperature, light weight, low erosion, 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 nanocomposites TPS with embedded health monitoring for inherent safety and real-time assessment of hypersonic TPS applications.
- Provide an analysis tool for the aerothermal modeling of reentry vehicles and rocket propulsion.
- Provide an analysis tool for thermal degradation modeling of new ablative materials.
- Provide ablation sensing to monitor the structural health of the ablative thermal protection system.

ABLATION TESTING & THERMAL MODELING



STATUS

- Investigated 3 approaches: Phenolic Impregnated Carbon Ablator (PICA), Silicone Impregnated Carbon Ablator (SICA); Carbon/Carbon Composites.
- Manufactured nanocomposite thermal protective coating; ablation testing with oxyacetylene torch; thermal modeling of TPS structures by integrating self-developed code with Fluent.

FUTURE WORK

- Ablation Testing and Analysis: Simulated Solid Rocket Motor (SSRM) is a small scale, liquid-fueled rocket burning kerosene and oxygen
- 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 258. ANALYSIS ENVIRONMENT FOR SAFETY ASSESSMENT OF LAUNCH AND RE-ENTRY VEHICLES

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Paul Wilde
- UNIVERSITY: Stanford University
- PRINCIPAL INVESTIGATOR: Dr. Juan J. Alonso
- STUDENT RESEARCHER: Mr. Francisco Capristan (MS)
- STATUS: Ongoing

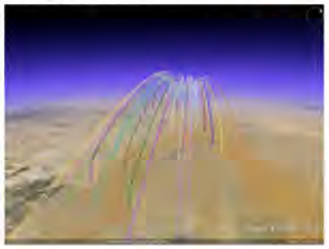
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- The ability to identify acceptable ranges of component reliabilities 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.

SIMULATED DEBRIS TRAJECTORIES



STATUS

- Debris propagation, gas dispersion, and blast overpressure have been implemented, and being fully coupled.
- Kernel density estimation implemented for calculating non-parametric density functions of debris landing on the ground.
- Casualty expectation (no sheltering) calculations already implemented.
- In-house trajectory optimization code provides initial trajectories for safety assessment.
- Previous studies from STS-107, and STS-111 used for validation.

FUTURE WORK

- Add sheltering models to the casualty expectation calculation.
- Add malfunction turns to the simulation.
- Fully integrate all the pieces of the analysis environment.
- Begin theoretical development for probabilistic inversion of safety requirements.

TASK 259. FLIGHT SOFTWARE VALIDATION & VERIFICATION WORKSHOP

PROJECT AT-A-GLANCE

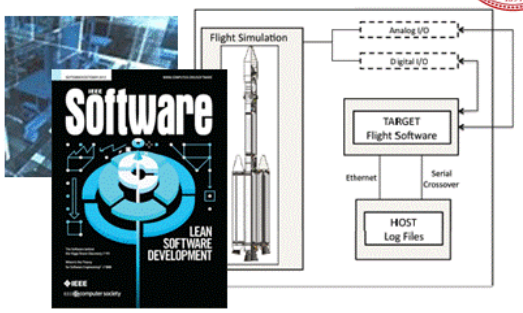
- AST TECH MONITOR: Paul Wilde
- UNIVERSITY: Stanford University
- PRINCIPAL INVESTIGATOR: Dr. Juan J. Alonso
- STUDENT RESEARCHER: None
- STATUS: Ongoing

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.
- Potential participants in workshop have been identified.
- Location and timing of workshop have been selected.

FUTURE WORK

- The intent is to hold this workshop during the Spring of 2013.
- Possibility of adding the output of workshop to road mapping activity sublevels

TASK 293. Reduced Order Non-Linear Structural Modeling

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Nick Demidovich
- UNIVERSITY: New Mexico Tech
- PRINCIPAL INVESTIGATOR: Dr. Keith Miller
- STUDENT RESEARCHER: Mr. Joshua Mendoza
- STATUS: New

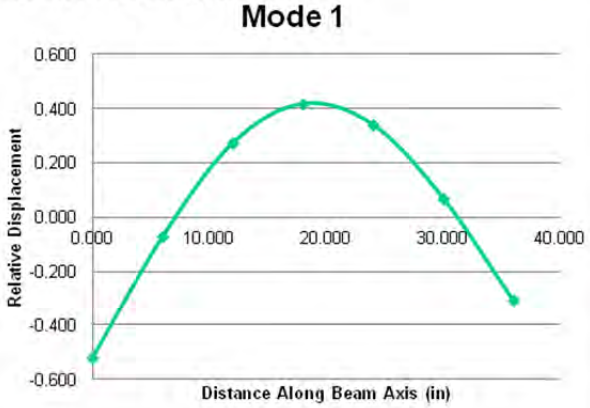
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Improve the capability of estimating the performance and safety margins of commercial space vehicles.

STATEMENT OF WORK

- Construct non-linear system level models derived from reduced order non-linear finite element models and also directly from structural test data.
- Numerical Experimentation
- Modal Testing
- FEA Implementing Physical Test Data
- Numerical Experimentation
  - FE Model Basic Concepts
  - Eigenvector Extraction
  - Matrix Manipulation
  - Model Assembly and Analysis
  - Code Analysis

EIGENVECTOR EXTRACTION



STATUS

- This project has just been initiated.

FUTURE WORK

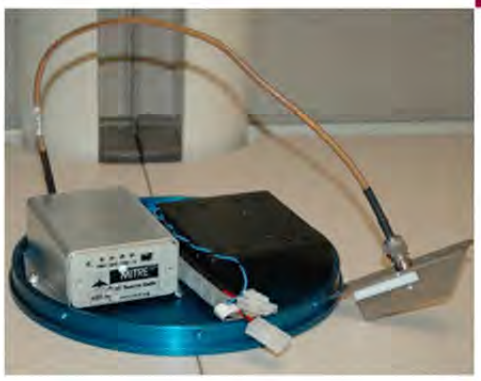
- Determine Source of Error in Current FE Models
- Re-Condition Matrices
- Properly Couple Test Data to Model

TASK 298. INTEGRATION EVALUATION OF ADS-B PAYLOADS

PROJECT AT-A-GLANCE
- AST TECHNICAL MONITOR: Nick Demidovich
- UNIVERSITY: New Mexico State University
- PRINCIPAL INVESTIGATOR: Dr. Patricia Hynes
- STUDENT RESEARCHER: None
- STATUS: Ongoing

RELEVANCE TO COMMERCIAL SPACE INDUSTRY
- The long term goal is to mature the Automatic Dependent Surveillance-Broadcast (ADS-B) system by flying it repeatedly in space, using flight data to make future versions lightweight and affordable for commercial space operators. ADS-B on commercial space vehicles will enable their seamless integration into the national airspace without disrupting the flight plans of other aircraft users. This will resolve a significant challenge to unlimited growth of the commercial space transportation industry.

STATEMENT OF WORK
- Comparative analysis from ADS-B captured data transmitted from SL6 and captured by ADS-B Receiver equipment against and vehicle IMU and WSMR radar data
- Comparative data analysis from SL7 and SL8 from ADS-B data transmitted from those flights and captured against flight data from WSMR radar and vehicle IMU.



STATUS
- Start Date: Contingent on SL7 launch- comparative analysis of flight data from SL6 with SL7 flight data
- Data Sources: White Sands Missile Range, Spaceloft XL rocket, ADS-B

FUTURE WORK
- Comparative data analysis for SL7 and SL8
- Explore launching on other platforms from Spaceport America

TASK 299. NITROUS OXIDE COMPOSITE TANK TESTING

PROJECT AT-A-GLANCE
- AST TECH MONITOR: Yvonne Tran
- UNIVERSITY: New Mexico Tech
- PRINCIPAL INVESTIGATOR: Dr. Warren Ostergren (PI), Dr. Robert Abernathy (Co-PI)
- STUDENT RESEARCHER: TBD
- STATUS: New

RELEVANCE TO COMMERCIAL SPACE INDUSTRY
- Safety will be enhanced by providing guidelines to protect the public from hazards associated with the failure of space vehicle components.

STATEMENT OF WORK
- Develop a test and instrumentation plan to quantify the fragmentation characteristics of a nitrous oxide explosion in composite cases.
  - Characterize fragmentation and blast hazard
- Utilize test and analysis results to validate or modify existing predictive models.
- Establish guidelines for safe separation distance to protect the public from accidental explosive events.
- Document technical material for the benefit of commercial users.

STATUS
- Initial test planning has commenced.

FUTURE WORK
- Establish a collaborative team of technical experts
- Define test matrix and instrumentation plan
- Procure composite cases

TASK 181. PHYSIOLOGICAL DATABASE DEFINITION & DESIGN

utmb Health

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Henry Lampazzi
- UNIVERSITY: University of Texas Medical Branch
- PRINCIPAL INVESTIGATOR: Dr. Jim Vanderploeg, MD
- STUDENT RESEARCHERS: Dr. Jennifer Law, MD; Dr. Charles Mathers, MD; Dr. David Reyes
- STATUS: Ongoing.

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- The emerging commercial space transportation industry 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. This task will improve pre-flight medica 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 better inform the need for and development of best practices and 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 system design.
- Identify the infrastructure and processes for capturing data from pre-flight, in-flight, and post-flight assessments and from research studies performed during spaceflight.

UNDERSTANDING HUMAN COMPLEXITY

STATUS

- Conducted workshop in March 2012
- Identified desired data elements for pre-flight, in-flight, and post-flight data.
- Identified desired elements of vehicle parameters.
- Secured NASA interest in hosting database on LSAH system.

FUTURE WORK

- Obtain commitment from commercial companies to participate.
- Draft SOP for control, security, confidentiality, and access.
- Final report and recommendations – Dec. 2012.

TASK 182. HUMAN SYSTEM RISK MANAGEMENT APPROACH

utmb Health

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Henry Lampazzi
- UNIVERSITY: University of Texas Medical Branch
- PRINCIPAL INVESTIGATOR: Dr. Jim Vanderploeg, MD
- STUDENT RESEARCHER: Dr. Jennifer Law, MD, Dr. Charles Mathers, MD
- STATUS: Completed

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	7	7
Least	21	20

STATUS

- Thirty-one risks have been identified and categorized.
- Ten risks for crew members and 11 for passengers were evaluated for mitigation strategies.
- Final report has been submitted.

FUTURE WORK

- The final report has been accepted for publication in a peer-reviewed medical journal (*Aviation, Space, and Environmental Medicine*).
- Follow-on project to create software system to identify and categorize risks and define mitigation strategies.

TASK 183. FLIGHT CREW MEDICAL STANDARDS AND PARTICIPANT MEDICAL ACCEPTANCE GUIDELINES

utmb Health

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Henry Lampazzi
- UNIVERSITY: University of Texas Medical Branch
- PRINCIPAL INVESTIGATOR: Dr. Richard Jennings, MD
- STUDENT RESEARCHERS: Dr. Leigh Lewis, MD, Dr. Chuck Mathers, MD
- STATUS: Ongoing.

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

- High blood pressure
- Heart disease
  - Bypass surgery
  - Stents
  - Implanted pacemakers
- Diabetes
- High cholesterol
- Allergies
- Neck, back, and extremity problems
- Cancer
- Psychiatric or psychological problems

STATUS

- Final document completed and posted on COE website for review.

FUTURE WORK

- Informed Consent recommendations to be completed.

TASK 184. HUMAN-RATING OF COMMERCIAL SPACECRAFT

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Henry Lampazzi
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. David Klaus
- STUDENT RESEARCHER: Ms. Christine Fanchiang (PhD)
- STATUS: Ongoing.

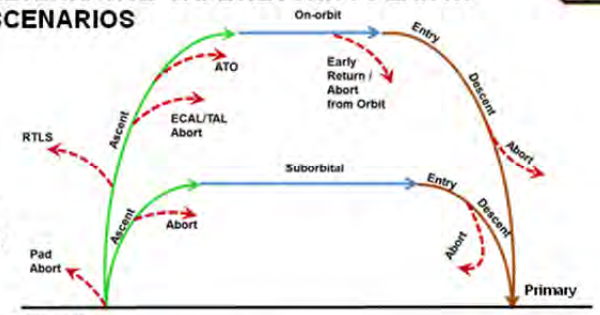
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- 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 will support the FAA's safety regulatory responsibilities.

STATEMENT OF WORK

- Solicit Human-Rating Working Group feedback against a list of pertinent terminology & definitions
- Assess existing FAA aviation design, production and operation certification processes to facilitate open discussion aimed at identifying best practices to anticipate and guide future regulatory needs.
- Contribute to definition of Human-Rating Ground Rules and Assumptions for systematic discussion amongst industry and public participants.
- Focus on 'safe return to Earth' scenarios.

ALTERNATIVE 'SAFE RETURN TO EARTH' SCENARIOS



STATUS

- Literature review of ~200 articles compiled
- Identified and aggregated over 300 terms relevant to commercial human spaceflight from 20 reference sources
- Established working document comparing NASA requirements and FAA regulations
- 2 papers (AIAA and IAC) published in FY12

FUTURE WORK

- Engaging COMSTAC support for terms and definition
- Reviewing aviation regulation for certification processes and best practices in analogous industries
- Contributing to FAA Ground Rules and Assumptions

TASK 255. WEARABLE BIOMEDICAL MONITORING EQUIPMENT FOR HUMAN SPACEFLIGHT

utmb Health

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Henry Lampazzi
- UNIVERSITY: University of Texas Medical Branch
- PRINCIPAL INVESTIGATOR: Dr. Richard Jennings, MD
- STUDENT RESEARCHERS: Dr. Anil Menon, MD, Dr. Jennifer Law, MD
- STATUS: Ongoing.

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Collection of biomedical data from the diverse population of commercial spaceflight participants (SFPs) will greatly assist the FAA in considering 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 completed.
- Equipment identified and procured for testing.

FUTURE WORK

- Equipment testing and verification in centrifuge.
- Final report with recommendations for use by commercial operators.

TASK 256. TOLERANCE OF CENTRIFUGE-INDUCED G-FORCE BY DISEASE STATE

utmb Health

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Henry Lampazzi
- UNIVERSITY: University of Texas Medical Branch
- PRINCIPAL INVESTIGATOR: Dr. Jim Vanderploeg, MD
- STUDENT RESEARCHERS: Dr. Becky Blue, MD, Dr. James Pattarini, MD, Dr. David Reyes
- STATUS: Ongoing.

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

- 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 (IRB) reviews and approvals obtained and implemented.
- Agreement with NASTAR completed.
- Test subject recruiting underway.
- Biomedical monitoring hardware selected and procured.

FUTURE WORK

- Continue recruitment of test subjects.
- Conduct training and evaluation in centrifuge.
- Evaluate biomedical monitoring equipment.
- Complete final report.

TASK 294. DEVELOPMENT OF MINOR INJURY SEVERITY SCALE FOR ORBITAL HUMAN SPACE FLIGHT

utmb Health

PROJECT AT-A-GLANCE

- AST TECH MONITOR: David Gerlach
- UNIVERSITY: University of Texas Medical Branch
- PRINCIPAL INVESTIGATOR: Dr. Richard Jennings, MD
- CO-INVESTIGATOR: Dr. Jonathan Clark, MD
- STUDENT RESEARCHER: Dr. James Cushman, MD
- STATUS: Ongoing.

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Injury severity scoring is a process by which complex and variable patient data is reduced to a single number. This value is intended to accurately represent the injured person's degree of critical illness. This project will conduct the background research and literature review and then develop a Minor Injury Severity Scale (MISS) for Orbital Human Space Flight (HSF) that identifies unacceptable injuries in the course of non-nominal HSF operations.

STATEMENT OF WORK

- Review the medical literature for existing injury scoring systems that may be useful for orbital spaceflight.
- Identify the assumptions that will drive the development of the MISS.
- Define and develop a Minor Injury Severity Scale and suggest potential mitigation strategies to protect the safety of crew members and SFPs on orbital flights.

CALCULATE INJURY SEVERITY SCORE

STATUS

- Literature review is underway.
- Existing injury scales and scoring systems are being evaluated for relevance to orbital space flight.

FUTURE WORK

- Complete literature review.
- Develop recommendations for MISS for human orbital space flight.
- Complete report and recommendations.

TASK 295. EFFECTS OF EMI AND IONIZING RADIATION ON IMPLANTABLE MEDICAL DEVICES

utmb Health

PROJECT AT-A-GLANCE

- AST TECH MONITOR: Henry Lampazzi
- UNIVERSITY: University of Texas Medical Branch
- PRINCIPAL INVESTIGATOR: Dr. Jim Vanderploeg, MD
- CO-INVESTIGATOR: Dr. Tarah Castleberry, DO
- STUDENT RESEARCHER: Dr. David Reyes, MD
- STATUS: New.

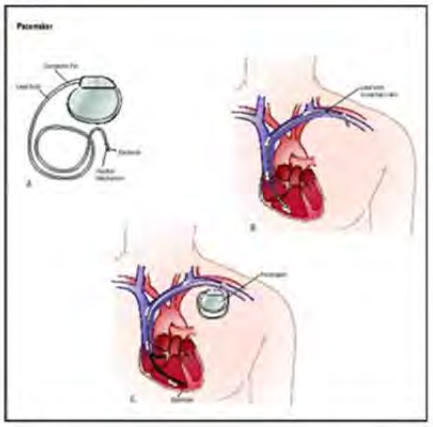
RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- As commercial SFPs begin flying some of them may have implanted medical devices such as pacemakers, medication pumps, or nerve stimulators. The impact on the function of these devices when exposed to electromagnetic interference (EMI) in the space craft or to higher energy radiation particles is unknown and could be potentially hazardous to the health of the SFP.

STATEMENT OF WORK

- Investigate known effects of EMI and ionizing radiation environments on the performance of implantable medical devices.
- Extrapolate potential impacts on the function of implanted medical devices in SFPs flying in spacecraft at suborbital and low Earth orbit altitudes.

IMPLANTED MEDICAL DEVICES



STATUS

- Literature review is underway.
- Existing data on EMI and ionizing radiation effects are being reviewed.

FUTURE WORK

- Complete literature review.
- Obtain data from equipment manufactures.
- Assess risks of EMI and radiation on device performance.
- Complete report and recommendations.

TASK 193. ROLE OF COE CST IN ENCOURAGE, FACILITATE AND PROMOTE (SECONDARY & HOSTED PAYLOADS)

PROJECT AT-A-GLANCE
- AST TECH MONITOR: Ken Davidian
- UNIVERSITY: Stanford University
- PRINCIPAL INVESTIGATOR: Prof. Scott Hubbard
- STUDENT RESEARCHER: Jonah Zimmerman (PhD)
- STATUS: Ongoing.

RELEVANCE TO COMMERCIAL SPACE INDUSTRY
- In our recent research roadmapping effort, identifying and characterizing the space transportation market was identified as a priority research task for the Center of Excellence. In order to find a tractable focus area, we took our industry partners' suggestion of investigating secondary and hosted payloads (SHP's). SHP's represent a unique opportunity to achieve low cost access to space, yet are rarely used. Our task will work to identify the barriers to SHP's and how they can be overcome.

STATEMENT OF WORK
- Phase I – Reach out to industry partners and utilize their expertise to obtain an understanding of the landscape.
- Phase II – Identify specific research objectives.
- Phase III – Complete the previously identified objectives via various analyses and studies.
- Phase IV – Disseminate results.

(CHIRP) COMMERCIALLY HOSTED INFRARED PAYLOAD

STATUS
- We have identified specific points of contact and engaged in discussions with five main industry partners who are involved in SHP's: ULA, SS/L, Scitor Corporation, Orbital Sciences Corporation, and Lockheed Martin.
- Our results suggest that programmatic issues are the primary barriers to SHP's. This includes scheduling differences, problems with monetization, and match making between primary payloads and SHP's.

FUTURE WORK
- Identify specific tasks that we can accomplish to mitigate programmatic barriers.
- Conduct Forum on Space Entrepreneurship Jan 31-Feb 1, 2013 Stanford University (SIEPR/COE CST)
- Launch new peer-reviewed journal "New Space"; Editor-in-Chief is Prof. Scott Hubbard

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

PROJECT AT-A-GLANCE
- AST TECH MONITOR: Ken Davidian
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. George Born
- STUDENT RESEARCHER: Mr. Bradley Cheetham (PhD), Ms. Juliana Feldhacker (PhD)
- STATUS: Ongoing.

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.

ESIL-02 WORKSHOP ATTENDEES

STATUS
- Wrote and presented 2012 IAC paper "Theory Based Analysis of the Commercial Crew to Orbit Transportation Industry Structure and Evolution" which was a third iteration of Michael Porter's Industry Structural Analysis on the commercial crew orbital transportation market segment.
- Conducted the second Emerging Space Industry Leaders (ESIL-02) Workshop in May 2012 in Washington DC
- Presented conclusions from ESIL-02 at IAC 2012

FUTURE WORK
- Future iterations of Industry Structural Analysis work.
- Maintaining industry contacts to identify appropriate partnerships
- ESIL-03 planned for November 2012 in conjunction with SpaceVision 2012
- Future ESIL workshops expected in other regional or industry areas

TASK 301. SPACEPORT REGULATION IN A POST-MODERN WORLD

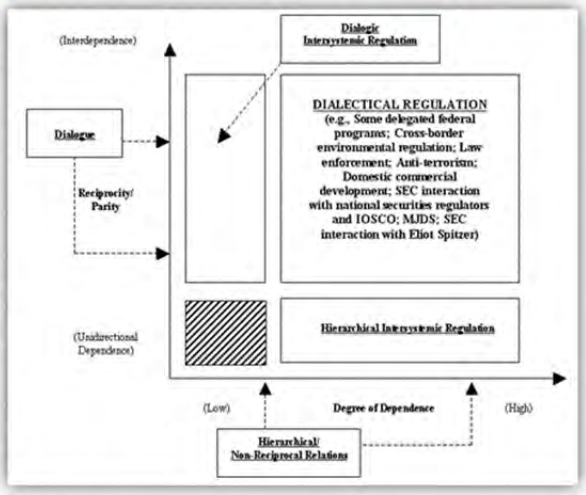
McGill

PROJECT AT-A-GLANCE
- AST TECH MONITOR: John Sloan, Mahamane Touré
- UNIVERSITY: McGill University
- PRINCIPAL INVESTIGATOR: Prof. Ram Jakhu
- STUDENT RESEARCHER: Ms. Diane Howard (PhD)
- STATUS: Ongoing.

GOAL OF THESIS
- Propose innovative and viable regulatory solutions which will help law-makers, regulators, and stakeholders better understand the ingredients of the stovepipes that have developed around spaceports in the US and Europe, the consequences of maintaining the systems as they stand, and increase their awareness of available mechanisms to facilitate integrated spaceport operations globally.

RELEVANCE TO COMMERCIAL SPACE INDUSTRY
- Currently, suborbital spaceport regulation is developing in two very different directions in the US and Europe. This has the potential to impact safety and the management of liability.

STATEMENT OF WORK
- Phase I – Define scope of study, terms, infrastructure
- Phase II – Historical examination; laws as they are
- Phase III – Comparative exercise
- Phase IV – Analysis and recommendations
- Phase V – Disseminate results



STATUS
- Phase 1-4 complete.
- Research has been provided to experts for feedback.

FUTURE WORK
- Continue work with identified entities positioned for this stage of norms emergence life cycle
- Include sources in Framework (1.4)
- Publish the work.

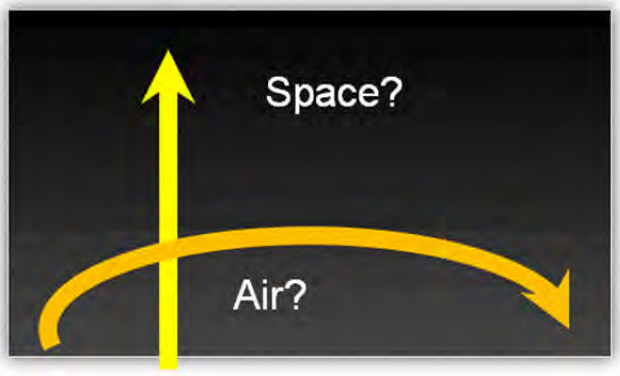
TASK 302. INTERNATIONAL COMMERCIAL SPACE REGULATIONS

McGill

PROJECT AT-A-GLANCE
- AST TECH MONITOR: John Sloan, Mahamane Touré
- UNIVERSITY: McGill University
- PRINCIPAL INVESTIGATOR: Prof. Ram Jakhu
- STUDENT RESEARCHER: Mr. Paul Fitzgerald (PhD)
- STATUS: Ongoing.

RELEVANCE TO COMMERCIAL SPACE INDUSTRY
- In anticipation of future inter-country travel via Spacecraft in Low Earth Orbit, a legal framework is required to deal with Air Traffic Management and Safety issues. This has the potential to impact the financial viability of such initiatives.

STATEMENT OF WORK
- Phase I – Define scope of study, terms, infrastructure
- Phase II – Historical examination; laws as they are
- Phase III – Comparative exercise
- Phase IV – Analysis and recommendations
- Phase V – Disseminate results (publication pending)

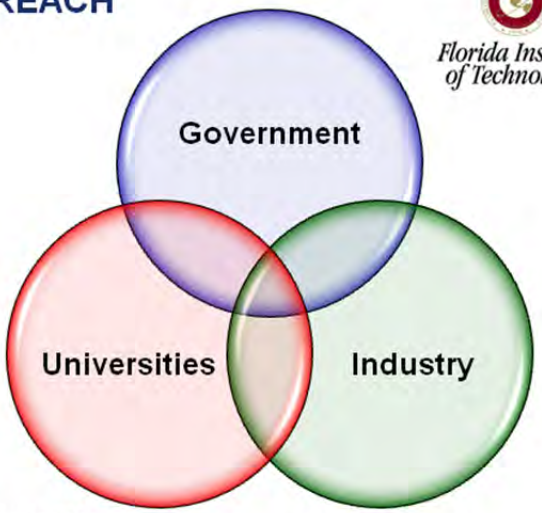


STATUS
- Phase I – IV complete.
- Research has been provided to experts for feedback.

FUTURE WORK
- Publish the work.

TASK 296. CESTAC SUPPORT & OUTREACH

Florida Institute of Technology



PROJECT AT-A-GLANCE
- AST TECH MONITOR: Ken Davidian
- UNIVERSITY: Florida Institute of Technology
- PRINCIPAL INVESTIGATOR: Dr. Tristan Fiedler
- STUDENT RESEARCHER: None
- STATUS: New

RELEVANCE TO COMMERCIAL SPACE INDUSTRY
- The COE CST industry advisory group, called the COE CST Advisory Committee (CESTAC) plays an essential role in the prioritization and evaluation of proposed and executed research tasks to derive industry input

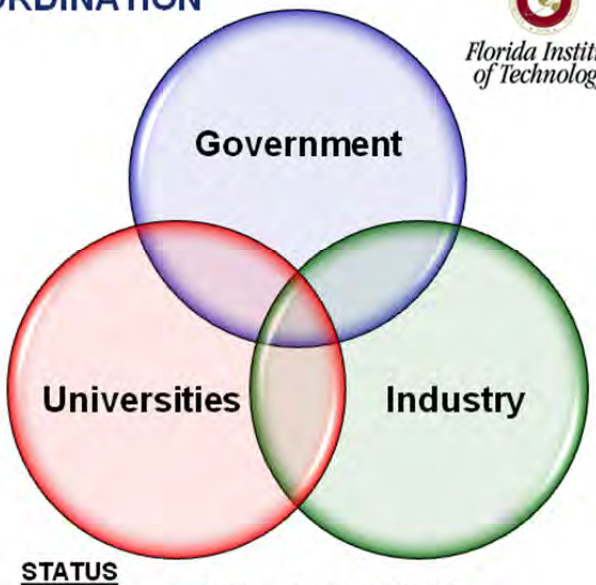
STATEMENT OF WORK
- CESTAC provides an independent consultative group input to the FAA COE CST from a broader commercial space industry community outside the formal Federal Advisory Committee (FACA) structure. Task 296 supports the CESTAC Chair and the CESTAC Liaison to the FAA COE CST participation at key FAA COE CST annual meetings and industry events

STATUS
- CESTAC review complete of Technical Reports for the FAA COE CST Tasks currently funded.
- Draft stage report due delivered December 2012.

FUTURE WORK
- The CESTAC Chair will produce a report addressing the COE CST Research portfolio and will provide suggestions of alternative tasks where deemed necessary.

TASK 300. COLLABORATION & COORDINATION

Florida Institute of Technology



PROJECT AT-A-GLANCE
- AST TECH MONITOR: Ken Davidian
- UNIVERSITY: Florida Institute of Technology
- PRINCIPAL INVESTIGATOR: Dr. Tristan Fiedler
- STUDENT RESEARCHER: None
- STATUS: New

RELEVANCE TO COMMERCIAL SPACE INDUSTRY
- Facilitates collaborative activities between members of the FAA COE CST to generate research findings directly aligned with the CST industry needs. Also works to build collaborations with external research entities and communities sharing common interests.

STATEMENT OF WORK
- Creation of a Florida Tech – FAA COE CST virtual seat at NASA Ames Research Center.
- Develop strategic activities to help meet collaborative goals of the FAA COE CST, including incorporation of affiliate members.
- Expand FAA COE CST social media influence.
- Coordination of affiliate membership and planning, logistics of annual FAA COE CST meetings as needed.

STATUS
- Dr. Fiedler elected head of the COE CST Subcommittee for Collaboration Coordination.
- Task commenced Dec 2012.
- Creation of virtual seat in progress.

FUTURE WORK
- As outline in Statement Of Work.

COE CST STUDENTS, PARTNERS AND PUBLICATIONS

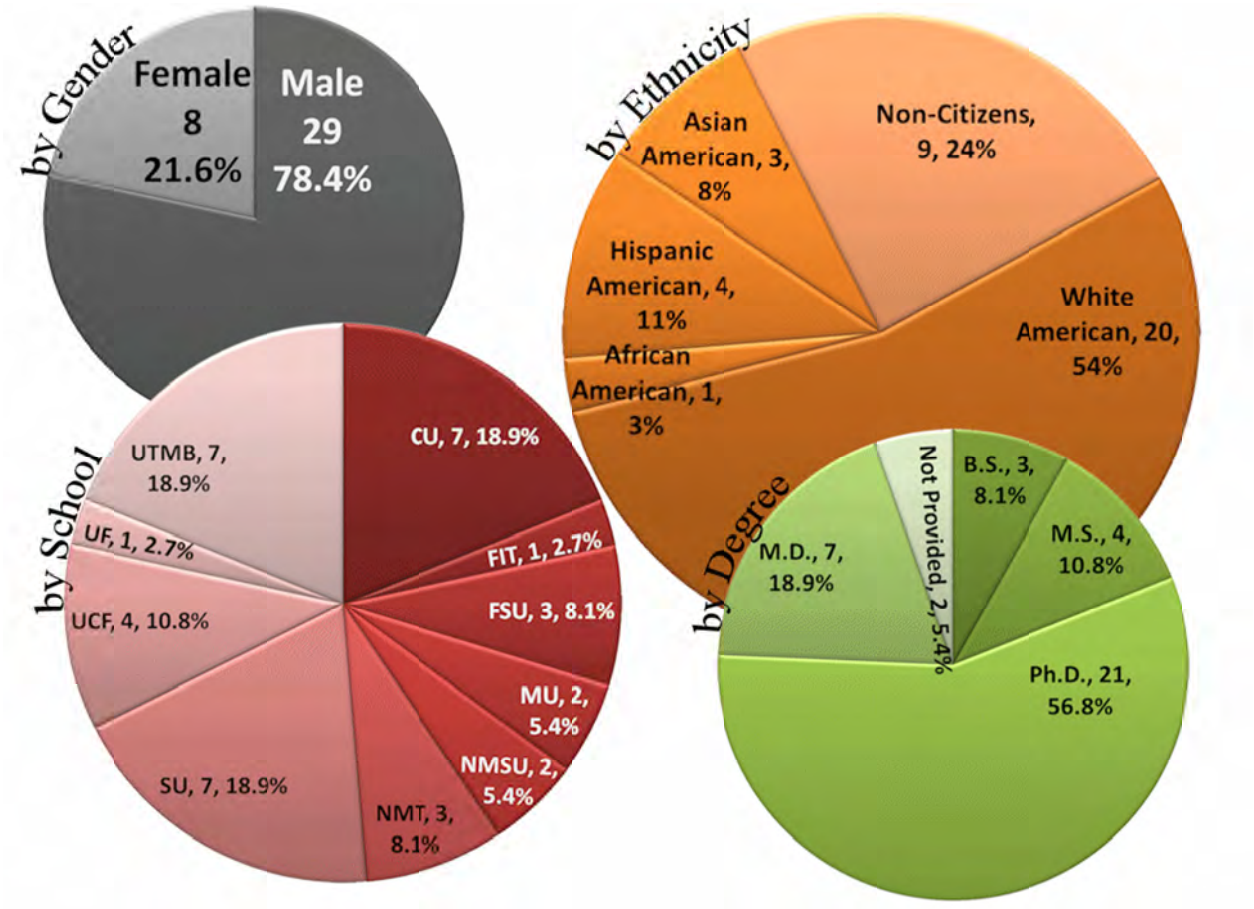
COE CST YEAR 2 STUDENTS

The following is a list and demographic information of the 37 COE CST students working on research tasks during the second year of operation.

- Blue, Rebecca (UTMB)
- Capristan, Francisco (SU)
- Carpenter, Cassandra (UCF)
- Cheetham, Brad (CU)
- Collins, Justin (FSU)
- Colvin, Tom (SU)
- Conrad, David (NMT)
- Cushman, James (UTMB)
- Deaven, Jacob (NMT)
- Fanchiang, Christine (CU)
- Feldhacker, Juliana (CU)
- Fitzgerald, Paul (MU)
- Francis, Griffin (FSU)
- Fujimoto, Kohei (CU)
- Gutierrez, Jaclene (NMT)
- Hammond, Marcus (SU)
- Herman, Jon (CU)
- Howard, Diane (MU)
- Law, Jennifer (UTMB)
- Lawrence, Jeremy (UCF)
- Li, Alan (SU)
- Mathers, Charles (UTMB)
- McGranaghan, Ryan (CU)
- Meisner, Daniel (NMT)
- Menon, Anil (UTMB)
- Mills, David (UF)
- Ocampo, Robert (CU)
- Padial, Jose (SU)
- Pattarini, James (UTMB)
- Rainer, Sebastian (FIT)
- Reyes, David (UTMB)
- Sharma, Aneesh (FSU)
- Smith, Andrew (SU)
- Strevel, Hank (NMSU)
- Yang, Xueping (UCF)
- Zhu, Jinfeng (UCF)
- Zimmerman, Jonah (SU)

Abbreviations: CU-University of Colorado Boulder, FIT-Florida Tech, FSU-Florida State University, MU-McGill University, NMSU-New Mexico State University, NMT-New Mexico Tech, SU-Stanford University, UCF-University of Central Florida, UF-University of Florida, UTMB-University of Texas Medical Branch at Galveston

COE CST Year 2 Student Demographics



COE CST YEAR 2 RESEARCH PARTNERS

The following is a list of the 17 COE CST research organization partners that have contributed to the year 2 COE CST research tasks.

- Air Force Research Lab – Kirtland
- Air Force Research Lab - Maui
- Baylor Center for Space Medicine
- University of Colorado LASP
- FAA Civil Aerospace Medical Institute
- Korean Government Grant
- Mayo Clinic Jacksonville
- Mayo Clinic Scottsdale
- Metropolitan State College of Denver
- NASA Ames Research Center
- NASA Headquarters
- NASA Jet Propulsion Lab
- NASA Johnson Space Center
- National Science Foundation (Student Fellowships)
- University of Missouri
- US Army
- Universities Space Research Assoc.

COE CST YEAR 2 INDUSTRY PARTNERS

The following is a list of the 28 COE CST industry partners that have contributed to the year 2 COE CST research tasks.

- Aerospace Concepts
- American Institute of Aeronautics and Astronautics (AIAA)
- Altius Space Machines
- Analytical Graphics Inc.
- Arianespace
- Bigelow Aerospace
- Boeing Co.
- Clear Channel Satellite
- Digital Globe
- Futron Corp.
- GeoEye
- Locked On Inc.
- Lockheed Martin Corp.
- NASTAR Center
- Orbital Sciences Corp.
- Orion America Technologies
- Paris Surgical Assoc.
- Scitor Corp.
- Sierra Nevada Corp
- Southwest Research Institute
- Space Florida
- Space Foundation
- Space Systems Loral
- Spaceport America
- Space Exploration Technologies (SpaceX)
- Special Aerospace Services
- Tauri Group
- United Launch Alliance
- Virgin Galactic
- Wyle Integrated Science & Engineering

COE CST YEAR 2 PUBLICATIONS

The following is a list of the 38 publications published or presented during COE CST year 2.

TASK 182-UTMB HUMAN SYSTEM RISK MANAGEMENT APPROACH

- Law L, Mathers CH, Fondy SRE, Vanderploeg JM, Kerstman EL. NASA's Human system risk management approach and its applicability to commercial spaceflight. Aviat Space Environ Med. 2013;84:68

TASK 183-UTMB FLIGHT CREW MEDICAL STANDARDS & PARTICIPANT MEDICAL ACCEPTANCE GUIDELINES

- Jennings, R. and Vanderploeg, J. "Flight Crew Medical Standards and Spaceflight Participant Medical Acceptance Guidelines for Commercial Space Flight" Task 183 Final Report, August 6, 2012

TASK 184-CU HUMAN-RATING OF COMMERCIAL SPACECRAFT

- Klaus, D.M., Fanchiang, C. and Ocampo, R.P. (2012) Perspectives on Spacecraft Human-Rating, AIAA-2012-3419, 43rd AIAA ICES, San Diego, CA, July 2012 (paper and presentation)
- Fanchiang, C., Defining an Operability Index for Human Spacecraft Design (student poster), 43rd AIAA ICES, San Diego, CA, July 2012
- Fanchiang, C., Johnson, M., and Ocampo, R. (2012) Evaluation of Commercial Human Spaceflight Laws and Regulations in the United States, IAC-12-D6.1.7 63rd IAC, Naples, Italy

- Close, S., R. Volz, R. Loveland, A. Macdonell, P. Colestock, I. Linscott, M. Oppenheim (2012), Determining meteoroid bulk densities using a plasma scattering model with high-power large-aperture radar data, Icarus, doi:10.1016/j.icarus.2012.07.033.
- Kelley, M., S. Pancoast, S. Close, Z. Wang (2012), Analysis of electromagnetic and electrostatic effects of particle impacts on spacecraft, Adv. Space. Res., 49, doi: 10.1016/j.asr.2011.12.023.
- Pifko, S., D. Janches, S. Close, J. J. Sparks, T. Nakamura, and D. Nesvorny (2012), Modeling the meteoroid input function at mid-lattitude using meteor observations by the MU radar, Icarus, in review.
- Li, A., S. Close and J. Markannen (2012), EISCAT space debris after the international polar year (IPY), IAC, 12.A6.1.8.

TASK 187-CU SPACE SITUATIONAL AWARENESS IMPROVEMENTS

- K. Fujimoto and D.J. Scheeres. 2012. “Correlation of Optical Observations of Earth-Orbiting Objects and Initial Orbit Determination,” Journal of Guidance, Control and Dynamics 35(1): 208-221.
- K. Fujimoto, D.J. Scheeres and K.T. Alfriend. 2012. “Analytical Non-Linear Propagation of Uncertainty in the Two-Body Problem,” Journal of Guidance, Control and Dynamics 35(2): 497-509.
- K. Fujimoto, D.J. Scheeres , and K.T. Alfriend. “Analytical Non-Linear Propagation of Uncertainty in the Two-Body Problem," paper presented at the 2011 AAS/AIAA Spaceflight Mechanics Meeting, New Orleans, February 2011. Paper AAS 11-202.
- A. Rosengren and D.J. Scheeres. “Averaged Dynamics of HAMR Objects: Effects of Attitude and Earth Oblateness,” paper presented at the 2011 AAS/AIAA Astrodynamics Specialist Meeting, Girdwood, Alaska, August 2011. Paper AAS 11-594.
- D.J. Scheeres and A. Rosengren. “Closed Form Solutions for the Averaged Dynamics of HAMR Objects,” paper presented at the 62nd International Astronautical Congress, Cape Town, South Africa, October 2011.
- K. Fujimoto and D.J. Scheeres. “Non-Linear Propagation of Uncertainty With Non-Conservative Effects," paper presented at the 2012 AAS/AIAA Spaceflight Mechanics Meeting, Charleston, SC, Jan/Feb 2012.
- S. Gehly, B. A. Jones, P. Axelrad, G. H. Born, "Minimum L1 Norm Orbit Determination Using a Sequential Processing Algorithm", paper presented at the 2012 AAS/AIAA Spaceflight Mechanics Meeting, Charleston, SC, Jan/Feb 2012.
- K. Fujimoto and D.J. Scheeres. “Non-Linear Bayesian Orbit Determination Based on the Generalized Admissible Region,” paper presented at Fusion 2012, the 15th International Conference on Information Fusion, Singapore, July 2012.
- D.J. Scheeres, M.A. de Gosson, and J. Maruskin. “Fundamental Limits on Orbit Uncertainty,” paper presented at Fusion 2012, the 15th International Conference on Information Fusion, Singapore, July 2012.
- A.J. Rosengren and D.J. Scheeres. “Long-term Dynamics of HAMR Objects in HEO,” paper presented at the AIAA/AAS Astrodynamics Specialist Meeting, Minneapolis, August 2012.
- A.J. Rosengren and D.J. Scheeres. “Prediction of HAMR Debris Population Distribution Released from GEO Space,” paper presented at the 2012 AMOS Meeting, Maui, September 2012.
- K. Fujimoto and D.J. Scheeres. “Rapid Non-Linear Uncertainty Propagation via Analytical Techniques,” paper presented at the 2012 AMOS Meeting, Maui, September 2012.
- A.J. Rosengren and D.J. Scheeres. “Long-Term Dynamics of High Area-to-Mass Ration Space Debris in GEO,” paper presented at the 63rd International Astronautical Congress, Naples, Italy, October 2012. Paper IAC-12, A6.2.5.
- K. Fujimoto and D.J. Scheeres. “Non-Linear Bayesian Orbit Determination: Angle Measurements,” paper presented at the 63rd International Astronautical Congress, Naples, Italy, October 2012. Paper IAC-12-C1.6.11.

TASK 193-CU ROLE OF COE CST IN EFP (GRADUATE WORKSHOPS)

- Cheetham, B., Feldhacker, J., Puera, A., Chandler, A., Kloberdanz, C., and Groswald, L., "Government's Role in Commercial Space from the Perspective of Emerging Industry Leaders", IAC-12-E6.4-D4.2.1, October 2012.
- Cheetham, Bradley W. "Theory Based Analysis of the Commercial Crew to Orbit Transportation Industry Structure and Evolution", IAC-12-E6.1.6, October 2012.

TASK 193-SU ROLE OF COE CST IN EFP (SECONDARY AND HOSTED PAYLOADS)

- Zimmerman, J., Hubbard S. and Davidian, K. "FAA Office of Commercial Space Transportation Research Roadmap", GLEX-2012.09.1.8, April 2012.
- Zimmerman, J., Hubbard S. and Davidian, K. "Research Roadmap for Commercial Space Transportation", IAC-12-E6.1.3, October 2012.
- Cheetham, B., Feldhacker, J., Herman, J. and Heeren, E. "Commercial Spaceflight Operations: Graduate Level Curriculum Development", IAC-12.E1.4.5, October, 2012.

TASK 228-NMT MAGNETO-ELASTIC SENSING FOR STRUCTURAL HEALTH MONITORING

- Conrad, D and Zagrai, A, (2011) “Active Detection of Structural Damage in Aluminum Alloy Using Magneto-Elastic Active Sensors (MEAS),” *Proceedings of SMASIS-11, ASME Conference on Smart Materials, Adaptive Structures and Intelligent Systems*, September 18 – 21, 2011, Scottsdale, AZ, paper: SMASIS2011-5219.
- Meisner, D and Zagrai, A (2012) “Magneto-elastic Active Sensors for Detection Of Incipient Fatigue Damage in Aerospace Structures,” International Youth Competition of Scientific Research Works “Student and Science & Technology Progress,” Taganrog, Russia, June 20, 2012.
- Conrad, D., Zagrai, A., Meisner, D, (2012) “Influence of Sensor Statistics on Piezoelectric and Magneto-elastic Damage Detection,” *Proceedings of SMASIS-12, ASME Conference on Smart Materials, Adaptive Structures and Intelligent Systems*, September 19 – 21, 2012, Stone Mountain, GA, paper: SMASIS2012-8255.
- Siler, D., Cooper, B., White, C., Marinsek, S., Zagrai, A., MacGillivray, J., Gutierrez, J., Tena, K., Magnuson, L., Puckett, L., Klepper, J., Jorgensen, A., Kessler, S., (2012) “Design, Development, and Assembly of Space Flight Structural Health Monitoring Experiment,” *Presentation at ASME Conference on Smart Materials, Adaptive Structures and Intelligent Systems*, September 19 – 21, 2012, Stone Mountain, GA.

TASK 247-FIT AIR & SPACE TRAFFIC CONSIDERATIONS FOR COMMERCIAL SPACE TRANSPORTATION

- Villaire, N., “Integration of Commercial Space Vehicle Traffic into the National Airspace System”, Task 247-FIT Year 1 Final Report, March 31, 2012.

TASK 253-UCF ULTRA-HIGH TEMPERATURE COMPOSITES FOR THERMAL PROTECTION SYSTEMS

- J.F. Zhuge, J. Gou, R.H. Chen and J. Kapat. 2012. "Finite Element Modeling of Thermo-Mechanical Response of Fiber Reinforced Polymer Composites under Constant Heat Flux," Composites Part A: Applied Science and Manufacturing. 43, 665-674.
- J.F. Zhuge, J. Gou, R.H. Chen, A. Gordon, J. Kapat, D. Hart and C. Ibeh. 2012. "Fire Retardant Evaluation of Carbon Nanofiber/Graphite Nanoplatelets Nanopaper-Based Coating under Different Heat Fluxes," Composite Part B: Engineering. 43, 3293-3305.
- J.F. Zhuge, J. Gou, R.H. Chen and J. Kapat, "Finite Difference Analysis of Thermal Response and Post-Fire Flexural Degradation of Glass Fiber Reinforced Composites Coated with Carbon Nanofiber Based Nanopapers," Composites Part A: Applied Science and Manufacturing, 43, 2278-2288, (2012)
- D. Lui, C. Carpenter, J. Gou, J. Kapat, A. Gordon. High Heat Flux Testing and Thermal Degradation Modeling of Ablative Composite Thermal Protection Systems (TPS). Student Poster at the Society for Advancement of Material and Process Engineering (SAMPE) Technical Conference, Charleston, SC, October 22-25, 2012

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