BCM

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

Center of Excellence for Commercial Space Transportation

# Federal Aviation Administration Center of Excellence for Commercial Space Transportation

## Year 7 Annual Report

## Executive Summary

December 31, 2017

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## LETTER FROM THE EXECUTIVE DIRECTOR

Center of Excellence for Commercial Space Transportation

This seventh Executive Summary of the work undertaken and the products produced by the Center of Excellence for Commercial Space Transportation highlights the breadth and depth of the work being accomplished at the now ten core universities, along with other agencies, many affiliate members, and an expanding group spaceflight companies across the country. The work summarized here demonstrates the research, education, and training necessary to support, safeguard, and promote the growing commercial space flight industry. It takes a team effort, visionary leadership, and an attitude of not accepting "no" for the answer when facing the challenges of ensuring safe access to space. Our goal is to make saying "yes" the correct and safest answer we can.

Through the guidance of the FAA Office of Commercial Space Transportation we have assembled a robust team of academia, industry, and government participants – all working together to push the edges of knowledge, science, and engineering to make the future brighter and safer for commercial space flight.

An exciting component of the information presented within is the growing number of students who are directly participating in the work of the COE. It is these individuals who will become the life-blood of workers, scientists, and engineers in the future. By engaging students at each of our universities in the research supporting commercial spaceflight, the Center of Excellence for Commercial Space Transportation will meet its mission of enabling safe access to space. We are also benefiting from an expanding number of companies and universities who have joined us as Affiliate Members, adding their research and expertise to solving the challenges of commercial space flight.

THANK YOU to the FAA Office of Commercial Space Transportation for your vision, direction, and support over the past seven years to enable these advances in commercial spaceflight.

James M. Vanderploeg, MD
Executive Director, COE CST


*Representing the FAA AST COE CST at the 2017 Next Generation Suborbital Researchers Conference (18-20 December, in Broomfield, CO) was (L to R): Dr. Jim Vanderploeg (UTMB), Nick Demidovich and Dr. George Nield (FAA AST), Eric Stallmer (CSF), and Dr. Tristan Fiedler (FIT).*

## 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 7 Annual Report Executive Summary.

The COE CST is now a collection of ten incredible universities (as will be described in more detail later in this document) supplemented by affiliate and associate members, and complemented by numerous private organizations and research institutions. Of course, within each of these entities are the people that make the COE CST what it is; the principal investigators, the students, the financial officers, the contractors, the business women (and men), the executives, the administrators, and the government researchers. It is the collective effort of these individuals that makes the research possible, provides matching cash and in-kind contributions, posts the extensive technical and financial data for government-required reports, and fundamentally makes the overall system function efficiently through their individual actions.

The first years of operation were focused on building the various types of relationships (e.g., research, administrative, financial, personal, etc.) among the many individuals at each of the original nine universities and government offices. Although the budget of the center may be relatively small, the complexity of the relationship network makes the smooth operation of this center more challenging than what may be encountered at other COEs with more universities and larger budgets. Despite this complexity, the COE CST has successfully emerged as a fully functional, cohesive unit.

Year 6 began the second half of the ten-year program. During this phase of the organization, emphasis is placed on raising the COE CST profile with industry to better understand the needs of the evolving commercial space marketplace, and to be better understood by the major marketplace actors.

Dr. George Nield, Associate Administrator of FAA AST, and Dr. Patricia Watts, National Program Director of the FAA COEs, are two individuals without whose support the COE CST could not function today. They are recognized as driving forces for the past successes of the COE CST and will be the source of any future accomplishments as well. The COE CST is very grateful for their support.

Each of these individuals, representing the dozens of participating organizations and institutions, cannot be given enough words of thanks or acts of appreciation in recognition for their contributions of time, effort, and treasure. Thank you ALL.

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 Mr. Ken Davidian, 202-267-7214, ken.davidian@faa.gov.

- January 25, 2018

## INTRODUCTION

This executive summary accompanies a more detailed, three-volume annual report of the FAA COE CST. The annual report volumes will be available on the COE CST web site:

- Volume 1 provides a full description of the FAA COE CST including its research, structure, member universities, funding, and research tasks.
- Volume 2 is a comprehensive set of presentation charts of each research task as presented at the Seventh Annual Technical Meeting in October 2017.
- Volume 3 is a comprehensive set of notes and links to recordings from all FAA COE CST teleconferences and face-to-face meetings.

The 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 COE CST became operational on August 18, 2010, with nine members. It has subsequently added an additional core university, as well as numerous Affiliate and Associate organizations, representing both academia and industry.

Brief introductions and general descriptions are provided for each of the COE CST Member Universities, the Affiliate Members, and the FAA Technical Monitors for the COE CST research tasks.

Next, this document describes the overall scope of COE CST research areas, and lists each of the research tasks initiated, conducted and concluded by the COE CST during the seventh year of operation. Finally, the report provides summary information of each task in the form of quad charts.

The Executive Summary concludes with a listing of the COE CST students, the partnering institutions from industry, the research organizations, and the technical publications delivered during the year.

## OVERVIEWS

### *FAA OFFICE OF COMMERCIAL SPACE TRANSPORTATION*

Despite its relatively small size, the FAA Office of Commercial Space Transportation (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 Air Transportation Centers of Excellence (COE) program was established by the Omnibus Budget Reconciliation Act of 1990, PL 101-508, Title IX, Aviation Safety and Capacity Expansion Act.

COEs are intended to be multi-year, multi-disciplinary partnerships of academia, industry, and government to combine world-class resources that will address current and future challenges for the aviation and aerospace communities, including commercial space transportation. The main goals of every COE include research, training and education, technology transfer and outreach.

The absolute uniqueness of the program partnerships is the mandatory one-to-one matching requirement for every federal dollar granted to a COE university to establish, operate and conduct research. 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. COE efforts which are jointly supported provide the U.S. citizens a return on their tax dollars. To date, the COE members have generated more than $300M in matching contributions to offset the research costs incurred by the government organizations.

In addition to the COE CST, there are currently 4 active FAA COEs, including:

- **The Center of Excellence for Technical Training and Human Performance (TTHP)** (on the web at coetthp.org), was established in 2016. The core focus of the COE for TTHP includes curriculum architecture, content management and delivery, simulation and part task training, human factors, analytics, safety, and program management. Core members include Auburn University, Drexel University, Embry-Riddle Aeronautical University (technical co-lead), Inter American University,

Oklahoma State University, Purdue University, Tennessee State University, the Ohio State University, the University of Akron, the University of Oklahoma (technical co-lead), Tulsa Community College, University of Nebraska-Omaha, University North Dakota, University of Wisconsin – Madison, Western Michigan University, and Wichita State University (administrative lead).

- **The Center of Excellence for Unmanned Aircraft Systems (UAS),** aka the "Alliance for System Safety of UAS through Research Excellence" (ASSURE, on the web at www.assureuas.org), was established in 2015. The core focus of the COE UAS includes air traffic integration, airworthiness, control and communication, detect and avoid, human factors, and low altitude operations safety. Core members include Mississippi State University (Lead), Drexel University, Embry-Riddle Aeronautical University, Kansas State University, Montana State University, New Mexico State University, North Carolina State University, Oregon State University, University of Alabama – Huntsville, University of Alaska – Fairbanks, University of California Davis, University of Kansas, University of North Dakota, The Ohio State University, Wichita State University, and Auburn University.
- **The Center of Excellence for Alternative Jet Fuels and Environment (AJFE)**, also known as the "Aviation Sustainability Center, (ASCENT, on the web at ascent.aero), was established in 2013. The core focus areas of ASCENT include alternative jet fuels: feedstock development, processing and conversion, regional supply and refining infrastructure, environmental benefits analysis, aircraft component deterioration and wear, fuel performance testing, environment: aircraft noise and impacts, aviation emissions and impacts, aircraft technology assessment, environmentally and energy efficient gate-to-gate aircraft operations, and aviation modeling and analysis. Core members include Washington State University (Lead), Massachusetts Institute of Technology (Co-lead), Boston University, Georgia Institute of Technology, Missouri University of Science & Technology, Oregon State University, Pennsylvania State University, Purdue University, Stanford University, University of Dayton, University of Hawaii, University of Illinois – Champagne Urbana, University of North Carolina – Chapel Hill, University of Pennsylvania, University of Tennessee, and the University of Washington.
- **The Center of Excellence for General Aviation,** aka the "Partnership to Enhance General Aviation Safety, Accessibility and Sustainability" (PEGASAS, on the web at www.pegasas.aero), and established in 2012. Major areas of focus include the enhancement of general aviation safety, accessibility, and sustainability by partnering the FAA with a national network of world-class researchers, educators, and industry leaders. Core members include Purdue University (lead), Florida Institute of Technology, Georgia Institute of Technology, Iowa State University, the Ohio State University, and Texas A&M University.
- **The Joint Center for Advanced Materials, (JAMS),** in operation since 2003, works closely with industry and government agencies on safety and certification initiatives that are related to existing and near- and long-term applications of composites and other advanced materials and manufacturing processes to aircraft applications, including large transport commercial aircraft, general aviation and unmanned aircraft system products. The overall goal is to ensure safe and reliable use of these materials in aircraft applications. Lead universities are Wichita State University and the University of Washington supported by University of Utah, Oregon State University, Florida International University, and University of California, San Diego.

Other COEs established by the FAA, who have completed their ten-year agreements and phased out of operation, include:

- 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), operated from 1996 to 2008.
- 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 2014.
- The Airliner Cabin Environment and Intermodal Research (ACERite) Center, in operation from 2004 to 2014.

## *FAA CENTER OF EXCELLENCE FOR COMMERCIAL SPACE TRANSPORTATION*

Below is a quick look at the major highlights and special mentions of COE CST year seven. The basic metrics of COE CST performance has also been updated to reflect the most recent events and activities.

### COE CST YEAR 7 HIGHLIGHTS

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

- **The seventh Annual Administrative Meeting (AAM7)** was held in Washington, DC, in conjunction with the FAA AST Annual Conference, on February 6-7, 2017. During this meeting, administrative topics were discussed, including the COE CST statement of purpose, the addition and removal of core members, the definition of "students" (discussed in more detail later in this document), the definition of "self-sufficiency" after the tenth year of operation, the reelection of the Executive Director (Dr. Vanderploeg was unanimously reelected for a second two-year term), upgrades to the Orion Management Information System (OMIS) database, implementation of new Department of Transportation policies (e.g., the data management plan, reporting of results, etc.), and plans for the upcoming Annual Technical Meeting.
- **The seventh Annual Technical Meeting (ATM7)** was held in Las Cruces, New Mexico, in conjunction with the International Symposium for Personal & Commercial Spaceflight, on October 10, 2017. During this meeting, four panels highlighted the activity in each of the four research areas, and provided an opportunity for interaction with all meeting attendees (photo of all ATM7 attendees on inside back cover). All technical presentations of COE CST research tasks presented or discussed at the ATM7 can be downloaded from the COE CST web site, www.coe-cst.org.

**Attendees at the COE CST Seventh Annual Administrative Meeting**

***AAM7 Attendees - left to right, front row:*** *Ms. Carol Gregorek (Orion America Technologies), Dr. Patricia Hynes (NMSU Lead PI), Dr. Patricia Watts (FAA COE Program Director), Ms. Karen Shelton-Mur (FAA AST Research Area 1 Lead), Dr. Guy Boy (FIT PI), Mr. Nick Demidovich (FAA AST Research Area 2 Lead), Dr. Tristan Fiedler (FIT, COE CST Collaboration Coordinator).* ***Left to right, back row:*** *Ms. Evelina Bern (FAA AST Deputy Program Manager), Mr. Fred Bowen (Orion America Technologies), Dr. Andrei Zagrai (NMT Lead PI), Mr. Ken Davidian (FAA AST COE CST Program Manager), Dr. Rajan Kumar (FSU Lead PI), Dr. Jim Vanderploeg (UTMB Lead PI, COE CST Executive Director), Dr. Tarah Castleberry (UTMB PI), Dr. David Klaus (CU Lead PI), Mr. Brad Cheetham (CU PhD Student and ESIL Workshop Leader), Dr. Juan Alonso (Stanford Lead PI).*

- **The *New Space* journa**l completed its fifth year featuring a wide range of topics pertaining to non-governmental aspects of space activities. The Editor in Chief of *New Space* is Scott Hubbard, former director of Stanford's participation in the COE CST prior to his retirement in 2015. Under Professor Hubbard's leadership, *New Space* became the "official journal of the COE CST," and the first issue in 2018 (volume 6, issue 1) will be dedicated to publications of COE CST research.


## COE CST YEAR 7 METRICS

Every year, COE CST performance is tracked through the measurement of basic metrics, including the number of active research tasks (a function of the level of funding available from the FAA AST), the number of principal investigators (an indicator of COE CST's research diversity), the number of students (an indicator of COE CST's impact), the number of publications (an indicator of the degree of COE CST knowledge creation). The number of unfunded tasks, research partners, industry partners, affiliate members, and associate members, are all a function of how well member universities are partnering with non-member research organizations. Finally, the amount of funding is provided for each fiscal year.

In year 7 of COE CST operation, 21 principal investigators (PIs) conducted 14 research tasks, resulting in 36 technical publications. After presentation of the research task summary charts (aka "quad charts"), this Executive Summary includes a list of all tasks, and provides a complete list of students, industry, research organizations, and publications.

Over these first seven fiscal years, the average annual administrative costs were just under 15% of the total budget. On the basis of six operating years (since year 2 is a combination of two fiscal years), the average is under 18%. The observed uneven distribution of administrative costs over the course of seven years stems from the timing of actual payments (e.g., paying for three bi-annual meetings from a single fiscal year's budget, instead of two).

| COE CST Metrics | Year 1 (FY10) | Year 2 (FY11-12) | Year 3 (FY13) | Year 4 (FY14) | Year 5 (FY15) | Year 6 (FY16) | Year 7 (FY17) |
|---|---|---|---|---|---|---|---|
| Active Tasks | 34 | 24 | 28 | 28 | 36 | 22 | 14 |
| Unfunded Tasks | 34 | 22 | 22 | 11 | 6 | 5 | 2 |
| Principal Investigators | 27 | 28 | 29 | 25 | 31 | 22 | 21 |
| Students | 31 | 37 | 55 | 47 | 61 | 28 | 23 |
| Publications | 0 | 38 | 28 | 22 | 29 | 19 | 36 |
| Research Partners | - | 17 | 20 | 27 | 27 | 11 | 14 |
| Industry Partners | - | 29 | 44 | 55 | 57 | 11 | 27 |
| Affiliate Members | 0 | 1 | 6 | 6 | 6 | 6 | 8 |
| Associate Members | - | - | - | 3 | 6 | 3 | 3 |
| Funding Profile | $2M | $2.4M | $1.1M | $1.1M | $1M | $1M | $1.4M |
| Administrative Overhead | 13.6% | 20.0% | 9.9% | 27.0% | 19.7% | 16.4% | 15.1% |

All information presented in this report is accurate as of the date of publication (late January, 2018). Any corrections identified after this date will be included in the COE CST Annual Report Volume 1 and on the COE CST web site.

### FAA AST TECHNICAL MONITORS

FAA AST Technical Monitors (TMs) are the links between FAA's research requirements and the work being performed by COE CST member universities. Below is a listing of the FAA COE CST TMs who contributed to the research efforts of the COE CST in year 7:

- Ms. Evelina Bern, COE CST Deputy Program Manager, Office of the Chief Engineer
- Mr. Ken Davidian, COE CST Program Manager, Office of the Chief Engineer
- Mr. Nickolas Demidovich, Office of the Chief Engineer
- Mr. Steph Earle, Office of Special Projects
- Mr. Henry Lampazzi, Licensing & Evaluation Division
- Ms. Karen Shelton-Mur, Office of the Chief Engineer
- Mr. John Sloan, Office of Strategic Planning
- Mr. Gunther Smiley, Space Transportation Development Division
- Ms. Yvonne Tran, Regulations & Analysis Division
- Dr. Paul Wilde, Deputy Chief Engineer

## COE CST MEMBER ORGANIZATIONS

The COE CST member organizations include three categories of organizations: member universities, affiliate member organizations, and associate member organizations. Member universities in 2017 include the newly added Baylor College of Medicine (BCM), 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).

### *MEMBER UNIVERSITIES*

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. As a single entity, the 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. Combined, the universities bring a large number of government, industry, and academic organizations into the COE CST network as research partners.

#### FLORIDA INSTITUTE OF TECHNOLOGY (FLORIDA TECH)

Florida Institute of Technology performs doctoral research and undergraduate and graduate education through its six academic colleges and schools with emphases on aviation, aeronautics, science, technology, engineering and mathematics. Research at Florida Tech focuses on mechanical and aerospace engineering, software and hardware resilient systems, biomedical engineering, space resource utilization, corrosion and space-related engineering, cloud physics and space weather, space traffic management and launch operations, vehicle and payload analysis and design, thermal systems, propulsion, and commercial space industry viability. Florida Tech serves as the primary COE CST liaison to industry for research partnership, and affiliate membership to the government, the private sector as well as academia. Historically known as FIT, Florida Tech's preeminent research centers and institutes include the Buzz Aldrin Space Institute, the

FAA Center of Excellence for General Aviation Research (PEGASAS), the FAA Center of Excellence for Commercial Space Transportation (COE CST), the School of Human-Centered Design, Innovation & Arts, the Harris Institute for Assured Information, and more.

### FLORIDA STATE UNIVERSITY (FSU)

FSU brings a range expertise and unique infrastructure and unparalleled testing facilities in many areas relevant to the COE CST. These include but are not limited to: cryogenics, thermal management, vehicle aerodynamics and controls, sensors, actuators, system health monitoring and high-performance simulations including multi-physics mechanics and flow surface interactions. We have substantial expertise in simulating, experimentally and numerically, the Vehicle Launch Environment and the associated challenges in aeroacoustics and aero-structures.

### NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY (NMT)

NMT is a science, math and engineering university that has more than a dozen research divisions that work with private industry, government agencies and other universities. The research divisions include the Petroleum Research and Recovery Center, the Institute for Complex Additive Systems Analysis, the Energetic Materials Research Testing Center, the world's largest lending library of seismology equipment, the Magdalena Ridge Observatory, the National Center for Genome Resources, the National Cave and Karst Research Institute, and the Langmuir Laboratory for Atmospheric Research.

### 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 Robert Goddard and Werner von Braun to the current era of commercial sub-orbital space transportation with Spaceport America and its operators, Virgin Galactic. SpaceX and UP Aerospace. New Mexico Space Grant Consortium, the 21st Century Aerospace Space Group and related aerospace research focuses on annual access to space for student and faculty experiments, unmanned aerial vehicles, and cube-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, spaceflight risk assessment, 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 (UTMB)


UTMB has a long history of medical support and human spaceflight physiological research with NASA. UTMB doctors have been involved in the commercial orbital and suborbital spaceflight industry, supporting space flight participant visits to the ISS, and preparing passengers and crew for suborbital space flights.

### A NEW MEMBER UNIVERSITY - THE BAYLOR COLLEGE OF MEDICINE (BCM)


The Baylor College of Medicine (BCM) is home to the Center for Space Medicine (CSM). The CSM is the only academic department/center in space medicine at any university or medical school. Established in 2008, it has over 70 members and 15 interdisciplinary faculty members. It offers a unique and popular four-year Space Medicine Track and awarded (with Neuroscience) its first Ph.D. in space medicine in 2015. BCM CSM was awarded a $246M NASA cooperative agreement in 2016 to lead a 12-year Translational Research Institute in collaboration with Caltech and MIT. BCM CSM is recognized as the leading academic space medicine research and education program in the world. Expansion plans for BCM CSM include a new Initiative called the Aerospace Medicine (ASM) program within the CSM. The CSM-ASM program will include membership in the FAA COE CST, new aerospace medicine clinical activities, enhanced educational activities, and expanded research programs. The result will be an unprecedented cutting-edge international center of excellence, combining research, education and clinical practice in aviation and space medicine. BCM CSM will be the go-to place in the world where space and medicine come together.

## Affiliate & Associate Members

With a limited budget and ever-tightening budget pressures on all federal agencies, the COE CST sponsoring organization, FAA AST, cannot provide funding to all the research universities and organizations that deserve it. In recognition of all the meaningful work being done outside the COE CST membership, two different mechanisms were developed to encourage membership in the COE CST without incurring any additional budget obligations. The two different mechanisms that encourage a growing membership roster are called Affiliate and Associate membership. Each of these is described below, and a list of past, current, and potential members are listed as well.

### *Affiliate Member Organizations*

To become a COE CST Affiliate Member, an organization must (a) be conducting research that is self-funded, or is funded by some organization other than FAA AST, that fits within the commercial space transportation road map framework (discussed below), and that can be openly disclosed at COE CST

public meetings, such as the Annual Technical Meeting (ATM), (b) partner with one of the current COE CST member universities who will act as the Affiliate's 'host,' and (c) voluntarily pay for all costs associated with attendance at the ATM. In exchange for these commitments, the COE CST will (a) welcome the organization as an Affiliate Member, (b) provide the Affiliate Member with "podium time" at the ATM, equal to that provided to any full COE CST member. The strategy of Affiliate Membership is to gain benefits derived from being part of the overall COE CST research network. As the network grows, so do the possible benefits that can be gained.

To date, there have been a number of COE CST Affiliate Members. Some joined in the early years of COE CST operation, and have been inactive in recent years, some have been active since the program began, and some are just now "knocking on our door," ready to become members in the near future. Below is a brief description or simple listing of these Affiliate Member organizations.

Other organizations are, have been, or soon will be, affiliate members of the COE CST, are listed below. Executive Summaries have featured brief descriptions of these organizations in the past, or will do so in the future. These organizations include:

- Embry-Riddle Aeronautical University
- McGill University
- National Aerospace Training and Research (NASTAR) Center
- Ohio State University
- Simpson College
- Solstar Space Company
- University of Nebraska at Lincoln
- University of Northern Florida
- University of Texas at Austin

## *Associate Member Organizations*

Associate Members are much more loosely associated with the COE CST, but their contributions can be very significant. During the seventh year of operation, the COE CST was proud to have the following institutions as Affiliate Members: NASA Ames Research Center, the MITRE Corporation, and the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR).

**Map of COE CST Member and Affiliate University Geographic Distribution**

## AWARDS AND RECOGNITION

During the past year, two women working on COE CST tasks, Dr. Sigrid Close of Stanford University, and Mary Anderson, a PhD student at New Mexico Tech, received achievement awards. We're proud of their accomplishments, we're delighted that they've been working on projects related to the commercial space transportation industry, and we're excited to highlight them here. Congratulations to Dr. Close and Ms. Anderson! Dr. Dan Scheeres and his student, of the University of Colorado Boulder, also were honored last year. We are very proud of their accomplishments as well!

### SIGRID CLOSE RECEIVES SPACE PHYSICS AND AERONOMY AWARD

The American Geophysical Union (AGU) awarded Dr. Sigrid Close of Stanford University the 2017 Space Physics and Aeronomy Richard Carrington (SPARC) Education and Public Outreach Award at a December meeting of the AGU. The award celebrates Dr. Close's contribution to "significant and outstanding impact on students' and the public's understanding of our science through their education and/or outreach activities."

### MARY ANDERSON RECEIVES TWO PRESTIGIOUS SCHOLARSHIPS

Mary Anderson is a doctoral candidate in the Mechanical Engineering Department at New Mexico Tech and a member of the Laboratory of Intelligent System and Structures (LISS) research team working with Dr. Andrei Zagrai. Her research comprises electromechanical impedance evaluation of space structures on orbit and the modeling of effects of space environment on the system and structure. Before entering grad school, Ms. Anderson completed an internship at the Ames Research Center at NASA. In her time as a graduate student, Ms. Anderson has received the New Mexico Space Grant fellowship for 4 semesters totaling $20,000 in research funding. In 2017, she was awarded the Lonnie and Maria Elena Abernathy Endowment for Native Americans in Engineering for $2500 from the Society of Women Engineers and the Elisabeth M. and Winchell M. Parsons Scholarship for $3000 from the American Society of Mechanical Engineers.

### CU PROFESSOR AND STUDENT HONORED

Distinguished Professor Daniel Scheeres was elected to the National Academy of Engineering (NAE) for his pioneering research on the motion of bodies in strongly-perturbed environments. Election to the NAE is among the highest professional distinctions accorded to an engineer. Under his mentorship, Scheeres' student, Chandrakanth Venigalla, Aerospace PhD student, was awarded a National Space Technology Research Fellowship.

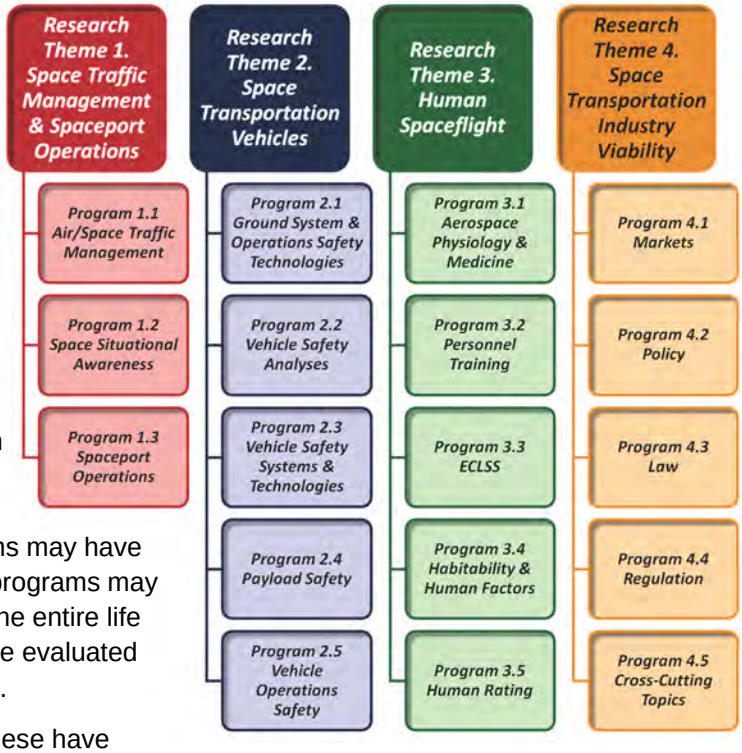
### UCF PROFESSOR HONORED

Dr. Subith Vasu received the 2017 Dilip R. Ballal Early Career Engineer Award from the ASME International Gas Turbine Institute, honoring outstanding accomplishments during the first seven years of a young professor's career. In addition to his many accomplishments, Dr. Vasu was the subject of a 2016 documentary, *Combustion Man*, produced by the Organization for the Prohibition of Chemical Weapons.

## COE CST RESEARCH AREAS, GOALS, AND TASKS

COE CST activity is defined by a framework defining different academic areas for every research task. Generally speaking, the four research areas encompass four distinct research domains: operational activities, the physical and engineering sciences, the biological and medical sciences, and the social sciences. A Space Transportation Research Road Map, last updated in 2015 and available on the web at www. coe-cst.org, was created to provide a detailed framework within each of these discipline areas. After each brief introduction to the four research areas, this section identifies the goals associated with each research area, and then lists the research tasks that were conducted during the seventh year of COE CST operation.

### COE CST RESEARCH AREAS




As mentioned above, the research conducted within FAA AST is broken into four major disciplines. Each discipline is identified by a distinct research theme and color: Space Traffic Management & Spaceport Operations (red), Space Transportation Vehicles Technologies (blue), Human Spaceflight (green), and Space Transportation Industry Viability (orange). Each of these research areas is divided into programs, and these are further divided into projects, themes, and tasks. The number of tasks conducted in each program can vary from year to year, and research is not necessarily conducted in all programs every year. Some research programs may have some number of tasks every year, and other programs may have never had a research task funded over the entire life of the COE CST. The priorities of FAA AST are evaluated every year to make the final funding decisions.

Each research area has multiple goals, and these have been revisited during the past year. In FY17, research goals have been identified for each research area that correspond to each of the two AST mission goals (i.e., public safety, or industry promotion).

*The COE CST held its seventh Annual Technical Meeting in conjunction with the International Symposium for Personal and Commercial Spaceflight (ISPCs) in Las Cruces, NM, in October 2017. COE CST research task banners were on display for all ISPCS attendees to review.*

## COE CST Research Goals

The goals of the four commercial space transportation research areas are listed below in tabular form. The color scheme introduced above is adopted for the table of research goals, but with a subtle distinction: The darker shade of each color is associated with the public safety research goals, and the lighter shade of each color is associated with the promotional research goals.

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

## COE CST Year 7 Research Tasks

COE CST research tasks conducted in FY17 in each of the four research areas are listed below and shown in the quad charts that follow. Most of the tasks were funded by the FAA AST to COE CST member universities, but also listed are research tasks conducted during this period by COE CST Affiliate and Associate members. (NB: Research tasks are frequently referred to by their task number, because the titles listed below and the titles given on the summary quad charts may not match exactly. Also, some tasks do not have an associated summary quad, and these are denoted with an asterisk.)

**Research Area 1. Space Traffic Management and Spaceport Operations**

- 186-SU, Space Environment Modeling Prediction, Drs. Sigrid Close & Nicolas Lee
- 187-CU, Space Situational Awareness, Dr. Dan Scheeres
- 319-UF, Space Vehicle Fragmentation Characterization, Dr. Norm Fitz-Coy
- 331-SU, Advanced 4D Special Use Airspace Research, Dr. Mykel Kochenderfer

- 360-MITRE (Associate), Integrated Aerospace Traffic Management Concepts, Mr. Amal Srivastava
- 375-DLR (Associate), Interoperable Air and Space Traffic Management, Mr. Sven Kaltenhäuser

**Research Area 2. Space Transportation Vehicle Technologies**

- 253-UCF, Composite Thermal Protection System Materials, Drs. Jan Gou & Jay Kapat
- 299-NMT, Nitrous Oxide Composite Tank Testing, Drs. Bin Lim & Andrei Zagrai
- 311-UCF, Robust and Low-Cost LED Absorption Sensor, Dr. Subith Vasu
- 323-NMT, Structural Health Monitoring Framework, Dr. Andrei Zagrai
- 325-FSU, Optical Measurements of Rocket Nozzle Thrust and Noise, Drs. Rajan Kumar, Farrukh Alvi, & Jonas Gustavsson
- 359-NMSU/UNF (Affiliate), Relaying Data from LEO to GEO Satellites, Dr. Brian Kopp (no quad chart)

**Research Area 3. Human Spaceflight**

- 308-UTMB, Suborbital SFP Anxiety Assessment, Drs. James Vanderploeg, Rebecca Blue, Tarah Castleberry, Charles Mathers, and Johene Vardman
- 309-UTMB, Suborbital Pilot Training Assessment, Drs. James Vanderploeg & Tarah Castleberry
- 310-UTMB, Increasing Cabin Survivability in Commercial Spacecraft, Drs. Charles Mathers, James Vanderploeg, Tarah Castleberry, Rebecca Blue, & Leigh Speicher
- 320-CU, Commercial Spaceflight Risk Assessment and Communication, Dr. David Klaus

**Research Area 4. Industry Viability**

- 193-CU, Emerging Space Industry Leaders Workshops, Mr. Brad Cheetham
- 304-FIT/MU (Affiliate), Legal Issues of Cross-Border Suborbital Flights, Dr. Ram Jakhu (no quad chart)


*Some attendees from the COE CST seventh Annual Technical Meeting, accompanied by the Virgin Galactic (VG) Medical Advisory Board, were provided an up-close-and-personal tour of the New Mexico Spaceport America, led by Mike Moses. Posing in front of a mock-up of the VG SpaceShipTwo, from left to right is Bill Lash, Mike Moses, Dr. Donghyeon Ryu, Nick Demidovich, Sven Kaltenhäuser, Ken Davidian (kneeling), Karen Shelton-Mur, Evelina Bern, Dr. Olga Stelmakh, Dr. Juergen Drescher, Dr. Richard Jennings, Dr. Jonathan Clark, Dr. Smith Johnston, Dr. Henry Lupa, Dr. Jeff Davis, Dr. Jan Stepanek, Dr. Kevin Fong, and Dr. Jim Vanderploeg.*

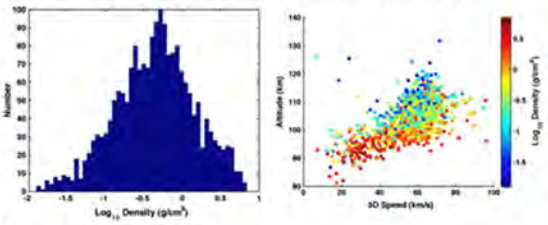
# TASK 186. SPACE ENVIRONMENT METEOROID AND ORBITAL DEBRIS MODELING & PREDICTION

**PROJECT AT-A-GLANCE**
- UNIVERSITY: Stanford University
- PRINCIPAL INVESTIGATOR(S): Dr. Sigrid Close
- Co-I: Dr. Nicolas Lee
- STUDENT(S): Diana Hernandez Juarez Madera, Lorenzo Limonta

**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**
- The research improves the current probability density functions that estimate the human-made and natural space debris and meteoroid environment by characterizing the meteoroid and orbital debris population. Research is conducted to determine the meteoroid bulk density function, identify scattering patterns based on the FDTD models, and identify the mechanisms for the effects of charging on electrical failures. Research on orbital debris includes filtering methods for larger satellite constellations, and the determination of debris propagation using near real time density data. Results from these activities are combined into a new threat assessment model.

**Bulk Densities of Radar-Detected Meteoroids**



**STATUS**
- Developed scattering model to determine meteoroid mass
- Correlated orbital parameters with meteoroid mass and density for predictive threat assessment

**FUTURE WORK**
- Refine FDTD scattering model to correlate measured radar-cross-section (RCS) with meteoroid mass
- Develop improved fragmentation and ablation models to determine ionization efficiency
- Develop probabilistic models for risk assessment

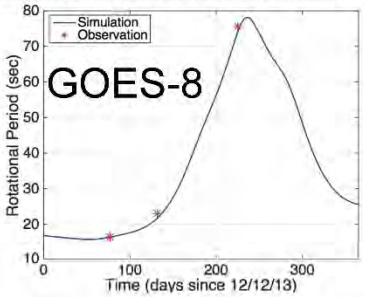
# TASK 187. SPACE SITUATIONAL AWARENESS

**PROJECT AT-A-GLANCE**
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. Dan Scheeres
- STUDENT RESEARCHERS: Several PhD students have been supported by this task over the last few years, most recently CK Venigalla and M. Pellegrino.

**RELEVANCE TO COMMERCIAL SPACE INDUSTRY**
- Orbit debris remains a fundamental issue for all aspects of space utilization. Specific challenges remain in performing lor term forecasts for specific pieces of orbit debris. While the population of debris is relatively well understood — research advances continue to open new windows on this population.

**STATEMENT OF WORK**
- Effective space situational awareness faces the challenge of bringing together observations from disparate sensors and sources, developing computationally efficient dynamic propagation schemes for orbits and their uncertainty distributions, and formulating accurate estimation methods for the purpose of quantifying and qualifying space-based activities.
  - Maximize the information extracted from usual sources of SSA data (minimize uncertainty)
  - Identify how data should be collected to maximize information content (maximize efficiency)
  - Recover and predict the space domain with more accuracy
  - Timely estimation of the space-based environment to create actionable information.

**Large Fluctuations of Spin Period in Defunct GOES-8 Satellite can be accurately fit by modeling Solar Radiation Pressure Effects**




**STATUS**
- Graduated two FAA-funded PhD students: Kohei Fujimoto, May 2013 & In-Kwan Park Fall 2015, started work with others
- Have a large combined student team focused on relevant SSA research topics of direct interest to the COE
- Presented over 34 distinct papers at 20 conferences
- Over 13 papers published with more in peer review

**FUTURE WORK: Task 327 — RSO System Mechanics**
- Next proposed stage of direct FAA funded research will focus on predicting space object orbits accounting for uncertainty, improving models for characterizing their dynamics as subject to non-gravitational forces, and investigating optimal evasion maneuvers given a non-zero impact probability.

# TASK 319. DEBRISAT PANEL PREPARATION AND FRAGMENT CHARACTERIZATION FOR THE PERIOD: FY17 Q3

UF UNIVERSITY of FLORIDA

**PROJECT AT-A-GLANCE**
- UNIVERSITY: University of Florida
- PRINCIPAL INVESTIGATOR(S): Norman Fitz-Coy
- STUDENT(S): Joe Kleespies

**RELEVANCE TO COMMERCIAL SPACE INDUSTRY**
- Accurate satellite breakup modeling is critical to achieve a comprehensive understanding of the orbital debris environment, which directly impacts the ability to conduct future commercial space missions. The DebriSat project's goal is to update existing satellite breakup models.

**STATEMENT OF WORK**
1. Research viable database engines and storage methods (status: completed)
2. Install and configure new database engine (status: completed)
3. Define and document structure of new database engine and subsequent relational tables. (status: completed)
4. Begin modification of the existing DCS front-end layer. (status: completed)
5. Complete modification of the existing DCS front-end layer. (status: completed)
6. Implement new image and file storage structure. (status: completed)
7. Begin addition of "3D" imaging system fields and formats. (status: completed)
8. Complete addition of "3D" imaging system fields and formats. (status: completed)
9. Documentation of upgrade process and maintenance protocols. (status: ongoing)

**DEBRISAT BEFORE, DURING, AND AFTER IMPACT**

**STATUS**
- See statement of work. Documentation of upgrade process and maintenance protocols is the only ongoing task. All other tasks have been completed.

**ECONOMIC IMPACT**
- Good space debris models facilitate effective space traffic management.

**FUTURE WORK**
- Complete the task number nine, to generate documentation of the upgrade process and maintenance protocols.
- Complete documentation of system and data transfer process from University of Florida to other project stakeholders.
- Development and documentation of example queries to be used to analyze the final data set.

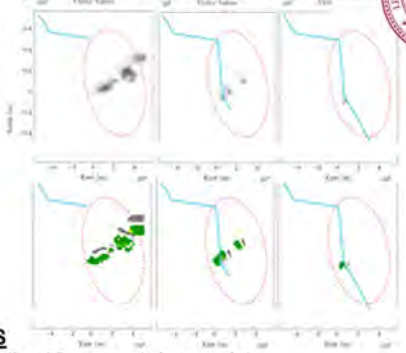
# TASK 331. ADVANCED 4D SPECIAL USE AIRSPACE

**PROJECT AT-A-GLANCE**
- UNIVERSITY: Stanford University
- PRINCIPAL INVESTIGATOR(S): Mykel J. Kochenderfer
- STUDENT(S): Rachael E. Tompa

**RELEVANCE TO COMMERCIAL SPACE INDUSTRY**
- During launches, a large segment of the airspace must be cleared to minimize safety risk, which has a significant impact on efficiency of commercial flights in the region, especially as launches become more frequent
- An important challenge is minimizing the impact on commercial air traffic.

**STATEMENT OF WORK**
- Use a Markov decision process to create optimal rerouting policies for an aircraft during a commercial space launch
- Use a realistic debris model to capture the inherent uncertainty of launch anomalies
- Explore a deep learning platform for future scalability and higher fidelity results (planning over a continuous model)
- Simulation studies across diverse scenarios for various operational and safety metrics
- Introduce metering aircraft "in time" to avoid the launch hazard
- Measure success against past aircraft rerouting and nominal aircraft trajectories using NASA's FACET

**Rerouting Aircraft During a Launch**



**STATUS**
- Discretized framework is complete
- Debris model is robust
- Deep learning transition is ongoing

**Economic Impact**
- During a launch out of Cape Canaveral Spaceport, approximately 50 flights are rerouted
- Each rerouted flight is estimated to result in a few thousand dollars of additional expenses in fuel, labor, and missed connections

**FUTURE WORK**
- Complete deep learning transition to take advantage of the scalability capabilities
- Investigate metering action space

# TASK 360. PROJECTING AIR TRAFFIC IMPACT OF BLOCKED AIRSPACES

MITRE

## PROJECT AT-A-GLANCE

- The MITRE Corporation
- PI: Amal Srivastava

## RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- The goal of this research is to enable transparency and collaboration in integrating of new entrants, including space operators, into the national airspace. This will be accomplished by developing models and techniques to:
  - Provide an ability to assess, well in advance, the impact of blocking airspaces due to space operations
  - Aid the operators in adjusting their plans to minimize their impact on the NAS when possible
  - Ensure impact assessment capability is easily accessible to a broad range of users, and using it requires no prior knowledge of air traffic pattern

## STATEMENT OF WORK

- Develop an air traffic projection model to predict traffic patterns and volume at any location in the national airspace, up to 12 months into future.
- Develop technique to enable a 'what-if' analysis impact assessment capability, whereby changes in blocked airspace's location, size, shape or time are instantaneously reflected in the projected impact metrics.
- Develop model to assess NAS impact of blocking airspaces.
- Develop a web-based prototype to demonstrate the concept of use of a capability derived from the model. See Figures 1 and 2 for sample customized views.

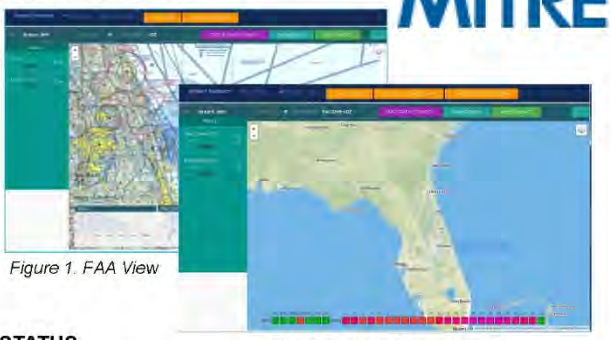


*Figure 1. FAA View*

*Figure 2. Space Operator View*

## STATUS

- Developed initial air traffic projection model
- Designed and established viability of techniques and data structure to enable 'what-if' analysis capability
- Developed web-based prototypes to illustrate concept of use

## ECONOMIC IMPACT

- Improve NAS efficiency in integrating space launch and re-entry operations

## FUTURE WORK

- Enhance and improve the projection and NAS impact models
- Add additional user groups, such as airlines, and perform economic modeling to provide additional impact metrics

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# TASK 375. INTEROPERABLE AIR AND SPACE TRAFFIC MANAGEMENT

## PROJECT AT-A-GLANCE

- DLR German Aerospace Center, Institute of Flight Guidance
- PRINCIPAL INVESTIGATOR: Sven Kaltenhaeuser
- Team: Frank Morlang, Tanja Luchkova, Jens Hampe, Dirk-Roger Schmitt

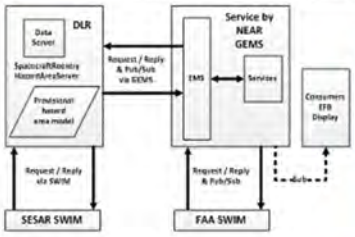
## RELEVANCE TO COMMERCIAL SPACE INDUSTRY

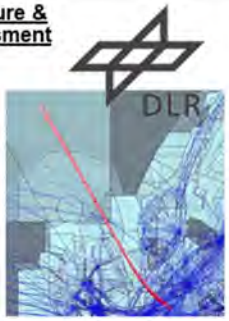
- With global growth of the commercial space industry there is a developing demand for space flight operations in and over Europe. Air Traffic Management (ATM) is playing a key role to address this challenge.
- The goal is to prepare the European ATM system to enable a safe integration of space vehicle operations (SVO) in a sustainable and efficient way. To enable global operations, interoperability of implemented technologies and procedures is an essential requirement and a specific focus of the DLR work program.

## STATEMENT OF WORK

- Categorization of relevant space flight operations and assessing their impact on European airspace using the DLR Space and Air Traffic Management (SATM) testbed.
- Development of measures and procedures for enabling efficient ways to optimize airspace usage for space flight operations while minimizing airspace segregation.
- Development of concepts and prototypes for a seamless, safe and secure implementation of space flight operations into the ATM flight planning and control processes using System Wide Information Management (SWIM) and related open and standard mainstream technologies.

**Interoperable SWIM architecture & European SVO impact assessment**




## STATUS

- A functional and interoperable SWIM service prototype has been developed. It was tested together with Embry Riddle Aeronautical University for provision of Reentry Hazard Area data in a SESAR SWIM←→FAA SWIM environment.
- A traffic impact analysis has been prepared and conducted for the suborbital SpaceLiner point-to-point return trajectory towards a European landing site.

## Economic Impact

- Provision of operational concepts and technological prerequisites to enable space flight operations in Europe.

## FUTURE WORK

- Refinement of traffic impact analysis framework and additional analysis of relevant space vehicle trajectories
- Applying advanced ATM concepts such as Flexible Use of Airspace, Flight Centric ATC and Dynamic Sectorization
- Enhanced functions for space flight SWIM services including all ATM planning and execution levels.

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

University of Central Florida

## PROJECT AT-A-GLANCE

- UNIVERSITY: University of Central Florida
- PRINCIPAL INVESTIGATOR(S): Drs. Jan Gou & Jay Kapat
- STUDENT(S): Marcus Francis & Haonan Song

## RELEVANCE TO COMMERCIAL SPACE INDUSTRY

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

## STATEMENT OF WORK

- Develop oxide-oxide ceramic matrix composites (CMCs) based on polymer derived ceramics for ultra-high temperature thermal protection systems.
- Develop top hard ceramic coatings for ultra-high temperature thermal protection systems.
- Ground testing of polymer derived ceramics composites (PDCC) thermal protection systems using Oxyacetylene exposure test, shock tube test, and hot jet facilities.
- Flight testing of PDCC-based solid rocket nozzles and in-situ sensing for structural health monitoring
- Thermo-mechanical modeling of polymer derived ceramics composites (PDCC) thermal protection systems

## OXYACETYLENE TORCH TEST OF PDCC THERMAL PROTECTION SYSTEMS

## STATUS

- Develop 3D oxide-oxide CMCs based on Nextel™ 720 fibers/SiOC ceramic matrix composites.
- Oxyacetylene exposure testing of PDCC thermal protection systems.

## FUTURE WORK

- Develop high performance front surface ceramic coatings for thermal protection systems
- Ground-based testing of PDCC thermal protection systems
- Flight testing of PDCC thermal protection systems using solid rocket motor
- 3D printing of UV-curable PDCC thermal protection systems

# TASK 299: NITROUS OXIDE COMPOSITE CASE TESTING

NEW MEXICO TECH
SCIENCE • ENGINEERING • RESEARCH • UNIVERSITY

## PROJECT AT-A-GLANCE

- UNIVERSITY: New Mexico Tech
- PRINCIPAL INVESTIGATOR(S): Seokbin (Bin) Lim, Andrei Zagrai
- STUDENT(S): Luis Ortega, Chris Rood
- TECHNICAL MONITORS: Yvonne Tran, Don Sargent

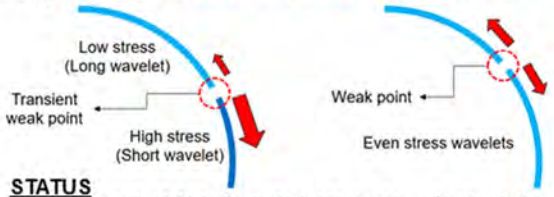
## RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Develop an understanding of fragmentation hazards from composite tanks used for fuel/oxidizer storage
- Develop a testbed for evaluating different storage tank materials or configurations at small and large scales

## STATEMENT OF WORK

- Test metallic and composite tubes to failure to understand fragmentation hazards
- Develop standard test procedures for composite materials under shock and high-rate loading
- Develop analytical and computational models to compare to experiments
- Provide data to help set guidelines for safe distances during launch of commercial vehicles

Hypothesis: the number of openings in a sample during a dynamic loading is related with the local speed of sound of the sample



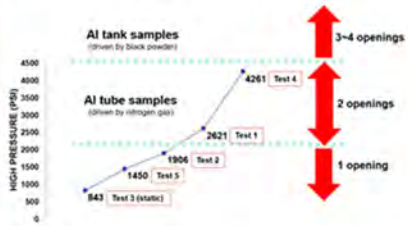

## STATUS

- 3 tests each of Al 6061 material tanks to understand the crack opening behavior
- 1 test with an Al liner with composite wrapped tank
- Develop methods/hypothesis to predict crack opening behavior
- Numerical simulations to predict the opening (in progress)

## FUTURE WORK

- In-depth study of the relation between openings and the local speed of sound during pressurization

It was able to identify the general opening tendency, and all the openings were evenly distributed along the samples




2.5mm. (0.1in.) Wall thickness (weak point)
19 in. Long, 6 in. Diameter, 6061 Al material

## TASK 311. ROBUST AND LOW-COST LED ABSORPTION SENSOR FOR SIMULTANEOUS, TIME-RESOLVED MEASUREMENTS OF $CO_2$

University of Central Florida

**PROJECT AT-A-GLANCE**
- UNIVERSITY: University of Central Florida
- PRINCIPAL INVESTIGATOR(S): Dr. Subith Vasu
- POST DOC(S): Anthony C. Terracciano, Ph.D.
- STUDENT(S): Michael Villar, Justin Urso, Akshita Parupalli, Erik Ninnemann

**RELEVANCE TO COMMERCIAL SPACE INDUSTRY**
- $CO_2$ measurements are relevant to the health and safety of the crew.
- Time-resolved measurements of $CO_2$ could be used to detect fuming which may lead to fire or explosion.
- Externally placed sensors could detect leaks.

**STATEMENT OF WORK**
- A sensor is used for the detection of $CO_2$.
- A cRIO is used for the sensor data processing and detection quantification.
- A model of the absorption of the broad-spectrum source characteristic of LEDs are explored for increasing the flexibility and understanding of the sensors response.
- Sensor design and housing must be adapted for spacecraft environment.
- Balloon tests were conducted to validate sensor responsiveness at micro-gravity conditions across a range of temperatures and pressures.

**Latest Sensor Design**

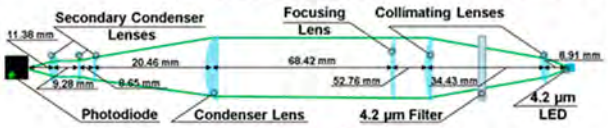



*Figure 1: LED Sensor Optical Setup*

*Figure 2: UCF Payload on HASP Balloon Flight Chassis*

**STATUS**
- The cRIO platform is to be replaced with an analog set of circuits and dedicated autonomous feedback loops for temperature control.
- Broad-spectrum absorption models are being explored to promote optimization efforts and increase sensor robustness.

**FUTURE WORK**
- Reducing the size of the system
- Increasing precision and expanding the applicable gases

## TASK 323. STRUCTURAL HEALTH MONITORING FRAMEWORK

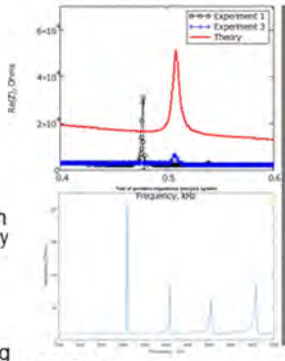
NEW MEXICO TECH
SCIENCE • ENGINEERING • RESEARCH UNIVERSITY

**PROJECT AT-A-GLANCE**
- UNIVERSITY: New Mexico Institute of Mining and Technology
- PRINCIPAL INVESTIGATOR(S): Andrei Zagrai
- STUDENT(S): Mary Anderson and David Hunter

**RELEVANCE TO COMMERCIAL SPACE INDUSTRY**
- Information provided by a vehicle's SHM system may be used to predict a component's remaining life and hence enable prognosis and mission scheduling in accordance with current and projected structural performance. SHM data may also assist in accident investigation if needed.

**STATEMENT OF WORK**
- Investigation of Structural and Sensor Fatigue due to Radiation. Our efforts in this task is directed toward exploring nature of material changes induced by radiation and creating predictive models for sensors performance under radiation condition which could affect SHM results for space vehicles.
- Adaptation of METIS hardware for electro-mechanical impedance measurements in space environment and payload development for future missions.
  It is anticipated that the new systems could allow for a electro-mechanical impedance testing. This feature is not currently available, but we intend to adapt new hardware for electro-mechanical impedance tests and develop new space experiments using introduced hardware.

**ECONOMIC IMPACT**
- The economic benefit includes avoiding very costly catastrophic events and reducing maintenance cost by replacing parts on "as needed" versus "lifespan" basis.




**STATUS**
- Experiment in radiation (gamma) environment were conducted.
- A predictive model for sensors performance under radiation has been developed and experimentally validated
- An impedance model for response of clamped circular plate typical to rocket payload was developed and validated.
- METIS hardware adaptation was initiated and portable impedance measurement system has been developed.

**FUTURE WORK**
- Explore multiplexity of impedance measurement system.
- Improve results impedance measurement in portable lightweight system.
- Consider nonlinear parameters to improve a model for sensors performance in radiation environment.

# TASK 325. OPTICAL MEASUREMENTS OF ROCKET NOZZLE THRUST AND NOISE

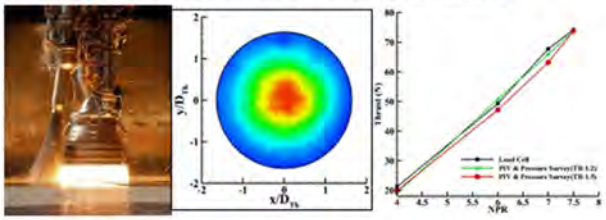
**PROJECT AT-A-GLANCE**

- UNIVERSITY: Florida State University
- PRINCIPAL INVESTIGATOR(S): Rajan Kumar & Farrukh Alvi, Jonas Gustavsson
- STUDENT(S): Rohit Vemula

**RELEVANCE TO COMMERCIAL SPACE INDUSTRY**

Measurement of nozzle thrust and noise is necessary for the design of future launch and reentry space systems and hypersonic vehicles. The improved aerodynamic performance and propulsion system will help increase payload capacity and safety for many government and commercial space transportation programs.

**Optical Measurements of Thrust and Noise**



**STATEMENT OF WORK**

- Development of a research plan based on state-of-art thrust and noise measurement techniques and discussion with NASA /commercial launch engineers to ensure the transition of technology from laboratory to full-scale implementation.
- Design of a scaled rocket nozzle to simulate realistic temperature and pressure conditions of the jet exhaust and carry out thrust and noise measurements in the FSU free jet lab.
- Design and develop advanced optical techniques for thrust measurements and characterize its performance at controlled conditions.
- Refine and test the measurement techniques over a wide range of test conditions.

**STATUS**

- Second generation nozzle designed and manufactured
- Extensive testing (velocity, pressure and acoustic surveys as well as load cell measurements) completed
- Ability to measure thrust using flowfield data validated against load cell

**FUTURE WORK**

- Additional analysis of acquired noise data
- Refined pressure and load cell measurements
- Design and development of active flow control methods
- Thrust optimization at low nozzle pressure ratios
- Noise reduction technique during launch operations

# TASK 308. ASSESSMENT OF SCREENING AND TRAINING REQUIREMENTS FOR SFPs REGARDING ANXIETY DURING REPEATED EXPOSURES TO SUSTAINED HIGH ACCELERATION

**PROJECT AT-A-GLANCE**

- University: The University of Texas Medical Branch
- Principal Investigator: James Vanderploeg, MD, MPH
- Co-Investigators: Rebecca Blue, MD, MPH; Tarah Castleberry, DO, MPH; Charles Mathers, MD, MPH, Johnene Vardiman, MS
- Residents: Rahul Suresh, MD

**RELEVANCE TO COMMERCIAL SPACE INDUSTRY**

- The viability of the commercial spaceflight industry will be dependent upon layperson participation, which requires a perception that flights are safe and enjoyable.
- Spaceflight participants are likely to have expectations regarding training and risk mitigation; efforts towards meeting expectations or educating the public may have beneficial effects for the industry.
- Spaceflight participants may have difficulty performing tasks in stressful scenarios, but may not fully understand how their own actions affect the risk profile of spaceflight activities

**STATEMENT OF WORK**

- Understand how minimally trained laypersons perform during simulated emergency in centrifuge-simulated suborbital spaceflight
- Identify preconceptions of risk, training requirements, and commercial spaceflight safety

**STATUS**

- Project data collection completed
- 157 subjects recruited, centrifuge trials completed June 2016
- Data analysis completed 2017

**FUTURE WORK**

- Presentation and publication of significant findings – publication anticipated 2018, presentation expected at Aerospace Medical Association Annual Scientific Meeting 2018
- Publication anticipated 2018, *Aerospace Medicine and Human Performance*

## TASK 309. ASSESSMENT OF PHYSIOLOGICAL SCREENING REQUIREMENTS & TRAINING MODALITIES FOR REPEATED EXPOSURES TO SUSTAINED HIGH G ACCELERATION

utmb Health Aerospace Medicine

**Project At-A-Glance**

- University: The University of Texas Medical Branch
- Principal Investigator: James Vanderploeg, MD
- Co-Investigator: Tarah Castleberry, DO
- Residents: James Pavel, MD; Wilfredo Rodriguez-Jimenez, MD

**Relevance to Commercial Spaceflight Industry**

- Repeated exposure of the crew to sustained high +Gx and +Gz acceleration in highly demanding spaceflight profiles is a new and untested paradigm. Identifying the unique physiological challenges, screening and training techniques will enable spaceflight operators to ensure safe operations.

**Statement of Work**

- Compare pilot performance and physiological response in aerobatic flights, centrifuge acceleration profiles, and actual spaceflight.
- Develop recommendations for pilot training and medical screening.


**Status**

- Collected data on pilots in centrifuge-simulated suborbital flight and aerobatic flight through 2017

**Future Work**

- Obtain physiological data during centrifuge runs, aerobatic flights and spaceflights in 2017/2018

## TASK 310. ASSESSMENT OF METHODS, PROCEDURES, AND TECHNOLOGIES AVAILABLE FOR THE PROTECTION OF SFPs IN COMMERCIAL SPACEFLIGHT VEHICLES

utmb Health Aerospace Medicine

**PROJECT AT-A-GLANCE**

- University: The University of Texas Medical Branch
- Principal Investigator: Charles H. Mathers, MD, MPH
- Co-Investigators: James M. Vanderploeg, MD, MPH; Tarah Castleberry, DO, MPH; Rebecca Blue, MD, MPH, Leigh Speicher, MD, MPH
- Residents: Alejandro Garbino, MD, PhD

**RELEVANCE TO COMMERCIAL SPACE INDUSTRY**

- Dedicated efforts towards the enhanced safety in spaceflight vehicles will improve the success of commercial space endeavors
- Direct applicability to design phase of commercial spaceflight vehicles, integration of medical efforts with cabin engineering

**STATEMENT OF WORK**

- Identify injury patterns associated with various restraint designs
- Identify injury patterns and relative risks of anthropometrically and demographically varied populations, including factors such as sex, obesity, advanced age
- Identify any best practices for restraint design in commercial spaceflight vehicles

**STATUS**

- Literature review and analysis completed 2017
- Abstract submitted for Aerospace Medical Association Annual Scientific Meeting presentation, 2018
- Manuscript submitted to Aerospace Medicine and Human Performance Journal; in review

**FUTURE WORK**

- Presentation and publication of significant findings – publication anticipated 2018, presentation expected at Aerospace Medical Association Annual Scientific Meeting 2018

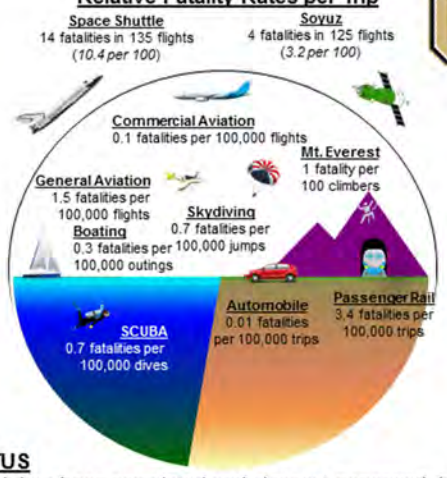
## TASK 320: COMMERCIAL SPACEFLIGHT RISK ASSESSMENT AND COMMUNICATION

**PROJECT AT-A-GLANCE**
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR(S): David Klaus
- STUDENT(S): Robert Ocampo (PhD 2016)

**RELEVANCE TO COMMERCIAL SPACE INDUSTRY**
- The risks and hazards of space flight must be presented to space flight participants "in a manner that can be readily understood by a space flight participant with no specialized education or training." - 14 CFR 460.45, Operator Informing Space Flight Participant of Risk, 2013

**STATEMENT OF WORK**
- **Year 1 of Task 320 (June 1, 2015 through May 31, 2016)**
- Define relative degrees of 'safe' and means of quantifying 'acceptable' levels of risk for commercial spaceflight
- Develop framework to deal with inflight medical issues
- Comparative perspective for understandable ways of communicating risks of spaceflight to the general public
- **Year 2 of Task 320 (June 1, 2016 through May 31, 2017)**
- Establish metrics for characterizing the notional 'Good Day, Not so Good Day, Bad Day' scenarios with a focus on recommended medical equipment provisioning and associated personnel training needs
- Characterize verification processes aimed at ensuring stated level of reliability (risk mitigation) is achieved for a given vehicle.

**Relative Fatality Rates per Trip**




**STATUS**
- Task has been completed and closeout paperwork initiated. 6 resultant publications complete or in progress. New follow on task 353 currently underway.

**Economic Impact**
- Total of 3 PhD students and 2 MS students involved in this task and preceding efforts from Task 184 Human-Rating

**FUTURE WORK (Task 353)**
- AIM 1: Review the FAA Recommended Practices (2014) and provide suggested edits and/or additional topic areas to be included in any future versions released;
- AIM 2: Provide design and operational considerations for each topic area including additional details, quantified where possible, and/or candidate design and operational solutions.

## TASK 193. EMERGING SPACE INDUSTRY LEADER WORKSHOPS

**PROJECT AT-A-GLANCE**
- UNIVERSITY: University of Colorado at Boulder
- PRINCIPAL INVESTIGATOR: Dr. Daniel Scheeres
- STUDENT RESEARCHER: Mr. Bradley Cheetham (PhD)

**RELEVANCE TO COMMERCIAL SPACE INDUSTRY**
- **Research** – workshops focus on industry viability research
- **Training** – emerging leaders are prepared to evaluate important industry dynamics and trends
- **Outreach** - networking opportunities are provided to participants to build networks that strengthen industry growth

**STATEMENT OF WORK**
- Identify key industry characteristics to facilitate EFP efforts
- Host targeted workshops to engage students and young professionals
- Support conferences to educate students and young professionals
- Incorporate young professional perspectives in ongoing industry planning efforts
- Disseminate information about commercial space industry to relevant audiences

**10th ESIL Workshop Participants**

**STATUS**
- 10th Emerging Space Industry Leaders (ESIL) Workshops Held in 2017
- 100+ total participants and 3 publications presented

**FUTURE WORK**
- No future work is anticipated.
- Presentations can be found at www.ESIL.space

## COE CST STUDENTS, PARTNERS, PUBLICATIONS, AND PRESENTATIONS

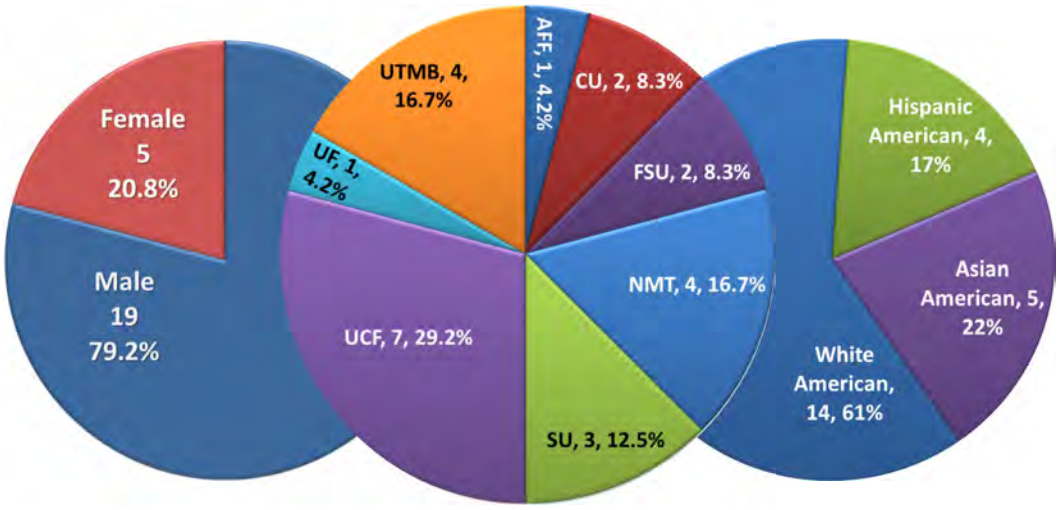
### COE CST YEAR 7 STUDENTS AND DEMOGRAPHIC CHARTS

The following is a list and demographic information of the 24 COE CST students (both funded and unfunded), working on research tasks during year 7 of operation.

- Anderson, Mary (323-NMT)
- Consoliver, Jakob (241-FSU)
- Francis, Marcus (253-UCF)
- Garbino, Alejandro (310-UTMB)
- Hernandez Juarez Madera, Diana (186-SU)
- Hunter, David (323-NMT)
- Kerkonian, Aram (304-AFF)
- Kleespies, Joe (319-UF)
- Limonta, Lorenzo (186-SU)
- Loparo, Zachary (311-UCF)
- Ninnemann, Erik (311-UCF)
- Ortega, Luis (299-NMT)
- Parupalli, Akshita (311-UCF)
- Pavela, James (309-UTMB)
- Pellegrino, Marielle (187-CU)
- Rodriguez-Jimenez, Wilfredo (309-UTMB)
- Rood, Chris (299-NMT)
- Song, Haonan (253-UCF)
- Suresh, Rahul (308-UTMB)
- Tompa, Rachael (331-SU)
- Urso, Justin (311-UCF)
- Vemula, Rohit (325-FSU)
- Venigalla, Chandrakanth (187-CU)
- Villar, Michael (311-UCF)

**Abbreviations:** CU-University of Colorado Boulder, ERAU-Embry Riddle Aeronautical University, 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

Each year, certain demographic data is collected on all COE CST students (by law). A summary of these data for gender, university, and degree representation, is shown below as simple pie charts.




### COE CST GENERAL AND PRIMARY PARTNERS

The following is a list of the general partner organizations that have contributed to the COE CST over the seven-year history:

- Ball Aerospace
- CSSI Inc.
- Dynetics, Inc.
- Jacobs Technology Inc.
- Lockheed Martin Space Systems Company
- National Aeronautics and Space Administration
- Pennsylvania State University
- Qinetiq
- Sierra Nevada Space
- Space Works Enterprises
- Spaceport America Consultants
- Spaceworks
- The Tauri Group
- Webster University
- XCOR Aerospace, Inc.

The following is a list of the primary partner organizations that have contributed to the COE CST over the seven-year history:

- American Institute of Aeronautics and Astronautics
- Orbital ATK
- Bachner Consultants, Inc.
- Ball Aerospace
- CEAVCO
- Cimmaron Software Services Inc.
- Digital Solutions
- Futron
- Lockheed Martin Space Systems Company
- Marketing Consultant
- NASTAR Center
- National Space Grant Foundation
- New Mexico Spaceport Authority
- NMSU Space Development Foundation
- Orbital Sciences Corporation
- Orion America Technologies
- Pennsylvania State University
- SATWEST
- Scitor Corporation
- Secor Strategies
- Space Florida
- Space News
- Space Systems/Loral
- Spaceport Sweden
- The Boeing Company
- United Launch Alliance
- Wyle Integrated Science & Engineering Group

## COE CST YEAR 7 PUBLICATIONS

The following is a list of the 36 publications and presentations completed during COE CST Year 7.

*186-SU*

Marshall, R., P. Brown and S. Close, Plasma distributions in meteor head echoes and implications for radar cross section interpretation. Planetary and Space Science, 143, p. 203-208, 2017

*253-UCF*

B. Wu, J. Gou, "Fabrication of Carbon Nanotube - Nonoxide Structural Ceramic Nanocomposites through Laser Sintering," U.S. Provisional Patent, Publication No. US20160016855 A1, Publication date: January 21, 2016.

J. Kapat, J. Gou, N. R. Nagaiah, J. Schmitt, "Power Generation System Using Closed or Semi-Closed Brayton Cycle Recuperator," World Intellectual Property Organization (WIPO) Provisional Patent, Publication No. WO/2016/161052, Publication date: October 6, 2016.

J. Skovron, J., Zhuge, J., Gou, J., A. Gordon, "Effect of Nanopaper Coating on Flexural Properties of a Fire-Treated Glass Fiber-Reinforced Polyester Composite," Journal of Composite Materials, doi: 10.1177/0021998316630584, (2016)

Y.Z. Cai, L.Q. Chen, H.Y. Yang, J. Gou, L.F. Cheng, X.W. Yin, H.F. Yin, "Mechanical and Electrical Properties of Carbon Nanotube Buckypaper Reinforced Silicon Carbide Nanocomposites," Ceramics International, Vol. 42, pp. 4984-4992, (2016)

Z. Liu, Y.B. Gao, F. Liang, B.X. Wu, J. Gou, M. Detrois, S. Tin, M. Yin, P. Nash, X.D. Tang, X.W. Wang, "Fabrication of Carbon Nanotube - Chromium Carbide Composite through Laser Sintering," Lasers in Manufacturing and Materials Processing, Vol. 3, pp. 1-8, (2016)

*308-UTMB*

Blue RS, Bonato F, Seaton K, Bubka A, Vardiman JL, Mathers CH, et al. The Effects of Training on Anxiety and Task Performance in Simulated Suborbital Spaceflight. Aerosp Med Hum Perform 2017; 88(7): 641-650."

Suresh R, Blue RS, Mathers CH, Castleberry TL, Vanderploeg JM. Dysrhythmias in Laypersons during Centrifuge-Simulated Suborbital Spaceflight. Aerosp Med Hum Perform 2017; 88(11)1-8.

Suresh R, Blue RS, Mathers CH, Castleberry TL, Vanderploeg JM. Sustained Accelerated Idioventricular Rhythm in a Centrifuge-Simulated Suborbital Spaceflight. Aerosp Med Hum Perform 2017; 88(8): 1-5.

*310-UTMB*

Speicher LL, Blue RS, Vanderploeg JM. Vehicle Restraint Considerations for Commercial Spaceflight. Submitted, in review, Aerospace Medicine and Human Performance.

*311-UCF*

Anthony Carmine Terracciano, Kyle Thurmond, Michael Villar, Justin Urso, Erik Ninnemann, Akshita Parupalli, Zachary Loparo, Subith S. Vasu, "Hazardous Gas Detection Sensor Using Broadband LED Based Absorption Spectroscopy for Space Applications, In preparation for submission to New Space."

Kyle Thurmond, Zachary Loparo, William P. Partridge Jr., Subith S. Vasu, "A Light-Emitting-Diode (LED) Based Absorption Sensor for Simultaneous Detection of Carbon Monoxide and Carbon Dioxide", Applied Spectroscopy, 2016, 70(6), 962-971.

*319-UF*

Kleespies, Joe, and Norman Fitz-Coy. "DebriSat, Big Data, and How It Relates to Small Satellites." Proceedings of the 31st Annual AIAA/USU Conference on Small Satellites, 2017.

Kleespies, Joseph, and Norman Fitz-Coy. "An Update on DebriSat's Debris Categorization System." Proceedings of the 67th International Astronautical Congress, 2016.

Kleespies, Joseph, and Norman Fitz-Coy. "Big impacts and big data: Addressing the challenges of managing DebriSat's characterization data." IEEE Aerospace Conference, 2016.
Kleespies, Joseph, and Norman Fitz-Coy. "DebriSat's Debris Categorization System: A Database-Based Solution to the Big Data Challenges Impacting the Future Regulation of Orbital Debris" Proceedings of the 7th European Conference on Space Debris, 2017.
Kleespies, Joseph, and Norman Fitz-Coy. "Performance Analysis of the DebriSat Debris Categorization System (DCS) Database Engine" Proceedings of the 68th International Astronautical Congress, 2017."
Rivero, M., et al. "Characterization of Debris from the DebriSat Hypervelocity Test." Proceedings of the 66th International Astronautical Congress, 2015.

*320-CU*

Klaus, DM (2017) Functional Integration of Humans and Spacecraft through Physics, Physiology, Safety and Operability. IEEE Aerospace Proceedings, paper no. 2346 (8.0505)
Ocampo, R (2016) Defining, Characterizing and Establishing 'Safe Enough' Risk Thresholds for Human Space Flight, Doctoral Dissertation, University of Colorado
Ocampo, R and Klaus, D (2016a) A Quantitative Framework for Defining "How Safe is Safe Enough?" in Crewed Spacecraft. New Space, 4(2): 75-82
Ocampo, R and Klaus, D (2017a) Challenges in Determining 'Safe Enough' in Human Space Flight. International Association for the Advancement of Space Safety (IAASS) Proceedings, Paper 153, 9th IAASS Conference, Toulouse, France, Oct 2017
Ocampo, R and Klaus, D (2017b) Adapting Pre-Hospital Emergency Medical Protocols for Commercial Space Flight [in review]
Ocampo, R and Klaus, D (2017c) A Risk vs. Usage Perspective on Human Space Flight Safety. [in revision]
Ocampo, RP and Klaus, DM (2016b) Comparing the Relative Risk of Space Flight to Terrestrial Modes of Transportation and Adventure Sport Activities. New Space, 4(3): 190-197

*323-NMT*

Anderson, M., Daniel, J.D., Zagrai, A., and Westpfahl, D.J. (2016) "Electro-Mechanical Impedance Measurements in an Imitated Low Earth Orbit Radiation Environment," Proceedings of the ASME 2016 International Mechanical Engineering Congress and Exposition, paper IMECE2016-66855, November 11-17, 2016, Phoenix, Arizona.
Anderson, M., Zagrai, A., Daniel, J.D., Westpfahl, D.J., Henneke, D., (2017) "Influence of Gamma Radiation on Piezoelectric Active Elements of Space Systems," Proceedings of 11th International Workshop on Structural Health Monitoring, 12-14 September 2017, Stanford University, California.
Anderson, M., Zagrai, A., Daniel, J.D., Westpfahl, D.J., Henneke, D., (2018) "Investigating Effect of Space Radiation Environment on Piezoelectric Sensors: Cobalt-60 Irradiation Experiment," ASME Journal of Nondestructive Evaluation, Diagnostics and Prognostics of Engineering Systems, Feb. 2018, Vol. 1, pp. 011007-011007-11. Published online Aug. 2017.
Hunter, D., Zagrai, A., Kessler, S. (2017) "Adaption of Electromechanical SHM for Space-based Platforms," presentation at SPIE's 24th Annual International Symposium on Smart Structures and Materials + Nondestructive Evaluation and Health Monitoring, 26-29 March 2017, Portland, Oregon, presentation 10170-39.
Zagrai, A., Hunter, D., Anderson, M., Daniel, J.D., Westpfahl, D.J., Henneke, D., Kessler, S., Demidovich, N. (2017) "Electro-mechanical Impedance Structural Diagnostics and Piezoelectric Sensor Fatigue in Space Environment," presentation at Commercial and Government Responsive Access to Space Technology Exchange (CRASTE), June 26-29, 2017, Indian Wells, California.

*325-FSU*

Rajan Kumar, "Measurement of rocket nozzle thrust and noise using optical methods", National Space & Missile Materials Symposium (NSMMS) & Commercial and Government Responsive Access to Space Technology Exchange (CRASTE), 19-23 June, 2016.

*375-DLR*

Drescher, Jürgen, Morlang, Frank, Hampe, Jens, Kaltenhäuser, Sven, Jakobi, Jörn, Schmitt, Dirk-Roger (2016) Commercial Space Transportation and Air Traffic Insertion - SESAR Requirements and the European Perspective. In: Proc. 32nd Space Symposium, Technical Track, Colorado Springs, Colorado, USA. Space Foundation, Colorado Springs, CO, USA
Kaltenhäuser Sven et al. (2017) Facilitating Sustainable Commercial Space Transportation Through an Efficient Integration into Air Traffic Management, New Space Journal, August 2017, ahead of print.
Kaltenhäuser, Sven (2017) A concept for improved integration of Space Vehicle Operation into ATM. 33rd Space Symposium, 3.-6. April 2017, Colorado Springs, CO, USA
Luchkova, Tanja und Kaltenhäuser, Sven und Morlang, Frank (2016) Air Traffic Impact Analysis Design for a Suborbital Point-to-Point Passenger Transport Concept. 3rd Annual Space Traffic Management Conference, 16.-18. Nov. 2016, Daytona Beach, FL, USA.
Morlang, Frank et al.(2017) Why a future commercial spacecraft must be able to SWIM, Journal of Space Safety Engineering, Volume 4 , p. 5-8

## COE CST YEAR 7 PRESENTATIONS

The following is a list of the 22 presentations completed during COE CST Year 7.

*186-SU*

NASA, November 2016
SCPNT Symposium, November 2016
Stanford Founding Grant Society, April 2017

*253-UCF*

C. Harris, J. Kapat, J. Gou, "Task 253: Ultra-High Temperature Thermal Protection Systems," 5th Annual Technical Meeting of FAA COE CST, Arlington, VA, October 26-28, 2015

M. Francis, H.N. Song, J. Kapat, J. Gou, "Task 253: Ultra-High Temperature Thermal Protection Systems," 7th Annual Technical Meeting of FAA COE CST, Las Cruces, NM, October 10, 2017"

M. Mohagheghi, H. Zawati, T. Pinol. J. Gou, C. Yu, J. Kapat, "Use of 1-D Finite Enthalpy Method for a High-Temperature Recuperator Made of Polymer Derived Ceramic Composite for a Supercritical Carbon Dioxide Power System," Proceedings of 5th International Symposium – Supercritical CO2 Power Cycles, San Antonio, TX, March 28-31, 2016

*308-UTMB*

Aerospace Medical Association Annual Scientific Meeting, Denver, CO, May 2017.

Centrifuge-Simulated Suborbital Spaceflight: The Role of Training and the Impact of Anxiety

Effects of Training on Anxiety and Task Performance in Simulated Suborbital Spaceflight.

Identification of Subject Anxiety and Risk of Non-Completion during Simulated Suborbital Spaceflight.

Incidence and Significance of Bradycardia during Centrifuge-Simulated Suborbital Spaceflight.

Motion Sickness Symptoms, Training Benefits, and Adaptation during Simulated Commercial Spaceflight.

Sustained Accelerated Idioventricular Rhythm in Centrifuge-Simulated Suborbital Spaceflight.

*310-UTMB*

Speicher LL, Blue RS, Vanderploeg JM. Vehicle Restraint Considerations for Commerical Spaceflight. Anticipated, Aerospace Medical Association Annual Scientific Meeting, May 2018.

*311-UCF*

A. Terracciano, M. Villar, J. Urso, A. Parupalli, W.P. Partridge Jr., J. Kapat, S. S. Vasu, "High Altitude Balloon Flight Test Demonstration of LED-Based Hazardous Gas Sensor in Harsh Environments for Space Applications", National Space & Missile Materials Symposium (NSMMS) Commercial and Government Responsive Access to Space Technology Exchange (CRASTE), Indian Wells, CA , 06/2017.

A. Terracciano, M. Villar, J. Urso, A. Parupalli, W.P. Partridge Jr., J. Kapat, S. S. Vasu, "High-Altitude Balloon Flight Demonstration of LED-Based NDIR Multi-Gas Sensor for Space Applications", Center of Excellence for Commercial Space Transportation Annual Technical Meeting(ATM8), Las Cruces, NM, 10/2017.

J. Urso, M. Villar, K. Thurmond, Z. Loparo, W.P. Partridge Jr., J. Kapat, S. S. Vasu, "Robust Sensors for Spacecraft Fire, Detection", Center of Excellence for Commercial Space Transportation Annual Technical Meeting (ATM 5), Washington, D.C., 10/2015.

K. Thurmond, J. Urso, M. Villar, W.P. Partridge Jr., S.S. Vasu, "A Light-Emitting-Diode (LED) Non-Dispersive Absorption Sensor for Early Fire and Hazardous Gases Detection", ESS/CI Spring Technical meeting, Princeton, NJ, 3/2016, paper #1B02.

M. Villar, J. Urso, W.P. Partridge Jr., J. Kapat, S. S. Vasu, "Progress in Development and Testing of a LED-Based Fire and Hazard Detection Sensor for Space Vehicles", National Space & Missile Materials Symposium (NSMMS) Commercial and Government Responsive Access to Space Technology Exchange (CRASTE), West Minister, CO, 06/2016.

*320-CU*

Conference on World Affairs (invited), Panelist, The 2nd Space Renaissance, Macky Auditorium, University of Colorado, Boulder, April 2017

FAA COE CST, Sixth Annual Technical Meeting, Task 320: Commercial Spaceflight Risk Assessment and Communication, Las Cruces, NM, October 2016

IEEE Aerospace Conference, Functional Integration of Humans and Spacecraft through Physics, Physiology, Safety and Operability, Big Sky, MT, March 2017

NSBRI Workshop on Piloting Spacecraft: Guidance and Control of Human Vehicles, (invited, presented via WebEx) 'Functional Integration of humans in piloted spacecraft', Houston, TX, Sept 2016

*375-DLR*

Kaltenhäuser, Sven und Morlang, Frank und Luchkova, Tanja und Hampe, Jens und Schmitt, Dirk-Roger (2016) Evolving Air Traffic Management towards an efficient integration of hypersonic air transportation. 2nd Symposium on Hypersonic Flight, 30. Jun. - 01. Jul. 2016, Rome, Italy.


COE CST ATM7 Attendees
Alan Spiers, OSU
Glenn Bedell
Nick Demidovich
Tristan Fiedler, FIT
Jeff Sutton, BCM
Joe Kleespies, UF
Moriba Jah, UT Austin
William Lash, MITRE
Joe Bullington
Rachel Tompa, SU
Billy Oates, FSU
Mykel Kochenderfer, SU
Jan Gou, UCF
Marielle Pellegrino, CU
Tim Fuller-Rowell, CU
Don Leslie
Karen Shelton-Mur
Richard Majestic
Ken Davidian
Sigrid Close, SU
Luis Ortega, NMT
John Gaebler, CU
Jim Vanderploeg, BCM
Carl Ehrlich
Seokbin Lim, NMT
Dara Parker
Onrej Doule, FIT
Tarah Castleberry, UTMB
Andrie Zagrai, NMT
TBD
Dan Hicks
Becky Blue, UTMB
Dave Klaus, CU
Melissa Force
Sven Kaltenhaeuser, DLR
Evelina Bern
Nicolas Lee, SU
Dave Zuniga
H.R. Zucker
Jim Zimmerman
Not shown: Penina Axelrad (CU), Dean Fulmer (MITRE), Subith Vasu (UCF), Fred Bowen (OAT), Dr. Juergen Drescher (DLR)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