Academic Quality and Workforce

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Aerospace Technology Research Conducted by Public Universities

A Report to the Texas Legislature
Senate Bill 458, 84th Texas Legislature

June 2016

DRAFT

Texas Higher Education Coordinating Board

Agency Mission

The Texas Higher Education Coordinating Board promotes access, affordability, quality, success, and cost efficiency in the state's institutions of higher education, through Closing the Gaps and its successor plan, resulting in a globally competent workforce that positions Texas as an international leader in an increasingly complex world economy.

Agency Vision

The THECB will be recognized as an international leader in developing and implementing innovative higher education policy to accomplish our mission.

Agency Philosophy

The THECB will promote access to and success in quality higher education across the state with the conviction that access and success without quality is mediocrity and that quality without access and success is unacceptable.

The Coordinating Board's core values are:
Accountability: We hold ourselves responsible for our actions and welcome every opportunity to educate stakeholders about our policies, decisions, and aspirations.
Efficiency: We accomplish our work using resources in the most effective manner.
Collaboration: We develop partnerships that result in student success and a highly qualified, globally competent workforce.
Excellence: We strive for preeminence in all our endeavors.

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Overview of Aerospace Technology Research

This report provides a summary of aerospace technology research conducted by public senior colleges and universities, as directed by Senate Bill 458, 84th Texas Legislature, Regular Session, codified as Government Code Chapter 481, Subchapter A, Section 481.0066, Aerospace and Aviation Office:

> (d-2)(3) a summary of work performed as part of the aerospace and aviation office's partnership with the Texas Higher Education Coordinating Board, including a summary prepared by the board of the research conducted by public senior colleges or universities, as defined by Section 61.003, Education Code.

Research Expenditures

The Texas Higher Education Coordinating Board (THECB or Coordinating Board) collects research expenditure data from Texas institutions of higher education in the special interest area of aerospace technology as part of each institution's annual financial report. Research expenditures are available electronically on the webpage www.thecb.state.tx.us/research. Table 1 shows total research expenditures in the special interest area of aerospace technology for the last three years combined.

Table 1. Aerospace Technology Research Expenditures, Fiscal Years 2013-2015

Institution	Aerospace Technology Research Expenditures 2013-2015
Prairie View A&M University	$70,000
Texas A&M University w/ System & Agencies	$14,290,000
Texas A&M University-Corpus Christi	$870,000
Texas Tech University	$220,000
The University of Texas at Arlington	$14,870,000
The University of Texas at Austin	$32,730,000
The University of Texas at Brownsville	$1,970,000
The University of Texas at Dallas	$4,870,000
The University of Texas at El Paso	$12,090,000
The University of Texas at San Antonio	$1,280,000
University of Houston	$5,400,000
University of Houston-Clear Lake	$530,000
University of North Texas	$3,940,000
Total	$93,100,000

Source: Coordinating Board, Annual Financial Reports

Table 2 shows the source of funding for these expenditures for the last three years combined.

Table 2. Aerospace Technology Research Expenditures, Fiscal Years 2013-2015

Source of Funds	Aerospace Technology Research Expenditures 2013-2015
Federal	$73,600,000
State Appropriation and Grants	$4,400,000
Institutional Resources	$10,200,000
Private	$4,900,000
Total	$93,100,000

Source: Coordinating Board, Annual Financial Reports

Awards for Research Grants

To compile a summary of work performed in the special interest area of aerospace technology research during academic year 2015, THECB staff identified the Texas public institutions of higher education that reported research expenditures in this area on their annual financial reports for Fiscal Year (FY) 2015. THECB staff then contacted institutional representatives from those institutions and requested a list of their active awards for FY 2015. This information is presented in the section "Awards for Aerospace Technology Interest Area" (see page 4).

Research grant awards typically are multi-year awards, and therefore, the total award amounts for active grants during FY 2015 is higher than the year's total expenditures.

Table 3 shows research grant awards for aerospace technology by source of funding. More than half of the award funding was from the National Aeronautics and Space Administration (NASA) and the national defense agencies Department of Defense (DOD), the Air Force, Army, and the Navy.

Table 3. Aerospace Technology Awards, Fiscal Year 2015

Source of Funds	Aerospace Technology Awards 2015
NASA	$50,300,000
Defense (DOD, Air Force, Army, Navy)	$40,200,000
National Science Foundation	$9,100,000
Other (federal, state, and undisclosed)	$6,100,000
Private and Nonprofits	$17,700,000
Sub-Recipient Funds	$19,700,000
Total	$143,100,000

Source: Institutions of higher education with expenditures in the special interest area of aerospace technology.
Note: The original source of sub-recipient funds is not reported.

Research Fields

Aerospace technology grants were awarded predominantly in the research field of engineering. However, apart from engineering, a large number of other research fields received awards in aerospace technology, including multiple fields in the natural sciences. Awards also were given in mathematics, manufacturing, and sociology. The list below shows the diversity of the research fields that received awards under the special interest area of aerospace technology:

- Aeromechanics
- Astronomy
- Biology
- Biochemistry
- Chemistry
- Computer Science and Computational Engineering
- Engineering: Aerospace Engineering, Chemical Engineering, Civil Engineering, Computer Engineering, Electrical Engineering, Environmental Engineering, Mechanical Engineering
- Engineering Geology
- Geosciences, Earth & Atmospheric Sciences, and Climate Science
- Health and Human Performance
- Manufacturing and Systems Engineering
- Materials Science and Materials Engineering
- Mathematics
- Nanoscience
- Physics, Astrophysics, and Astrodynamics
- Renewable Energy Science
- Sociology
- Space Science

Research Topics

Given the large number of research fields involved in aerospace technology research, research topics under investigation are accordingly diverse. The topics or categories listed provide a general summary of the variety of research topics described, which are in the following section, “Awards for Aerospace Technology Interest Area” (page 4). The list of research topics is not comprehensive, since some specialized research topics are difficult to classify based on the information available. The list is qualitative and captures the main topics addressed by aerospace technology research. The purpose of this information is to provide insight into the range of topics researched.

Aeromechanics: aircraft design, satellites, missile guidance, turbulent flow, plasma studies and propulsion, flight control, atmospheric entry, manufacturing, autonomous vehicles

Astrophysics: orbit determination, trajectory optimization, space debris, impact studies

Biological Processes: bioreactors, space-based waste, habitat design, weightlessness studies, neuroscience, immune system studies, microbes and pathogens in space, chromosome radiation exposure, stem cell studies

Chemistry: synthetic fuel, lubrication, oxygen generators, CO2 retrieval

Computer Techniques: modeling, data mining, optimization, autonomous transport and unmanned aerial vehicles, control systems, uncertainty modeling, video algorithms, cloud computing

Electronics: sensors, signal processing, antennae, energy efficiency, thermal management, robotics, instrumentation

Engine and Power Plant Design: mechanics, thermodynamics, rotors, gas dynamics, detonation dynamics, oxygen recovery, alternative fuels engines, nontoxic propulsion, noise reduction, thrusters

Materials Studies: fatigue, strength, testing and characterization, metamaterials, high temperature materials, manufacturing, coating, superconductivity, thin film batteries

Micro/Nano Scale Studies: nanofluids, energy storage, electrochemical energy storage, material damage, sensor materials, radiation protection, photocatalytic conversion

Planetary Studies: atmosphere, magnetosphere, ionosphere, thermosphere, solar wind, dust dispersal, gravimetry, geodesy, laser ranging, remote sensing, climate change data

Awards for Aerospace Technology Interest Area

The following sections provide a summary of research awards in the special interest area of aerospace technology that were active during FY 2015. The compilation serves as a snapshot from one year and shows the array of research fields involved and the variety of research topics investigated within the aerospace technology interest area. These data were provided to the Coordinating Board by the institutions from their internal listings of research awards and were then compiled in a uniform format, which includes:

- Title
- Principal Investigators
- Department, Center, or Institute
- Institution
- Discipline
- Funding Agency
- Award Number
- Award Amount
- Brief Abstract

For this report, expenditures are not tied to award amounts. This report, for example, lists awards that were active during FY 2015, even though the award may have been made in another fiscal year. In most cases, only partial award amounts would have been expended during FY 2015.

Texas A&M University (TAMU) with Agencies

Texas A&M University and its service agencies listed 18 active awards in aerospace technology for FY 2015. The total award amount was $7,716,082. During that year, TAMU's research expenditures for awards in aerospace technology were $3,956,536. Information for the identified active awards are provided.

Title: *Intelligent Motion Video Algorithms for Unmanned Air Systems (UAS): Phase II*
Principal Investigator(s): John Valasek; James Turner
Department, Center, or Institute: Aerospace Engineering Department
Institution: Texas A&M University
Discipline: Aerospace Engineering
Funding Agency: Raytheon
Award Number: C11-00707 (PO 132946)
Award Amount: $600,000
Abstract: The proposed work seeks to conduct applied research for the purpose of enabling activities that will enable a pathway for basic academic research at TAMU to be transitioned into larger Raytheon Corporate Research and Development efforts for operational systems. The technical objective of the proposed effort is to extend the work in Phases I-III to enhance, extend, and demonstrate the utility of motion-based video algorithms developed with the Reinforcement Learning/Approximate Dynamic Programming methodology; assist with the development and test of the Common Ground Control Station; conduct basic work on video processing algorithms with the Land, Air, and Space Robotics Laboratory; and develop platform-positioning algorithms in support of advanced UAS platforms.

Title: *Thermal and mechanical non-equilibrium effects on turbulent flows: fundamental studies of energy exchanges through direct numerical simulations, molecular simulations and experiments*
Principal Investigator(s): Diego Donzis, Rodney Bowersox, Simon North, William L. Hase
Department, Center, or Institute: Department of Aerospace Engineering
Institution: Texas A&M University
Discipline: Hypersonics and Turbulence
Funding Agency: Air Force Office of Scientific Research
Award Number: C13-00027 (Grant No. FA9550-12-1-0443)
Award Amount: $2,223,000
Abstract: Utilizing internal energy exchange for intelligent control of basic fluid dynamic processes is of direct relevance to Air Force Office of Scientific Research (AFOSR) scientific objectives, especially for turbulence flows. The very limited work on the

subject suggests strong interactions between thermal non-equilibrium (TNE) and turbulence. This project aims at both advancing our understanding of the effect of thermal (rotational, vibrational) and mechanical non-equilibrium on compressible turbulence and proposing new technological advances in the strategies to generate and control turbulence. Due to the intrinsic multidisciplinary nature of the scientific problem, a combination of state-of-the-art massive direct numerical simulations (DNS), detailed molecular dynamics simulations, and novel laser-based experimental approaches will be used to explore the detailed physics at levels of fidelity and at a range of parameters not previously possible.

Title: *CORA - Critical Optical Research Applications (Project is closing)*

Principal Investigator(s): Alfriend, Kyle
Department, Center, or Institute: Texas A&M Engineering Experiment Station
Institution: Texas A&M University
Discipline: Aerospace Engineering
Funding Agency: Pacific Defense Systems
Award Number: C13-00335 (Subrecipient Agreement dated 12/21/12)
Award Amount: $260,000

Abstract: The Texas A&M Engineering Experiment Station will provide technical support to Pacific Defense systems in the area of space situational awareness in support of their contract with the Air Force Maul Optical and Supercomputing (AMOS) site. This broad technical support includes, but is not necessarily limited to, the analyses and development of algorithms, suggestions for areas of investigation that will enhance SSA (Space Situational Awareness), and evaluation of other programs.

Title: *REU Site: Texas Center for Undergraduate Research in Energy and Propulsion*

Principal Investigator(s): Eric L. Petersen and Devesh Ranjan
Department, Center, or Institute: Texas Center for Undergraduate Research
Institution: Texas A&M University
Discipline: Mechanical, Aerospace, Materials, and Chemical Engineering
Funding Agency: National Science Foundation
Award Number: C13-00522 Grant No. EEC-1263196
Award Amount: $443,921

Abstract: Insufficient energy research and the shortage of people pursuing advanced degrees in engineering are both topics of supreme importance in modern times, and with this proposed REU site, we intend to target both problems through a collaborative effort between TAMU and the University of Texas at Brownsville (UTB). The objectives of the site emphasize the positive benefits of providing longer-term exposure to research through year-round opportunities for selected students at TAMU and UTB and repeat summer experiences.

Title: *PEGASAS FAA General Aviation Center of Excellence*
Principal Investigator(s): John Valasek, Xiubin Wang, Stefan Hurlebaus, Yunlong Zhang, Thomas Ferris, H. Gene Hawkins, Paul Carlson
Department, Center, or Institute: Texas A&M Engineering Experiment Station
Institution: Texas A&M University
Discipline: Aerospace, Civil, Industrial and Systems Engineering
Funding Agency: FAA
Award Number: M1302752 (Cooperative Agreement 12-c-GA-TEES)
Award Amount: $1,038,428
Abstract: The Texas A&M Engineering Experiment Station has partnered with five other major universities (Purdue, Georgia Tech, Ohio State, Iowa State, and Florida Institute of Technology) as part of the FAA General Aviation Research Center of Excellence. The Center of Excellence is named PEGASAS. This center will solicit FAA research in the area of General Aviation for a 10-year period starting in 2013.

Title: *Orbit Determination, Prediction, and Characterization of High-Altitude, Faintly Measurable Resident Space Objects (RSO)*
Principal Investigator(s): Alfriend, Kyle and John Junkins
Department, Center, or Institute: Texas A&M Engineering Experiment Station
Institution: Texas A&M University
Discipline: Astrodynamics
Funding Agency: Federal Government
Award Number: M1400539 (Contract No. TSC-1054-40017)
Award Amount: $979,377.09
Abstract: This Statement of Work (SOW) describes a basic astrodynamics research plan to develop and extend current space situational awareness (SSA) algorithms for orbit determination, long-term orbit prediction, and identification of the attributes of high-altitude space objects, with specific emphasis on faint smaller objects and materials. The subcontractor team of TAMU and the University of Buffalo will improve Geosynchronous Earth Orbit (GEO) small object tracking, identification and catalog maintenance by leveraging emerging science and technology capabilities in the public domain. TAMU will be the overall technical lead for the proposed Orbit Determination, Prediction, and Characterization of High-Altitude Faintly Measurable RSO project.

Title: *Robust Cooperative Target Engagement with Operator-Independent Low-Cost Autonomous Weapons*
Principal Investigator(s): John Hurtado
Department, Center, or Institute: Texas A&M Engineering Experiment Station
Institution: Texas A&M University
Discipline: Aerospace Engineering
Funding Agency: Air Force Research Laboratory
Award Number: BAA-RWK-2013-0001 (Grant No. FA8651-13-1-0006)
Award Amount: $250,000
Abstract: Currently, the Air Force faces asymmetrical conflict scenarios in which expensive, highly precise weapons are used against low-cost targets that may be easily

replaced or are even considered expendable. These scenarios commonly required prohibitive operator involvement, which can significantly reduce overall operational efficiency. The fundamental mismatch between the cost to destroy a target and the cost to replace it creates an environment of diminishing return in terms of Air Force resources and investment. The goal of this project is to develop a framework of algorithms that enables multiple target engagement with a swarm of low-cost, heterogeneous autonomous weapons systems. Moreover, we will produce control and communications algorithms and methodologies that allow low-cost weapons to neutralize identified targets with minimal operator oversight and maximal robustness against varying types of uncertainty. The products will be displayed in hardware demonstrations.

Title: *Space Signatures for Rapid Unambiguous Identification of Satellites*
Principal Investigator(s): John Junkins
Department, Center, or Institute: Texas A&M Engineering Experiment Station
Institution: Texas A&M University
Discipline: Aerospace Engineering
Funding Agency: Applied Defense Solutions, Inc.
Award Number: M1502626
Award Amount: $170,000
Abstract: To develop methods to solve the Nonlinear Reachable Set (NIRS) problem to enable and enhance indications and warnings capabilities, and to develop relevant resident space taxonomies and high performance computing ability.

Title: *Active Combustion Control of Augmentor Dynamics Using Robust High-Frequency Energy Deposition*
Principal Investigator(s): Paul Cizmas
Department, Center, or Institute: Texas A&M Engineering Experiment Station
Institution: Texas A&M University
Discipline: Aerospace Engineering
Funding Agency: Physics, Materials, and Applied Mathematics Research, L.L.C.
Award Number: M1403154 (8044-S1)
Award Amount: $24,500
Abstract: Work with sponsor to identify the system properties, perform system modeling, design an augmentor component for the Phase I benchtop and prototype demonstrations, perform laboratory benchtop demonstrations of sponsor's novel energy deposition actuators, characterize the baseline TAMU facility augmentor performance, and evaluate the influence of the sponsor's novel Active Combustion Control approach on the magnitude and bandwidth of the instabilities/resonances observed in modern augmentors, etc.

Title: *Phase 2: Development of Analysis Tools for Induction Heating of SMAs*
Principal Investigator(s): James Boyd and Dimitris Lagoudas
Department, Center, or Institute: Texas A&M Engineering Experiment Station
Institution: Texas A&M University
Discipline: Aerospace Engineering
Funding Agency: The Boeing Company
Award Number: M1501738 (PO 1082917)
Award Amount: $51,459
Abstract: The application of Shape-Memory Alloy (SMA) actuation technology requires improved modeling for the understanding and design of associated active components. Recently, Boeing engineers have begun experimental development of a novel method of quickly heating SMA components, allowing them to actuate in just seconds. However, the initial work on these methods was purely empirical. Phase 1 of this study was funded to explore, derive, and implement coupled electromagnetic and SMA constitutive models required to capture the behavior of SMA components subjected to large magnetic fields of the type required to induce induction heating. Phase 2 will further develop the models and also optimize the design of magnetic flux concentrators and electrical systems. This will allow us to both understand and improve the developments made in the laboratory.

Title: *Cloud Computing-Based Robust Space Situational Awareness*
Principal Investigator(s): Raktim Bhattacharya, Bani Mallick, and Liang Faming
Department, Center, or Institute: Texas A&M Engineering Experiment Station
Institution: Texas A&M University
Discipline: Aerospace Engineering
Funding Agency: DOD-Air Force-Office of Scientific Research
Award Number: M1502987 (FA9550-15-1-0071)
Award Amount: $671,412
Abstract: Space situational awareness (SSA) refers to the ability to view, understand, and predict the physical location of natural and manmade objects in orbit around Earth, with the objective of avoiding collisions. This research provides a cloud-based system that can address the growing needs of the space community for a reliable space situational awareness. In the spirit of Dynamic Data-Driven Application Systems (DDDAS), the proposed research incorporates various sensors across the globe, as well as other astrodynamics databases, to continuously improve the quality of space awareness, and directly addresses the new data-sharing trend in the SSA community.

Title: *Vision-Based Navigation for Orion*
Principal Investigator(s): Daniele Mortari
Department, Center, or Institute: Texas A&M Engineering Experiment Station
Institution: Texas A&M University
Discipline: Aerospace Engineering
Funding Agency: NASA-Shared Services Center
Award Number: M1402681
Award Amount: $300,000

Abstract: This research consists of continuing, extending and optimizing the software packages partially developed for vision-based attitude and position (pose) navigation using Moon/Earth images taken by the Orion visible camera and/or by star trackers. The main purpose is to prove Orion vision-based autonomy in pose estimation using a visible camera or star trackers. This will constitute reliable backup navigation software when communications with Earth ground stations are not available due to antenna failure or Moon occultation.

Title: *RI: Small: Collaborative Research: Cooperative Autonomous Vehicle Routing Algorithms with Resource and Localization Constraints*
Principal Investigator(s): Sivakumar Rathinam
Department, Center, or Institute: Texas A&M Engineering Experiment Station
Institution: Texas A&M University
Discipline: Mechanical Engineering
Funding Agency: National Science Foundation
Award Number: M1503402 (IIS-1527748)
Award Amount: $241,292
Abstract: This research is to develop novel algorithms to enable the successful deployment of a team of autonomous unmanned vehicles for surveillance applications in GPS-denied environments. The research addresses the following fundamental problem: Given a set of vehicles and targets to visit, find a path for each vehicle such that each target is visited at least once by some vehicle; the error in the position estimate of each vehicle at any time instant is within a given bound; and an objective, which depends on the travel and sensing costs, is minimized.

Title: *Development of Stretchable Gas Barrier Nanocoating*
Principal Investigator(s): Jaime Grunlan
Department, Center, or Institute: Texas A&M Engineering Experiment Station
Institution: Texas A&M University
Discipline: Mechanical Engineering
Funding Agency: Zodiac Aerospace
Award Number: M1402003 (Research Agreement No. M1402003)
Award Amount: $220,985
Abstract: Develop nanocoatings for gas barrier also using non-brominated flame retardants. Incorporate enough coating to meet all coating/seam strength requirements; Incorporate heat resistant coatings (only on slide fabrics) in order to pass radiant heat test requirement.

Title: *Proposals for Federal Agencies to Develop Unmanned Aerial System (UAS) Applications*
Principal Investigator(s): Behbood Zoghi
Department, Center, or Institute: Texas A&M Engineering Experiment Station
Institution: Texas A&M University
Discipline: Technology Commercialization
Funding Agency: Remotely Piloted Solutions LLC, dba Aviation Unmanned

Award Number: M1500941 (Task Order No. 001)
Award Amount: $5,000
Abstract: This research is to support proposal efforts for funding opportunities with federal agencies to develop unmanned aerial system (UAS) applications for agriculture, energy, emergency/disaster response, and other applications as identified by the sponsors.

Title: *Proximity Navigation Near and Mapping of Asteroids*
Principal Investigator(s): John Junkins
Department, Center, or Institute: Texas A&M University Aerospace Engineering
Institution: Texas A&M University
Discipline: Aerospace Engineering
Funding Agency: NASA-Stennis Space Center
Award Number: M1303212 (NNX13AM75H)
Award Amount: $188,851
Abstract: Involving analytical algorithmic and sensor management, the basic research proposed is an enabling technology that drives the next generation asteroid detection and mapping missions.

Title: *One Stop Shopping Initiative - NASA Scholarship (Minority University Research and Education Project) - 2013 MUREP Scholarship*
Principal Investigator(s): Rodney Bowersox and Laura Olivarez
Department, Center, or Institute: Texas A&M University Aerospace Engineering
Institution: Texas A&M University
Discipline: Aerospace Engineering
Funding Agency: NASA-Stennis Space Center
Award Number: M1400360 (NNX13AR99H)
Award Amount: $25,357
Abstract: The NASA MUREP Scholarship is a competitive scholarship opportunity that focuses on underserved and underrepresented students in the Science, Technology, Engineering, and Math (STEM) disciplines, thereby addressing the critical shortage of qualified STEM professionals that the nation is facing.

Title: *2013-2014 Aeronautics Scholarship Program*
Principal Investigator(s): Rodney Bowersox
Department, Center, or Institute: Texas A&M University Aerospace Engineering
Institution: Texas A&M University
Discipline: Aerospace Engineering
Funding Agency: NASA-Stennis Space Center
Award Number: M1401682 (NNX14AE41H)
Award Amount: $22,500
Abstract: NASA education scholarships and research opportunities for aeronautics are directed toward enhancing the state of aeronautics for the nation; transforming the nation's air transportation system; and developing the knowledge, tools, and technologies to support future air and space vehicles.

Texas A&M University-Corpus Christi (TAMU-Corpus Christi)

Texas A&M University-Corpus Christi listed four active awards in aerospace technology for FY 2015 with a total award amount of $504,411. During that year, award titles and funding agencies were redacted for nondisclosure awards, and TAMU-Corpus Christi's research expenditures for awards in aerospace technology were $203,294. Information for the identified active awards are provided.

Title: *Nondisclosure award*
Principal Investigator(s): Ronald George
Department, Center, or Institute: Division of Research, Commercialization, and Outreach
Institution: Texas A&M University-Corpus Christi
Discipline: Engineering
Funding Agency: N/A
Award Number: N/A
Award Amount: $250,000
Abstract: To develop guidance technologies for obstacle avoidance with partial control system failure; autonomous auto rotation algorithms; technology for on-board Sense and Avoid (SAA) capability; collision avoidance by cooperative target tracking under connectivity changes; ground-based SAA using machine learning, computational modeling and control algorithms; assessment of unmanned aerial system surface and air-volume environmental impacts; and strategies for mitigation in compliance with FAA and other applicable standards.

Title: *Nondisclosure award*
Principal Investigator(s): Steven Seidel
Department, Center, or Institute: Division of Research, Commercialization, and Outreach
Institution: Texas A&M University-Corpus Christi
Discipline: Engineering
Funding Agency: N/A
Award Number: N/A
Award Amount: $90,637
Abstract: To develop guidance technologies for obstacle avoidance with partial control system failure; autonomous auto rotation algorithms; technology for on-board Sense and Avoid (SAA) capability; collision avoidance by cooperative target tracking under connectivity changes; ground-based SAA using machine learning, computational modeling and control algorithms; assessment of unmanned aerial system UAS surface and air-volume environmental impacts; and strategies for mitigation in compliance with the Federal Aviation Administration and other applicable standards.

Title: *Nondisclosure award*
Principal Investigator(s): Jerry Hendrix
Department, Center, or Institute: Division of Research, Commercialization, and Outreach
Institution: Texas A&M University-Corpus Christi

Discipline: Engineering
Funding Agency: N/A
Award Number: N/A
Award Amount: $147,903
Abstract: To conduct research tasks into unmanned and autonomous flight technologies.

Title: *Nondisclosure award*
Principal Investigator(s): Jerry Hendrix
Department, Center, or Institute: Division of Research, Commercialization, and Outreach
Institution: Texas A&M University-Corpus Christi
Discipline: Engineering
Funding Agency: N/A
Award Number: N/A
Award Amount: $15,871
Abstract: Develop assessment criteria to evaluate providers of Unmanned Aerial Vehicles (UAVs) for use in refinery infrastructure inspection.

Texas Tech University (Texas Tech)

Texas Tech University listed six active awards in aerospace technology for FY 2015 with a total award amount of $697,239. During that year, Texas Tech's research expenditures for awards in aerospace technology were $147,890. Information for the identified active awards are provided.

Title: *NASA FELLOWSHIP: Advancement of Membrane-aerated Biological Reactors (MABRs) via Post-inoculation Hibernation and Novel Membrane Fabrication for Enhanced Mission Sustainability (Dylan Christenson)*
Principal Investigator(s): Audra Morse and William Jackson
Department, Center, or Institute: Department of Civil, Environmental and Construction Engineering
Institution: Texas Tech University
Discipline: Civil and Environmental Engineering
Funding Agency: NASA
Award Number: NNX13AL52H
Award Amount: $74,000
Abstract: Objective: Assess the impact of specific surface area on reactor performance during uniform loading. Method: Three Bench-scale (1:10 of full scale) MABRs with different specific surface areas (200 m2/m3, 150m2/m3, and 100 m2/m3) were challenged with a space-based (Early Planetary Base) waste stream. This waste stream has a high strength (Carbon and Nitrogen ~ 800-1000mg/L) and has a low C:N ratio.

Title: *Complete Restoration of the Apollo Lunar Surface Experiments Packages* (*ALSEPs) Data for April through June 1975 and the Associated Metadata*

Principal Investigator(s): Seiichi Nagihara
Department, Center, or Institute: Department of Geosciences
Institution: Texas Tech University
Discipline: Geosciences
Funding Agency: NASA
Award Number: NNX13AD47G
Award Amount: $250,526

Abstract: We propose to extract binary files for recently located open-reel digital magnetic tapes containing raw data from all the instruments of all five Apollo Lunar Surface Experiments Packages from the three-month period of April through June 1975. We propose to extract binary files from these tapes, fully process them into scientifically meaningful data and archive them in the Planetary Data System Lunar Data Node in formats that are easily accessible to the public.

Title: *Biological Treatment for Wastewater Stabilization in Support of Manned Space Exploration: Further Research Needs*

Principal Investigator(s): William Jackson and Audra Morse
Department, Center, or Institute: Department of Civil, Environmental and Construction Engineering
Institution: Texas Tech University
Discipline: Civil and Environmental Engineering
Funding Agency: NASA
Award Number: NNX15AC87A
Award Amount: $81,294

Abstract: Texas Tech University has over 14 years of experience designing, building, and testing biological processors for treatment of space-based waste streams. This work culminated in the design and testing of CoMANDR I and II (Co-diffusion Membrane Aerated Nitrification Denitrification Reactor) in support of the Advanced Water Recovery Test at Johnson Space Center (JSC). Results from both the testing at Texas Tech and JSC support the further redevelopment of biological pretreatment, in conjunction with desalination, to lower Equivalent System Mass (ESM) and increase overall water recovery. We propose to continue testing a new rectangular reactor geometry to better facilitate inclusion into standard flight hardware, minimize overall volume, and maximize performance and reliability. We will compare this design with a dual-stage reactor configuration to determine if one or two stage reactors have lower ESM, considering the overall treatment efficiency. We will further investigate the efficacy of using ultra low (<3) pH bioreactor effluent as a potential flushing or de-scaling solution with no impact to the overall process train efficiency. Finally, we will conceptualize a flight experiment to evaluate the assumptions that have been made regarding the microgravity compatibility and biofilm development/function. The completion of these objectives will greatly advance the development of biological processing of space-oriented wastewater processing, which may greatly increase the sustainability of future manned space exploration and habitation.

Title: *Processing an Addition of Apollo Lunar Surface Experiments Packages (ALSEPs) High-Order Data Products and Metadata to the Planetary Data System*

Principal Investigator(s): Seiichi Nagihara
Department, Center, or Institute: Department of Geosciences
Institution: Texas Tech University
Discipline: Geosciences
Funding Agency: NASA
Award Number: NNX15AI82G
Award Amount: $146,258

Abstract: The ALSEPs were deployed at the Apollo 12, 14, 15, 16, and 17 sites. Data from 14 experiments were transmitted to Earth from November 1969 to September 1977 (Table 1). The National Space Science Data Center currently holds raw datasets (unprocessed data received from the Moon) for all the ALSEP experiments (except for the Laser Ranging Retroreflector Experiment) for the final 19 months of the ALSEP operation (March 1976 through September 1977). Another three months of raw data (April through June 1975) will be added early next year. These raw datasets were extracted from the archival data tapes generated in the 1970s. They have not been utilized by many researchers for three reasons: First, the raw data are simply digital counts from the instruments' various output channels and have not been translated into scientifically meaningful values (temperature, magnetic field, etc.); second, these binary files are not easily usable on contemporary computers; third, in each binary file, pieces of data from all the experiments are intermeshed. Therefore, someone knowledgeable about the bit-level organization of the entire record needs to separate the data packets and repackage them for the individual experiments before these experiments can be analyzed scientifically.

Title: *Determining Muscle Strength in Space-Flown Caenorhabditis Elegans*

Principal Investigator(s): Siva Vanapalli and Jerzy Blawzdziewicz
Department, Center, or Institute: Department of Chemical Engineering and Department of Mechanical Engineering
Institution: Texas Tech University
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX15AL16G
Award Amount: $65,000

Abstract: A major impediment to long-duration space travel is loss of muscle mass and strength during spaceflight. Surprisingly, the small worm Caenorhabditis elegans is a good, cost-effective model for studying the effects of spaceflight on muscle. Our past experiments on Earth and on the International Space Station have shown that the expression of key muscle genes that encode members of a muscle attachment complex is reduced in Caenorhabditis elegans during spaceflight. A key open question is if, and how, these changes in gene expression result in reduced muscle strength in response to spaceflight.

Title: *Computational Model for Spacecraft/Habitat Volume*
Principal Investigator(s): Simone Hsiang
Department, Center, or Institute: Department of Industrial Engineering
Institution: Texas Tech University
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX14AT57A
Award Amount: $80,161
Abstract: The proposed work seeks to address the risk of incompatible vehicle/habitat design. We plan to produce computational modules and databases with capabilities such as predicting effects of pressurized garments on crew performance; demonstrating the effects of architecture, environmental factors, and time on self-sustaining activities; and facilitating assessment of emerging design concepts.

The University of Texas at Arlington (UT-Arlington)

The University of Texas at Arlington listed 60 active awards in aerospace technology for FY 2015, with a total award amount of $12,652,917. During that year, UT-Arlington's research expenditures for awards in aerospace technology were $5,468,666. Information for the identified active awards are provided.

Title: *Feasibility of Detonative Processes*
Principal Investigator(s): Lu, Frank K
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Illinois Tool Works, Inc.
Award Number: N/A
Award Amount: $6,378
Abstract: To examine detonative processes for industrial applications.

Title: *Foil Bearings for Electric Motor-Assisted Turbochargers for Unmanned Aerial System/Unmanned Global System Application*
Principal Investigator(s): Kim, Daejong
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Brayton Energy
Award Number: OSD13-PR5
Award Amount: $33,999
Abstract: This project involves design of foil bearings for electric motor-assisted turbo charger (electric turbo compound) for Shadow 200 rotary engine. UT-Arlington is a subcontract to design foil bearings and bench test at high speed up to 240,000rpm. The foil-bearing design in this project is for an overhung rotor with a BLDC motor and turbocharger hybrid system with unique rotordynamics challenge.

Title: *Simultaneous Strain and Temperature Measurement Using a Single Fiber Bragg Grating (FBG) Coated with a Thermochromic Material*

Principal Investigator(s): Huang, Haiying
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: DOD-Navy
Award Number: N00014-14-1-0636
Award Amount: $200,027

Abstract: The goal of this study is to demonstrate simultaneous strain and temperature measurement using a single FBG coated with a thermochromic material. To achieve this goal, the proposed research will focus on: 1) establishing a simulation model to facilitate the design and optimization of FBGs; 2) synthesizing and characterizing the thermochromic material; and 3) realizing the FBG sensors using conventional silica single-mode fibers and custom-made polymer waveguides. The proposed research will address the fundamental limitation of conventional FBG sensors, which is the cross-sensitivity to both strain and temperature variations. By introducing the FBG spectral bandwidth as an additional sensing parameter, the proposed concept will facilitate using a single FBG sensor to simultaneously and independently measure strain and temperature. The project is expected to realize more accurate and more robust optical fiber sensors for Structural Health Monitoring (SHM) systems. The broader deployment of SHM systems will enable the Navy to maintain its fleet more economically, manage its assets more effectively, and improve its mission readiness.

Title: *Collaborative Research: Self-circulating, Self-regulating Microreactor for On-chip Gas Generation from Liquid Reactants*

Principal Investigator(s): Meng, Desheng
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Science Foundation
Award Number: CBET-1444473
Award Amount: $125,834

Abstract: For the reminder of the project, we (UT-Arlington and Michgan Tech) will mainly focus on the design and microfabrication of Microbial electrolysis cell (Meng and Friedrich); the characteristic studies of the pumping effect, including the correlations to determine liquid pumping rate (Meng and Zhu); effects of channel design and back pressure (Zhu and Meng); and fuel utilization (Meng and Zhu). The scope and milestones of this project will not be affected by the relocation of Principal Investigator Meng's research group (MuSES Lab). For the next year, we expect to focus our efforts on the inoculation and development of the microfluidic MEC and the effects of the self-pumping mechanism at the micro-level. Significant efforts will be put into journal publications during the next reporting period to disseminate information to the scientific community.

Title: *An Integrated Experimental-Numerical Framework for Study of Early Fatigue Damage*
Principal Investigator(s): Huang, Haiying
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: DOD-Air Force
Award Number: FA9550-14-1-0319
Award Amount: $451,781
Abstract: The goal of this project is to establish an integrated numerical-experiment framework to derive the grain-level dislocation patterns from fatigue-induced surface morphology changes. Such a framework will enable us to obtain quantitative information on the evolution of the dislocation pattern during the crack-initiation stage. Based on the dynamic behavior of the dislocation pattern, constitutive rules customized for each individual grain can be established for fatigue life prediction.

Title: *Remote Generation and Steering of Ultrasound Using Microwave*
Principal Investigator(s): Huang, Haiying
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: DOD-Navy
Award Number: N00014-11-1-0971
Award Amount: $300,000
Abstract: The objectives of this research are: 1) to understand the electrical-mechanical coupling of piezoelectric (piezo) wafer actuator (PWA) and 2) to establish a multi-physics design framework that optimizes the electrical and mechanical matching of the PWA to achieve maximum power conversion. This study will lead to the development of a new class of unpowered wireless ultrasound actuator (UWUA) that can be remotely and selectively excited using microwave. Wireless steering of ultrasound using UWUA arrays will be demonstrated.

Title: *Distributed Wireless Antenna Sensors for Boiler Condition Monitoring*
Principal Investigator(s): Huang, Haiying
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Department Of Energy
Award Number: DE-FE0023118
Award Amount: $399,311
Abstract: The research objective is to study the materials development, sensor design, multivariant analysis, and wireless interrogation of flexible antenna sensor arrays to realize distributed condition monitoring of coal-fired boilers at a low cost. We will focus on researching the wireless antenna sensors for a) detecting soot accumulation on steam pipes and b) monitoring temperature and strain distribution

of steam pipes. The proposed research will address three fundamental challenges: 1) realize flexible dielectric substrates for high temperature applications; 2) extracting multiple measures from a single sensor response; 3) demonstrate wireless interrogation of distributed passive antenna sensor arrays. The expected outcomes include: i) a methodology to realize low-cost antenna sensor arrays that can sustain high temperature and harsh environments, cover a large area, conform to curved surfaces, and can measure multiple physical parameters at multiple locations; ii) a wireless interrogation technique that can remotely interrogate the distributed antenna sensors from a long distance, with a high resolution and at high speed; and iii) material and fabrication recipes for fabricating flexible dielectric substrates with the controlled dielectric properties.

Title: *Collaborative Center I Ucrc in Energy Efficient Electronic Systems*
Principal Investigator(s): Agonafer, Dereje
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Science Foundation
Award Number: IIP-1134821
Award Amount: $898,750
Abstract: The Center for Energy-Efficient Electronic Systems (E3S) will establish an Industry/University Cooperative Research Center (I/UCRC) with a collaborative research partnership between Binghamton University (State University of New York), Georgia Institute of Technology, the University of Texas at Arlington, The University of Illinois at Urbana-Champagne, and Villanova University. Fifteen industry partners, including Bloomburg, Panduit, HP, Corning, IBM and General Electric have committed to joining the center upon its establishment. E3S will partner with industry, federal labs, and academia to develop systematic methodologies for operating electronic systems and cooling equipment synergistically, as dynamic self-sensing and self-regulating systems that are predictive, stable and verified in real time. The center enjoins computer scientists, mechanical and electrical engineers, systems scientists and industrial engineers, in a synergistic multidisciplinary team to address these issues.

Title: *Goal I Experimental and Theoretical Investigation of Thermal Transport in Three Dimensional Integrated Circuits*
Principal Investigator(s): Jain, Ankur
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Science Foundation
Award Number: CBET-1236370
Award Amount: $216,641
Abstract: The proposed research investigates thermal transport in three-dimensional integrated circuits (3D ICs) and develops novel experimental samples to measure

and compare temperature rise in 3D ICs with previously developed modeled. The proposal research will involve industry partners from IBM, Intel and AMD.

Title: *CAREER Digital Microfluidics to Optimize and Screen Three Dimensional Tissue-Based Analytical Processes*
Principal Investigator(s): Moon, Hyejin
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Science Foundation
Award Number: ECCS-1254602
Award Amount: $400,000
Abstract: The primary objective of this CAREER proposal is to establish a strong interdisciplinary program in micro/nanofluidic systems and biochemical/analytical technologies. A novel microfluidic screening platform integrated with multiple functional components for various biochemical and analytical processes will be developed based on electrowetting-on-dielectric (EWOD) digital microfluidic (DMF) principle. Toward this goal, the proposed CAREER project sets the following specific aims: 1) Three-dimensional cell and tissue culture on EWOD DMF; 2) characterization of EWOD multiplexing performance; 3) development of various novel unit functions of bioseparation; and 4) seamless integration of EWOD DMF with conventional analytical methods, as well as investigation of novel detection/sensing methods utilizing EWOD DMF.

Title: *Scalable Fabrication of Fractal Nanoparticles for Electrochemical Energy Storage*
Principal Investigator(s): Meng, Desheng
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Science Foundation
Award Number: CMMI-1439494
Award Amount: $116,036
Abstract: This award was transferred from Dr. Meng's previous institution, Michigan Technological University, to UT-Arlington.

Title: *Scalable Fabrication of Fractal Nanoparticles for Electrochemical Energy Storage*
Principal Investigator(s): Bowling, Alan P
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Science Foundation
Award Number: DUE-1432750
Award Amount: $48,791
Abstract: This proposal seeks funding to investigate the use of mechatronics instruction to promote experiential learning in the curriculum of the mechanical and aerospace

engineering department. The current curriculum in the Department of Mechanical and Aerospace Engineering (MAE) at UT-Arlington leans towards theoretical investigations of mechanics, along with basic mechanical design. This work is intended to use mechatronics instruction to improve the experimental aspect of our instruction in mechanics. Mechatronics merges electronics and mechanical engineering (ME), allowing students to use motors and actuators, along with other hardware, to generate the forces that produce motion. This allows an experiential investigation of the theoretical predictions based on the modeling techniques, which are the current focus of the ME curriculum. It also provides an alternative learning mode that some students may find a more motivating or accessible introduction to mechanics. This will allow a deeper understanding of the relationship between theoretical and experimental investigations of mechanics.

Title: *A Fundamental Study of a Fuel Injection Strategy Based on the System Dynamics of Selected Modes of Supersonic Steamwise*
Principal Investigator(s): Maddalena, Luca
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Aeronautics and Space Administration
Award Number: NNX12AG46A B0620P1
Award Amount: $227,297
Abstract: The research, a combined experimental and numerical effort, will focus on fundamental science relevant to air-breathing hypersonic propulsion. The objectives of the proposed investigation are to explore the feasibility of an injection and mixing concept based on a selected and predetermined vortex dynamics strategy. The investigation will explore the effects of compressibility and heat release in a flow-mixing configuration designed to probe the interaction of specific streamwise vortical structures. The numerical analysis will be used to investigate the existence and receptivity of characteristic scales (i.e. modes) for non-reactive and reactive (including the effects of finite rate chemistry) flows.

Title: *ARRA CAREER Passive Wireless Sensor Networks for Bio-Inspired Sensor Skins*
Principal Investigator(s): Huang, Haiying
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Science Foundation
Award Number: CMMI-0846074
Award Amount: $429,993
Abstract: The research objective is to exploit a revolutionary sensor concept for the realization of engineered sensor skins. The proposed sensor skin will be studied to imitate the sensation of human skin, especially the sense of pain for early warning of body damage. An unprecedented wireless sensor with integrated sensing and data transmitting capabilities is proposed.

Title: *Development of Engineering Tools for Non-Linear Transient 3 Dimensional Rotor Dynamics and Thermal Analyses of Oil Free*

Principal Investigator(s): Kim, Daejong
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Korea Institute of Machinery and Materials
Award Number: N/A
Award Amount: $96,188

Abstract: The Principal Investigator performed a feasibility study of oil-free version of the sponsor's 120kW micro gas turbine (MGT) generator. The feasibility study confirmed the oil-free version is feasible with advanced foil bearings, and high-level design and prediction tools. The objectives of this proposal are: 1) to develop a computational tool for the transient 3D rotor dynamics of a foil bearing-supported, gas-generating turbine and generator shaft connected with a quill shaft, and 2) to develop a computational tool for the thermal analysis of a rotor-bearing system to be developed for KIMM's 120 kW MGT. This work involves mostly computational work and computer software development for the sponsor.

Title: *Development of Nano-Based Heat Transfer Fluid with Enhanced Thermal Properties for Solar Thermal Applications*

Principal Investigator(s): Shin, Donghyun
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Abengoa Solar New Technologies, S.A.
Award Number: N/A
Award Amount: $80,000

Abstract: Nanofluids are stable colloidal suspensions of nanoparticles in a base fluid medium. The sizes of the particles dispersed in the liquid medium are typically less than 100 nm. These colloidal dispersions of nanoparticles have been studied as advanced heat transfer fluids for various applications, such as microelectronics, fuel cells, and hybrid-powered engine. It has been observed that the heat transfer coefficient in nanofluids is significantly higher than that of the base fluid. The exact reasons leading to this increase in heat transfer coefficient has been a subject of great debate. For nanofluids to possess these superior heat transfer properties, it is important that the nanoparticles remain colloidally suspended in the medium, and do not aggregate or precipitate out. Molten salts are already important heat transfer fluids used in solar and other high temperature engineering systems. Dispersing nanoparticles in molten salts can enhance the thermal properties of these fluids, such as thermal conductivity and specific heat capacity, etc. However, the high temperature of the inorganic fluxes targeted (up to 600ºC), as well as their strongly ionic nature represent important hurdles in the development of improved high-temperature nanofluids based on molten salts. The anticipated problems are addressed in the proposed research.

Title: *AFFORDABLE MATERIAL QUALIFICATION FOR COMPOSITE ROTOCRAFT STRUCTURES*

Principal Investigator(s): Makeev, Andrew Vladimirovich
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Georgia Institute of Technology
Award Number: RC217-G3
Award Amount: $345,369

Abstract: Accurate three-dimensional mechanical properties are essential for understanding complex deformation and failure mechanisms for materials with highly anisotropic constitutive properties. Among such materials, glass-fiber and carbon-fiber reinforced polymer-matrix composites play a critical role in the advanced rotorcraft structural designs. A large number of different methods and specimen types currently required to generate three-dimensional allowables for structural design slow down the material characterization. Also, some of the material constitutive properties required for understanding the deformation and failure mechanisms are never measured due to prohibitive cost of the specimens used for the material characterization. Costly experimental iterations to qualify every new composite material system delay insertion of advanced materials that address performance and operations efficiency requirements for aircraft structural designs, and limit the design space of material configurations. The goal of the proposed effort is to enable affordable qualification of composite materials for rotorcraft structures. The specific objectives are: 1) to minimize the number of test methods required for material qualification, and 2) to more heavily rely on analysis (virtual tests) to capture material strength and fatigue behavior.

Title: *Advanced Materials Technology*

Principal Investigator(s): Makeev, Andrew Vladimirovich
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Vertical Lift Consortium, Inc.
Award Number: W911W6-12-2-0003
Award Amount: $297,076

Abstract: A key goal of this project is to advance material technologies for improving rotorcraft material strength and fatigue performance and also lightning strike and corrosion protection. Specific objectives include the following: a) screen state-of-the-art material technologies, including polymer-matrix and metal-matrix composites; b) select the most promising materials for improved material performance and acceptable handling and processing qualities; and c) develop a database of material properties for use in rotorcraft design. Thus, a knowledge base providing a foundation for the insertion of advanced materials in rotorcraft applications will be developed.

Title: *Fly Ash Removal*
Principal Investigator(s): Lu, Frank K
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: General Electric Power & Water
Award Number: 900539349
Award Amount: $233,623
Abstract: To remove fly ash from boilers using pulse detonation technology.

Title: *Novel Tools for Characterizing Material Microstructure*
Principal Investigator(s): Makeev, Andrew Vladimirovich
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Universal Technology Corporation
Award Number: 15-S7407-14-CI
Award Amount: $150,000
Abstract: The objective of the proposed effort by UT-Arlington under a subcontract to the Universal Technology Corporation (UTC) is to develop tools to break through the current object size limitations of micro-focus x-ray computed tomography (CT) for enabling accurate microstructural material characterization of USAF-relevant materials and structures based on partial CT scanning.

Title: *Common Material Qualification for Laminated Composites Improving Confidence in Material Allowables*
Principal Investigator(s): Makeev, Andrew Vladimirovich
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: SCRA Applied R & D
Award Number: 2015-322 NRTC-FY15-S
Award Amount: $300,000
Abstract: This project will develop efficient common methods for consolidated standardized material characterization. It will be the first attempt to modify the existing material qualification programs based on transitioning the results of the recent ONR and VLRCOE 6.1 efforts at UT-Arlington, including the development of new methods to measure the material properties of composite materials, based on reduced number of coupon test methods and establish reduced material allowables for efficient common material qualification. The proposed effort will integrate the new test methods in the design of the reduced test matrices to lower implementation costs for the new and improved material systems.

Title: *Molten Salt Nanomaterials (Nanofluids): Investigation of Thermophysical Properties for Enhanced Thermal Energy*

Principal Investigator(s): Shin, Donghyun
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Texas Engineering Experiment Station
Award Number: C6071 M1402238
Award Amount: $138,625
Abstract: The specific heat capacity values of a variety of molten salts were enhanced by ~20-120 percent on dispersing nanoparticles at ~0.1 - 1 percent mass fraction (Shin and Banerjee, J. Heat Transfer/JHT, 2013, 2011; Int. J. of Heat and Mass Transfer/IJHMT, 2011, Shin and Banerjee, Int. J. of Structural Change in Solids/ IJSCS, 2010). The thermo-physical properties of the nanomaterials (e.g., thermal conductivity, k [W/m2-K]; viscosity, m [N-s/m], and specific heat capacity, Cp [J/kg-K]) were found to be highly sensitive to the small variations in the synthesis protocol (Shin and Banerjee, IJSCS, 2010). The level of enhancement was highest for material samples with stable formulation of nanoparticles in the solvent which in turn led to the nucleation and growth of a compressed layer (a semi solid layer similar to properties of "ice", i.e., a semi-solid state of the solvent molecules) from the surface of the nanoparticles.

Interfacial thermal resistance, (Rk, [m2-K/W], also known as "Kapitza Resistance") for these materials was calculated using Molecular Dynamics (MD) simulations. Material property enhancement was found to inversely scale with Rk, where the property values were most sensitive to the variation of Rk (this is termed as the "nanofin effect"). Hence, Rk is expected to be the most dominant parameter that affects the level of enhancement of the thermo-physical property values of these nanomaterials. Rk can be affected by the material composition of the of the various components of the mixture, and can be affected by the formation of "compressed layer," as well as local concentration gradients induced by the presence of the nanoparticles in the mixture. The predictions from these numerical and analytical models were found to match the experimental data within the bounds of the measurement uncertainty.

Title: *Production of Synthetic Oil from Lignite Coal Using Catalytic Direct Liquefaction*

Principal Investigator(s): Dennis, Brian
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: TRT Holdings, Inc.
Award Number: N/A
Award Amount: $255,000
Abstract: The purpose of this project is to produce several liters of synoil from Texas lignite coal using the direct liquefaction process developed in a previous phase of the project. The synoil will be used for assays to be performed by an external commercial lab. The project is divided into three tasks: 1) The first task focuses on preparing solvent and catalyst for the UT-Arlington process; 2) the second task

involves converting lignite to synoil using the UT-Arlington direct liquefaction process; and 3) the third task is separation of the synoil from unreacted solids.

Title: *Study of Gasdynamic Processes*
Principal Investigator(s): Lu, Frank K
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Illinois Tool Works, Inc.
Award Number: N/A
Award Amount: $44,448
Abstract: Gasdynamic processes in a tube consisting of unsteady shocks and expansions are studied. These processes are important for understanding and developing industrial processes.

Title: *Spray Cooling and PCM Technology for Data Center*
Principal Investigator(s): Agonafer, Dereje
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Mestek, Inc.
Award Number: N/A
Award Amount: $115,000
Abstract: Air side economizers significantly reduce the cost of cooling data centers. Spray cooling complements an air side economizer by having the capacity to reduce the dry bulb temperature, as well as controlling the specific humidity. We will be building a test rig (funded by Mestex) and perform numerous experiments and modeling to optimize the technology.

Title: *Innovative Tools for Structural Diagnostics of Rotorcraft Composites*
Principal Investigator(s): Makeev, Andrew Vladimirovich
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Bell Helicopter Textron
Award Number: N/A
Award Amount: $200,000
Abstract: In this project, Bell joins with UT-Arlington to offer TAI state-of-the-art material characterization technologies, which will enable production of high-quality composite parts. The key technology to be transferred to TAI is the structural diagnostics tools enabling accurate characterization of manufacturing defects and structural damage in fatigue-critical composite structures based on three-dimensional micro-focus Computed Tomography (CT) measurements. Key requirements for the diagnostic technology include: a) ability to generate accurate subsurface geometry data for a composite structure with manufacturing defects

(such as ply-waviness and voids as shown in figure and structural damage (matrix cracks and delaminations) based on micro-focus CT measurements; and b) the automated ability to convert the geometry data into three-dimensional structural finite element models for assessment of the effects of defects and structural damage on performance.

Title: *Concealed Rrh Thermal Simulation*
Principal Investigator(s): Agonafer, Dereje
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Commscope, Inc Of North Carolina
Award Number: 8001020001/001147501
Award Amount: $48,000
Abstract: Create CFD model of the concealed RRH (Remote Radio Head) module and verify whether the temperature across the RRH is within allowable limits at various ambient temperatures (0 to 50C)

Title: *Birth-to-Death (from Die Metal/Passivation Processing to Board Assembly) Modeling Methodology for the Optimization of*
Principal Investigator(s): Agonafer, Dereje
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Semiconductor Research Corporation
Award Number: 2014-KJ-2512
Award Amount: $160,000
Abstract: This project will deliver a model to experiment correlation database as well as a hierarchical and modular BLR analysis ANSYS toolbox, along with component dependent guidelines.

Title: *Advanced Estimation and Control-Oriented Technologies for Space Applications*
Principal Investigator(s): Subbarao, Kamesh
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Hi-Tech Bangla
Award Number: N/A
Award Amount: $50,450
Abstract: The objectives of this project is to develop advanced estimation and control-oriented technologies for, 1. Orbit Determination, Estimation and Trajectory optimization, 2. Characterization of uncertainty in the position and velocity of space debris object leading to better conjunction analysis and evaluation of collision probability with space assets

Title: *Thermal Management of Electronic Devices Using High Precision Additive Manufacturing*
Principal Investigator(s): Jain, Ankur
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Microfabrica, Inc.
Award Number: N/A
Award Amount: $2,800
Abstract: Thermal management of electronic and photonic devices, and similar systems is a key technological challenge that hinders performance and results in reliability related problems. A number of approaches have been used in the past for ensuring optimal heat removal from electronic devices. This project will carry out a survey of the literature to summarize various thermal management approaches being used for thermal management. Based on the literature survey, advantages and disadvantages of various approaches, particularly with respect to additive manufacturing will be summarized. This study will be carried out in the context of cooling of electronic devices, photonic devices such as lasers, and for advanced electronic architectures, such as three-dimensional integrated circuits (3D ICs). A final report summarizing the findings will be prepared and submitted to Microfabrica.

Title: *Support L-3 Effort to Evaluate NUWEMT in L-3 Link Simulation Environment*
Principal Investigator(s): Dogan, Atilla
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: L3 Communications Holdings, Inc
Award Number: PO-JN42944
Award Amount: $7,477
Abstract: Dr. Atilla Dogan has developed the NUWEMT to model and simulate the effect of nonuniform wind encounter on aircraft dynamics. This approach was successfully used to model and simulate the dynamics of both tanker and receiver in aerial refueling operation. Among the methods used for the validation of NUWEMT was the 2004 Air Force Research Laboratory AAR (Automated Aerial Refueling) program test flight. The test flight involved a piloted Lear Jet 25 as a surrogate UAV flying behind a KC-135 tanker aircraft. A MATLAB/Simulink simulation environment was developed that includes full nonlinear 6-DOF models of both aircraft, implementation of NUWEMT, controllers for both aircraft to fly the same trajectories as in the test flight. The simulation also includes the models to generate the prevailing wind and the turbulence with the same characteristics as in the test flight. The results of the simulation have demonstrated that the implementation of NUWEMT can successfully simulate the dynamic response of the Lear Jet as it flies at the contact and observation positions and maneuvers between them while the tanker aircraft flies straight level and makes constant altitude turns.

Dr. Dogan has provided L-3 Link with his MATLAB/Simulink-based simulation model of a EQ-II aircraft flying as the receiver in formation with a KC135R tanker aircraft for aerial refueling. This EQ-II & KC-135R simulation model employs the NUWEMT for modeling the aerodynamic coupling between the aircraft in aerial refueling operations. L-3 Link has assigned an engineer evaluating the NUWEMT implementation in this simulation model to assess its adaptability to L-3 Link simulation environment and needs. The engineer has developed a set of questions and comments while evaluating the EQ-II & KC-135R simulation model. Dr. Dogan will work with the engineer to address his questions and comments.

Title: *Development of Nanoparticle Embedded Heat Storage*
Principal Investigator(s): Shin, Donghyun
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Mitsubishi Electric Corporation
Award Number: N/A
Award Amount: $10,984
Abstract: In this project, we propose nanoparticle embedded PCM as thermal energy storage. Doping proper nanoparticles into selected PCM candidates that has the melting point under 200 °C is possible to enhance the overall specific heat capacity, and thus increase the effective thermal energy storage density. Possible PCM candidates in this specific temperature range include a couple of molten salts whose maximum heat of fusion is 370 kJ/kg according to the literature. Possible nanoparticles include silica (SiO_2), titania (TiO_2), or alumina (Al_2O_3) nanoparticles, considering their chemical and themal stabiities. These oxide nanoparticles are very cheap compared with common nanometer-sized additives, such as carbon nanotubes, graphens, metal nanoparticles, etc., and thus, the cost increase by material and manufacturing can be minimized. We will explore the chemistry of the reactions thermochemically and study the synthesized ionic nanofluids as a function of temperature. The thermal stability of ionic nanofluids will be also evaluated using available laboratory tools. We will also test their thermal/fluidal/material characteristics. We have most of the necessary equipment such as a modulated differential scanning calorimeter (MDSC), a rheometer, an electron microscope (SEM & TEM), etc.

Title: *Portable Hyperbaric Chamber*
Principal Investigator(s): Lu, Frank K
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: American Association For Hyperbaric Awar
Award Number: N/A
Award Amount: $16,173
Abstract: Design, fabrication and preliminary testing of a hyperbaric chamber.

Title: *Solar wind-magnetosphere coupling periods with large IMF*
Principal Investigator(s): Lopez, Ramon E
Department, Center, or Institute: Department of Physics
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Aeronautics and Space Administration
Award Number: NNX09AI63G A8243P1
Award Amount: $339,990
Abstract: We will investigate the nonlinear response of the magnetosphere to changes in the solar wind magnetic field during periods when the solar wind magnetic field is large. We will do this primarily through the use of global magneto-hydrodynamic simulations of the solar wind interacting with the magnetosphere. Simulations results will be verified using data sets from various spacecraft missions and ground-based observations.

Title: *An Ion Chromatograph for Extraterrestrial Explorations*
Principal Investigator(s): Dasgupta, Purnendu K
Department, Center, or Institute: Department of Chemistry and Biochemistry
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Aeronautics and Space Administration
Award Number: NNX11A066G A8243P1
Award Amount: $1,148,205
Abstract: The Phoenix Mars Lander is the first to have ever carried out an in situ wet analysis of extraterrestrial soil. The unanticipated results of this mission have been extraordinary and intriguing. Notable has been the finding that a large fraction, if not most, of the soil Cl is present as the perchlorate (ClO4?) anion, very likely as Mg(ClO4)2, which has many implications. The first important implication is that the failure to detect organic compounds upon heating the soil may not really imply the absence of organics, as perchlorate is a potent oxidant when heated and will oxidize any organics present in the sample. Interestingly enough, the Thermal and Evolved Gas Analysis (TEGA) systems on the Viking Landers showed methyl chloride (CH3Cl) and dichloromethane (CH2Cl2) well above blank values. At the time, these were ascribed to terrestrial contamination. Recent analysis of terrestrial desert soils under the Viking TEGA protocol demonstrates the evolution of the very same compounds, CH3Cl and CH2Cl2, when 1 percent Mg(ClO4)2 is added to the soil sample. A second important implication of a large amount of Mg(ClO4)2 present in Martian soil is the possibility of liquid water on Mars? surface in the recent history of the planet, as water can remain in the liquid state as Mg(ClO4)2 brine down to ?70.

Title: *The Altitudinal Distribution of Magnetospheric Energy Input and its Influence on the Upper Atmosphere*
Principal Investigator(s): Deng, Yue
Department, Center, or Institute: Department of Physics
Institution: The University of Texas at Arlington

Discipline: N/A
Funding Agency: National Aeronautics and Space Administration
Award Number: NNX13AD64G A8243P1
Award Amount: $407,668

Abstract: Accurate description of both the total amount electromagnetic energy from the magnetosphere and the spatial distribution of this energy is significant to understand how the upper atmosphere responds. However, the energy altitude distribution is poorly documented and its effects on the upper atmosphere has not been investigated in any detail, yet they remain fundamental to correctly interpreting and specifying the ionosphere and thermosphere. Therefore, we will investigate the altitudinal energy distribution and the influence on the thermosphere through both data analysis and model simulations. Specifically, the goal of this study is as follows: 1) Investigate the conductivity ratio between E and F regions and the dependence of the ratio on the season and geomagnetic conditions using the electron density profiles from COSMIC satellites measurements and empirical models. It will give us a systematic view of the relative significance of E and F conductivities and Joule heating in the high-latitude region. 2) Simulate the conductivity ratio between E and F regions using different General Circulation Models (GCMs) and identify the significance of soft particle precipitation to the conductivity altitudinal distribution. The influence of different altitudinal distributions of conductivity and Joule heating on the thermosphere will be investigated as well. It will significantly improve our capability to describe the atmosphere response to the external drivers. 3) Specify the correlation between the soft particle precipitation and Poynting flux in the cusp region using DMSP measurements. The primary heating mechanisms, including Joule heating and particle precipitation, for the substantial neutral density enhancement in the cusp region will be studied using the GCMs. This study will substantially help us to unveil the cusp neutral density mystery and improve the understanding of M-I coupling. This investigation will make significant contributions to three science questions from the Helio-physics Roadmap. Specifically, it will greatly advance our understanding of the plasma-neutral gas coupling and significantly improve our capability to describe the upper atmosphere response to external drivers. This project will strongly improve our capability to describe of the magnetospheric energy distribution in the upper atmosphere and magnetosphere-ionosphere-thermosphere interaction.

Title: *Vertical Winds: Possible Forcing and Influence on The Upper Atmosphere*
Principal Investigator(s): Deng, Yue
Department, Center, or Institute: Department of Physics
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Aeronautics and Space Administration
Award Number: NNX14AD46G A8243P1
Award Amount: $274,302

Abstract: An accurate description of vertical winds in the thermosphere is essential to understand how the upper atmosphere responds to the geomagnetic storms. Even small vertical winds have a significant effect on the atmospheric density,

composition, dynamics, electrodynamics and ionosphere because of the large vertical gradients. However, vertical winds have not been observed systematically, and the simulations of effects on the upper atmosphere are very limited. Recent observation deployments and modeling developments now permit substantial progress on this problem. Observations from satellites and expanding ground-based networks, such as Fabry-Perot interferometers (FPIs) in Alaska and Brazil, are providing unprecedented coverage for understanding the role of vertical wind dynamics. Developments in first-principles models, such as the non-hydrostatic model, enable significant improvement on vertical wind simulations. Therefore, it is timely to investigate vertical winds and influence on the upper atmosphere through complementary data analysis and model simulations. In this project, the data sets from FPI ground-based observations, along with DMSP and CHAMP satellites, and the simulations from the non-hydrostatic General Circulation Model(GCM) will be used to investigate F-region vertical winds due to different forcings at both high and low latitudes and to characterize their influence on the ionosphere and thermosphere. Specifically, we will do the following: 1) Analyze FPI vertical wind observations at F-region altitudes in the aurora zone. The correlation of vertical wind with geomagnetic energy inputs will be investigated. The observations will be compared with simulations from the non-hydrostatic Global Ionosphere-Thermosphere Model (GITM). It will greatly improve our capability to describe the neutral wind responses to the magnetospheric energy inputs. 2) Simulate vertical winds in the cusp during storm periods with GITM in high resolution. The term analysis of the neutral continuity equation will be conducted to study the relative significance of vertical wind to the neutral density. It will significantly advance our understanding of the neutral dynamics and its relationship to upper atmosphere, storm time response. 3) Process data of FPI observations at F-region heights from equatorial Brazil and conduct a climatological study of vertical wind at low latitudes for the first time. The climatology of vertical winds will be compared with the GITM simulations. It will give us an unprecedented view of the nighttime vertical wind at low latitudes, which is critical to specify the dynamics of the upper atmosphere. 4) Investigate the influence of vertical wind caused by the perpendicular ion-drag force on the equatorial thermosphere anomaly (ETA) for the first time using the non-hydrostatic GITM. It will help us to unveil the ETA mystery and greatly advance the understanding of the momentum coupling between ionosphere and thermosphere. The overall goal of this project is to substantially improve the description of the dynamics in the upper atmosphere associated with vertical winds and advance our understanding of the coupling between ionosphere and thermosphere. This investigation will make significant contributions to the scientific objectives of the NASA The Living With a Star (LWS) Focus Science Topic: Thermospheric wind dynamics during geomagnetic storms and their influence on the coupled magnetosphere-ionosphere-thermosphere system. Specifically, it will improve modeling and characterization of thermospheric wind processes during disturbed periods and improve understanding of the role of winds in ionospheric storm time dynamics. Furthermore, this investigation will make important contributions to three science questions from the Heliophysics Roadmap. We intend to interact with space physicists on the team to work on problems of overlapping interest that may be identified.

Title: *A Combinations Approach to Design of an Aerospace Grease*
Principal Investigator(s): Aswath, Pranesh
Department, Center, or Institute: Department of Materials Science & Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Boeing
Award Number: 836901
Award Amount: $130,123
Abstract: The goal of this project is to develop a grease that exceeds the BMS3-33 requirements for grease in the aerospace industry. A combinatorial approach will be used with Design of Experiments to develop a new high-performance grease, or greases, that meet the specific goals of this project. The specific goals of the project are to meet all the specifications of BMS3-33 and exceed the specifications in the list that follows: i) Increase load carrying capacity of the grease from 60 Kg to 200 Kg (ASTM D2596); ii) Reduce the 4 ball wear scar diameter from the current requirement of 0.90 mm to less than 0.40 mm (ASTM 2266); iii) Reduce the friction in 4 ball wear test from 0.07 to 0.035 or lower (ASTM 2266); iv) Reduce the fretting wear protection from a weight loss of 0.9 mg to less than 0.7 mg (ASTM 4170); v) Increase the Timken load carrying capacity from the 50 Kg standard to greater than 75 Kg (ASTM 2509); and vi) Increase the Dynamic life from the current 30,000 to 60,000 or better.

Title: *Microfluidic Electrochemical Reactor (MFECR) for Oxygen Recovery from Carbon Dioxide*
Principal Investigator(s): Dennis, Brian
Department, Center, or Institute: Center for Renewable Energy Science and Technology (CREST)
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Aeronautics and Space Administration
Award Number: NNL15AA08C
Award Amount: $513,356
Abstract: The aim of this project is to design, build, and demonstrate a MFECR to perform carbon dioxide electrolysis to enhanced oxygen recovery. We will demonstrate a 75 percent or greater recovery of oxygen from a pure carbon dioxide stream, which is a significant improvement over the 50 percent recovery provided by the Carbon Dioxide Reduction Assembly (CDRA) that is currently used. This improvement in conversion is based on the use of novel cathode nanocomposites that have high selectivity toward the production of ethylene. An anode coated with a novel high surface area nanocatalyst allows for high rates of oxygen evolution at low potentials. The proposed approach combines the carbon dioxide reduction and oxygen generation into a single compact reactor that can be operated at room temperature and pressure. The MFECR design is based on microfluidics and has a large surface-area-to-volume ratio that leads to high current densities and mass transfer rates. This allows us to minimize the size and weight of the reactor. The MFECR is powered by a pulsed power supply, which improves the longevity by preventing the formation of carbon on the cathode.

Title: *The Role of Solar Wind Fluctuations in Solar Wind-Geospace Coupling*
Principal Investigator(s): Lopez, Ramon E
Department, Center, or Institute: Department of Physics
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Aeronautics and Space Administration
Award Number: NNX15AJ03G A8243P1
Award Amount: $165,477
Abstract: Understanding the processes that transfer solar wind energy and momentum to the magnetosphere and ionosphere (i.e., geospace) is central to heliophysics science. We propose to investigate the role of solar wind fluctuations in solar wind-geospace coupling using global simulations of real events that can be converted into numerical experiments. The primary science area to be addressed is Solar Wind – Magnetosphere coupling / Dayside Outer Magnetosphere (#6 in B.2 H-SR of ROSES 2014), with a secondary focus on Magnetosphere – Ionosphere Coupling / Magnetotail (#8). Specifically, we will address these science goals:
1. Do solar wind fluctuations enhance the transfer of energy from the solar wind to geospace?
2. How do solar wind fluctuations affect the merging interaction with the solar wind, as well as the viscous interaction with the solar wind?
3. Are there unique features of ionospheric dissipation of energy that are related to the magnitude of solar wind fluctuations?

Title: *White Paper for use of Unmanned Aerial Vehicles (UAVs) to Support Intelligent Transportation Operation and Management*
Principal Investigator(s): Mcnair, Michael
Department, Center, or Institute: UT Arlington Research Institute
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Texas A&M University System
Award Number: 09-1XXIA004
Award Amount: $24,126
Abstract: The scope of this task is to develop a white paper on the use of UAVs to support future transportation operations and management in major highway corridors in Texas. Texas A&M Transportation Institute (TTI) is working on a plan for future intelligent highway corridors in Texas. The development of UAVs for the commercial market is emerging and may open up new applications and services in the transportation operations and management area. To accomplish this task, TTI and the University of Texas at Arlington Research Institute (UTARI) will collaborate to produce a white paper.

Title: *Strategic Directions for Autonomous Transport Systems*
Principal Investigator(s): Mcnair, Michael
Department, Center, or Institute: UT Arlington Research Institute
Institution: The University of Texas at Arlington
Discipline: N/A

Funding Agency: Battelle Memorial Institute
Award Number: US001-0000397629
Award Amount: $46,710
Abstract: The roadmap has, as its primary objective, the identification of a limited set of the most critical technology issues involved in establishing a plan for intelligent, autonomous vehicle operations. Because there is no single national authority for the transportation network of the U.S., there is no attempt to completely coordinate the roadmap across all jurisdictions, but instead, the intent will be to document the key characteristics and research that are most likely to be utilized across multiple implementations and installations.
Objective 1: Develop the information required to construct the roadmap.
Objective 2: Draft roadmap. The roadmap will be contained within the final report documenting the information collected during the effort.

Title: *Neurocognition, Controls, Efficient Communication, and Enhanced Decision for Fast Satisficing in Autonomous Military Teams*
Principal Investigator(s): Lewis, Frank
Department, Center, or Institute: N/A
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: DOD-Navy
Award Number: N00014-13-1-0562
Award Amount: $491,903
Abstract: This proposal responds to ONR special notice 13-SN-005. It is to develop a rigorous unified basic science framework for fast satisficing and efficient decision and control paradigms with limited information for future U.S. military teams of autonomous dynamic agents in data-overload environments. We will develop rigorous new scientific results at the intersection of cognitive neuroscience, psychology, network science, multi-agent decision, non-linear control theory, reinforcement learning, and differential game theory.

Title: *3D Meta-Optics for High Power Lasers*
Principal Investigator(s): Magnusson, Robert
Department, Center, or Institute: N/A
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: University of North Carolina Charlotte
Award Number: 20100669-02-UTA
Award Amount: $436,912
Abstract: The Nanophotonics Device Group will design edge filters using particle swarm optimization (PSO) codes to optimize their qualities to meet spec. The goal is to design a sharp edge filter (ideally with ~2 nm transition band) using guided-mode resonance (GMR) concepts and associated structures. The spectral band of interest is 2.0-4.0 ?m. Single-layer and multilayer resonant elements with two- and four-part period profiles will be designed using low-loss dielectrics. Devices with 1D and 2D patterning will be designed. Similarly, we will design GMR devices (filters,

mirrors, polarizers) with high-quality, pre-specified spectral expressions (narrowband reflection, narrowband transmission, wideband high reflection, wave plates) using PSO to minimize internal field strengths. We will compute all internal fields in detail with our codes at all points within the device. Moreover, we will design GMR elements for polarization control. Preliminary results on resonant retarders operating in reflection and transmission show new phase-control capabilities. These half-wave and quarter-wave retarders may have uses in the high-energy laser systems under development in this project. Finally, we will contribute to fabrication of large-area structures, as needed, using an existing 266-nm-wavelength interferometric nanolithography system (periods down to 200 nm and area up to 100 cm2).

Title: *Formal Modeling, Monitoring, and Control of Emergence in Distributed Cyber-Physical Systems (DCPS)*

Principal Investigator(s): Johnson, Taylor
Department, Center, or Institute: Department of Computer Science Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: DOD-Air Force
Award Number: FA8750-15-1-0105
Award Amount: $138,321

Abstract: As Air Force warfighting missions incorporate increased distributed autonomy, emergent global behavior may arise from interactions between individual autonomous agents. Example Air Force systems that may in the coming years incorporate increased autonomy resulting in little-to-no direct human monitoring and intervention include drone (UAV) swarms and satellite constellations. Novel methods are needed to ensure such DCPS have trusted assurance to meet their mission requirements – and only their mission requirements – in spite of potential emergent distributed behavior, attacks, and failures. Understanding distributed emergence and being able to respond to it through trusted and assured responses will allow warfighters to continue fighting and adapting through engagements, enabling strategic agility in Air Force missions. Ultimately, developing theoretical and practical tools for understanding and responding to the fundamental phenomena of emergence will support the Air Force goal to fly, fight, and win … in air, space, and cyberspace.

This proposal suggests the development and use of scalable formal methods that focus on the following: 1) specification and verification, 2) runtime monitoring, and 3) trusted and assured control. These components of the project's mission will all be conducted in conjunction with a fourth focus of a rigorous evaluation on DCPS with prototypical features of modern Air Force systems like UAV swarms and satellite constellations.

Title: *Practical Co-Prime and Nested Samplers and Arrays For Radar and Radar-Sensor Networks*

Principal Investigator(s): Liang, Qilian
Department, Center, or Institute: Department of Electrical Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: DOD-Navy
Award Number: N00014-13-1-0043
Award Amount: $478,499

Abstract: The theory of co-prime sensor array signal processing will be explored, and a new approach is proposed for radar-sensor networks in both temporal and spatial domains, using a co-prime pair of samplers. The theory is applied to radar-sensor network data sampling and target recognition.

Title: *Graduate Research Fellowship Program*

Principal Investigator(s): Petruso, Karl
Department, Center, or Institute: Department of Sociology
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Science Foundation (NSF)
Award Number: DGE-1144240
Award Amount: $260,500

Abstract: The proposal funds Laura Henderson through the NSF Graduate Research Fellowship Program to conduct her research on Inverse Problems in Unresolved Space Object Identification.

Title: *Thermal Characterization of Cylindrical Electrochemical Energy Storage Devices Through Analytical and Experimental Methods*

Principal Investigator(s): Wetz, David
Department, Center, or Institute: Department of Electrical Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: DOD-Navy
Award Number: N00014-13-1-0819
Award Amount: $152,078

Abstract: Electrical energy storage is a critical component needed by the Navy in their mission to become a more efficient and electric fleet. Despite the existing commercial availability of energy storage devices with widely varying power and energy densities, several recent incidents have reiterated the urgent need for improving the ability to gauge and predict the operational safety of Lithium-ion batteries. Especially when operated at high power, as is needed in the vast majority of Navy applications, the inherent heat generation during the operation of a Li-ion battery causes the temperature of the cells to rise considerably and this heat is a major contributor to cell aging. Such thermal dynamics need to be fully understood at a fundamental analytical level to enable the development of robust, fully validated thermal design tools. Such tools are expected to aid in design of high-performance batteries that operate safely. The proposed work is a first step toward the development of such models by determining solutions of the fundamental energy conservation equations that govern heat transfer in cylindrical Li-ion batteries. We propose to develop and experimentally validate steady-state and transient analytical models to predict the temperature field in a Li-ion battery as a function of heat generation rate, geometry, and convective cooling conditions. These models will account for the anisotropic thermal conductivity of Li-ion cells, which recent work indicates is a key factor in determining the accuracy of thermal models. The models will be used to study various thermal vs. electrical design trade-offs in such cells. A second direction of research will focus on measurement of anisotropic thermal conductivity of cylindrical Li-ion cells as a function of SOC and aging of the cell. This research will help us to understand and quantify possible age deterioration of the cell due to thermal cycling.

Title: *Multiscale Thermal Characterization and Evaluation of Electrochemical Energy storage Materials, Cells and Modules at Monimal and High C Rates*

Principal Investigator(s): Wetz, David
Department, Center, or Institute: Department of Electrical Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: DOD-Navy
Award Number: N00014-14-1-0752
Award Amount: $288,601

Abstract: This proposal requests funds to purchase hardware that will provide a unique capability to thermally investigate, evaluate, and characterize electrochemical materials, cells, and modules. The state-of-the-art equipment will provide macro/micro-scale thermal characterization capabilities that make it possible to carry out a multi-scale analysis of energy storage systems (ESSs), starting from microscale materials characterization up to system-level thermal measurements on large, multi-cell modules. ESSs involve disparate length scales, starting from ?m-sized electrode materials all the way to modules with dimensions on the order of meters. To thermally characterize over such disparate scales, it is important to integrate together equipment with varying capabilities. However, once integrated, the single system as a whole enables thermal characterization from the micron-scale all the way to the bulk scale. Between the PI/Co-PI's laboratories at UT-Arlington, there are currently four DOD funded efforts studying multiple facets of ESSs. The first, an Office of Naval Research (ONR) Young Investigator Program effort, is aimed at understanding how cells age when they are cycled at high current rates, which generates intense heat internally. The second ONR effort is aimed at developing methodologies that best enable integration of different types of ESSs into a hybrid energy storage module (HESM). The third ONR effort is aimed at characterizing the thermal properties of EESs. In the fourth effort, an ONR Small Business Innovation Research effort, we are working with a small business in Missouri to develop and experimentally evaluate novel cooling structures for cylindrical ESSs when they are operated at extreme current rates. Each of these efforts will benefit from an experimental capability of measurement and characterization of thermal properties at the micro/macroscale. The equipment requested, totaling $285,841, includes a FLIR-SC6103-InSb-IR camera, a two-channel 60V-240 A/channel MACCOR programmable cycler, an OptoTherm-MI320-IR microscope, an SR844 Stanford Research Systems lock-in-amplifier, a Keithley 2182A nanovoltmeter, and a T3600 Dell computer.

Title: *Evaluation and Characterization of the Thermal Properties of Electrochemical Energy Storage Devices through Analytical and Experimental Methods*
Principal Investigator(s): Wetz, David
Department, Center, or Institute: Department of Electrical Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: DOD-Navy
Award Number: N00014-14-1-0846
Award Amount: $99,960
Abstract: Electrical energy storage plays a key role in the Navy's mission to be a more efficient and electric fleet. There are several system-level challenges associated with electrochemical storage and conversion using Li-ion cells, which have a propensity to overheat. Our preliminary research has resulted in measurement of thermal transport properties of Li-ion cells. We have also carried out experimentally validated analytical modeling of thermal transport in Li-ion cells. It is now proposed to carry out thermal measurements on a test cell undergoing periodic charge-discharge in conditions similar to those expected in a realistic energy conversion device undergoing periodic charge and discharge. Thermal measurements using embedded and external thermocouples and a heat flux sensor will help us understand the thermal dynamics of a Li-ion cell in realistic conditions. In conjunction with these measurements, an analytical model will be developed to predict the expected temperature distribution in these conditions. The proposed research will help develop a fundamental understanding of the thermal dynamics of Li-ion cells undergoing periodic charge and discharge. In addition, experiments will be carried out to measure the internal temperature of Li-ion cells with embedded thermocouples. Both in-house and manufacturer-provided Li-ion cells with this capability will be utilized. Experiments will be carried out to develop a capability for measuring the internal temperature and outgoing heat flux. These measurements will be used to proactively predict the thermal health of the cell. The proposed experimental and analytical modeling research is expected to result in an enhanced fundamental understanding of thermal issues in Li-ion cells, leading to tools and methodologies for the design and optimization of future energy conversion tools.

Title: *Unmanned Aircraft Systems Consortium (UASC)*
Principal Investigator(s): Dogan, Atilla
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Center For Innovation At Arlington
Award Number: N/A

Award Amount: $36,000

Abstract: The Center for Innovation at Arlington, LLC (CFI) will lead the Unmanned Aircraft System Consortium program that serves as a catalyst for the emergent unmanned and autonomous aircraft and vehicle systems (UAS) industry to create training and educational opportunities to prepare individuals for jobs in the aviation sector. CFI will collaborate with aviation industry partners, UT-Arlington, Arlington Independent School District, Tarrant County College, Workforce Solutions for Tarrant County, and Texas government and federal agencies, to identify specific training and educational needs, and the modified or new curriculum needed for the training. CFI will subcontract with UT-Arlington to do the following:

1) Participate in project advisory meetings.

2) Conduct research to identify a sample set of universities that are offering UAS curriculum in Texas, the United States, and the World, and catalog details of these UAS curricula.

3) Given the desired skill sets in the area of UAS established by CFI, determine which skills can be obtained through four-year undergraduate level education versus skills that will require graduate level effort.

Title: *Detonation Dynamics*

Principal Investigator(s): Lu, Frank

Department, Center, or Institute: Department of Mechanical & Aerospace Engineering

Institution: The University of Texas at Arlington

Discipline: N/A

Funding Agency: National Collegiate Inventors & Innovators (NCIIA)

Award Number: 11706-14

Award Amount: $25,000

Abstract: This proposal is a resubmission of the NCIIA proposal with the same title that was submitted in February of 2014. Currently, all engines are designed to operate using the less efficient subsonic burning process known as deflagration. Detonation Dynamics (DDs) engines are designed to burn all types of fuels using the more efficient supersonic process known as detonation, resulting in a relative increase in efficiency of more than 90 percent, compared to conventional gas turbine engines. DDs revolutionary and highly efficient detonation engines will replace conventional engines in cars, boats, ships, trains, electrical power plants, airplanes, and rockets. Currently, no detonation engines exist on the market. Our detonation generator, the DET-O-GENTM is a pulse detonation engine (PDE) coupled with a linear electric power generator (LPG). A PDE consists of a tube that produces repeated detonations from combusting fuel and air. A LPG generates electricity from oscillatory motions induced by repeated detonations from the PDE. The DET-O-GEN can operate using diesel and natural gas, and hence, is a Bi-Fuel (BF) generator. The DET-O-GENBF is able to provide electricity more efficiently than conventional diesel generators and natural gas turbine generators.

Title: *Acquisition of an In situ Micro/Nano-Mechanical Characterization System for Qualitative Study of Fatigue-induced Microplasticity*

Principal Investigator(s): Huang, Haiying
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: DOD-Air Force
Award Number: FA2386-14-1-3013
Award Amount: $348,385

Abstract: The acquisition of an in situ micro/nano-mechanical characterization system consisting of a compact mechanical tester, a Scanning Whitelight Interferometric (SWLI) surface profiler, and an Electron Backscatter Diffraction (EBSD) module is proposed. The SWLI surface profiler and the compact mechanical tester will be integrated together to provide in situ, three-dimensional surface profiling of fatigued specimens with nanometer vertical resolution and sub-micron lateral resolution. An existing Scanning Electron Microscopy (SEM) will be retrofitted with the EBSD module to provide the capability of measuring the dislocation pattern in the fatigued specimen. We plan to use the requested system to perform quantitative study on the correlation between the surface morphology changes and dislocation patterning in fatigue specimens. Since surface morphology changes are directly correlated to the fatigue-induced microplasticity, systematic study of the surface morphology evolution may reveal the physical mechanisms governing the early fatigue damage development. The requested system will facilitate establishing and validating an integrated experimental-numerical framework for the study of the physical mechanics underlying early fatigue damage development. A full proposal on this project is currently under review by the multi-scale structural mechanics and prognosis program at the Air Force Office of Scientific Research. If successful, this project will produce a physics-based methodology that will ultimately lead to an adaptive multiscale simulation model capable of realistically describing the evolution of the fatigue damage state. Such a framework will demonstrate the concept of the 'digital twin' paradigm on a model material. In addition, we will also use the SWLI surface profile to study the accumulative effects of high temperature on thermal protection coating materials and aerospace high temperature materials.The requested equipment will establish a new capability for two departments at UT-Arlington to perform mechanics and materials studies at the micro- and nano-scale. The unique features of the requested system, including fast speed, in situ imaging, and automatic scanning, will relieve graduate students of time-consuming tasks and allow them to dedicate their time to more intellectual work. The materials obtained from the requested equipment will be incorporated into undergraduate and graduate courses to illustrate the multi-scale nature of the material damage process.

Title: *Unbiased Observation of Titan's Dynamic Ionosphere Using a Constellation of Miniature Satellites*

Principal Investigator(s): Subbarao, Kamesh
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington

Discipline: N/A
Funding Agency: National Aeronautics and Space Administration
Award Number: NNX14AO82H
Award Amount: $59,500
Abstract: The research objective of this proposal is to prove that global, simultaneous, and unbiased observations of the ionosphere of the Saturn moon Titan can be provided by small, computer chip-scale satellites. These observations can be used to validate models such as the Titan Global Ionosphere-Thermosphere Model (T-GITM). This work also will benefit NASA's Planetary Science Research Program by advancing spacecraft-based instrument technology and satellite miniaturization, thereby enhancing the data return of future scientific missions.

Title: *CT Scanning and Measuring Defects in High Mofulus Carbon Epoxy Fatigue Test Article*
Principal Investigator(s): Makeev, Andrew Vladimirovich
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Integrated Systems Solutions, Inc.
Award Number: PO100618
Award Amount: $20,000
Abstract: A simple demonstration of the UT-Arlington CT scanning capability to Naval Air Systems Command.

Title: *SMIRFF: Smart Maintenance, Inspection, And Repair Free-Flyer*
Principal Investigator(s): Subbarao, Kamesh
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: National Institute of Aerospace
Award Number: C15-2A00-UTA
Award Amount: $6,000
Abstract: Submitted entry into the 2014 NASA Revolutionary Aerospace Systems Concepts Academic Linkage (RASC-AL) Competition. Being presented is a design concept for a tele-operated, free-flying extravehicular activity (EVA) inspection robot. A broad overview of the system requirements is discussed, followed by an introduction to the design concept, its features and subsystems, and finally, the technology feasibility. Concluding remarks will mainly comprise the future work planned upon the pursuit of the design concept.

Title: *Pathways to Innovation Program 2015*
Principal Investigator(s): Fernandez, Raul
Department, Center, or Institute: TMAC
Institution: The University of Texas at Arlington
Discipline: N/A

Funding Agency: Venturewell
Award Number: N/A
Award Amount: $2,250

Abstract: UT-Arlington has been invited to join the 2015 cohort for Pathways to Innovation, a program dedicated to the enhancement of entrepreneurship in undergraduate education. This program is run by VentureWell (Formally NCIIA) under the auspices of the National Science Foundation-funded Epicenter at Stanford University. UT-Arlington will be an active participant in a community of institutions selected to learn and implement best practices for diffusion of entrepreneurship activity.

Title: *Fischer-Tropsch Reactor Heat Exchange Modeling*
Principal Investigator(s): Dennis, Brian
Department, Center, or Institute: Center for Renewable Energy Science and Technology (CREST)
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Greenway Innovative Energy, Inc
Award Number: N/A
Award Amount: $61,000

Abstract: This project involves the development and application of a numerical model for predicting the temperature field in a Fischer-Tropsch (F-T) reactor. The model will be applied to the sponsor's current F-T reactor design to determine the catalyst bed temperature field for different operating conditions. The simulation model will be used to analyze any new designs during the sponsor's effort to improve the reactor performance.

Title: *Natural-Gas-to-Liquid-Fuels Process Development & Support*
Principal Investigator(s): Dennis, Brian
Department, Center, or Institute: Center for Renewable Energy Science and Technology (CREST)
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Greenway Innovative Energy, Inc.
Award Number: N/A
Award Amount: $232,000

Abstract: The purpose of this research is to optimize the sponsor's process for converting natural gas to synthetic fuel that will be marketed as a refinery-blend stock and potentially as a jet-fuel blend or no-sulfur diesel. In a previous project, our benchtop process was modified and used to perform extended tests of the Gas-to-Liquid (GTL) catalyst prepared at UT-Arlington. In this project, we will test the catalyst and process robustness with a reactant gas mix that simulates the output of a commercial reformer. We will also explore modifications in the composition and preparation of the catalyst with the goal of improving the catalyst productivity and selectivity.

Title: *Lightning Strike Protection*
Principal Investigator(s): Makeev, Andrew Vladimirovich
Department, Center, or Institute: Department of Mechanical & Aerospace Engineering
Institution: The University of Texas at Arlington
Discipline: N/A
Funding Agency: Lancaster Packaging, Inc.
Award Number: PO #0360179
Award Amount: $60,000
Abstract: The UT Arlington will accomplish fatigue testing and evaluation to assess durability of the protection technologies. LORD E1007575 (film) and E1006760/E1006761 (spray-up) coatings on S2/8552 glass/epoxy and IM7/8552 carbon/epoxy composite panels will be evaluated. Other materials might be considered, depending on the availability of resources. Up to six different material iterations and five panels/specimens per iteration will be tested. The specimens will be delivered to UT-Arlington machined to final dimensions. UT-Arlington will setup the test, including all the fixturing, and provide all the instrumentation, including the digital image correlation (DIC) strain measurement capabilities. All tests will be performed at 72°F RTA lab conditions. In addition, UT-Arlington will perform Abacus Unified finite element simulations to determine stresses in the composite fatigue test specimens.

The University of Texas at Austin (UT-Austin)

The University of Texas at Austin listed 77 active awards in aerospace technology for FY 2015, with a total award amount of $44,177,815. During that year, UT-Austin's research expenditures for awards in aerospace technology were $11,289,589. Information for the identified active awards are provided.

Title: *Simulation of Rocket Plume Impingement and Dust Dispersal on the Lunar Surface*
Principal Investigator(s): Goldstein, David B
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX08AW08G
Award Amount: $482,395
Abstract: During planned lunar missions, the exhaust plumes from arriving and departing vehicles will strike the lunar surface and cause sprays of regolith material. Those particulate sprays represent a safety and operations hazard and constitute a major outstanding problem. This project focuses on such gas and dust flows that involve rarefied/continuum transition, compressibility, gas mixtures, two-phase flow and gas-surface interaction – physical effects best modeled by direct numerical simulation.
We will analyze the problem of plume impingement as a rocket takes off from, or lands on the lunar surface. The plume effects will be parametrically examined with an established Navier-Stokes equation solver in the near field. The direct

simulation Monte Carlo method will then use the unsteady Navier Stokes code output along a hemispherical boundary to model the surrounding rarefied atmosphere. The computations will be performed using codes we have already developed for workstations and massively parallel computers.
Our long-range goal is to develop a comprehensive understanding of where the plume gas and dust go during and after rocket operations near the lunar surface. The objective of this proposal is to bridge the hydrodynamic and free molecular regimes in modeling of flows of gas and dust and create a firm computational model applicable to a range of design problems.
We will achieve our objective by pursuit of the following specific goals:
1) Understand the continuum-rarefied transition region;
2) Understand the gas condensation on surrounding surfaces;
3) Model the lifting of dust/debris from the surface and its entrainment on the continuum flow;
4) Determine where lofted dust and debris go in the far field, and in particular, how they impact nearby structures such as walls and domes;
5) Determine how multiple rocket nozzles influence the far field dust/debris distribution; and
6) Determine how non-axisymmetric vehicle maneuvers influence the dust/debris distribution.
This research will support both the basic science and the lunar exploration science goals of the LASER program by studying the disturbances of lunar regolith and the evolution of rocket plume gases during lunar operations. The work will contribute to NASA Strategic Goal 6 to establish a lunar return program having the maximum possible utility for later missions to Mars and other destinations. In particular, because lunar dust was considered a major problem during Apollo operations, the investigations proposed are directly relevant to NASA's Vision for Space Exploration and the LASER program to extend "... human presence across the solar system, starting with a human return to the Moon by the year 2020 ..."

Title: *Direct Numerical Simulation of Comet Impacts and Low-Density Atmospheric Flow on the Moon and the Effects on Ice Deposition in Cold Traps - Phase 2*
Principal Investigator(s): Goldstein, David B
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX09AM60G
Award Amount: $458,619
Abstract: Episodic comet impacts bring water to the Moon. Lunar Prospector and Clementine data likely support the contention that there are water ice reservoirs in the permanently shaded craters near the lunar poles, and the Lunar Crater Observation and Sensing Satellite (LCROSS) impact mission is soon to search for ice at two points in a north polar crater. We propose to explore how trapped polar ice would likely have condensed after an impact. We will analyze two classes of atmospheric flow: i) both the early and the later stages of comet impact flows, and ii) circum-lunar sublimation and condensation driven winds. For both of these flows

we will also examine the effects of specific local geography on condensation into the LCROSS target crater. The immediate effects of cometary impact will be parametrically examined with the hydrocode SOVA. The direct simulation Monte Carlo method will then use SOVA output to model the subsequent transitional-to-rarefied atmosphere. The merging of the two codes is complete and provides a unique and sophisticated ability to model such large-scale, hybrid, unsteady problems. To date, we have developed the ability to simulate 3D comet impacts – from the hydrodynamics of the initial seconds all the way to the free-molecular regime – and have examined the evolution of water vapor ejected from a variety of lunar impacts. We have examined both perpendicular and oblique impacts as the water vapor separates from the rock and first moves as a near-continuum and later as a rarefied temporary atmosphere around the moon.

Our proposed further analysis is critical to understanding the effects of cometary bombardment of the airless planets and asteroids in general, to determining the distribution of possible surface ice and for future lunar surface exploration via landers or impactors. It also has obvious implications for the creation of a lunar exosphere and contamination of the lunar surface due to the upcoming human return to the Moon.

We aim to utilize data obtained by the Clementine, Prospector, HST, Apollo, and perhaps the LCROSS and LRO (Lunar Reconnaissance Orbiter) missions, both to constrain the modeling and as targeted data to be interpreted. Our team approach with graduate students, undergraduates, faculty, and senior researchers has proven extremely successful in the past, and we will continue to utilize it on this project.

Title: *Simulation of Io's Atmosphere*
Principal Investigator(s): Goldstein, David B
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX09AV10G
Award Amount: $615,291

Abstract: We have been developing the ability to model Io’s complete atmosphere using a sophisticated rarefied gas model, radiation and electron transport models, and ab initio chemistry models that account for many, if not most, of the known relevant physical phenomena. We propose to use our models to interpret a wide range of observations of Io.

Our long-term goal is to improve the understanding of Io’s global atmosphere as a boundary between the surface and the plasma torus around Jupiter. Our objective in this proposal is to more completely integrate the various models and compare their predictions to observations of atmosphere, aurora, and surface frosts, composition, and temperatures obtained by Voyager, Hubble, Galileo, Cassini and New Horizons.

Our rationale is that only by developing a composite view of the coupled physical processes through simulations matched to observations can we more fully understand Io's atmosphere and how it is linked to the surface and to the larger

Jovian environment. Our specific goals are: 1) compare improved atmosphere models, including high-energy chemical reactions to aurora observations and observed species distributions; 2) determine if asymmetric radiative surface heating and the dramatic gas-dynamics during eclipse substantially contribute to the observed asymmetric frost and atmospheric distributions; 3) couple radiation absorption to the gas dynamics to improve simulation correspondence with atmosphere thermal observations; and 4) improve the radiation transfer model and compare results to existing visible, ultraviolet (UV) and vacuum ultraviolet (VUV) data sets.

Please note that this represents a joint effort, and two proposals are being submitted, one from The University of Texas at Austin and one from Pennsylvania State University. The technical content of each proposal is the same. Only the budgets differ.

Title: *Modeling the Plumes on Enceladus*
Principal Investigator(s): Goldstein, David B
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX10AF10G
Award Amount: $285,717

Abstract: The youth and brightness of the Enceladus surface appears due to active plume activity resurfacing the planet with condensates. It is thus critical to understand subsurface flow in the conduits, what comes out of the sources and how material returns to the surface. Moreover, a detailed understanding of how gas and particles enter Saturnian orbit to populate the E ring is lacking. Cassini data suggest that the source of particulates in the plumes is most likely condensation of vapor into micron-sized droplets or crystals. The condensation occurs in a highly non-equilibrium two-phase flow. The gas stream further separates from the particle stream as the flows become non-collisional and is impacted by plasma. These processes of condensation in the cold plume and the transport of particles out into the Saturn E-ring will show the fingerprint of the nature of the vapor source.

We have modeled rarefied particle-laden plumes and thin atmospheres with a direct simulation Monte Carlo (DSMC) method and a related free-molecular model and have begun to understand what Cassini saw at Enceladus. We have also developed a set of molecular dynamics simulations of the condensation of water into droplets in rocket nozzles and have completed energetic MD simulations of dissociative water chemistry. These models capture the essential physics of the complex condensation and far field processes and are suitable for use in DSMC simulations. To understand the complex flow fields, we have developed a 3D radiation transport code that models spectrally and spatially resolved images and includes multi-path photon scattering. The proposed work concentrates upon the gas and particle flows and considers how such flows originate and evolve from the base of the conduits into the free-molecular gas regime in the far field. Our goal is to model Cassini observations to relate complex plume atmosphere to the geological surface and near-surface processes.

Title: *Sensor Swarms For Atmospheric Entry Operations*
Principal Investigator(s): Akella, Maruthi R
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX09AW25G
Award Amount: $339,052
Abstract: Key technological objectives for future planetary explorations include the use highly miniaturized and highly integrated sensor/payload suites. Distributed swarms of low resource, and therefore, low-cost sensors allow for phased, strategic, and reliable approaches to on-orbit and dynamics accelerated flight sensing. The primary focus of the research proposal is toward establishing sensor swarms for atmospheric entry operations. Research progress will be directed into the technology areas of collaborative sensing and control and hardware test-bed-based implementation. The proposal will seek to formulate efficient information management architectures, wherein each sensor platform operates using only locally available data apart from globally shared information such as mission objectives.

Terrestrial Microelectromechanical (MEMS) accelerometers and attitude rate sensors have increased in accuracy with a corresponding reduction in mass and power. However, MEMS devices do not provide accuracies comparable to navigation-grade sensors. This proposal will investigate the achievable performance of a swarm of MEMS accelerometers and attitude-rate sensors acting in collaborative manner against the classical single navigation grade sensor. The concept is that, systematically, a sufficient number of MEMS sensors may mathematically provide comparable performance to a single navigation grade device and be competitive in terms power and mass allocations when viewed on a systems level. The implication is that both inertial navigation system design and fault detection, identification, and recovery could benefit from a system of MEMS devices in the same way that swarm sensing has benefited Earth observation and astronomy. A survey of the state of the art in inertial sensor accuracy scaled by mass and power will be provided to show the "specific error" in MEMS and navigation graded devices, a mathematical comparison of multi-unit to single-unit sensor errors will be developed, and preliminary applications to Constellation vehicles will be explored.

Title: *Task Title: Paradigm*
Principal Investigator(s): Fowler, Wallace T
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA

Award Number: NNX09AM51A
Award Amount: $374,919

Abstract: UT-Austin is developing a picosatellite to demonstrate autonomous rendezvous and docking in a teaming arrangement with Texas A&M University. The program is planned to have four progressive missions culminating with a demonstration of AR&D. The UT-Austin team designed our first spacecraft as part of our Paradigm (Platform for Autonomous Rendezvous and Docking with Innovative GN&C Methods) program. The UT-Austin spacecraft has the call sign BEVO-1. It is scheduled for launch aboard STS-127 in May 2009.

The project next step is to develop the second mission spacecraft to continue investigations of JSC Dragon GPS receiver, to investigate 1st generation IMUs, reaction control systems, and attitude control actuators. The plan at this point is to demonstrate controlled attitude and translational adjustments using on-orbit targeting and guidance, to evaluate all communication links (especially spacecraft-to-spacecraft) and to evaluate on-orbit video capability.

Title: *Development of Demonstrably Predictive Models for Emissions from Alternative Fuels-Based Aircraft Engines*

Principal Investigator(s): Clemens, Noel T
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Strategic Environmental Research and Development Program
Award Number: W912HQ-11-C-0035
Award Amount: $1,869,166

Abstract: Relevance: Jet-engine emissions including soot, NOx, and unburnt hydrocarbons pose a growing health hazard and environmental threat. While Fischer-Tropsch (FT) fuels blended with conventional aircraft fuels show significant reduction in soot emissions, the variety of sources from which alternative fuels can be derived leads to considerable uncertainty in the soot and NOx emissions from specific blends. Predictive computational models will enable computational optimization of engines in order to reduce emissions.

Even without the use of alternative fuels, accurate modeling of soot and NOx emissions from aircraft engines is very difficult due to the complex physical and chemical transformations that take place in a highly chaotic turbulent reacting flow environment. The gas phase reactions that transform hydrocarbon fuels into soot particles, the subsequent particle/particle interactions, and surface oxidation require very detailed models for predictive accuracy. Furthermore, NOx evolution in military aircrafts operated in fuel-rich conditions can be affected by radiation due to the soot particles. The modeling problem is even more complex with alternative fuels due to the introduction of different chemical structure of the FT or bio-derived fuels. Before models can be used on practical flow problems, they have to be validated. The lack of well-characterized experiments severely hampers this process. We believe that only an integrated program involving detailed modeling of soot and NOx emissions, combined with a targeted experimental component, will

provide critical breakthroughs in understanding emissions in alternative fuels-burning engines.

Technical Objective: The objective here is to propose a broad program that not only develops detailed pollutant models for large eddy simulation (LES) based gas turbine engine simulations, but also provides a mathematical strategy for model validation. We envision a multi-step modeling program starting from fundamental first principles analyses of pollutant formation all the way to rigorously validated models for industrial/AFRLLES codes. The proposed work consists of two main components: 1) An LES modeling component where detailed kinetic models for soot and NOx will be developed, and 2) an adaptive experimental component where well-characterized re-configurable experiments will be used along with a novel search-and-destroy (SAD) approach to pinpoint the source of modeling error. This demarcation between the components is done only for the sake of clarity in the presentation. The actual work will require modelers to interact with the experimental group regularly. The SAD approach will provide a mathematical framework for this collaboration. The models developed here will be transitioned to industrial codes at Rolls Royce and AFRL.

While the development of detailed soot and NOx models, in themselves, are significant advances, the most important feature of this proposed work is the experimental validation driven model development strategy. The one-of-a-kind experimental measurements to be made here will provide unprecedented information about particulate and NOx evolution in flames. The experimental configuration is chosen to replicate realistic mixing conditions inside an aircraft engine. By using these detailed measurements in the SAD approach, it will be possible not only to provide a measure of model accuracy but to actually guide model development by pinpointing the source of modeling error. This strategy will provide an efficient framework for model development and validation.

Title: *Low-Dimensional Dynamical Characteristics of Shock Wave/Turbulent Boundary Layer Interaction in Conical Flows*

Principal Investigator(s): Tinney, Charles E
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: DOD-Air Force
Award Number: FA9550-11-1-0203
Award Amount: $599,999

Abstract: The proposed research aims to characterize the transient shock wave/turbulent boundary layer interaction in a conical flow at various nozzle pressure ratios. In conical flows, the transient motion of the shockwave causes asymmetric separation of the boundary layer, resulting in highly unsteady lateral forces and excessive thermal loads on the structure. Discrepancies between the frequencies associated with the shock motion and the characteristic frequencies of the incoming turbulent boundary layer suggest that the interaction is nonlinear. Higher-order stochastic models are thus necessary to fully characterize the mechanisms responsible for provoking SWTBLI phenomenon. The study will comprise an experimental investigation of both velocity and fluctuating wall pressure signatures in the vicinity

of the SWTBLI region and at various nozzle pressure ratios in a thrust optimized, parabolic contoured axisymmetric nozzle. A unique combination of POD-based, low-dimensional analysis tools and higher-order system identification techniques will identify the linear and higher-order mechanisms by which the unsteady turbulent boundary layer provokes a transient interaction with the shock wave.
If successful, the research will provide a physical understanding for SWTBLI in conical flows. Such an experimental database is non-existent and will provide a necessary platform for developing more robust numerical prediction tools that can be extended to cope with larger more complex systems, especially where experimental measurements seem impractical within the foreseeable future. The database will also provide the conditions by which existing analytical tools can be adapted to handle higher-order transient systems. The long term goal of this program is to develop effective control strategies for reducing the violent lateral and thermal loads acting on the structure. An accurate prediction of the shockwave motion is a prerequisite for developing effective strategies for control. Reliability and operability of first generation hypersonic vehicles are strongly dependent on a reduction of these loads.

Title: *Simulation of Gas Dynamics in the Pluto-Charon System*
Principal Investigator(s): Goldstein, David B
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX11AD88G
Award Amount: $445,000

Abstract: As New Horizons approaches Pluto/Charon, it becomes increasingly necessary to better understand the atmospheric dynamics to be expected in Pluto's hydro-dynamically escaping N2/CH4 atmosphere. Relative diffusion, radiative heat exchange, sublimation and condensation driven winds, and perhaps photochemistry in the gas, all contribute to the atmospheric dynamics. Also unique to the Pluto/Charon system would be the potentially substantial influence Charon could exert on the escape morphology, perhaps even acting as a temporary sink for material.
We propose to utilize our recently developed computational global circulation model for low-density atmospheres to examine the 3D unsteady gas dynamics and escape in the Pluto/Charon system. Our codes, developed to simulate Io's sublimation and volcanic atmosphere, as well as plumes on Enceladus and impacts on the moon, include models for spatially variable frost coverage, plasma impact heating and chemistry, radiative transport, particle and dust grain dynamics and temporal variability.
We aim to adapt our simulation abilities to Pluto and include a second gravitating body (Charon). Our goal is to develop a di-global circulation model to aid in interpreting the atmospheric dynamics of the coupled system. Such a development would be of use in understanding atmospheric dynamics on Triton and on Kuiper Belt Objects, if any with volatiles are found.

Title: *National Space Grant and Fellowship Program - Texas Space Grant Consortium*
Principal Investigator(s): Fowler, Wallace T
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX10AI96H
Award Amount: $3,360,000
Abstract: The Texas Space Grant Consortium (TSGC) has administered and operated programs for the National Space Grant & Fellowship (NSG&FP) program since 1989. Texas Space Grant Consortium Mission Statement: The Texas Space Grant Consortium's mission is to education, inspire, and motivate students at all levels to pursue careers in science, technology, engineering and mathematics; to assist in the professional development of faculty members and researchers in pursuits aligned with NASA's mission; and to engage students and the general public in sharing and shaping the experience of exploration and discovery. The primary impact of TSGC on the state of Texas is in the areas of development of a STEM technical workforce with a strong focus on underserved minority participation through its fellowships and scholarships, its undergraduate NASA-focused Design Challenge program, and its annual LiftOff Summer Teacher Institutes at NASA-JSC. Goals and Objectives /Areas of Emphasis: The TSGC strategic goals align with the NASA's Educational Outcomes. Our goals focus on: minority/underserved participation enhancement; fellowship and scholarships; longitudinal tracking of program participants; STEM workforce development; higher education improvement projects; seeding new space-related research: K-12 teacher workshops and pre-college programs; public awareness activities; and efficient consortium management.

Title: *Improved Estimation of Mass Variations within the Earth Climate System from Gravity Recovery and Climate Experiment (GRACE)*
Principal Investigator(s): Chen, Jianli
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX12AJ97G
Award Amount: $706,347
Abstract: We propose to quantify mass variations within Earth's climate system using satellite gravity measurements from the GRACE. The unique aspect of our approach is to employ advanced forward modeling techniques that effectively combine geographical and other information with GRACE data to obtain estimates that are free of bias and spatial leakage. The objective is to improve the accuracy and spatial resolution of GRACE-estimated mass variations in the Earth climate system through improved quantification and correction of spatial leakage, optimal removal of spatial and temporal noise, and then to apply the improved GRACE estimates to study large-scale mass variations in the Earth's climate system. Specifically, the proposed investigation will focus on the following subjects:

1) Further development of global forward modeling techniques that can more accurately recover mass variations from GRACE time-variable gravity fields on a global basis, relative to standard approaches using GRACE spherical harmonic solutions. The forward modeling approach has been successfully applied to regional studies of ice mass balance of polar ice sheets and mountain glaciers. Extending this technique to a global scale can improve the accuracy of GRACE estimates and provide a coherent picture of mass variations in the Earth's system. The goal is to obtain estimates on a grid (e.g., 1 x 1 deg) that are free of conventional bias and leakage contamination.
2) Quantification of uncertainties of GRACE-estimated mass change based on different parameterizations of the modeling scheme and comparisons among estimates from different data processing methods, including global forward modeling, regional forward modeling, mascon solutions, rescaling, and other methods.
3) Improved estimation of long-term ice mass change rates of polar ice sheets and major mountain glaciers from GRACE gravity date through global forward modeling and comparison with estimates from other estimation methods.
4) Improved estimation of terrestrial water storage (TWS) change from GRACE through global forward modeling and comparison with estimates from other estimation methods (and products), and validation of GRACE-estimated mass changes using estimates from advanced land-surface models.
5) Improved estimation of oceanic mass change rate, (non-steric global mean sea level (GMSL) change rate) based on global forward modeling, which offers a unique means to significantly reduce leakage effect from TWS change and ice loss signals from polar ice sheets and mountain glaciers.
6) Providing the science community with improved GRACE monthly mass fields (on 1 x 1 deg grids) derived from global forward modeling. This product will be a supplementary dataset to those derived from rescaling based on land surface models, and potentially have smaller errors as they do not depend on land surface models.

The focus of this research is water and ice mass redistribution over time. It will help better estimate and understand global MSL change, reduce uncertainty in sea level change assessments and predictions, and close the budget of global MSL changes. It will also produce improved understanding of ice mass change of polar ice sheets and mountain glaciers, and TWS change over land. The proposed global forward modeling approach can help provide a coherent picture of global mass variation with significantly improved accuracy and spatial resolution, and offer a unique and effective means for quantifying ice mass change in regions of particular interest, such as small Arctic islands (e.g., Iceland, Svalbard, Novaya Zemlya) and Northwest Canadian islands.

The proposed investigation primarily addresses one of the major goals of the GRACE and its follow-on missions on identification and quantification of mass variation in the geophysical fluids envelop of the Earth's system to better understand climate change.

Title: *Modeling Gravity Field and Earth Deformation from Monsoonal Flooding in Brahmaputra Delta and Gangetic Plain using Hydrographic, Gravity Recovery and Climate Experiment (GRACE), and GPS Data*

Principal Investigator(s): Bettadpur, Srinivas V
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Columbia University
Award Number: 1(GG006669)
Award Amount: $95,376

Abstract: Background: The second largest seasonal hydrological signal evident in GRACE data is over the Ganges-Brahmaputra Delta (GBD). This water storage change represents an immense load on the Earth's surface, and is also readily observed using GPS data. The GRACE mission has until now provided an 8-year long record of this loading signal.

The goal of the investigation "Modeling Gravity Field and Earth Deformation from Monsoonal Flooding in Brahmaputra Delta and Gangetic Plain using Hydrographic, GRACE and GPS Data" (PI: M. Steckler, Lamont Doherty Earth Observatory, Columbia University, being submitted to NASA in response to the research announcement NNH10ZDA001N-GRACE) is to utilize this geodetic dataset, in conjunction with a large database of GPS deformation, and in situ hydrographic measurements, to determine lateral variations in the elastic properties of the Earth. These lateral variations are influenced by, and contribute to the study of, the contrast between the thin crust covered with 20+ km sediments at the GBD, and the ancient craton of India. The role of the GRACE data products in this study is to provide estimates of water storage variations in and near the Gangetic plain, upstream of GBD. The GRACE data enables this effort by compensating for the absence of Indian hydrological data in the relevant regions.

The goal of this proposal from The University of Texas Center for Space Research (UTCSR)is to contribute to the above investigation by processing, validating, and distributing the data products described in the section below.

Statement of Work

1. Overall framework: The UTCSR tasks are geared toward the production of validated estimates (including error bounds) of mass loading in the South Asia region.
2. Maps of mass loading over South Asia: UTCSR will deliver gridded values of mass loads derived from the latest version of GRACE data products.
3. Basin-averaged mass estimates: UTCSR will deliver time-series of integrated mass loads, and their error estimates, for basins within south-Asia, with the basin geometry to be defined as necessary for this research.

Title: *Long Wavelength Variations of the Earth's Gravity Field from Satellite Laser Ranging*

Principal Investigator(s): Cheng, Minkang
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering

Funding Agency: NASA
Award Number: NNX12AK13G
Award Amount: $310,388

Abstract: During the eight years of its mission, the Gravity Recovery and Climate Experiment (GRACE) has achieved a dramatic improvement in the Earth's mean gravity field, and has successfully measured the mass flux and water transport between the atmosphere, ocean and land, as well as the mass balance of the polar ice sheets. The mission operation for GRACE has been approved to 2013, and a GRACE follow-on mission is planned. However, it appears likely that there will be a gap between the two missions. Recent results indicate significant changes in the polar ice sheets, likely due to global climate change, and it is critical to continue monitoring, if possible, the ice sheet mass changes between the two missions. These mass changes, possibly exhibiting an acceleration over the last several years, may be reflected in an apparent deceleration in the rate of change in J2 as determined from satellite laser ranging (SLR) tracking of geodetic satellites. Other low-degree terms, such as C21 and S21 (associated with the orientation of the Earth's principal figure axis) have also shown recent departures from the long-term trends. In addition, J2 determined from SLR has been an essential component for the GRACE science application because of the significant aliasing effects apparent in the GRACE-derived estimates. It is critical that this time series continues to monitor this important geodetic signal. SLR data has also, over the past three decades, provided long-term, stable determinations of the Terrestrial Reference Frame due to its accurate tie to the Earth's center of mass. GRACE is insensitive to geocenter motion (or the equivalent degree-one gravity harmonics), yet the amount of mass redistribution associated with the seasonal geocenter variation is significant.
The objective of this proposal is an extension (continuation) and enhancement to NASA NNX08AE99E to analyze the long-term SLR data for determining the low-degree (large spatial scale) portion of the time-varying gravity field. In particular, we propose to 1) continue to provide a consistent time series of J2 and geocenter motion to support the GRACE science applications, 2) provide an improved long-term time series of the degree 2 geopotentional coefficients to study the deceleration of the variations in the Earth dynamic oblateness and variations of the Earth's figure axis for improving understanding of the large scale long-wavelength mass exchange within the Earth system and to provide better constraints for mantle rheology and core-mantle coupling, 3) improve the determination of the large-scale (to degree and order 5 or higher) of the gravity field to provide a means for possible gap-filling between the two GRACE missions.

Title: *Long-Term Variability of Earth Rotation, Low-Degree Gravity, and Climate Change*
Principal Investigator(s): Chen, Jianli
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX12AM86G
Award Amount: $643,385

Abstract: We propose to investigate long-term variability of Earth rotation and low-degree gravitational change and their connections with air and water mass variationsassociated with large-scale climate changes, using historical Earth rotational observations, advanced climate models (for the atmosphere, ocean, and land hydrology), gravity measurements from the Gravity Recovery and Climate Experiment (GRACE) satellite, and other geodetic measurements, e.g., satellite laser-ranging (SLR) data. The main objectives are to quantify decadal and interannual variations of low-degree spherical harmonics (e.g., C20, C21, and S21) of the gravity field, using multiple sources of data and to investigate their applications in understanding long-term variability of the climate system.
Specifically, the proposed investigation will focus on the following subjects:
1) Quantification of long-term (including decadal and interannual) variations of degree-two spherical harmonics (e.g, C20, C21, and S21) during the past 50 years using Earth rotational observations, including polar motion (X, Y) and length-of-day (LOD).
2) Quantification of long-term variations of low-degree spherical harmonics for the past 50 years using estimates from advanced atmospheric and oceanic general circulation models, and land surface models. We will analyze how implementation of mass balance constraints among the atmosphere, ocean, and hydrosphere will affect the estimation of these low-degree gravity changes.
3) Investigation of long-term variations of low-degree spherical harmonics (e.g., C20, C21, and S21) using the extended record (expected to exceed 10 years) of GRACE observations, and 30+ years time series of SLR solutions.
4) Estimation of contributions to long-term, low-degree gravitational changes from land hydrology, ocean, and cryosphere using observational data from GRACE satellite gravimetry and other available data resources.
5) Investigation of the sensitivity of decadal and interannual variations of low-degree gravity field to individual contributions from different components of the Earth’s climate system, through comparisons between observed low-degree gravitational changes (from Earth rotation, SLR, and GRACE) and estimates from climate models and satellite observations. We will evaluate the sensitivity over different time spans (interannual, decadal, and long-term trend) of low-degree gravity changes to individual contributors.
6) Investigation of possible connections between low-degree gravity changes to major climate change events, including accelerated polar or mountain glacier ice melting and related global sea-level rise in the recent decade(s).
The century long record of accurately measured Earth rotational change provides a unique means for studying long-term variability of degree-2 gravitational changes, especially the two non-zonal terms (C21 and S21). Advanced atmospheric, oceanic, and hydrological models offer an alternative to study long-term air and water mass redistribution of the Earth system, although the models are expected to have limited accuracy at longer than interannual time scales. It's been a challenging task to quantify cryospheric mass change, due to the lack of observational data, especially over the time period before the recent decade. GRACE provides a new means for quantifying cryopsheric, hydrological, and oceanic contributions to gravity change in a coherent way and can help diagnose the sensitivity of low-degree gravity changes to large-scale mass changes in the different components of the Earth system.

The proposed investigation primarily addresses one of the four major goals of the NASA Earth Surface and Interior program ("Geopotential field research that addresses the measurement of mass transport within the Earth System") and can help advance some of the scientific goals recommended with the National Research Council's Decadal Study 2007.

Title: *Fundamental Study of Interactions Between Pulsed High-Density Plasmas and Materials for Space Propulsion*

Principal Investigator(s): Raja, L L
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: DOD-Air Force
Award Number: FA9550-11-1-0062
Award Amount: $1,899,972

Abstract: A team led by researchers from UT-Austin, working with researchers at the University of Illinois at Urbana-Champaign (UIUC), is proposing a five-year program to study the interactions between pulsed high-density thermal plasmas and material surfaces. Our program will integrate experiments, materials characterization, and plasma/materials modeling. We will use pulsed plasmas generated by capillary arc discharges and plasma-armature railguns to systematically expose various materials under controlled and reproducible conditions. In the first year, we will focus on reconciling experimental results and models of ablation for single-crystal silicon, aluminum oxide, and tungsten. The principal focus will be computing the conditions that determine the onset and rate of ablation of materials exposed to thermal plasmas. The proposed research will be anchored by a systematic physical modeling effort. The plasma discharge systems will be modeled with high-fidelity computational simulations that will fully characterize the capillary arc and railgun plasma and in particular the state of the plasma in the immediate vicinity of the materials. Materials modeling approaches including atomic-scale molecular dynamics and continuum phase-field techniques will be used to quantify the processes by which particles and radiant fluxes from the plasma cause morphological and chemical changes to the materials. Finally, next-generation materials, including diamond bonded on to novel substrates, will be investigated for their high ablation-resistance properties. Overall, the scientific understanding of plasma-materials interaction developed in this research program will inform the design and development of new material systems that serve current and future space propulsion needs.

Title: *Understanding the Lunar Crater Observation and Sensing Satellite (LCROSS) Impact Event and Characterizing the Nature of the Permanently Shadowed Region on the Moon*

Principal Investigator(s): Goldstein, David B
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering

Funding Agency: NASA
Award Number: NNX13AH12A
Award Amount: $20,704

Abstract: We propose to build on work done so far to simulate the LCROSS impacts. The simulations of the LCROSS impact will emphasize progressive improvement in the physical modeling. In particular, we aim to do the following:

1) Include a more detailed investigation of the specific terrains associated with the impact sites (utilizing publicly released Lunar Reconnaissance Orbiter (LRO) laser altimeter data).

2) Improve the modeling of how vapor is released from the grains, both aloft and on the surface. Currently ice is assumed to be a thin transparent layer on grains of fixed albedo. We aim to include grains having different ice fractions and purities, to accommodate different light scattering/absorbing properties and thermal properties.

3) Improve the time-averaged modeling of observations as we did during the run-up to the LCROSS impact on 9 Oct 2009. That is, the flows of gas and dust are fast, and using a finite shutter speed or ensemble averaging several exposures for some observation blurs the observation but improves the SIN ratio.

4) Model plume opacity as a function of wavelength, especially along the high angle plume axis, and upgrade the model to include multiple scatterings if needed (following the methodology previously employed by the UT-Austin co-Investigator).

5) Incorporate the effects of latent heat transfer to/from and the expected spectral color/albedo changes of the sublimating grains.

6) Incorporate a parameterized separate pure ice component (e.g., from a buried pure ice layer potentially reached by the high angle component of the plume).

7) Incorporate the ability in the code to generate spectra along lines of sight akin to the type generated by LCROSS, LRO, and ground-based observatories. We have already generated Mie spectra for a range of grain sizes. These spectra must be sampled on a grain-by-grain basis in the illuminated field of view to generate spectra within the model to compare to the S-S/C observations. Such spectra, when based on the Apollo grain size vs. core depth measurements, may be used to understand the LCROSS penetration depth. We may use the low and high angle plume mass and spectral color ratios to differentiate the grain/ice characteristics at two different depths by relating the results to the Schultz et al (2010) experiments.

Individually, these enhancements of the physical modeling are not that hard to incorporate in the code, but each introduces new assumptions and parameters. In particular, we aim to compare more geometrically complex models (e.g., non-axisymetrical plume component axes and S-S/C viewing and flight path angles) to the observations.

Title: *MSPI Engineering Support*
Principal Investigator(s): Davis, Edgar S
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: California Institute of Technology Jet Propulsion Laboratory

Award Number: 1427764
Award Amount: $262,000

Abstract: The University of Texas Center for Space Research (UTCSR) shall provide the opto-mechanical and mission design services of Ab Davis for the work described in the following tasks:
Task 1: Opto-mechanical design
1.1 Review and support establishment of camera design requirements to fit specific mission requirements for both airborne instrument demonstration, and Earth orbiting, missions.
1.2 As needed, conduct engineering analysis and 2D layout studies to support engineering design decisions to include but not limited to: thermal, structural, camera configuration, gimbal geometry, and stray light control (both in camera and as mounted on the host satellite or aircraft).
1.3 Review and support development of camera fabrication processes and test procedures.
1.4 Participate in detailed design reviews at Jet Propulsion Laboratory (JPL).
Task 2: Mission design
2.1 Review science application requirements, propose and/or evaluate specific camera system concepts for both airborne and Earth orbiting missions.
2.2 As needed, prepare preliminary studies of camera system resources requirements (e.g. mass, power, data rate, volume, field of view, and rough-order-of-magnitude of cost) to support systems engineering decisions.
3. Reporting and schedule coordination
The UTCSR engineer will support weekly telephone conferences that are hosted by JPL. These telecon coordinate the activities of JPL and its subcontractors on the Multiangle SpectroPolarimetric Imager (MSPI) projects. He will contribute draft material to JPL's final report on the project.

Title: *A Novel Highly Efficient Scheme for the Boltzmann Equation*
Principal Investigator(s): Varghese, Philip L
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX11AM72H
Award Amount: $266,979

Abstract: In fluid dynamics, the limits of continuum mechanics are surpassed when the mean free path of molecules becomes equivalent to the characteristic length scale. This can occur in hypersonic transition when molecular scales are equivalent to roughness height, during atmospheric entry, in spacecraft attitude control plumes, and in the small dimensions of micro- and nano-scale devices. Within these regimes, the Boltzmann equation must be solved to accurately model the physics. Methods such as direct simulation Monte Carlo (DSMC) have been developed to provide solutions to the equation. However, DSMC has difficulty simulating complex gas models with unsteadiness, intricate geometry, or chemistry. It also tends to produce noisy solutions that are difficult to couple with continuum solvers.

New discrete velocity methods that require less computational cost and produce less statistical noise are being developed as an alternative to DSMC.
The problems with DSMC can be addressed by a discrete velocity method if the Boltzmann equation is solved using several key innovations recently developed at The University of Texas at Austin. The results provide the exciting prospect of efficient, cost effective, quiet, and accurate solutions to the Boltzmann equation. The current innovations utilize a statistical method called variance reduction where properties of equilibrium distributions are used to greatly reduce statistical noise and reduce computational time. A second key innovation is a method for allowing arbitrary post-collision velocities to be mapped back onto a discrete grid in velocity space. Both innovations opened the door to my development of a solver utilizing non-uniform velocity grids and schemes for moving a distribution function between different velocity grids.
I propose to advance the current discrete velocity model to a version that handles adaptivity in the velocity grid and includes rotational and vibrational internal energy. Velocity grid adaptation will greatly enhance the ability of a discrete velocity code to produce more accurate results for any quantity of interest. The inclusion of internal energy better represents physical reality, and with internal energy included, multiple species can be used in simulations. Accurate representation of the distribution function allows for more accurate and efficient simulations. The discrete velocity method I develop will be a large step toward a fully capable flow solver that can be coupled with continuum solvers to correctly model flow with rarefied gas effects. The increased accuracy without exorbitant cost addresses NASA's strategic goals by allowing easy access to computational solutions.

Title: *Toward Active Control of Noise from Hot Supersonic Jets*
Principal Investigator(s): Tinney, Charles E
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: University of Mississippi
Award Number: 12-10-019
Award Amount: $233,701
Abstract: Year 1: (a) Review of experimental and simulated databases on heated supersonic jet flows. (b) Fabrication of 32 channel near-field pressure array. (c) Experimental campaign at National Center for Physical Acoustics (NCPA) using near field array. The first phase of the proposed Statement of Work will begin by reviewing existing databases comprising concurrent simulations from Combustion Research and Flow Technology, Inc. (CRAFT Tech) and past NCPA experimental studies of supersonic cold/heated jet flows. Upon review of these databases, a 32-channel, near-field pressure array will be constructed, which will be used during the NCPA experiments. This array will be designed to capture pressure signatures in the near-field regions of the jet flow and will accommodate for changes in the shear layer growth rate and for changing jet conditions (temperature, nozzle geometry, and upstream conditions). Upon completion of the first phase, and in coordination with NCPA and Auburn University (Auburn), an experimental campaign will be

performed at NCPA to characterize the effects of nozzle configuration on jet-noise production for fully expanded and over-expanded jet conditions. Three nozzle configurations will be tested and will comprise: (a) smooth-bore conic nozzle without centerbody, (b) smoothbore conic nozzle with centerbody, and (c) faceted nozzle without centerbody. UT-Austin will be responsible for providing the 32-channel, near-field pressure array and associated Data Aquisition (DAQ) hardware. The near-field array will be synchronized with other instruments provided by NCPA and Auburn.
Year 2: Data analysis and sound source identification using Year 1 data. The second year will focus on developing data analysis techniques using the pressure, velocity, and far-field acoustic data acquired from the NCPA experimental campaign in the first year. These techniques will be used to distinguish the various characteristic noise sources in the heated supersonic flow for all design conditions studied. An objective will be to quantify linear and nonlinear coherence between near-field and far-field quantities and develop methods for extracting the time dependent, low-dimensional source field.
Year 3 Option: Enhanced development of experimental and computational tools. Develop experimental near-field array based on a computationally optimized pseudo-sensor algorithm. Perform experimental/numerical data fusion using new measurements conducted in the third year.

Title: *Imagine Now to Innovate for the Future*
Principal Investigator(s): Fowler, Wallace T
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Rio Grande Valley Science Association
Award Number: RGVSA-TX-2011-00001
Award Amount: $97,899
Abstract: Dr. Wallace Fowler, Director of Texas Space Grant Consortium and Aerospace Engineering Professor, Dr. Judit Ries, a Research Astronomer, and Margaret Baguio, the Senior Education and Outreach for Texas Space Grant Consortium (TSGC), all from The University of Texas Center for Space Research (UTCSR), will identify and develop the educational material for the Rio Grande Valley Science Association in order to inspire certified teachers and Grade 4-9 youth to study and eventually enter STEM-related fields. They will emphasize currently available NASA educational resources and NASA satellite data. Where necessary, Ries and Baguio will adapt the material for summer camp offerings. Baguio and Ries together will conduct the 40 hours of educator workshops each year to prepare elementary and middle school teachers to infuse NASA resources into summer, after school, and Saturday STEM enrichment programs. Each team member will assist with overall recruitment, engagement, and project replication while helping with evaluation. As a pmi of involving students in science education, they will help organize and advertise student- and teacher-sponsored NASA activities and events in locations throughout the Rio Grande Valley.

Title: *Quantitative Measurements of Ablation-Products Transport for Turbulence Model Validation*

Principal Investigator(s): Clemens, Noel T
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX11AN55H
Award Amount: $263,000

Abstract: In recent years, NASA has developed renewed interest in the study of ablation owing to the need to develop suitable thermal protection systems for spacecraft that undergo planetary entry. Ablation is a complex multi-physics process, and codes that predict it require a number of coupled submodels, each of which requires validation. For example, Reynolds-averaged Navier Stokes (RANS) and large-eddy simulation (LES) codes require models of the turbulent transport of ablation products under variable compressibility and pressure gradient conditions; however, suitable scalar-velocity data under relevant conditions are very rare. One means of obtaining such data is to transpire a gas, such as Nitric Oxide (NO), into a turbulent boundary layer and to measure its dispersion with a technique such as planar laser-induced fluorescence (PLIF). Alternatively, a new technique has been developed at The University of Texas at Austin that uses PLIF of a low-temperature sublimating ablator (naphthalene) to enable visualization of the ablation products in a hypersonic turbulent boundary layer. However, for either the transpired gas or low-temperature ablation techniques to be useful, their fluorescence signals must first be studied over the wide range of pressures and temperatures that may be present in a given wind tunnel. Fluorescence models of NO and naphthalene vapor will be obtained by monitoring the fluorescence signals of these species in a pressure and temperature controlled test cell. The goal of this project is to conduct the fundamental spectroscopic measurements that are required to enable the acquisition of quantitative images of the transport of the ablation products of a re-entry vehicle model in a supersonic wind tunnel. The proposed work will mainly be conducted at research laboratories on the campus of The University of Texas at Austin under the supervision of Dr. Noel Clemens. This work will complement the NO PLIF work being conducted in the Mach 10 wind tunnel at NASA's Langley Research Center, since recent work has demonstrated problems with making the measurements quantitative. This proposal relates directly to sections 14.3.1 (Entry and Ascent TPS) and 9.1.1 (Rigid TPS) of NASA's Space Technology Roadmaps Technology Area Breakdown Structure.

Title: *A New Method for Imaging Mixture Fraction in Turbulent Non-premixed Flames*

Principal Investigator(s): Clemens, Noel T
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: National Science Foundation
Award Number: CBET-1134020
Award Amount: $322,779

Abstract: The further improvement of combustion models for turbulent non-premixed combustion is severely limited by the lack of measurements of mixture fraction and its dissipation in complex reacting systems. Currently, the highest fidelity mixture fraction measurements are inferred from Raman/Rayleigh scattering, but these measurements are difficult to apply in more applied combustion environments where walls, soot, or particles may be present. We propose to develop a new technique that holds promise for enabling space- and time-resolved imaging of a conserved scalar in turbulent reacting flows, and which can be applied in a wider range of environments than alternative techniques. This new technique is based on using two-photon, laser-induced fluorescence (LIF) of a noble gas (e.g., Kr or Xe), which is seeded into the fuel or oxidizer stream. Noble gases are inert in the presence of combustion and so can be treated as a conserved scalar. The noble-gas LIF measurement gives the mole fraction of the conserved scalar, but a temperature measurement and state relationship are required to infer the mixture fraction (i.e., mass fraction of atoms originating in the fuel stream). This work will build on a proof-of-concept experimental campaign that was conducted during the fall 2009 in a collaboration between Dr. Jonathan Frank of Sandia National Labs and the Principal Investigator (PI). These experiments convincingly demonstrated that Kr planar LIF holds great promise as a technique to image mixture fraction in turbulent non-premixed flames with sufficient signal-to-noise ratio to derive the scalar dissipation field.

Our main objectives will be the following: (i) To improve our understanding of the technique's limitations, particularly regarding the need for an assumed state relationship; (ii) to determine if the technique can be applied with higher-hydrocarbon fuels where laser beam absorption, fluorescence interference and quenching may add additional difficulties; (iii) to combine the technique with particle image velocimetry (PIV) to obtain important and still unique mixture-fraction velocity correlation data in flames; (iv) to investigate two-photon Xe LIF as an alternative conserved scalar; and (v) to explore combining noble-gas LIF with filtered Rayleigh scattering to obtain simultaneous temperature fields when particles/soot/walls are present.

Intellectual Merit: The proposed work has as its objective the further development of a new diagnostic technique, which holds promise for enabling measurements of mixture fraction and its dissipation in non-premixed combustion systems. The main conserved scalar of interest is krypton, although xenon will be investigated. The combined two-photon LIF will enable conserved scalar measurements to be made in more applied flows, such as confined combustors, or in flows with particles. This feature will enable one to combine mixture fraction imaging with PIV, and potentially to make conserved measurements in flows with soot or soot precursors. It also can be used effectively as a technique for studying mixing/combustion where safety concerns preclude the use of toxic-gas markers.

Broader Impacts: This new technique holds promise for enabling measurements of mixture fraction (or a related surrogate conserved scalar quantity) in combustion environments where such measurements were previously not practical, such as gas turbines, IC engines, fires, and supersonic combustors. Noble-gas LIF is potentially much easier to implement than alternative techniques, and it is likely that the technique will see much wider use in academics, government, and industry. The data that can be provided by the technique could potentially impact

the accuracy of advanced combustion models, and therefore, impact a wide-range of technologies including those that utilize sustainable fuels. As great strides are made in computational engineering, we must not lose sight of the importance of validating the computations, and this will require that we maintain and develop the experimental infrastructure that enables the acquisition of the needed data. It is further critical that underrepresented segments of the society participate in this scientific progress. For this reason, the PI will leverage several university programs aimed at recruiting and retaining outstanding students from underrepresented minority groups.
The PI will do this by increasing his already extensive activities in this regard. In particular, he will conduct outreach through giving lectures on aerospace engineering to minority high school students, mentor minority undergraduates in research projects, increase his efforts in recruiting minority graduate students and he will supervise summer interns from Huston-Tillotson University, a historically black college located less than one mile from the UT-Austin campus.

Title: *Toward Large Eddy Simulation (LES) Modeling of Full-scale Gas-turbine Combustors*

Principal Investigator(s): Clemens, Noel T
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Department of Energy
Award Number: DE-FE0007107
Award Amount: $497,638

Abstract: The focus of this project is the development of advanced LES-based combustion modeling tools that can be used to design low emissions combustors burning high hydrogen content fuels. In particular, we develop models for two key topics: 1) Flame stabilization, lift-off, and blowout when fuel-containing jets are issued into a crossflow at high pressure, and 2) Flashback dynamics of lean premixed flames with detailed description of flame propagation in turbulent core and near-wall flows. The jet in crossflow (JICF) configuration is widely used for rapid mixing of reactants, in both the premixing chamber and in axially staged configurations. The high reactivity of hydrogen strongly impacts the flame stabilization mechanism in JICF by altering the structure of the reaction zone. This, in turn, changes the blowoff and emission characteristics. Lean premixed combustors are also sensitive to combustion instabilities, leading to flashback where the flame stabilizes in the premixing zone. Since hydrogen is highly flammable with a higher laminar flame speed compared to conventional fuels, the propensity for flashback is increased. The availability of high-fidelity predictive computational models will provide a significant boost to the design of next generation gas turbines.
LES is ideally suited for modeling this problem since it is inherently unsteady, three dimensional, and describes large-scale mixing accurately. However, combustion and near-wall turbulence interactions occur predominantly at the small scales and will require modeling. The fundamental modeling issues are two-fold. First, the flame stabilization mechanism in such gas turbines includes a combination of premixed flame propagation, autoignition, and locally diffusion flame-like structure.

But the primary reaction zone operates in fully premixed or stratified/partially-premixed mode. Consequently, the LES model for gas turbines should account for combustion mode changes, while being able to predict lift-off and blowout.
Second, the interaction of the flame front with a wallbounded turbulent flow modulates the flow structures and alters the flame topology. In the near-wall region, the anisotropic turbulent structures will non-trivially impact flame motion. Since these structures are not resolved in LES, detailed models for these interactions need to be developed.
Here, a novel hybrid probability density function (PDF)/extended flamelet approach is developed for describing the complex combustion process. The extended flamelet approach will allow detailed chemical kinetics and unsteady flame effects to be included.
A mixture-fraction/progress variable system is used to map the thermochemical composition space. The flame structure is described using a combination of non-premixed and premixed flamelet solutions, with a modeled indicator function determining the local burning regime. The joint PDF of flamelet variables will be directly evolved, which will allow detailed modeling of the small-scale spatial distribution. The 7-dimensional PDF transport equation will be solved using a specifically designed Eulerian quadrature method of moments (QMOM) approach, providing a fully deterministic solution technique that can be employed in any CFD code. The dissipation rates of the scalars, as well as their cross-dissipation rates, will be modeled using a non-equilibrium dynamic approach that adapts the model based on the instantaneous LES solution. To account for the misalignment between the turbulent scalar flux and the scalar gradient observed in the flows considered here, a quadratic scalar flux formulation will be developed.
To ensure model validity in gas turbine-like conditions, we propose a three-stage hierarchical validation approach. In the first stage, a suite of canonical experiments and DNS data will be used to provide preliminary validation of LES models. At the second stage, JICF experiments at UT-Austin will be used to model flame stabilization in pitched jets. A variety of fuel compositions, pitch angles, and crossflow conditions will be considered. Further, a unique high-pressure rig experiment of a stable lean-premixed burner with a swirled premixing chamber and pilot-based stabilization will be used to provide high-fidelity data for validation. In the third stage, flashback will be triggered in the same high-pressure rig to study flame propagation. A variety of triggering conditions, fuel compositions, and stratification levels will be experimentally studied. We will collaborate with industrial partners to transfer the combustion models, experimental data, and simulation results.
Project objectives - The work is divided as follows:
Goal 1. Formulate LES-based hybrid PDF/flamelet approach for multi-regime combustion in gas turbines.
Goal 2. Develop a comprehensive set of validation-specific experiments for flame stabilization in JICF and flashback dynamics.
Goal 3. Use a validation pyramid approach to demonstrate model accuracy in practical operating conditions and transfer models to industrial collaborators.
Potential impacts of the project - the outcomes of this project will be:
Development of a hybrid PDF/extended flamelet model for LES that can capture flame stabilization accurately using detailed chemical kinetics.

Detailed turbulence and combustion models for predicting flame propagation in a flashback event.
Extensive set of reacting pitched JICF experiments and high-pressure experimental data for stationary premixed combustion and flashback dynamics using simultaneous laser diagnostics.
Implementation of models into open source computational tools and transfer to industry.

Title: *Collaborative: Long-Term and Interannual Variability of Antarctic Ice Sheet Mass Balance from Satellite Gravimetry and Other Geodetic. Limited Review.*

Principal Investigator(s):	Chen, Jianli
Department, Center, or Institute:	Center for Space Research
Institution:	The University of Texas at Austin
Discipline:	Engineering
Funding Agency:	National Science Foundation
Award Number:	ANT-1043750
Award Amount:	$493,163

Abstract: The primary goal of the proposed investigation is to improve estimation of long-term and interannual variability of Antarctic ice sheet mass balance at continental, regional, and catchment scales, using satellite gravity measurements from the Gravity Recovery and Climate Experiment (GRACE) and other geodetic measurements, including satellite laser altimetry data from the Ice, Cloud, and land Elevation Satellite (ICESat), and bedrock GPS observations.
We will focus on the following subjects: 1) Improve quantification of long-term mass change rates over Antarctica using GRACE gravity data with a longer record (over 10 years by the end of this project) and newer generation(s) of products; 2) develop advanced numerical forward modeling techniques that can accurately correct leakage effects associated with GRACE data processing, and significantly improve spatial resolution of GRACE mass rate estimates over Antarctica; 3) better understand crust uplift rates due to postglacial rebound (PGR) and present day ice load change over Antarctica via PGR models, GPS measurements, and combined analysis of GRACE and ICESat elevation changes; 4) investigate interannual variations of ice mass over Antarctica at continental and catchment scales and connections to regional climate change (e.g., changes of temperature and snow precipitation); and 5) better quantify uncertainty of GRACE estimates of Antarctic mass balance by comparing results from varied GRACE products (e.g., from different data processing centers, global spherical harmonics solutions vs. mascon solutions).
The major deliverables from this study will be 1) improved assessments of ice mass balance for the entire Antarctic ice sheet and potential contribution to global mean sea level rise, 2) estimates of regional ice mass change rates over Antarctica, with focus along the coast in the Amundsen Sea Embayment and the Peninsula in West Antarctica and in Wilkes and Victoria Lands in East Antarctica, 3) estimates of interannual ice mass change over Antarctica at various spatial scales, and 4) assessments of uncertainty of GRACE ice rate estimates and PGR models errors over Antarctica.

Quantifying ice mass balance of the Antarctic ice sheet is of great importance for understanding climate change but limited by the lack of temporally and spatially adequate measurements. The major advantages of GRACE time-variable gravity data include: 1) high temporal resolution at monthly intervals, 2) a continuous and long time series (exceeding 10 years), and 3) direct measurements of mass change, distinct from elevation or ice velocity measurements from other remote sensing techniques. GRACE satellite gravity data have proven to be a unique and successful means for measuring ice mass change rates of polar ice sheets and to validate estimates from other remote sensing measurements.

The intellectual merits of the proposed investigation include: 1) providing improved assessments of Antarctic ice mass balance at different temporal and spatial scales with unprecedented accuracy, an important contribution to broad areas of polar science research; 2) combining high accuracy GPS vertical uplift measurements and PGR models to better quantify long-term crust uplift effects that are not distinguishable from ice mass changes by GRACE; and 3) unifying the work of several investigations at the forefront of quantifying ice sheet and glacier mass balance and crustal uplift based on a variety of modern space geodetic observations.

The broader impacts of the proposed activities include: 1) the project will actively involve student participation and training, through the support of two graduate students; and 2) the project will contribute to general education and public outreach (E/PO) activities (the PI has been participating an E/PO team at the Center for Space Research through a federally funded project), and the results from this investigation will help inspire future geoscientists and promote public awareness of significant manifestations of climate change. This project involves no fieldwork in the Antarctica.

Title: *Multi-functional Flaps for High-efficiency High-speed Coaxial Compounds*

Principal Investigator(s): Sirohi, Jayant

Department, Center, or Institute: Center for Mechanics of Solids, Structures, and Materials

Institution: The University of Texas at Austin

Discipline: Engineering

Funding Agency: University of Maryland

Award Number: Z845803

Award Amount: $415,000

Abstract: The objective of this task is to dramatically increase the high-speed capability of coaxial compound helicopters using innovative multi-functional lift flaps for reduced vibration, improved efficiency/performance, and reduced weight via swashplateless primary control.

Coaxial compound has emerged as one of the several potential solutions for high-speed rotorcraft – along with tilt-rotors and slowed-rotor compound – since the successful resolution of critical technology shortcomings associated with the earlier XH-59A demonstrator. These shortcomings – low efficiency/high fuel consumption, high empty weight fraction, high vibration, and challenges associated with reducing rotor speed – have now been mitigated in the X2 Technology Demonstrator by innovative use of the modem technologies of advanced airfoils (double-ended at root and super-critical at tip), advanced materials (Titanium to graphite-epoxy blades), active vibration control in the fixed-frame, and advanced propulsion (high-efficiency pusher propeller instead of turbojet thrust). The premise behind this research is that the potential of smart rotors and active systems, which have matured over the last fifteen years, if brought to bear on this advanced coaxial rotor system, can bring about dramatic improvements in its capabilities. Some of the current technical challenges are: 1) reduced efficiency due to large reverse flow area in high-speed flight (80% of retreating side, at t=0.8, 20% rpm reduction, 250 kt); 2) high weight penalty due to active force generators in the fixed-frame to cancel the high vibration levels due to stiff blades; and (3) weight and drag penalty due to high root stresses, as well as a large hub. The intent of this task is to address all of these issues systematically via simultaneous performance control, vibration control, and primary control through multi-functional, on-blade flaps.

For a conventional rotor, the action of flaps is by now well understood: its role in vibration control established, its potential for performance improvement reliably demonstrated, and its promise of primary control analytically explored, though not practically realized due to lack of actuation authority. The focus of this research will be on a coaxial rotor, and the action of flaps will be dramatically different. In a conventional rotor, the flap can operate predominantly as a lift generator for vibration control. For primary control, the flap must operate as a moment generator to achieve the significantly higher control authority required. In a coaxial compound, the lifting action alone can be used to accomplish all three purposes. Firstly, primary control can be accomplished more suitably for several reasons: roll moment naturally balanced, hence limited lateral cyclic; rotor off loaded in high-speed, hence limited longitudinal cyclic; and rotor meant to act only as lifter, hence stiff in torsion blades now an advantage. Selective deployment only on the advancing side of each rotor suffices (advancing flap concept similar to advancing blade concept). Secondly, performance improvement can be accomplished in a more targeted manner focused on special physics of this rotor: reverse flow on the retreating side can be maintained at lower angles of attack (no cyclic pitch variation); and deployment schedule on both rotors can be used to control lift-offset (LOS), mitigate effects of negative lift near the tip, and prevent under surface stall in reverse flow. Thirdly, vibration reduction, even though the mechanism here remains the same as conventional, can be accomplished with lesser actuation – baseline lowered if hub phased appropriately plus presence of two rotors. Thus, a rigid rotor coaxial compound appears tailor-made for smart operations.

Compared to a conventional rotor, limited analytical capabilities or experimental data sets exist for a coaxial rotor. Existing analytical capabilities either focused on rigid rotor aerodynamics and wake modeling or equivalent single-rotor aeromechanics, mostly limited to hover and level flight. Most experimental studies have been performed on small-scale rotors with diameters on the order of 3-4 feet. Two sets of nominally full-scale coaxial rotors were tested in hover in the Ames full-scale tunnel. Both rotors were 25 feet in diameter with untwisted blades, and were not representative of the advanced blades required for high-speed coaxial compounds. Despite the fact that this study was performed more than 50 years ago, it remains the benchmark against which analytical predictions are correlated. Therefore, two important activities of this task will be: 1) development of a

comprehensive analysis of a smart coaxial rotor for the fundamental understanding of its aeromechanics in level and maneuvering flight, and 2) measurement of detailed forward-flight data – performance, pressures, blade loads and hub loads- on each rotor of a coaxial system.
Proposed Objectives: The objectives are to carry out analytical (comprehensive CFD/CSD) and experimental (hover and Mach-scale wind-tunnel tests) investigations for fundamental understanding of the aeromechanics of smart coaxial rotors with active flaps. The coaxial flaps will be special; they will take full advantage of the advancing blade concept, use the stiff in torsion blades beneficially, and carry out multiple functions simultaneously and will reduce vibration, improve performance, and implement primary control (swashplateless). An advancing lift flap (selectively deployed on advancing side) will be studied and compared to a more conventional lift/moment flap. The objectives of the analytical investigation will be to: 1) develop aeromechanical analysis with multiple rotors and fuselage; 2) carry out systematic study to compare and size the flaps, and determine optimal deployment for maximum effectiveness in high-speed flight; and 3) expand analysis to maneuvering flight (up to 2.5g). The objectives of the experiment will be: 1) obtaining unique data (pressure, blade loads, hub loads, blade deflections, torque) on a baseline (no flaps) coaxial rotor, separately for individual rotors, for fundamental understanding and validation; 2) design and develop active coaxial rotor with flaps and systematically gather data under open loop actuation to compare advancing flaps with conventional; and 3) expand to closed loop for simultaneous performance, vibration, and primary control.

Title: *ICESat-2 Data Products, Algorithms, Calibration/Validation and Ground Systems*
Principal Investigator(s): Urban, Timothy J
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX12AI19G
Award Amount: $181,000
Abstract: The work performed under this proposal will support each of the several tasks identified for the Science Definition Team (SDT) as summarized on page A.12-2 of the Call for Proposals. Based on the proposed team's unique experience with ICESat (sometimes referred to as ICESat-1) and the broader experience of the University of Texas Center for Space Research (UTCSR) with other missions (e.g., TOPEX/POSEIDON, GRACE), the goals of this proposal are to continue to provide advice and expertise to the SDT to ensure compatibility between the science requirements, the mission requirements, and the laser altimeter design. In particular, participation in the SDT by the proposal team will include contributing to a Calibration and Validation (Cal/Val) plan and other studies to ensure ICESat-2 derived elevations support the primary mission goal of accurately determining long-term changes in the Greenland and Antarctic ice sheets. Such studies reflect the proposal team’s first-hand experience with the ICESat mission goals and science requirements, experience that is essential for ICESat-2.

Title: *Satellite Laser Ranging Support Services for the Ground Network Project Office (MLRS)*
Principal Investigator(s): Shelus, Peter J
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNG12VI01C
Award Amount: $3,113,373
Abstract: The University of Texas at Austin shall provide services to support satellite laser ranging operations and the maintenance and calibration of the McDonald Laser Ranging Station (MLRS) for NASA. The period of performance of the work will be for five years.

The major effort of this contract is the operational support for SLR at the MLRS located at the McDonald Observatory in Fort Davis, Texas, and the continued collection and verification of high-quality satellite laser ranging data. In support of the operational effort, we will be responsible for the maintenance and calibration of the MLRS. We will select and train qualified technical personnel who will be responsible for the operations and maintenance of the satellite tracking station. We can utilize the services of the NASA Space Communications Networks Services contract for logistics support (parts, repairs, and replacement), engineering and software consultation, and surveying.

Title: *Toward Closed-loop Control of Unstart in Scramjets: Development of Tools for Optimal Design of Sensors and Actuators*
Principal Investigator(s): Clemens, Noel T
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Spectral Energies, LLC
Award Number: SB1201-001-1
Award Amount: $465,500
Abstract: Summary of Accomplishments in Phase I and II

The overall objective of this program is development of a novel framework for optimal design of sensors and actuators for use in closed-loop control of dual-mode scramjet engines. In Phase I, the framework was developed by analyzing new measurements of unstart in the UT-Austin Mach 1.8 inlet-isolator, which could be perturbed by a downstream flap and/or upstream pulsed air jets. A new algorithm (CUSUM) was developed that enables superior detection of shock propagation using pressure data. Furthermore, system identification of the Mach 1.8 data revealed that linear dynamic models were largely inadequate in representing the dynamics. In contrast, nonlinear models performed well for predicting data for large variations in flap angle and jet pulsing frequency. In our Phase II work to date, a new direct-connect wind tunnel model has been developed at UT-Austin that is cold-flow with its design directly based on the RC-18 direct-connect supersonic combustion tunnel isolator.

The Phase II analysis has enabled the establishment of a more robust system identification framework for the shock motion dynamics that is validated under a wider range of conditions, with different sensor locations and actuator types, and under a wide range of non-reacting/reacting flow conditions. A new geometry-based shock localization algorithm has been implemented that is driven by simultaneous high-frequency pressure measurements made at multiple locations. A Kalman filter formulation has also been accomplished, while fusing results from a wide array of change detection schemes to permit a robust and optimal characterization for the leading edge of the shock system. This framework is currently being exercised to achieve closed-loop control of unstart using downstream flap actuation with changes to stagnation pressure serving as a priori unknown disturbance sources.

The technical objective of the remaining Phase II effort is to implement model-based, closed-loop control in the RC-18 direct-connect combustion facility. The closed-loop control algorithms implemented in cold flows to date at UT and RC-18 are based upon PD and PID designs and therefore, model-free. Using model-based, closed-loop controllers has the strong potential for bringing improved robustness properties, while at the same time enhancing the controller response times. The system identification models derived from our prior Phase II studies (both at UT-Austin and the AFRL RC-18 hot flow tunnel) will enable the control law design. The goal is to regulate the shock train as close as possible to the throat to while at the same time ensuring that the shock does not move downstream of some pre-specified location to enable peak engine performance. These studies will permit a systematic characterization of stability margins and quantitative estimates of closed-loop controller performance with respect to the time-constants of the actuator and magnitudes of the disturbance sources.

Title: *Collaborative Research: Fundamental Studies of Plasma Control Using Surface Embedded Electronic Devices*

Principal Investigator(s): Raja, L L
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Department of Energy
Award Number: DE-SC0008312
Award Amount: $240,000

Abstract: Proposed is a fundamental study of mechanisms and processes that enable active control of plasma discharge using semiconductor surfaces and embedded electronic devices within these surfaces. The project brings together Principal Investigators with backgrounds in experimental and theoretical/modeling work from The University of Texas at Dallas and The University of Texas at Austin. Intellectual Merit: The proposed study will investigate secondary electron emission (SEE) from semiconductor surfaces having embedded electronic devices. To the best of our knowledge, no such study has ever been attempted, even though it could lead to the formation of whole new classes of plasma-based devices and systems. We are motivated by recent articles and simple theory, which gives strong reason to believe that embedded electronic devices can be used to exert

control over the SEE coefficient of semiconductor surfaces (and maybe other surface types as well). The research will explore empirical limitations of such control and will develop a model-based understanding of the limitations of such SEE control. Furthermore, the research will explore how such sub-surface electronic devices can best be used to exert control over an associated plasma.
At the very least, the proposed research program will accomplish three major goals: 1) Provide a theory/computational model-based description for how embedded electronic devices can affect control over SEE from semiconductor surfaces; 2) provide experimental data on the variations in SEE that embedded electronic devices actually achieve, including detailed experimental examination of both the capability to control SEE and the limitations to that control; and 3) finally, detailed measurements and modeling of plasma characteristics during active SEE control, as part of exploring how sub-surface devices can exert control over a plasma discharge.
Broader impact on technology: The proposed research can have a significant broader technological impact. One can easily imagine many ways to use such real-time, real-space control of electron emission from semiconductor surface. These include plasma density and uniformity control, plasma current spike suppression, and so-called "plasma transistors." Additionally, we envision broader impact on plasma process technology through an etch control approach using the well-known steric hindrance effect and embedded electronic devices which inject electrons to surface areas one desires to etch. The result could be a capability to do mask-less, real-time definition of etching patterns.

Title: *Autonomous, Vision-Based Satellite Proximity Operations for Inspection, Health Monitoring, and Surveillance in Orbit*

Principal Investigator(s):	Russell, Ryan P
Department, Center, or Institute:	Center for Space Research
Institution:	The University of Texas at Austin
Discipline:	Engineering
Funding Agency:	Georgia Tech Research Corporation
Award Number:	RD451-S1
Award Amount:	$225,000

Abstract: This statement of work establishes the performance, engineering, and management requirements associated with supporting the Georgia Tech effort. UT-Austin will provide labor and management necessary to adequately perform the tasks below.
Task A: Design "Information-Rich" Deputy Surveillance Orbits
1A. Investigate/implement conventional relative motion dynamical models.
2A. Implement CURVE model for use at Earth with a variety of fidelity levels.
3A. Extend previous work on surveillance orbit design to eccentric case of Tschauner-Hempel, and the CURVE model of various levels of fidelity.
4A. Perform design trades in the new models that optimize observability and coverage of chief.
Task B: Optimal Control of Relative Motion
1B. Implement a custom version of the Hybrid Differential Dynamic Programming (HDDP) algorithm for relative motion dynamics.

2B. Use feedback laws from HDDP to fly in the presence of perturbations the chosen design surveillance orbit(s).
3B. Investigate the use of HDDP for the terminal guidance/rendezvous problem.
Task C: Robust Relative Motion and Pose/Shape Estimation from Visual Data
1C. Assist the Georgia Tech team with depth invariant visual serving together with augmented bearing-only depth estimation algorithms to estimate range and maintain strong visual lock on target satellite.
2C. Assist the Georgia Tech team with the development of a relative distance estimation algorithm from visual data.

Title: *Army Multi-Role Rotor (MRR)*
Principal Investigator(s): Sirohi, Jayant
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Sikorsky Aircraft
Award Number: SA-908NP
Award Amount: $285,024
Abstract: The University of Texas at Austin's Department of Aerospace Engineering and Engineering Mechanics (UT-Austin) will support Sikorsky Aircraft Corporation (SAC) during the MRR program. Specific tasks include performing internal pneumatic flow analyses on the RSB and AAC concepts, and providing design, fabrication, and test support for a reduced-scale RSB whirl test.

Title: *Computational Modeling of Ultra-High Speed Neutral Plasma Jets and Their Interactions with Materials Generating Extreme Conditions*
Principal Investigator(s): Raja, L L
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Stanford University
Award Number: 60300258-107109-A
Award Amount: $372,000
Abstract: Year 1
1) Development of Magneto-Hydro Dynamic (MHD) model. The model couples fluid mechanical aspects of a plasma flow with the electromagnetic processes that drive the plasma in the coaxial gun. Model will be exercised for nominal input energies of few kJs. 2) Development of molecular dynamics materials model.
Year 2
1) Simulation of Plasma Gun at High Input Energies. A Model will be developed for coaxial plasma gun operation under scaled up input energies of 64 kJ, which is almost and order of magnitude higher than input energies investigated in Year 1.
2) Study of materials damage caused by plasma interaction with the surface Model will be exercised to understand the damage caused by plasma interaction with the surface for the high input energies into the coaxial gun.
Year 3

1) Simulation of Plasma Jet Interactions with Target Material SLLrfaces. The MHD model will be used to study the high-energy plasma jet interactions with target material surfaces. The plasma computational domain will be extended to include the entire plasma external jet as it interacts with the target material surface.
2) Study of materials damage caused by Plasma interaction with the surface. The Year 2 activities for materials modeling will be continued in Year 3.

Title: *Space Catalog Uncertainty Modeling Using High Fidelity Dynamics, Multicomplex Step Derivatives, and GPUs*
Principal Investigator(s): Russell, Ryan P
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Georgia Tech Research Corporation
Award Number: RD446-S1
Award Amount: $199,000
Abstract: This statement of work establishes the performance, engineering, and management requirements associated with supporting the Georgia Tech effort. UT shall provide labor and management necessary to adequately perform the tasks below.
Task 1: Develop and mature fast high-fidelity computation of spacecraft trajectories. Task 2: Develop and mature novel techniques for fast and accurate computation of spacecraft uncertainty. Task 3: Build software library of plug-and-play modules. Task 4: Testing of the library on real and simulated catalogs. Task 5: Program wrap-up activities.

Title: *ES-Ma Te: Efficient Sensor Management for Optimal Multi-task Performance*
Principal Investigator(s): Akella, Maruthi R
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Knowledge Based Systems, Inc.
Award Number: 5351.200-UTA-2012-5
Award Amount: $223,049
Abstract: Knowledge Based Systems, Inc. (KBSI) has been invited to submit a Phase II proposal for Efficient Sensor Management for Optimal Multi-Task Performance (ESMa Te). The goal of the ES-Ma Te research is to investigate and develop techniques for an efficient sensor resource manager (SRM) for sensor scheduling specific to tasks required by a missile defense planning system. Planning for an SRM capability is a critical functionality for command and control, battle management, and communications (C2BMC) as it would dynamically assign sensors in response to changing priority and complexity, and hence, alter the relative effectiveness of the battle plan. The ES-Ma Te technology will support MDA's vision of Phased Adaptive Approach (PAA) to build a ballistic missile defense system (BMDS) for defense of homeland against an intercontinental ballistic missle (ICBM) and defense of friends and allies against short and medium range missile attacks.

The BMDS uses multiple disparate and spatially separated sensors for multiple simultaneous tasks, such as target search, detection, acquisition, discrimination, and target tracking. Each of these tasks consists of minimalizing uncertainty in estimation of some underlying stochastic process. In a multi-raid scenario, the finite sensor resources are stressed to provide information for situation assessment and to support weapon assignment and fire control.
Objective: The objective of this support project is to critique and refine ES-Ma Te project requirements, review and critique ES-Ma Te methodology, and provide technical inputs to, and support KBSI in technical reviews with sponsors.

Title: *Active Control of Shock-Wave Boundary Layer Interactions (SBLIs) Using Pulsed Plasma Jets*
Principal Investigator(s): Clemens, Noel T
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Creare Inc.
Award Number: 67868
Award Amount: $235,000
Abstract: Statement of Work (SOW) for The University of Texas at Austin (UT-Austin): The overall goal of this program is to advance pulsed plasma jet actuators demonstrated in Phase I to TRL 4+. We are developing these actuators for control of SBLIs. We will refine the actuator design, placement, and forcing methods through a combination of modeling, quiescent flow testing, and SBLI flow testing. Phase II will culminate with a test of the actuators in a mixed-compression, supersonic inlet model at Wright-Patterson Air Force Base (WPAFB).The bulk of the UT-Austin work scope will focus on testing of the actuators in single SBLI flowfields at UT-Austin. UT-Austin will also participate in meetings and consult on the design and implementation of the actuators. This SOW defines the effort required for the The University of Texas to support Creare, Inc., in the development of pulsed plasma jet actuators for SBLI control. This work involves testing of multiple actuator arrays in the High-Speed Wind Tunnel at UT-Austin.

Title: *The Multiscale Interaction of Vibrational Energy Transfer and Turbulent Combustion in Supersonic Flows*
Principal Investigator(s): Varghese, Philip L
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: DoD-Air Force
Award Number: FA9550-12-1-0460
Award Amount: $1,367,367
Abstract: Motivated by the nature of flows inside scramjet engines, we ask the following question: Can we use thermal nonequilibrium that is naturally present in the flow to fundamentally alter the performance of the engine? There is evidence that vibrationally excited molecules have very different reaction rates than predicted by

conventional chemical kinetics models developed for gas-phase combustion. Vibrational nonequilibrium also leads to thermal energy transport and deposition to regions of the flow far from the source of vibrational excitation. This energy exchange could affect turbulent mixing, and hence the fundamental structure of turbulent flames. We hypothesize that these combined effects of modified chemistry and energy exchange across scales will fundamentally alter the Kolmogorov turbulence cascade, as well as models used for the flame structure in both non-premixed and premixed systems. We further argue that creating vibrational nonequilibrium in a flow may provide a means to control reaction rates thereby facilitating favorable reactions or inhibiting undesirable ones. We will explore the use of vibrational nonequilibrium as a means to control reacting gasphase systems with applications ranging from materials synthesis to scramjet combustion. The program has two main targets: 1) Understanding the laminar flame structure in diffusion flames, when one of the flow streams is vibrationally activated, and 2) understanding the impact of vibrational nonequilibrium on the turbulence energy cascade and flame propagation in turbulent flames. Current experimental and computational tools are inadequate to isolate thermal nonequilibrium effects from other interactions. We propose to use high-fidelity Raman measurements to quantify the degree of vibrational nonequilibrium. Laser diagnostic tools will be used to characterize this flame structure under varying levels of nonequilibrium. Since even these measurements only provide limited access to the flame physics, direct numerical simulations (DNS) will be used to analyze the energy cascade and vibrational energy transfer. A novel inhomogeneous master equation method will be developed to couple quantum chemistry computations to macroscopic flame simulations.

Title: *Wall Turbulence with Designer Properties: Identification, Characterization, and Mechanical Manipulation of Energy Pathways*

Principal Investigator(s): Goldstein, David B
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: California Institute of Technology (Cal Tech)
Award Number: 52-1093210
Award Amount: $356,503

Abstract: At UT-Austin we will run a sequence of direct numerical simulations of turbulent boundary layers or channel flows to examine the transfer of turbulent kinetic energy between different modes and scales. We aim to examine the injection of different eddy length scales at the solid surfaces via models of passive surface textures, as well as active control through surface deformation, individual actuators or movable barriers. We also aim to examine the use of bulk body forces acting on the flow to tease out the physical mechanisms of such energy transfer. We intend to directly simulate the experimental conditions to be examined at Cal Tech where feasible. If necessary, we will run at lower Reynolds numbers than the experiments can achieve. The work will be done by undergraduate, graduate, or post-doctoral students supervised by co-I Goldstein, as suitable, and will be coordinated via periodic discussions with the rest of the research team.

Title: *ICESat-2 Precision Orbit and Pointing Determination (POD/PPD)*
Principal Investigator(s): Urban, Timothy J
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX13AB40G
Award Amount: $2,850,610
Abstract: ICESat-2, scheduled for launch in mid-2016, will provide key measurements of the ongoing changes in the elevation of polar ice sheets, sea ice freeboard, and vegetation height (Abdalati et al., 2011). Its science objectives are to: quantify polar ice-sheet contributions to current and recent sea-level change and the linkages to climate conditions; quantify regional signatures of ice-sheet changes to assess mechanisms driving those changes and improve predictive ice sheet models; estimate sea-ice thickness to examine ice/ocean/atmosphere exchanges of energy, mass and moisture; measure vegetation canopy height as a basis for estimating large-scale biomass and biomass change; and enhance the utility of other Earth observation systems through supporting measurements. To meet these objectives, ICESat-2 will use a space-based LIDAR system to make precision-range measurements between the ICESat-2 observatory and Earth. These measurements are then combined with output from Precision Orbit Determination (POD), which provides em-level knowledge of the observatory position in space and time, and Precision Pointing Determination (PPD), which provides arc second-level knowledge of the laser pointing direction for each laser pulse. Together, the measured range and POD/PPD solutions yield the position of the laser spot on the surface of Earth to a horizontal accuracy of 6.5 meters.
This proposal describes the development of a tested operational system to perform PPD during the life of the ICESat-2 mission, including pre- and post-launch analyses that support that development and verify its performance. It also covers limited support for ICESat-2 POD, which will be led by the Planetary Geodynamics Laboratory (Code 698) at NASA's Goddard Space Flight Center. The University of Texas Center for Space Research (UTCSR) has a long heritage of POD for geodetic altimetry missions, including GRACE, SEASAT, and TOPEX/Poseidon - with specific expertise in space-based GPS - and has worked with Code 698 on many of these missions. In addition, UTCSR pioneered the development of PPD techniques for the original ICESat mission. This proposal is tailored to the unique structure and design of the ICESat-2 mission to maximize the science return of the data collected by generating an operational PPD product that meets the demanding needs of the science altimetry data.

Title: *Gravity Recovery and Climate Experiment (GRACE) Follow-On Mission*
Principal Investigator(s): Bettadpur, Srinivas V
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: California Institute of Technology (Cal Tech) Jet Propulsion Laboratory

Award Number: 1478584
Award Amount: $2,654,871

Abstract: To build upon and to ensure the continuation of the ground-breaking Science and Applications of the measurements of mass flux within the Earth System from the joint NASA/DLR (Deutsches Zentrum für Luft- und Raumfahrt i.e., German Aerospace Center) GRACE mission, the two sponsoring agencies have agreed to fly a GRACE Follow-On (GRACE-FO) mission. Scheduled to launch in August 2017, the GRACE-FO mission consists of the same primary science payload and architecture as the GRACE mission, suitably modified or updated for the passage of 15 years. In addition, the GRACE-FO mission carries a demonstration Laser Ranging Interferometer (LRI). The Cal Tech/Jet Propulsion Laboratory (JPL) is responsible for the management of the GRACE-FO mission, in partnership with the GFZ German Research Center for the Geosciences.

Considerable experience from the GRACE mission has been brought to bear in the definition and concept development of the GRACE-FO mission. The University of Texas at Austin Center for Space Research (UTCSR) has been a part of the GRACE-FO mission concept's definition process, based on experience as the home institution for the GRACE mission. Within this proposal, UTCSR outlines a Statement of Work and provides estimated costs to support JPL through the implementation (definition/design/development phase B/C/D) and operations (Phase E) phase of the GRACE-FO mission.

The overall scope of the proposed UTCSR effort includes science support for GRACE-FO, including through the Project Science Advisory Group (PSAG); science support for the mission systems engineering activities, such as mission architecture development, operations concept development, requirements verification, mission design science trade studies, science support for test program; support for GRACE-FO mission operations, such as science instrument and data quality trending, science operations; and the development, installation, and operation of the elements of the GRACE-FO Science Data System from the definition through the operations phases (B/C/D/E); and the mission science data product calibration, validation, and verification activities.

The intellectual and technical basis for the role and proposed activities of UTCSR within the GRACE-FO mission is founded on its experience and role in the GRACE mission. The GRACE Principal Investigator (PI), its Science Operations Manager (SOM), its operational Level-2 Science Data System (SDS), and several other mission science and operations support activities currently reside at UTCSR. These GRACE activities were themselves a continuation of the leading role of UTCSR in the development of the GRACE mission proposal, its architecture, its science data system, and its mission operations concept during all phases of the GRACE mission.

Title: *Time Series Prediction for Satellite Ballistic Coefficients-Phase II*
Principal Investigator(s): Wilson, Clark R
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Omitron, Inc

Award Number: UTA12-001216
Award Amount: $321,208

Abstract: The following is an initial draft of the plan. This will be further developed jointly with UT-Austin and AFSPACE/A9 as work progresses toward deliverable I shown below.

I. Omitron and UT-Austin will coordinate with A9 to establish a test data set for agreed upon satellites, study periods, and applicable ASW data files.

2. UT-Austin with participation from Omitron will finalize the auto-regression (AR) based ballistic coefficient forecast techniques identified in Phase I, to include desired robustness features, such as outlier identification, and optimization of AR model.

3. UT-Austin with participation from Omitron will investigate the ASW SP dynamic models and related orbital attributes to identify incomplete perturbations or other physical processes that affect the application and fine-tuning of the final AR algorithm.

4. UT-Austin will extend the above analysis to determine its applicability to solar radiation pressure (SRP) model parameter forecasting.

5. Omitron will investigate the efficacy of applying autoregressive (AR) forecasting to the fast-varying (multi-arc) components of the ballistic coefficient.

6. UT-Austin will collaborate with Omitron to create a FORTRAN and/or C-based application prototype that is compatible with the ASW software suite and data structures, and that encompasses as much automation as possible.

7. UT-Austin will test the new application on satellites with known frontal area characteristics, such as the Gravity Recovery and Climate Experiment (GRACE).

8. Omitron will conduct a catalog-wide test of the new application in terms of satellite prediction accuracy performance, in contrast to testing in model parameter space.

9. UT-Austin will perform an independent academic review of the latest A9 model for drag coefficient variation during satellite reentry.

10. Omitron will numerically assess the latest A9 model for drag coefficient variation.

Title: *Research Area 1: Mechanical Sciences: Detailed Measurements of the Aeroelastic Response of a Rigid Coaxial Rotor in Hover*

Principal Investigator(s): Sirohi, Jayant
Department, Center, or Institute: Center for Mechanics of Solids, Structures, and Materials
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: DOD-Army
Award Number: W911NF-13-1-0463
Award Amount: $280,000

Abstract: The objective of the proposed research is to develop a fundamental understanding of the aeromechanics of a coaxial counter-rotating (CCR) rotor system in hover, through a combination of detailed experimentation and physics-based analyses. Measurements will be performed on a 6-ft. diameter, Mach-scale CCR rotor system, in a new hover test facility at The University of Texas at Austin. First-order analyses based on a vortex ring emitter model (VREM) will be developed in parallel

and validated with experimental data. The goal of the VREM is to predict the wake structure, as well as interaction of the tip vortices shed by upper and lower rotors. Compared to high-fidelity aerodynamic analyses, such as the free-vortex wake model, it is expected that this analysis will yield significant insight into the fundamental physics and rotor interaction at a low-computational cost. In addition, such a first-order analysis can easily be used as a conceptual and preliminary design tool. As part of a collaborative research and development agreement (CRADA) with ARL (Aberdeen Proving Ground, MD), there will be exchange of experimental data, as well as numerous technical discussion to enhance the state-of-art of coaxial rotor systems.

Title: *Design of an Attitude Control System for the Sunjammer Spacecraft*
Principal Investigator(s): Lightsey, Glenn
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Micro Aerospace Solutions, Inc
Award Number: UTA13-000519
Award Amount: $87,648

Abstract: Background: Micro Aerospace Solutions, Inc. (MAS) is performing a space mission known as Sunjammer teamed with L'Garde, Inc. on a NASA Technology Demonstration mission to demonstrate propellant-less navigation on a deep space mission. The mission uses an innovative solar sail to provide propulsion without propellant. MAS will provide spacecraft component selection, pointing, guidance, power systems, control and communication for the solar sail to prime contractor L'Garde. The University of Texas at Austin's (UT-Austin) Satellite Design Lab (SDL) has been designing, building, testing, and operating small satellites since 2003. The SDL proposes to design an Attitude Control System (ACS) for the Sunjammer spacecraft to meet the mission requirements as specified by MAS.

The Sunjammer mission has two distinct on-orbit phases, known as Pre-orbit boost (Phase 1) and Post-orbit boost (Phase 2). In Phase 1, attitude control is performed with conventional actuators, including thrusters, reaction wheels, and other systems as determined by MAS. After Phase 2, attitude control is provided by a reduced actuator suite, which includes the deployed solar sail. UT-Austin's SDL will provide technical assistance with the design of the ACS for both mission phases 1 and 2. The SDL will produce a design description document and a high-fidelity simulation showing the expected on-orbit performance of the system. Also, to the extent possible, the SDL will support the development and demonstration of flight software to implement the control system on the embedded microprocessor using the tools provided by MAS. SDL personnel will support all technical meetings and correspondence by email, conference calls, and distance productivity tools, such as Skype, WebEx, Connect, etc. At the conclusion of the period of performance, the SDL will generate a final report that will research findings made over the entire task and act as a final deliverable for the task.

Title: *RACE: Radiometer Atmospheric CubeSat Experiment*
Principal Investigator(s): Lightsey, Glenn
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: California Institute of Technology Jet Propulsion Laboratory
Award Number: 1478359
Award Amount: $516,381
Abstract: Background: Jet Propulsion Laboratory (JPL) is performing a space mission known as RACE (Radiometer Atmospheric CubeSat Experiment) to conduct Spaceborne validation of an Indium Phosphide (InP) radiometer. The University of Texas at Austin (UT-Austin) Satellite Design Lab (SDL) has developed a low-cost, three-unit CubeSat satellite bus, which is being flown on multiple space missions starting in 2014. The SDL proposes to deliver a flight unit heritage copy of its three-unit CubeSat satellite bus with the integrated RACE radiometer instrument provided separately by NASA JPL. The 3U CubeSat will be fully functional and ready for launch vehicle integration and testing. The bus will be capable of meeting the RACE mission requirements. The CubeSat bus will be based on the SDL's heritage bus design. Minor modifications to the heritage design will be made as necessary to accommodate the instrument.

Title: *Predictive Large Eddy Simulation (LES) modeling and Validation of High-pressure Turbulent Flames and Flashback in Hydrogen-enriched Gas-turbine Combustion*
Principal Investigator(s): Raman, Venkatramanan
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Department of Energy
Award Number: DE-FE0012053
Award Amount: $500,000
Abstract: The overall objective of this project is the development of predictive computational models for LES of hydrogen-enriched combustion in gas turbines. In particular, we focus on two key topics: 1) Behavior of high-pressure turbulent flames with and without equivalence ratio variations, and 2) flashback propagation through a turbulent boundary layer. Modern gas turbines consist of two key components: the premixing section where fuel and air are molecularly mixed, and the primary combustion section that supports the main flame and is located at the end of the mixing section. Due to the high reactivity of hydrogen, there is an increased risk of the main flame moving upstream into the premixing section, damaging the fuel inlet section. Additionally, the premixing section may not be sufficiently long to fully premix the reactants. In some designs, spatial inhomogeneity of mixing might be used to control the flashback process. Such cases will introduce equivalence ratio fluctuations in the main flame. Understanding and modeling flashback and the effect of incomplete mixing on flame propagation is critical for the design of hydrogen-enriched systems.

LES is ideally suited for modeling this problem since it is inherently unsteady, three-dimensional, and describes large scale mixing accurately. However, combustion and near-wall turbulence interactions occur predominantly at the small scales and will require modeling. The fundamental modeling issues are two-fold. First, the flashback flame propagation is highly sensitive to the characteristic of the boundary layer, especially the near-wall structure of the flow. The presence of the low-density burnt gases behind the flame causes a blockage effect, which results in the flow separating from the wall and moving around the flame. This causes a strong recirculation zone in front of the flame in the direction of propagation. Second, as the flame flashes back, the level of premixing decreases, and the flame encounters large-scale fluctuations in equivalence ratio, as well as unmixed fuel and air. Near the fuel inlet nozzle, the flame actually is close to the fully non-premixed limit. This change in combustion regime alters the flame dynamics and significantly changes the flashback speed. Equivalence ratio fluctuations could also be present in stable flames, where the mixing section, either by design or otherwise, creates inhomogeneities. Hence, LES models that account for flame/turbulence interaction and change in combustion regime need to be developed. Here, a probabilistic multi-dimensional flamelet model with detailed kinetics is developed to describe this multi-regime combustion. Unlike existing flamelet approaches, this method directly incorporates the variation in equivalence ratio as a parameter in the model. This allows the effect of flame propagation across fuel composition gradients to be included accurately. For use in LES, the joint-PDF of the flamelet variables, which includes mixture fraction as a surrogate for equivalence ratio and a set of progress variables, needs to be obtained. Here, the joint-PDF transport equation is solved using either a Lagrangian approach or a quadrature-based Eulerian approach. A second more detailed model that accounts for dissipation rate fluctuations at the small scales will be considered when equivalence ratio fluctuations are large. The dissipation rates of the scalars, as well as their cross-dissipation rates, will be modeled using a nonequilibrium dynamic 1 approach that adapts the model based on the instantaneous LES solution.

A comprehensive experimental program is proposed that will provide detailed insight into high-pressure flame physics and will serve as validation data. The experimental program will focus on two component problems at moderately high pressures (up to 6 atm), namely flashback in a channel and lean premixed turbulent flame behavior with and without equivalence ratio variations.

Using detailed laser diagnostic tools, the physics of flashback including the interaction of the boundary layer with the propagating flame front will be studied. Further, flame stability and structure in stratified flows with variable equivalence ratios will also be studied.

Since detailed experiments cannot be performed at gas turbine conditions, we use surrogate tools to ensure model validity in practical use. Models for the interaction of boundary layer and flame, as well as the stratified flame and turbulence will be tested independently using the experimental data developed in this work. In addition, direct numerical simulation (DNS) data from Sandia National Laboratory and legacy experimental data available in the literature will be used to supplement the experimental data. Existing experimental data from a lab-scale swirl burner, developed based on input from GE Global Research and Siemens, Inc., and designed to replicate a single can of gas turbine combustor, will be used as a more

complex validation case. Test rig data from GE and Siemens will be used to demonstrate the applicability of the models in realistic flow conditions. All models developed here will be implemented in an open source software, and will be transferred to our industrial partners and interested researchers.
Project objectives: The overall objective of the project is to develop predictive computational models for high-hydrogen content fuels in high-pressure gas turbines. In particular, we seek predictive LES models for capturing flame flashback and propagation in high-pressure gas turbines. Using a combination of targeted experiments, legacy data, and high-resolution DNS data, we will demonstrate the predictive accuracy of the models for gas turbine operating conditions.
The main goals of the project are as follows:
Goal 1. Develop LES-based multidimensional flamelet model and PDF approach for variable equivalence ratio combustion and flashback in gas turbines.
Goal 2. Develop a high-fidelity experimental database at moderate pressures (6 atm) for channel-based flashback and variable equivalence ratio combustion.
Goal 3. Conduct a hierarchical validation to demonstrate predictive accuracy of LES models in gas turbine simulations, and transfer technology to industry.
The outcomes of this project will be:
Development of a multi-regime combustion model based on multi-dimensional flamelet approach combined with a stochastic PDF model, which can capture the effect of equivalence ratio fluctuations and changes in combustion regimes.
Detailed experimental studies at moderately high pressure (up to 6 atm) of flashback in a channel with varying hydrogen content in the fuel.
Extensive experimental dataset of pressurized stratified flames with varying levels of stratification and hydrogen content.
Implementation of models into open source computational tools and transfer to industry.

Title: *RailPAc: A Rail Electrode-Based Plasma Actuator for High-Authority Aerodynamic Flow Control*

Principal Investigator(s):	Raja, L L
Department, Center, or Institute:	Center for Aeromechanics Research
Institution:	The University of Texas at Austin
Discipline:	Engineering
Funding Agency:	DOD-Army
Award Number:	W911NF-14-1-0226
Award Amount:	$218,229

Abstract: The proposed research is motivated by a critical need for an effective plasma actuator technology that can address flow control applications in high Reynolds number atmospheric pressure flight conditions. We have recently developed a novel plasma-based aerodynamic flow actuator concept called the Rail Plasma Actuator ("RailPAc" for short) with the help of an ARO Short Term Innovative Research (STIR) grant. This proposed research seeks to continue development of this concept through a three-year research project.
The RailPAc is a magnetohydrodynamic plasma actuator. It consists of a pair of parallel rails embedded conformably to the airfoil surface. A plasma arc is initiated

at one end of the rails, and is propelled arc along the rails by a self-induced Lorentz force. The moving arc induces a wall jet due to entrainment and compression of air. The induced wall jet imparts momentum to the boundary layer and alleviates stall. The arc can be repetitively initiated at a frequency tailored to specific flow phenomena; in this research, we propose to address retreating blade stall on a helicopter rotor in forward flight.

The RailPAc seeks to provide a significant (at least an order of magnitude) improvement in the actuation authority compared to existing plasma flow actuators available today for atmospheric pressure operation. The RailPAc preserves all of the desirable properties of plasma actuators, such as no moving parts, nearly instantaneous actuation speeds, high bandwidth, and no structural surface penetration, while overcoming the most important drawback of existing plasma actuators, i.e. very weak actuation authority.

The ARO funded STIR grant provided us with seed funding to develop and provide preliminary characterization of a prototype/demonstration RailPAc device. As part of this short-term project a prototype device was developed and tested in quiescent air as well as in a low speed wind tunnel setting on an airfoil surface. The proposed studies will build on those research activities that have been initiated during the STIR grant.

In the proposed work, we will develop and characterize a prototype/demonstration RailPAc device. The device will be tested in a quiescent (still)-air and in a low-speed wind tunnel on an airfoil configuration to quantify various parameters of interest for aerodynamic flow control. We will attempt several head-to-head comparisons of the RailPAc with data available in the literature for other actuators such as the Dielectric Barrier Discharges (DBDs). A variety of plasma and flow diagnostics will be conducted. Plasma measurements include high-speed visible imaging of the plasma actuator and the transient current-voltage characteristics for the discharge. Flow measurements include thrust/impulse measurements in quiescent air to quantify momentum transfer to the flow from the RailPAc and Particle Imaging Velocimetry (PIV) to quantify aerodynamic flow induced by the RailPAc. We will provide high-fidelity magnetohydrodynamic (MHD) computational simulations of the RailPAc phenomena. Finally, we will test the RailPAc on an 8 ft. diameter, 6-in. chord Mach-scaled rotor in hover to assess its static stall alleviation capability in a rotating environment.

Title: *Geodetic Contributions to Data Records of Earth System Mass Flux*

Principal Investigator(s):	Ries, John C
Department, Center, or Institute:	Center for Space Research
Institution:	The University of Texas at Austin
Discipline:	Engineering
Funding Agency:	California Institute of Technology Jet Propulsion Laboratory
Award Number:	1479726
Award Amount:	$308,015

Abstract: Satellite laser ranging to mid- and high-altitude geodetic satellites (LAGEOS-1, LAGEOS-2, Starlette, Stella, and Beacon-C) will provide a nearly four-decade record of the mass variations at the longest wavelengths, including geocenter

motion (i.e., degree-1). In addition to the length of this time series, it is clear that the second-degree zonal harmonic of the geopotential (C20) is better determined from these data than from Gravity Recovery and Climate Experiment (GRACE) data alone (the GRACE estimates for C20 are affected by long-period, tide-like aliases.) These data, therefore, will also be used during the overlap with the GRACE mission to improve the estimates of the degree-2 harmonics, as well as for estimating the degree-1 harmonics (geocenter) that cannot be determined from GRACE alone. The newly launched laser target, LARES, will be examined as an augmentation to the current set of satellites being used.
Reprocessing the satellite laser ranging (SLR) time series will yield a set of low-degree gravity harmonics (approx. to degree and order 5) consistent with GRACE at the longest wavelengths. Note the synergy in both directions. GRACE provides an accurate mean gravity field model for the higher degree and order coefficients, which enables more accurate geodetic satellite orbits and better SLR results, while SLR provides geocenter and C20 results that GRACE cannot capture as accurately.

Title: *A Comprehensive Study of 3D Shock/Turbulent Boundary Layer Interaction Physics: Flow Morphology and System Dynamics*
Principal Investigator(s): Clemens, Noel T
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Florida State University
Award Number: R01748
Award Amount: $245,050
Abstract: Professor Noel Clemens of the Department of Aerospace Engineering and Engineering Mechanics at The University of Texas at Austin will support the proposed program on shock/boundary layer interactions by performing a comprehensive experimental program to complement the work done at Florida State University and The Ohio State University.
In the work conducted at UT-Austin, we will investigate the flow-field structure and unsteady motions of shock-induced, separated flows of increasing complexity. In particular we will focus on the following interactive flows:
1. Canonical 2D compression ramp interactions of varying strength.
2. Swept compression ramp interactions of varying strength.
3. Swept compression ramp interactions with side-wall influence.
4. Shock-induced separation in a confined geometry with a subsonic downstream boundary condition.
Two facilities at the UT-Austin High-Speed Wind Tunnel laboratory will be used for this study: The High-Speed Wind Tunnel and The Direct-Connect Isolator Wind Tunnel.

Title: *Comprehensive Reduced-order Modeling and Validation for Loads and Flight Stability of a Flapping Wing*

Principal Investigator(s): Sirohi, Jayant
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: New Mexico State University
Award Number: Q01586; 830832-1
Award Amount: $285,000

Abstract: Project Overview: The proposed research is relevant to the Micromechanics Research Center and specifically targets the following thrust areas:

• Mobility, Control, and Energies for the Resource Constrained Systems – Aeromechanics at small scales to enable the design of agile, efficient, gust-tolerant aerial platforms.

• Sensing, Perception, and Processing for Size and Resource Constrained Systems – State estimation, goal recognition, and sensor fusion for navigation.

The goal of the project is to develop a reduced-order, control-oriented aeroelastic model of the dynamic forces produced by flapping wings. In parallel, piezoelectric-shaped sensors will be developed that can measure the modal deformation of the wing and provide feedback for the reduced-order model. This will enable real-time, on-board calculation of the vehicle state and control inputs, increasing the maneuverability, as well as level of autonomy of the vehicle. The focus will be on wings in the size range of large insects and small birds (less than 10-cm wingspan), operating at the corresponding flapping frequency. This project is directly relevant to the MAST vision of developing highly maneuverable aerial vehicles that can operate in confined environments or outdoors in gusty environments. Specifically, the proposed research will address the following areas listed in the solicitation for white papers:

• Methods, models and simulations, sensors, and platforms for increased operational speed, risk tolerance and platform collaboration in complex environments on MAST SvVaP constrained systems

• Low complexity methods with sufficient accuracy for dealing with uncertainty in sensing and operating in complex environments

• Hardware architectures targeted at implementing and accelerating critical MAST relevant algorithms

Title: *Convexification and Real-Time Optimization for Optimal Autonomous Joint Task and Path Planning*

Principal Investigator(s): Acikmese, Behcet
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: DOD-Navy
Award Number: N00014-14-1-0314
Award Amount: $126,044

Abstract: The objective of the proposed research is to develop an analytical and numerical framework to reliably solve complex real-time optimal Joint Task and Path Planning (JTPP) problems onboard autonomous single or multi-vehicle systems. The

proposed effort will develop new methods for the convexification of optimal control and parameter optimization problems associated with JTPP.
Convexification is at the core of our formulation and it is particularly important since it facilitates the use of fast and trustworthy numerical optimization methods (convex optimization) in solving JTPP problems. Leveraging from our recent advances in convexification and real-time custom convex optimization, we propose to develop robust onboard solution methods for complex JTPP problems.
Once Unmanned Aerial, Ground, or Underwater Vehicles (UAV, UGV, or UUVs) are deployed to carry out a given set of missions, the goal is to allocate them to specific tasks and schedule these tasks such that certain mission objectives are optimized while the mission constraints are satisfied. This allocation and scheduling problem must be solved in real-time, based on the available information for the operational environment. We refer to this problem as the task planning problem. The second key problem is the vehicle path planning problem, where the specific control actions and the corresponding state trajectories must be computed in real-time in order to command the vehicle to perform its allocated mission tasks. Ideally, the solutions of both problems must be obtained jointly, the JTPP problem, to utilize the on-board resources optimally while satisfying both the mission constraints and the physical constraints of the unmanned vehicle.
The optimization problems resulting from the autonomous vehicle JTPP are very complex due to the large number of possibly non-convex constraints. Beyond the complexity due to size and nonconvexity, the need for obtaining solutions in real-time without an expert in the loop poses another key challenge. The third major challenge is to adapt the JTPP solution method as the problem parameters change, that is, as the problem priorities and constraints change due to changes in the operational conditions or vehicle capabilities. It is not practical to anticipate and prepare for every possible combination of potential changes for a mission at design time. Hence, autonomous adaption of the real-time planning methods is a required capability for robustly adaptive autonomy.
Different JTPP solution approaches have been proposed in the past. However they are either very problem specific, or they consider numerical optimization, such as nonlinear programming or mixed integer programming, as a "black-box computational tool." The approach of using generic numerical optimization tools is generally not appropriate for real-time computations due to the lack of rigorous convergence guarantees and their excessive computational complexity.
The proposed research will tackle these challenges and provide the necessary algorithmic capabilities by progressing in two complementary research thrusts.
Thrust I – Convexification and Mixed Integer Convex Programming Formulation of JTPP: What are the set of non-convex problem constraints that can be convexified with quantifiably minimal or no loss of optimality? Can the rest of the non-convex constraints be captured effectively using a small to moderate number of binary variables? Leveraging from our recent advances in "lossless convexification" of non-convex path planning problems, this thrust aims to produce analytical results to formulate JTPP problems as real-time tractable Mixed Integer Convex Programming (MICP) problems. Our formulations will keep the number of binary variables to a minimum and will lead to custom Branch and Bound (B&B) methods together with custom convex optimization methods to enable real-time tractability of the resulting MICP problems.

Thrust II – Development of robust, custom, real-time optimization algorithms: What are the challenges of Convexification and Real-Time Optimization for Autonomous Task and Path Planning in adapting modern Interior Point Method (IPM) algorithms of convex optimization together with B&B to solve the MICP problems for real-time solutions of JTPP? How can we automate the IPM customization process and B&B methods as the JTPP problem structure and parameters change during a mission? This thrust aims to develop robust onboard implementable B&B and IPM algorithms customized for real-time JTTP solutions. The algorithm customization aims to increase the computational speed by two to three orders of magnitude relative to generic algorithms by exploiting specific problem structures. Such computational speedups will enable the real-time solution of these MICP problems for JTPP. Since the customization can be done systematically, we aim to automate this process for real-time use. This capability will enable the automated customization of the optimizers to handle the changes in the JTPP problem structure caused by varying mission parameters, ultimately resulting in a resilient and adaptive onboard solution capability for JTPPs.
The proposed algorithmic capability will be demonstrated on real-time processors to verify that they meet the stringent real-time computing requirements. Further, we will present a technology validation and maturation plan to flight-test these algorithms into a higher level of technology readiness.
The expected outcomes include methodologies, computational tools, and insights needed to develop new, scalable solution methods that significantly enhance JTPP capabilities for the U.S. Navy's unmanned vehicle platforms. Such tools will reduce design/certification time and costs, and drastically improve run-time adaptability and flexibility, hence the performance and resilience, of the U.S. Navy's autonomous systems.

Title: *CubeSat Autonomous Rendezvous & Docking Software (CARDS)*
Principal Investigator(s): Lightsey, Glenn
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX13AQ84A
Award Amount: $93,339
Abstract: This task creates spacecraft mission manager software to autonomously (i.e., without direct human operator intervention) maneuver a CubeSat's orientation and position relative to another vehicle in a proximity rendezvous and docking scenario from an initial distance of 1 km to a close in distance of 1 m. The algorithms are tailored for the unique resource and actuation limitations of a CubeSat operating in low Earth orbit. The software will be demonstrated in real-time in the lab using an embedded microprocessor system that has CubeSat flight heritage.

Title: *Main Engine Ignition from High-Area-Ratio Nozzles*
Principal Investigator(s): Tinney, Charles E
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: National Institute of Aerospace
Award Number: T13-6500-UTEX, T.O. #6515UTEX
Award Amount: $212,968

Abstract: The subcontractor will perform the work and services as defined in awarded task orders. The task orders will provide detailed descriptions of the work and activities to be performed and will be issued by the institute contract representative. These activities fall into broad categories as outlined below, but are not limited solely to the activities noted. Individual task order requirements may involve any or all categories of activities.

1. Systems Analysis, Advanced Concepts and Mission Analysis

• Research Objective: Identify and perform studies for decision-makers that provide sensitive information, such as architectures, advanced concepts, and complex systems and technology trades to NASA and other government agencies to enable informed programmatic and technical decisions.

• Key Emerging Technologies:
  - Campaign Assessment tools to enable Mars, Lunar, and other Near Earth Objects
  - Paradigm-shifting systems based on advanced concepts to minimize cost, risk, and improve performance parameters
  - Safe and affordable transportation systems that enable travel between Earth and space (especially beyond Low Earth Orbit)
  - Robotic system technologies that enable immersive virtual human exploration

• Technical Capabilities:
  - Aerospace systems analysis expertise addressing the full spectrum of NASA mission objectives from advanced aircraft design through planetary exploration
  - World-class experts, methods and tools to enable systems analysis in support of any key decision-maker
  - Campaign analysis
  - Mission and trade study analysis
  - Advanced mission and systems design and analysis
  - Life cycle cost and uncertainty analysis
  - Risk analysis
  - Technology assessment portfolio analysis
  - Radiation protection to sustain long duration human presences beyond Low Earth Orbit.

2. Planetary Traversing, Capture and Entry Technology

• Research Objective:
  - Enable planetary exploration through design and development of the following aeroassist elements
  - Precise, safe entry, descent, and landing
  - Accurate, robust aerocapture
  - Aggressive, reliable aerobraking
  - Assured ascent and rendezvous

- Key Emerging Technologies:
  - Robust pinpoint landing with local hazard avoidance
  - Accurate reliable aerocapture
  - A predictive capability for traversing planetary atmospheres
  - Sustainable, renewable exploration systems to expand human presence beyond Low Earth Orbit.
- Technical Capabilities:
  - Optimal trajectory design
  - High-fidelity flight simulation
  - Aerodynamic database development, analysis, and testing
  - Aerothermal analysis and testing
  - Control and guidance algorithm and loads development
  - Aeroshell design
  - Structures and materials

3. Aerosciences

- Research Objective:
  - Exploit innovative flow management to enable development of revolutionary aerospace vehicles
- Key Emerging Technologies:
  - Boomless supersonic flight
  - Precision trajectory and thermal control of entry vehicles
  - Hypervelocity mixing and combustion for air breathing propulsion (M>10) Smart/adaptive aircraft
  - Smart noise suppression for unobtrusive flight for all classes of vehicles (fixed wing and rotary wing) Synergistic system design for safe, quiet, clean, efficient, secure, and affordable commercial transportation
- Technical Capabilities:
  - Flow physics modeling, prediction, and control Aerodynamic testing, analysis, and design Steady and unsteady computational codes
  - Aero and structural acoustics-prediction and control
  - Aerothermal testing, analysis, and design
  - Scramjet propulsion flow path design, testing, and analysis
  - Advanced diagnostics and measurement techniques
  - Sub-scale prototyping
  - Sonic boom minimization techniques
  - Rotorcraft aeromechanics

4. Structures and Materials

- Research Objective:
  - Enable advanced structures and materials research and technology development for all aerospace applications except engines
- Key Emerging Technologies:
  - Intelligent, highly efficient, smart/adaptive structures that significantly improve vehicle aerodynamic and stability performance by adapting to the external environment
  - Nanostructured materials fabricated by nano-scale assembly processes for sensors, microdevices, and microelectronics, and production scale-up to bulk materials

- Biologically inspired materials that exploit self-assembly fabrication processes resulting in highly efficient, functionalized, radiation resistant, and self-healing materials
- Integrated vehicle health monitoring systems utilizing distributed sensors and remote wireless communications for sensor signal recording, data storage, and processing
- Design and develop multi-functional materials/systems to enable new classes of systems

• Technical Capabilities:
  - Advanced materials and processing
  - Analytical and computational methods
  - Nondestructive evaluation
  - Mechanics, dynamics, and durability.
  - Aeroelasticity and unsteady aerodynamics
  - Erectable and deployable structures

5. Intelligent Aerospace Automation and Controls Systems

• Research Objective:
  - Exploit vehicle physics, develop future aerospace system technologies and systems integration synergies to achieve:
    - o Safe, economically viable, transportation of persons or materials from any point on the Earth's surface to any other point on the Earth or to Low Earth Orbit and beyond
    - o The acquisition of data from flight in any planetary-like atmosphere
    - o Support of national security objectives including threat detection

• Key Emerging Technologies:
  - Physics-based automation systems for vehicle-critical applications
  - Self-repairing autonomic systems enabling fully automated vehicles
  - Soft computing - neural nets, fuzzy logic systems, and genetic algorithms based on physical understanding of the system
  - Dynamic, distributed vehicle control and management enabling revolutionary vehicles design spaces or dramatically improved mission performance.
  - Software system safety analysis
  - Intuitive automation support allowing safe and reliable operation of complex aerospace vehicles, including Unmanned Aerial Systems in the National Airspace System
  - Failure detection and identification, real-time system identification and plant modeling, adaptive controls and nonlinear controls, robust multivariable controls, control of elastic and aeroelastic response, guidance methods and optimization
  - A digital airspace with on-demand, affordable, point-to-point air transportation system
  - Virtual research center; virtual cradle-to-grave design, invention, multidisciplinary optimization, certification; efficient knowledge/wisdom acquisition and utilization
  - Advanced cognitive computing, to include:
    - o True, multi-sensory virtual reality
    - o High-fidelity, end-to-end simulation and design
    - o Creative decision-making computers

- Autonomous data mining and analysis

- Key Technical Capabilities:
  - Vehicle dynamics – mathematical modeling, configuration assessment, and phenomenology characterization
  - Control and guidance algorithm and system development
  - Safe, high integrity real-time digital systems (including software) High integrity, high reliability autonomous vehicle systems
  - Specification, verification, and validation of mission critical software systems
  - Electromagnetic modeling, prediction and assessment, including interference effects
  - Advanced radar and radiometer sensors for aircraft and spacecraft application
  - PiloVautomation integration technologies, crew station design methods, and vehicle operations concepts

6. Atmospheric and Vehicle Sensor System Technology

- Research Objective:
  - Develop advanced sensors and measurement technology to enable the exploration of the Earth and Solar Systems and the development of revolutionary aerospace vehicles and systems
  - Adaptive and self-organizing sensors of physical and chemical phenomena
  - Highly accurate, precise spectroscopic and radiometric measurement technology
  - Advanced instrument concepts (reduced mass, power, and volume)
- Key Emerging Technologies:
  - Self-Organizing Networks of Sensors with highly integrated structure, sensor, and processing systems to enable incorporation of knowledge into aerospace vehicle operations
  - Multi-functional sensor systems with integrated "processing to solutions" capability
  - Adaptive and self-organizing sensors of physical and chemical phenomena
  - Highly accurate, precise spectroscopic and radiometric measurement technology
  - Advanced instrument concepts (reduced mass, power, and volume)
- Technical Capabilities:
  - Advanced atmospheric remote sensing concepts and instrumentation
  - Advanced laser materials and electro-optical systems technology development
  - Multidisciplinary engineering and synergistic capabilities including lasers, optics, detectors, thermal, structural, and data systems

7. Atmospheric Chemistry, Climate, and Radiation Science

- Research Objective:
  - Provide understanding of key atmospheric processes and trends through a portfolio of measurements and atmospheric modeling, analysis, and prediction
  - Identify emerging scientific technologies Conduct space-based observations
  - Develop predictive models
  - Develop advanced instrument and data processing technologies
- Key Emerging Technologies:
  - Cloud and aerosol micro-physics for climate modeling
  - Three-dimensional coupled climate chemistry modeling for climate prediction
  - Remote sensing technology to enable observations from all orbits

- Measure, analyze, and model key components of Earth's atmosphere
- Required Technical Capabilities:
  - Remote sensing technology development
  - Field observations of key physical processes and satellite data validation.
  - Large-scale scientific information systems
  - Small satellite systems
  - Advanced atmospheric measurement, modeling, analysis, and prediction technique

Title: *Gravity Recovery and Climate Experiment (GRACE) Extended Mission*
Principal Investigator(s): Tapley, Byron D
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNL14AA00C
Award Amount: $6,784,282
Abstract: INTRODUCTION

1.1 This Statement of Work (SOW) defines the work to be performed during a follow-on of the current GRACE contract, NAS5-97213, with The University of Texas at Austin Center for Space Research (UTCSR). The GRACE mission was extended as a result of the NASA Headquarters Senior Reviews in 2007, 2009, 20011, and most recently, in 2013. This contract will continue work as proposed and approved by the 2013 NASA Headquarters Senior Review mission extension.

BACKGROUND

In 1997 the Office of Mission to Planet Earth (currently known as the Earth Science Division) at NASA Headquarters, after a rigorous, two-phased selection process, selected UT under the direction of the PI to design, develop and operate the GRACE mission. The GRACE Mission is a joint effort between NASA and the DLR (Deutsches Zentrum für Luft- und Raumfahrt, i.e., German Aerospace Center). The Principal Investigator also represented NASA in the negotiation of the Memorandum of Understanding (MOU) between NASA and DLR outlining the cooperative efforts required for GRACE mission success.

This joint effort involves oversight and participation in mission planning and operations, science algorithm and software development and maintenance, validation and data product generation, distribution and archival, science community user support, communication and public engagement and publication of results in scientific journals and technical meetings in support of the GRACE Mission. The GRACE Mission produces a new model of the Earth's gravity field on approximately 30-day intervals. This 30-day sample allows for the determination of both a high-accuracy static field (or mission average mean field) and its time variations at monthly intervals. The GRACE Mission will continue to define the gravity fields by flying two polar-orbiting satellites in a loosely controlled tandem formation. Variations in the Earth's gravity field, resulting from variations in the Earth's mass distribution, will cause the distance between the two satellites to vary. This variation will be measured with a precision better than 1.0 microns by a microwave link between the two satellites. The position of each satellite is determined by using GPS measurements collected onboard each satellite. Analysis of this data has resulted in numerous advances in earth science relating to oceanography, land surface hydrology, and observation of polar ice mass change. The measurements collected by the GPS Radio Occultation Co-Experiment have been recognized as an important input for numerous international Weather Prediction Models. In addition, the 2013 NASA Senior Review process acknowledged the value of mass flux observations being operationally assimilated into hydrological models to support analysis of regional hazards, such as floods and drought.

Title: *ARMADILLO Flight Unit*
Principal Investigator(s): Fowler, Wallace T
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: DOD-Air Force
Award Number: FA9550-13-1-0216
Award Amount: $110,000
Abstract: I. Background
The University of Texas at Austin (UT-Austin) Texas Spacecraft Lab (TSL) was selected as the winner of the University Nanosatellite Program (NS-7) competition in January 2013. The national competition is held by the Air Force Office of Scientific Research (AFOSR) and Air Force Research Lab (AFRL). The winner of the competition is provided with two years of additional funding and technical support to enable the winning institution to build and launch its designed satellite. UT-Austin's satellite entry is known as ARMADILLO: Atmosphere Related Measurements And Detection of submILLimeter Objects. This proposal requests the two additional years of funding that are provided to the winner of the NS-7 competition. The funding will be used to procure all the necessary hardware to assemble and integrate the ARMADILLO Flight Unit satellite, which is expected to be launched in 2015.
Under the terms of this proposal, The University of Texas at Austin will perform the following tasks:
1. Design, fabricate, and test a working version of the ARMADILLO Flight Unit in its Texas Spacecraft Lab.
2. Work with University Nanosatellite Program (UNP) personnel to ensure that the ARMADILLO satellite meets all UNP requirements.
3. Provide ongoing development and test support through the ARMADILLO preflight environmental qualification and testing.
4. Support all meetings and project requirements as necessary.

Title: *Density Control: A Decentralized Control Paradigm Enabling Coordinated Autonomous Vehicle Swarms*
Principal Investigator(s): Topcu, Ufuk
Department, Center, or Institute: Institute for Computational Engineering and Sciences
Institution: The University of Texas at Austin

Discipline: Applied Research
Funding Agency: DOD-ARPA
Award Number: D14AP00084
Award Amount: $622,961

Abstract: Innovation: The objective of this proposal is to develop an adaptive architecture and the core algorithmic capabilities necessary to coordinate and control swarms of hundreds to thousands of autonomous vehicles via swarm density control. Our approach is based on the breakthrough idea of designing Markov chains that govern swarm behavior to satisfy high-level mission goals in a decentralized, on-board-implementable architecture, while balancing resource use across the swarm. This approach breaks away from traditional swarm control methods that control individual vehicle motions directly and in a tightly coupled manner to achieve the desired swarm behavior. Instead, we control the overall swarm motion directly by synthesizing a Markov chain that is used by each vehicle to determine its own motion commands independently and as a function of its state. Hence, vehicle motion commands are generated locally in a decentralized manner. Each vehicle makes independent motion plans to follow these commands, which result in the desired swarm behavior/motion. This approach is made feasible by our recent breakthrough in formulating the swarm control problem as a density control problem. In this framework, swarm density evolves as a Markov chain over the operational space, i.e., the Markov chain acts as a control policy to guide the overall swarm. The design of Markov chains that meet mission constraints and specifications, and optimize mission goals is based on our recent discoveries in the convexification of these design problems.

Title: *An Investigation into the Unsteadiness of Tvashtar's Plume*
Principal Investigator(s): Trafton, Laurence M
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX14AO39G
Award Amount: $279,554

Abstract: High-quality panchromatic images of Tvashtar, a Pele class active plume, were obtained by the Long Range Reconnaissance Imager (LORRI) during the New Horizons (NH) flyby of Io on Feb. 28 to March 3, 2007, and are calibrated and available in the Planetary Data System (PDS). These NH images of Tvashtar, which have among the best plume resolution observed during any mission, constitute the first and only time-series imaging of extraterrestrial volcanic plume activity. They record several instances of an asymmetric canopy wave traveling down on only one side of the plume and an evolving organized discrete particulate pattern that reflect the unsteadiness at the vent and condensation in the upper spout and canopy. The particulate properties are poorly known, especially the extent to which entrained particles are refractory vs. condensed plume gases. We propose to exploit these unique images to gain insight into Tvashtar's unsteadiness by constraining the time and length scales of processes in the spout and at the vent using a time-dependent DSMC simulation of the unsteady behavior for a large Io

plume. Our objective is to gain insight into the non-axisymmetric process giving rise to the unsteadiness of Tvashtar's plume; and thence, to understand in this context the origin of the asymmetric traveling wave and the organization of the discrete structure. Our specific goals are as follows:

- Measure the period and projected accelerating length scale of the lone descending notch and bump ("wave") in Tvashtar's tangential canopy; and measure the similarly accelerating projected characteristic length scales of the descending organized discrete structures ("filaments") in Tvashtar's plume.
- Estimate the length and frequency scales of the unsteadiness of Tvashtar's vent and spout, using simulations of small eddies propagating from the unresolved vent and constraining these eddies to produce the observed time and length scales in the canopy.
- Investigate through simulation the efficacy of unsteady pulsing of gas rising in the expanding spout (as constrained above) on organizing particulate structure in the canopy. Compare the canopy particulate patterns formed by condensates generated in the spout within periodic gas density pulses that are therefore periodically deposited in the expanding canopy, with the patterns formed by the periodic enhanced deposition of refractory particles (which could be out of phase with the gas fluctuations if the refractories fail to track them.) Verify whether condensation dominates the particle complement of the plume.
- Assuming the above length and frequency scales traced back to the vent, constrain the unsteadiness of the unresolved venting process using parameterized fire fountain and lava lake models with introduced axial asymmetry, as required by the lone traveling wave.

This proposal aligns with the goals and objectives of the ORP program by modeling a dynamical process (unsteady volcanic plume activity on Io) and enhancing the scientific yield of the Io flyby portion of the New Horizons mission.

Title: *Plasma-Based Reconfigurable Photonic Crystals and Metamaterials*
Principal Investigator(s): Raja, L L
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Stanford University
Award Number: 60803373-114411
Award Amount: $361,367

Abstract: A comprehensive computational modeling effort will accompany most of the experimental studies described in this proposal. The UT-Austin group (Raja) has developed significant expertise in the high-fidelity modeling of high-pressure microdischarges, atmospheric pressures plasma jets, microwave-sustained plasmas, and wave-plasma interactions; all of these topics are of relevance to the research addressed in this proposal. The goals of this effort are as follows:
1) Provide a physics-based description and optimization of plasma discharges being studied.

2) Provide an understanding of nonlinear mechanisms of plasma-EHF/THz wave coupling and the resulting plasma properties and its impact of device lifetime.
3) Provide understanding of gas breakdown mechanisms within embedded cavities in PMM and PPC architectures.

Title: *Rapid Structural Analysis Methods from OpenVSP Geometry*
Principal Investigator(s): Chaput, Armand J
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: National Institute of Aerospace
Award Number: T13-6500-UTEX, TO No. 6528-UTEX
Award Amount: $66,146
Abstract: Background. Advanced aircraft concepts, both manned and unmanned, are being pursued that require advanced modeling tools and techniques for vehicle developmental research, as well as sub-scale validation of key enabling attributes. Tasks are outlined that will provide improved capability through the conceptual design of transformational flight vehicles, along with fabrication and testing of a sub-scale prototype with specific efforts into enabling technologies, such as advanced/rapid structural modeling, multi-body simulation and advanced control system algorithm development.
Research Objectives. The objectives of this research are as follows:
- Develop and validate advanced/rapid structural analysis methods from existing Open Vehicle Sketch Pad (VSP) analysis tools.
- Develop, improve, and validate Distributed Electric Propulsion (DEP) tools that can analyze closely coupled aero-propulsive effects.
- Develop dynamic analysis methods and results relating to the Tethered CentriFugally-Stiffened (TCFS) concept; develop flight control algorithms for a multi-body advanced concept; design, develop, fabricate and bench test subscale proof of concept vehicles to validate the new analysis methods.

Title: *Guidance and Control Architecture Design and Demonstration for Low Ballistic Coefficient Atmospheric Entry*
Principal Investigator(s): Acikmese, Behcet
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX14AE87A
Award Amount: $89,999
Abstract: We propose to develop an active guidance and control (G&C) system for ADEPT (Adaptable Deployable Entry and Placement Technology) aeroshells to accomplish lift-guided aerocapture and entries in Venus, Mars, and other planetary missions. Currently, an ADEPT vehicle is being developed as a lander for Venus missions, and an aeroshell is integrated as a passive drag generating decelerator and thermal protection system for a ballistic entry. An active control scheme using

deployable aerosurfaces for large payloads, as proposed here, has not been demonstrated in practice. In addition to developing an actuation mechanism concept for the aeroshell, we will implement a control-centric dynamic model that incorporates the coupled aerodynamic effects. Recent advances in convex optimization solvers and constrained reachability analysis allow us to quantify the set of all reachable planetary orbits in each mission scenario. This technology enables the ADEPT vehicle to act as both a lander and an orbiter for future Venus missions.

Title: *New Approaches to Understanding Roughness-Induced Transition*
Principal Investigator(s): Goldstein, David B
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: DOD-Air Force
Award Number: FA9550-15-1-0345
Award Amount: $183,464
Abstract: Boundary layer transition often occurs due to small surface roughness that introduces disturbances, which grow and spread. We propose a new two-pronged attack on receptivity, transition, and near-wall turbulence control using a unique combination of recently developed DNS and matched experimental techniques. By attacking receptivity, we aim to delay transition when the least energy is required for control. Eventually, transition is inevitable at high Reynolds numbers. We, thus, will study how to limit spreading nascent turbulent wedges into fully developed turbulence. We have recently shown that it is possible to partially cancel steady disturbances created by roughness by introducing opposite-sign vorticity using "anti-roughness" or to introduce smaller-scale distributed roughness that cloaks the larger roughness. The later technique would be especially promising as a means of preconditioning a laminar-flow surface to prevent later fouling in operation that would interrupt laminar flow. We propose to obtain a more general, more fundamental understanding of roughness receptivity and how to exploit that knowledge to mitigate roughness-induced disturbances before they generate transition. Large roughness elements cause a wedge of turbulence, and transition often occurs through a merging of turbulent wedges. The turbulence spreads by tilting and turning of the background spanwise vorticity through a sequence of quantized events. The spreading mechanism occurs close to the wall, along the wedge edge, through stepwise increments in wedge width. Obliquely propagating coherent structures occur in the center of the wedge and in turbulent channel flow. These structures propagate at the same angle as the wedge, suggesting a commonality between the more easily isolated wedge spreading mechanism and the near-wall turbulence cycle. We propose to study turbulent wedge physics in its own right and also as a simplified proxy for fully turbulent boundary layers.

Title: *Scoping Requirements and Technology Needs for a Drag-free System for Next Generation Gravity Field Missions*

Principal Investigator(s): Bettadpur, Srinivas V
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: California Institute of Technology (Cal Tech) Jet Propulsion Laboratory
Award Number: RSA 1515297
Award Amount: $50,000

Abstract: Proposal Objectives and Approach: The Gravity Recovery and Climate Experiment (GRACE) Follow-On mission, scheduled for a 2017 launch, will continue the now invaluable, global time series of mass transport across Earth, and it is hopeful that it will achieve slightly better performance than its predecessor, GRACE, via improved instrumentation, in particular using a laser interferometer for the intersatellite ranging. Previous studies have indicated that the GRACE Follow On will likely be primarily limited in spatial resolution by a combination of temporal aliasing errors (undersampling high frequency geophysical signals), as well as the accuracy with which one can remove the effect of non-conservative forces from the data using the on-board accelerometer (Loomis et al, 2011; Wiese et al 2011a). The accelerometer error is expected to be the dominant source of measurement error for a mission with similar error characteristics as the GRACE Follow On for long wavelength geophysical signals. If the accelerometer is removed in favor of a drag-free system, the performance at low frequencies improves. Note that this analysis does not include the effect of temporal aliasing errors; however, Loomis et al. (2011) clearly show in their manuscript that flying drag-free with a laser interferometer leads to more accurate gravity fields than flying GRACE-like accelerometers with the laser interferometer. This result implies that the accelerometer contributes in limiting the performance of the mission. Recognizing that future missions that do fly drag-free will likely be limited in performance by temporal aliasing errors, Wiese et al. (2011b, 2012) showed that such errors could be lowered via the introduction and optimal placement of a second pair of satellites in an inclined orbit (this architecture is referred to here as GRACE-2) coupled with sophisticated data processing algorithms (Wiese et al., 2011a). The addition of a second pair of satellites in a lower-inclined orbit reduces the effect of aliasing errors substantially at the higher degrees. This reduction in aliasing errors, coupled with the lower measurement noise that laser interferometry and the drag-free system provide, results in substantial improvements in the accuracy, and spatial and temporal resolution of the derived gravity fields (Wiese et al, 2011b), offering an 80 percent reduction in overall error, and improving basin-scale mass estimates anywhere from 25 percent to 75 percent depending on the location. While this study was quite informative regarding the expected performance of the GRACE-2 architecture, there were some limitations that we want to address in this proposed effort. First, the drag-free system error was not modeled in a realistic fashion. Errors were ingested as range-rate measurement errors, rather than treating them as an error in removing a non-conservative force. Second, there are still open questions as to what performance requirements are actually needed for either accelerometers or a drag-

free system to achieve the desired accuracy and resolution that is expected from a GRACE-2 architecture. It is useful to note that flying drag-free has the additional benefit of allowing for lower mission altitudes, which can greatly improve the spatial resolution of the gravity field maps, making possible observations of a greater diversity of geophysical mass-flux signals. As such, it is useful to separate the scientific benefits that are realized through a lower-mission altitude, versus the lower measurement error associated with the drag-free system.
The key research objectives of this study are, therefore, as follows:
1) To establish performance requirements for a drag-free system and/or an accelerometer for removal/measurement of non-conservative forces for future GRACE-2 architectures.
2) To establish if such performance can be met with existing technology.
3) Identify development or mission realization pathways going forward.
The expected deliverables from this project will be in the form of a journal article outlining in detail the expected accuracy and spatial and temporal resolution of the derived gravity fields from a GRACE-2 architecture using both a drag-free system, as well as accelerometers for the removal of non-conservative forces. It will also include recommendations for any necessary technological innovations to maximize the scientific return of the mission.

Title: *Onboard Autonomy, Coordination, and Coverage Algorithms for Spacecraft Swarms*
Principal Investigator(s): Akella, Maruthi R
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX14AK46A
Award Amount: $199,122
Abstract: The primary goals of this research proposal are toward establishment of onboard autonomous coordination and coverage algorithms to enable satellite swarm operations. A highly focused three-year study is envisioned. One of the most crucial requirements for autonomous spacecraft swarms is to maintain coordinated flight among physically distinct (heterogeneous) elements, while at the same time being capable of self-optimization and collision avoidance. This proposal significantly builds upon certain novel control theoretic consensus approaches recently formulated by the Principal Investigator. The most salient feature of these autonomy algorithms is that they have the potential for enabling tens and scores of satellites to perform coordinated maneuvers for coverage and collision avoidance in a fully decentralized setting. Mathematical tools from spectral graph theory are introduced to model inter-agent information exchanges and also time/state-dependent changes within the communication topologies. The satellites within the swarm can be viewed to follow rules of "avoidance" from each other and "gather" to maintain the prescribed coverage functions according to pre-defined artificial potential functions. The coverage analysis will additionally seek the implementation of realistic models for onboard vision/imaging systems. Also as part of the proposed study, various distributed path-planning (swarm reconfiguration), coverage maintenance, and collision avoidance strategies will be

compared for CubeSat class of satellites using the following metrics: delta-V spend during maneuvers (or fuel use during continuous finite thrusting), time required for swarm to re-configure to a different operational mode, and distance of closest approach within the swarm cluster.

Title: *Integrating Gravity Recovery and Climate Experiment (GRACE) and GRACE Follow On Data into Flood and Drought Forecasts for the Continental U.S.*
Principal Investigator(s): Bettadpur, Srinivas V
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX15AD24G
Award Amount: $104,325
Abstract: By now, the significance of the 12+year data record of global mass flux variability from the joint US/German GRACE mission is very well established through several studies of the global and regional water cycle processes. Assimilation of the operational GRACE data products, available with some delay, into land-surface models is progressing through early stages of research. The next frontier in this area is the assimilation of the low-latency, near-real time GRACE and GRACE Follow-On data products into the flood and drought forecasts activity.
In this effort, we propose to research aspects of the problem of production and utilization of low-latency GRACE and GRACE Folllow-On mass flux data products pertinent to: (i) the consistent creation and representation of total water storage information from the two missions specific to the continental US domain of this proposal, (ii) their respective error estimates, and (iii) the suitable representation of this data for its assimilation into a land-surface model. The outcomes of this research will lead to: (i) the extraction of the mass flux to greatest sensible spatial-temporal resolution specific to this domain and application, and (ii) a seamless transition of the use of data from GRACE to the GRACE Follow-On mission.

Title: *Solid-State Shear Sensors for High-Speed, High-Temperature Flow Applications*
Principal Investigator(s): Tinney, Charles E
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Silicon Audio Labs, (SA) Inc
Award Number: UTA15-000007
Award Amount: $90,000
Abstract: Major Project Tasks: The following Gantt chart outlines all major project tasks.
Task
1. Design and tape-out sensors (UT-Austin, Dr. Hall)
2. Microfabricate sensors (UT-Austin, Dr. Hall)
3. Sensor packaging for laboratory evaluation (SA)
4. Laboratory evaluation of sensor bandwidth (SA)
5. Laboratory evaluation of shear stress sensitivity (SA)

6. Rigorous Experimental characterization of sensitivity vs. temperature in controlled environment (SA)
7. Packaging of sensors for high speed flow test (UT-Austin, Dr. Tinney)
8. High speed flow measurements (UT-Austin, Dr. Tinney)
9. Preparation of final reports and samples for sponsor

The models that have been developed will be applied to the design of the sensors to meet all required Air Force specifications. Ultimately, these designs are manifested in a mask-layout (i.e., tape out), which defines all relevant sensor dimensions in the microfabrication process. In Task 2, sensors will be fabricated using an already established process flow in Dr. Hall's group at UT-Austin. Once fabrication is complete, sensors will be packaged for laboratory evaluation, per Task 3 in the Gantt chart. Tasks 4-6 describe component-wise evaluation in controlled environments (i.e., in non-aerodynamic environments). Evaluation of bandwidth and sensitivity (Tasks 4 and 5) will be based on reciprocal methods in which the sensor is actuated in shear by applying a swept AC actuation voltage, while the resulting lateral displacement of the top surface is measured using laser Doppler vibrometry. This measurement enables a system-identification to be performed on the sensor so that all critical system parameters are known. In turn, the measurements enable assessment of sensitivity in the sensing mode, taking advantage of the reciprocal nature of piezoelectric transducers. Measurements on preliminary prototypes are provided in subsequent sections of this proposal.

Task 6 is also a component-wise evaluation in which a pressure sensor with non-overlapping electrodes will be mounted on a surface capable of achieving 1,200 K (non-aerodynamic environment). The pressure-sensor will be biased with 5-V DC while a small AC signal (500 mV) is applied to actuate the sensor using the ferroelectric modality. A remotely positioned laser Doppler vibrometer (LDV) will record the sample's velocity and displacement at several controlled temperatures. 50-K increments will be used as the temperature is ramped up from room temperature to 1,200 K. Again, via reciprocity of the ferroelectric sensor system, results from these tests will be used to assess the sensitivity of the sensor vs. temperature. The high temperature environment will be constructed using either special high-temperature furnaces with optical access in Dr. Hall's MEMS processing laboratory, or by testing over a propane torch. In either case, temperature readings will be recorded using a standard thermocouple. The maximum adiabatic temperature of a propane torch using air is 2,268 K. We intend to explore several materials in Phase I. Our first material will be a composition of lead zirconate titanate (PZT) which is very common in piezoelectric modalities due to high remnant polarization. Newer materials specifically developed for high temperatures will be evaluated including Langasite (La3Ga5Si014). Findings from these high-temperature tests will confirm the accuracies of the electric circuit models used to design the sensors at said elevated temperatures. Silicon Audio has extensive experience in developing accurate electrical circuit models for predicting the outputs of numerous sensors types.

In Task 7 and 8, completed sensor prototypes will be mounted flush to the floor of a Mach 5 wind tunnel located at UT-Austin; total temperatures are on the order of 350 K (cold). Transducer outputs will be recorded at 2-MHz sampling rate. The static shear stress at the wall of the test section is estimated to be 60 Pa, based on isentropic equations.

Finally, as summarized in Task 9, all final reports and presentations will be prepared for the sponsor.

Title: *Numerical Modeling of Europa Plumes*
Principal Investigator(s): Goldstein, David B
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: California Institute of Technology (Cal Tech) Jet Propulsion Laboratory
Award Number: RSA 1510016
Award Amount: $90,068

Abstract: Roth et. al 16 recently interpreted Hubble Space Telescope (HST) observations of aurora around Europa as indicative of a south polar plume of water vapor having temporal variation correlated with orbital phase. Since Europa is believed to have a thin icy crust overlying a deep water ocean, the presence of a plume exposing oceanic samples to direct spacecraft study represents exciting possibilities. By studying such a plume and its source region(s) with the Europa Clipper, one might learn the physical conditions near the top of the ocean (water temperature, salinity, and pressure), the chemistry, and possibly search for signs of microbial life. One might also learn about the nature of the conduit from the putative ocean to the surface: whether it is short and straight or long and convoluted, whether the plume material was percolated through a porous medium, or even if the source is simply some shallow pool and not the ocean itself.

The reported plume height of -200 km is consistent with that of vapor expanding into vacuum from a water vapor source at the triple point of water, 273 K, but subject to energy loss in its passage to the surface (e.g., friction, heat, and mass exchange in the passageway). But the plume details are missing. Is the plume quasi-steady – having a constant mass flow on a ballistic time scale of -1500 s? Is the mass flux sufficient for the flow in the plume to be collisional? The flow may be collisional near the vent but rapidly transition to free-molecular as it expands into the vacuum of space. This is the situation on Enceladus. If the vent mass flow is greater than Enceladus, then molecules descending under the influence of gravity may interact with the rising molecules and form a canopy shock wave. This process occurs in volcanic plumes on Io. And if there are several nearby source regions, the plumes may interact and be turned through complex shock structures. Plume-plume interaction appears to occur on both Enceladus and Io.

The Europan plumes may contain particulates (perhaps indicated by dark deposits surrounding old vents along some linae). On Io volcanic plumes contain S02 and Sn condensates, as well as ash, while on Enceladus the predominantly water vapor plumes contain ice grains or water droplets, some of which contain salt. On Io and Enceladus some of the particulates move substantially differently from the vapor, and their paths depend on their size, how they originated, and how they interact with the vapor.

The vapor and possibly particulate plume arising from the southern polar regions of Europa are a key signature of what lies below the surface. Multiple instruments, perhaps like those carried by Cassini to Saturn, may measure the gas-particle

plume over the source region and provide details of the surface features. Modeling of what may be expected from the plumes is crucial to mission success, as it aids selection and design of instruments and ensures the safety of the spacecraft. The most likely source for Europan plumes is a subsurface liquid reservoir of somewhat saline water and other volatiles boiling off through crevasse-like conduits into the vacuum of space. Observations of interest will largely focus on inferring subterranean conditions and processes driving the plumes and determining the chemistry of vapor and particles.

While we can make analogies to Enceladus and Io plumes, we are impeded by a lack of well-constrained boundary conditions for modeling an Europan plume. We can reasonably assume a water/vapor/particulate flow through crevasses and similar subsurface conditions, as on Enceladus. Above the surface the thermal, gravitational, radiative and plasma environment will be more similar to conditions on Io. To bring the pieces of the puzzle together requires simulation of the physics. With detailed physical modeling, we can aid in long-term planning for future missions to that most interesting satellite.

Our long-term goal is to develop detailed insight into the sources of the plumes rising from Europa to better understand the plume formation, the subsurface environment, the evolution of the body, and to relate the plumes to the sea below and to aid mission planning. Our objective in the current proposal is to perform a preliminary study of possible Europa plume scenarios, using what we have learned about Io and Enceladus, and to aid in the instrument design and selection for a Europa Clipper type of mission.

To pursue our objective, we propose two specific goals:

Goal 1: To provide to the community a baseline simulation of a plausible Europa plume. The simulation can include the complex physical phenomena we have already simulated for the Io and Enceladus plumes: transition from continuum to rarefied flow, water photo-chemistry, three dimensional gas dynamics from multiple vents, coupled movement between vapor molecules and solid grains, tracking trace species, charged particle impact from the Iovian plasma torus, etc.

Goal 2: To quantify the sensitivity of the computed values of observed quantities to the values assumed for the physical parameters input to the models to determine which parameters are the most sensitive and thus may be best constrained by observation through a spacecraft mission. For example, peak H2O column density observed by stellar occultation may be sensitive to the spreading angle of the plume's orifice but not to the photo-dissociation rate.

Title: *Collaborative Architectures for Unmanned Air Systems within Denied Environments*
Principal Investigator(s): Akella, Maruthi R
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Leidos Inc.
Award Number: PO10167703
Award Amount: $125,000
Abstract: Background: DARPA is soliciting innovative research proposals in the area of advanced collaborative autonomy for aerial platforms as described in their Broad

Agency Announcement (BAA) titled "Collaborative Operations in Denied Environment (CODE)." Solicitation Number: DARPA-BAA-14-33. The Government is using a phased acquisition approach for the CODE program. Phase 1 will be focused on developing CODE system level analysis, system architecture, system design, and the assessment of critical technologies. Track A is for system integrators, who will be invited to bid on Phases 2 and 3 based upon the results of their Phase 1 activities.

Title: *Convex Optimization to Support the Generalized gUidance, Navigation & Control Architecture for Reusable Development program (GUARD) Project*
Principal Investigator(s): Acikmese, Behcet
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Scientific Systems Co., Inc (SSCI)
Award Number: 1597-UTA
Award Amount: $29,500
Abstract: We will provide support for the SSCI proposal by Dr. Jovan Boskovic to develop a convex optimization based framework and preliminary algorithms for autonomous proximity operations. This proposal responds to the NASA SBIR/STTR 2014 solicitation.
Task 1: Development of Matlab-based simulation environment capturing the relative dynamics of two spacecraft in a planetary (Earth) orbit. The simulation model will contain models of spherical and J2 gravitational, and aerodynamic drag forces.
Task 2: Development of convex optimization-based, proximity translational path-planning algorithms, which are based on the high-fidelity linearized models of the relative spacecraft motion. The path planning will incorporate control and relative state constraints, and will minimize fuel use. We will also explore real-time implementation of the algorithms via custom Interior Point Method algorithms of convex programming.
Task 3: Development of feedback control algorithms to track the optimized trajectories in the presence of uncertainties and disturbances. They will provide robustness to modeling uncertainties.
Task 4: Analyze high-fidelity simulation results generated by SSCI. This effort will feed into our support of Phase II proposal preparation effort.

Title: *Capstone Marketplace – UT-Austin*
Principal Investigator(s): Chaput, Armand J
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Stevens Institute of Technology
Award Number: RT 131-UT Austin-20141029
Award Amount: $10,000

Abstract: Research, develop, and implement new tools and resources within or available through the marketplace website to better enable outreach, participation, partnership, scale-up and transition.
1. Collaborate with UT=Austin researchers to develop informational and/or instructional resources that integrate processes, methods, and lessons learned from their Systems Engineering Design Course Initiative. These resources will be added to the Capstone Marketplace website for academic use by traditional and systems engineering related academic discipline students, faculty, and project sponsors.
2. Research the means to, and begin the development of, SE requirements for capstone engineering projects for accreditation organizations.
3. Investigate a clear path to transition to a non-SERC entity of a scalable, robust, and stand-alone Capstone Marketplace.

Title: *Phase II Holistic resident space objects (RSOs) Awareness Algorithms*
Principal Investigator(s): Russell, Ryan P
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Emergent Space Technologies, Inc.
Award Number: UTA14-001102
Award Amount: $72,856
Abstract: Objective: The ultimate goal of this project is to provide the U.S. Air Force (AF) with algorithms capable of processing and fusing space surveillance data with improved abilities to detect, track, identify, and characterize RSOs. In Phase II we continue research and development (R&D) of our algorithms and integrate and test them in the Air Force Research Lab (AFRL) Ananke environment using simulated observations and, if provided by AFRL, real-world observations.
Scope: The objectives and anticipated results of Phase II are as follows:
1. Adaptive HME Learning Parameter. Develop and test a method to automatically adjust the HME learning parameter.
2. HME with Multiple Bidirectional Reflectance Distribution Function (SRDF) Models. Implement and test the HME with banks of different BRDF models
3. Advance Finite Set Statistics (FlSST) Research. Research, implement, and test non-Gaussian propagation and estimation, tracklet generation for target birth, RSO-dependent detection probability, and a parallelized FISST multi-target filter.
4. Advanced Propagation Methods. Research, develop and test advanced methods of propagating 3-degrees-of-freedom (3DOF) and 6-degrees-of-freedom (6DOF) spacecraft motion and uncertainty.
5. Integrate and Test (I&T) HME, FISST and Advanced Propagation. Integrate our HME with advanced propagation and FISST-based algorithms and test their effectiveness in the AFRL Ananke environment with simulated and, if provided by AFRL, real-world observations.

Title: *ES-Ma Te: Efficient Sensor Management for Optimal Multi-task Performance*
Principal Investigator(s): Akella, Maruthi R
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Knowledge Based Systems Inc
Award Number: 5351.250-UTA-2015-1
Award Amount: $106,450
Abstract: Proposed Tasks for UT-Austin:

1. Define the scope of Quality of Service (QoS) prediction problem.
   a. Define the multi-dimension QoS metric and structure, define dynamic constraints and relationship between QoS and sensor measurements.
2. Establish QoS propagation methodology.
   a. Investigate and formulate QoS propagation approach.
   b. Establish the correctness of the formulation.
   c. Propose method for verification and validation of the QoS propagation approach.
3. Sensor resource allocation for QoS management.
   a. Methodology for optimizing expected QoS4. The expected deliverables will be:
   a. Quarterly progress reports; and
   b. Final Technical Report at the end of period of performance.

Title: *Development of an Inductively Coupled Plasma Torch Facility for Research on High-Temperature Materials*
Principal Investigator(s): Varghese, Philip L
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: NASA
Award Number: NNX15AH17A
Award Amount: $470,000
Abstract: We propose to develop an inductively coupled plasma flow facility that will enable research and development of high-temperature materials, and research on non-equilibrium, gas-surface chemical reactions occurring during high-speed re-entry into planetary atmospheres. The proposed high-temperature flow facility will enable research into a range of areas and enable new opportunities for further work in extreme environments. The facility that will be developed is a 50 kW inductively coupled plasma (ICP) torch, which will operate continuously and produce temperatures up to 10,000 K. When spacecraft enter a planetary atmosphere, shock and friction heated non-equilibrium atmospheric gases (at 3,000 K or more) interact with the vehicle surface thermal protection system (TPS) that is commonly ablative. Candidate TPS materials of interest to NASA include epoxy novolac resins (Avcoat) and phenolic-impregnated carbon (pica). TPS performance depends critically on processes that characterize gas-TPS surface interaction, which may include surface-catalyzed recombination reactions, nitridation and oxidation reactions with TPS material, in-depth diffusion of gas

species into the TPS, and solid-phase chemistry, among others. Furthermore, current models sometimes predict features that are not observed in arcjet tests, or fail to predict features that are observed. It is clear that better understanding of the physics of high-temperature ablation, and improved validation of models, is required before TPS margins can be reduced.

The proposed facility will provide the capability to obtain quantitative experimental data that will enable development and validation of models for the thermal response of candidate TPS materials. The free-stream flow will be free from metallic contaminants typical of arc-jet flows. The free-stream gas will have controlled composition, variable oxygen levels, controlled heat flux, and its thermodynamic state will be well characterized by laser-based optical diagnostics. Spontaneous Raman scattering will be demonstrated for absolute concentration measurements of major species, and laser absorption for minor species. Laser-induced fluorescence measurements will be used for measurements of selected trace species. Thermal non-equilibrium of the free-stream will be measured quantitatively using quantum state-resolved high dispersion Raman spectroscopy, so that its effect on observed reactions can be assessed. The ablation products from materials exposed to the high-temperature gas will be measured quantitatively using optical diagnostics and gas-sampling probes. The proposed ICP facility will enable improvements in TPS modeling capability, and the increased confidence in the models will result in reduced design margins for thermal protection systems. The practical consequence would be significant savings in structural weight of spacecraft.

Title: *Texas Space Grant Consortium Program Activities*
Principal Investigator(s): Fowler, Wallace T
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Industry Affiliates Program
Award Number: N/A
Award Amount: $1,935,675

Abstract: The Texas Space Grant Consortium has the following objectives:

- Foster sharing of space related course materials among consortium academic institutions.
- Foster the development of multi-institutional space research efforts including industry-university teaming.
- Foster high-quality, graduate-level space research at consortium academic institutions.
- Use interest in space to increase participation in science and mathematics in the public schools.
- Foster space-related programs and curricula for public schools and for the public.
- Increase the pool of high school graduates who enter college to study science, mathematics, and engineering, with emphasis on underrepresented minorities and women.

Title: *Constrained Trajectory Optimization Applied to Multiple Gravity Assist Spacecraft Missions*

Principal Investigator(s): Russell, Ryan P
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Astrium SAS
Award Number: UTA12-000936
Award Amount: $100,000

Abstract: The objectives of the proposed research are as follows: 1) Utilize and enhance recent developments in Hybrid Differential Dynamic Programming (HDDP), a constrained optimal control method designed for general use on highly nonlinear, challenging optimal control problems; and 2) develop a software tool for interplanetary space trajectory optimization customized to handle general maneuvers and constraints for missions of interest to Astrium. The proposed research collaboration between The University of Texas at Austin and Astrium is scoped in content, duration, and budget to support a Ph.D. research and thesis.

Title: *Computational Modeling for Plasma and Electrically Assisted Combustion*

Principal Investigator(s): Raja, L L
Department, Center, or Institute: Center for Aeromechanics Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: King Abdullah University for Science & Technology
Award Number: 1975-05 CCF
Award Amount: $62,738

Abstract: Introduction and background: Recent studies have demonstrated potential benefits of externally generated plasmas and sub-critical electric fields in enhancing the stability and performance of combustion systems. The interactions of plasma and combustion involve highly complex processes through the exchange of chemically active species and heat. As an example of the mutual interaction, a common engineering approach to generate plasmas relies on high-intensity electric fields, which strongly interact with ions produced by the combustion process. The combustion process also influences plasma behavior through gas heating and the yield of a large number of charged and radical particles. A fundamental understanding of the plasma-flame interactions and the utilization of their characteristics for advanced combustion systems are the main objectives of the proposed project.

For practical applications, there are three ways to take the advantage of plasmas to improve combustor performance. First, plasma-pretreatment can be utilized to generate hydrogen, ozone, and radicals. Plasma-assisted fuel reforming is an example of this pre-treatment application. Second, direct application of plasma sources inside the combustor can effectively modify various combustion performance metrics. For example, the electron impact chemical reactions within discharge channels may lead to flame stability, burning velocity enhancement, and reduction of soot formation. A plasma burner has been implemented in diesel exhaust systems to regenerate diesel particulate filter systems under the low

temperature/oxygen and high-flow conditions. Although the burner was successfully commercialized, the fundamental mechanism of plasma-assisted combustion has not been clearly understood yet, due in part to the complexities associated with the plasma-combustion interactions. Third, plasma technology can also be utilized in the after-treatment of exhaust gases. However, this subject has been extensively studied and has weak relevance with combustion, and thus will not be considered under the proposed project.

The electrically enhanced combustion has also been studied and the favorable effect on flame stability has been documented. The mechanism has been commonly attributed to the "ionic wind" effect, which refers to the modification of the motion of charged particles by the electric field potential. Recent studies using AC fields, however, indicated that other chemical kinetic and transport effects may also become important, albeit without convincing evidence. By applying AC potentials, enhanced flame stability for nonpremixed laminar jet flames, premixed Bunsen flames, and nonpremixed turbulent jet flames could be obtained, and propagation speed enhancement for triple flames in jet mixing layers and outwardly propagating flames could be determined.

Development of predictive computational modeling capability will also be conducted under the proposed project, by incorporating comprehensive first-principle sub-models for plasma and flame chemistry interactions. The scope provides an excellent opportunity for collaboration with Prof. Raja at UT-Austin who has extensive experience in high-fidelity modeling of plasma physics and chemistry and the application of these models for plasma assisted combustion.

The proposed research will be conducted over a period of six years in collaboration with researchers at the Clean Combustion Research Center (CCRC) at KAUST. This proposal is part of the Center Competitive Funding (CCF) program in KAUST.

Title: *Convex Optimization-Based Landing Guidance Under Aerodynamic Forces*

Principal Investigator(s):	Acikmese, Behcet
Department, Center, or Institute:	Center for Space Research
Institution:	The University of Texas at Austin
Discipline:	Engineering
Funding Agency:	Blue Origin, LLC
Award Number:	UTA13-001078
Award Amount:	$136,000

Abstract: Motivation: The current guidance architecture for PM4 involves an off-board trajectory optimizer with onboard closed-loop control to track the pre-computed trajectory. This traditional approach is very common in the aerospace industry, but also has not benefitted from many of the advances since the Apollo era. If the vehicle deviates significantly from the path, it can be expensive (propellant-wise) and unnecessarily aggressive to return to the originally planned profile. To effectively deal with uncertainties, a suite of guidance profiles are generated and loaded onboard so the flight software can pick the closest one at the start of the landing maneuver. This approach takes a lot of development time and must be re-done if critical performance parameters change during the design. Ideally, the vehicle would compute the desired trajectory onboard for the real-time flight conditions and control to that new profile down to the target (perhaps repeating the process). Limited processor power and a lack of flight heritage have been the two significant hurdles for improving on the traditional approach. With the proliferation of unmanned aerial vehicles (UAVs) and vertical takoff, vertical landing (VTVL) rocket hoppers equipped with powerful onboard processors, there is a significant shift towards autonomous path planning. Several real-time guidance algorithms are rapidly accruing flight experience and eliminating these barriers. Lastly, this is a technology that will directly apply to our future vehicles, such as GS1 and SV and is, therefore, a worthy investment for our future GNC architectures.

Background: A critical piece of any onboard optimization routine is the ability to quickly and reliably converge to a feasible (and preferably optimal) solution. Certain optimization algorithms have guaranteed convergence properties based upon the type of constraints used in the problem. The trick is to formulate the guidance problem in such a way that it can be solved with one of these algorithms. A popular area of research in this field is convex optimization. An optimal control problem that fits into the convex framework can be solved quickly and reliably with well-known algorithms. General trajectory design problems can be solved by off-the-shelf solvers (included with Matlab, like CVX), but an on-board solver will likely need to be tailored to our specific problem in order to reduce computation time and memory footprint. The standard rocket trajectory optimization problem is non-convex, meaning it requires a nonlinear program solver to find the answer, and even then, it's not guaranteed to converge to a feasible solution. Certain modifications and assumptions must be made to formulate the problem in a convex manner. If these are done properly, the convexified problem can be shown to be the optimal solution for the original non-convex problem as well. Convexifying a nonlinear problem is a new field of research, and novel techniques are still being discovered.

Title: *Cold Gas Thruster for Deep Space Industries CubeSat*
Principal Investigator(s): Fowler, Wallace T
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Deep Space Industries
Award Number: UTA14-000863
Award Amount: $36,529

Abstract: Background: Deep Space Industries (DSI) is performing a space mission to demonstrate a mobile spacecraft on-orbit. UT-Austin's Texas Spacecraft Lab (TSL) has developed a low-cost, cold gas thruster using rapid prototype printed technology that is intended for use on small satellites. Two flight units of this thruster were delivered for NASA's Interplanetary NanoSpacecraft Pathfinder In Relevant Environment (INSPIRE) CubeSat mission, which is planned for flight in 2015. The proposed design is a four-nozzle, five-valve device that can provide approximately 30 m/sec of delta-velocity. The amount of impulse that can be provided is a function of the tank volume, which can be maximized to fit the available volume in the spacecraft. Depending on the nozzle configuration, the

thruster may be used to provide attitude control torques or center of mass acceleration in a body-fixed direction.
The UT-Austin TSL proposes to deliver this device, with small changes as needed to meet DSI's mission requirements, for flight on their technology demonstration mission.

Title: *A 3D Printed Thruster for the Prox-1 Spacecraft*
Principal Investigator(s): Fowler, Wallace T
Department, Center, or Institute: Center for Space Research
Institution: The University of Texas at Austin
Discipline: Engineering
Funding Agency: Georgia Institute of Technology (Georgia Tech)
Award Number: 1600196622
Award Amount: $60,000
Abstract: Background: Georgia Tech is building a nanosatellite known as Prox-1, which has requirements for orbit propulsion. UT-Austin's Texas Spacecraft Lab (TSL) has developed a spacecraft cold-gas thruster device based upon a 3D printed technology that is suitable for Prox-1's mission requirements. Georgia Tech has requested that the TSL prepare a proposal quotation for providing a 3D printed thruster in support of the Prox-1 spacecraft. The 3D printed cold-gas thruster provided for Jet Propulsion Lab's INSPIRE CubeSat is based on the same technology that will be used for the Prox-1 thruster.
The TSL proposes to design, fabricate, and test a 3D printed cold-gas thruster for the Prox-1 spacecraft to meet the mission requirements as specified by Georgia Tech.
The activity will consist of a custom-tank thruster design to meet the Prox-1 mission requirements. After this design has obtained approval from the Georgia Tech Prox-1 team, an engineering design unit (EDU) will be fabricated and tested in a vacuum chamber at the TSL to demonstrate performance and identify any corrections to the initial design. After the EDU has been tested, final modifications will be made, and a flight unit will be fabricated, acceptance tested, and delivered to Georgia Tech for integration into the Prox-1 spacecraft. Ongoing technical support will be provided to Georgia Tech within the scope of the effort throughout the remainder of the period of performance. The TSL will produce a design description document showing the expected on-orbit performance of the device and a detailed computer-aided-design (CAD) model. The flight unit thruster with acceptance documentation will be provided as a deliverable.

Title: *Systems Engineering Design Course Curriculum Development*
Principal Investigator(s): Penrod, Clark S
Department, Center, or Institute: Applied Research Lab
Institution: The University of Texas at Austin
Discipline: Applied Research
Funding Agency: DoD-Navy
Award Number: N00024-07-D-6200/0022 CLN0001 AA AB AC
Award Amount: $494,770

Abstract: The task objective is to: 1) complete development of the UT-Austin concept for hands-on project based education of Systems Engineering as a fundamental principle of design and 2) test transition of the concept at another university. The work to be accomplished consists of development and/or testing of the following:

a. Course syllabi and lecture materials on the fundamental principles of systems engineering to hands-on, unmanned aerial system (UAS) capstone design projects for aerospace students.

b. Other design, test, and evaluation course materials related to systems engineering design of UAS.

c. Student project request for information (RFI), request for proposal (RFP), and system design and development (SDD) "contract" documents required to implement the competitive course concept.

d. Student team peer evaluation system description and grading rubric.

e. First and second semester design and milestone reviews and evaluation criteria.

f. End of semester grading rubrics and suggested evaluation concepts.

g. Workshop instructional materials that introduce systems engineering and its practical application to extramural student project participants. The specific application for the current contract period will be to aerospace student projects, but the basic concept will be applicable across engineering disciplines.

h. Validated plans for, and lessons learned from, transition of the UT-Austin design concept to Texas A&M University (TAMU), Department of Aerospace Engineering. The lessons learned will be developed by TAMU and incorporated by UT-Austin in improved transition products, as appropriate.

The University of Texas at Brownsville (UT-Brownsville)

The University of Texas at Brownsville listed three active awards in aerospace technology for FY 2015, with a total award amount of $578,744. During that year, UT-Brownsville's research expenditures for the awards were $214,158. Information for the identified active award is provided.

Title: *Research Experiences for Undergraduates (REU) and Research Experience for Teachers (RET) Site in Physics at the University of Texas Brownsville*

Principal Investigator(s): Joey Key
Department, Center, or Institute: Center for Gravitational Wave Astronomy
Institution: The University of Texas at Brownsville
Discipline: Physics
Funding Agency: National Science Foundation
Award Number: 1461237
Award Amount: $395,000

Abstract: One of the main reasons for establishing and continuing an REU site is to gain visibility as an undergraduate program at the state and national level, to start attracting students from community colleges and universities in South Texas who do not have the opportunity of performing research at their home institutions, and

to attract talented students from underrepresented minorities who are not aware of the opportunity for physics graduate studies at UT-Brownsville.
The RET is key to a better student college-readiness preparation through the active training collaboration and support of local area high school teachers. The project coordinator for this REU-RET site is a former Brownsville Independent School District (BISD) high school physics teacher. The UT-Brownsville DP&A plays an active role in training area high school physics teachers, and there is a great interest in participating in research activities during the summer. Most of these teachers are Hispanic American, and their professional development through this experience provides more effective role models for a local high school population that is predominantly Hispanic (98% in Brownsville).

Title: *Research Experiences for Undergraduates (REU) and Research Experience for Teachers (RET) Site in Physics at the University of Texas Brownsville*

Principal Investigator(s):	Mario Diaz
Department, Center, or Institute:	Center for Gravitational Wave Astronomy
Institution:	The University of Texas at Brownsville
Discipline:	Physics
Funding Agency:	National Science Foundation
Award Number:	1156600
Award Amount:	$158,029

Abstract: This summer research experience for undergraduates will have a close mentoring and guidance system from the faculty in place during the entire duration, fostering interaction and active participation by students through seminars, lunch meetings, colloquia, and presentations. The site will have a teacher component by incorporating three high school teachers from the Brownsville area into the experience. Two of these teachers will be UT-Brownsville graduates interested in developing a close interaction between the educational programs at their high schools and the university. All of these teachers will develop smaller subprojects to be carried on with their students during the school year, with the purpose of participating in the regional science fair.

Title: *Research Experiences for Undergraduates (REU) Site: Texas Center for Undergraduate Research in Energy and Propulsion*

Principal Investigator(s):	Sanjay Kumar
Department, Center, or Institute:	Engineering and Computer Science Department
Institution:	The University of Texas at Brownsville Subaward from Texas A&M University
Discipline:	Engineering and Computer Science Department
Funding Agency:	National Science Foundation
Award Number:	EEC-1004859
Award Amount:	$25,715

Abstract: Insufficient energy research and the shortage of people pursuing advanced degrees in engineering are both topics of supreme importance in modern times, and with this proposed REU site we intend to target both problems through a collaborative effort between Texas A&M University (TAMU) and the University of

Texas at Brownsville (UT-Browsville). The objectives of the site emphasize the positive benefits of providing longer-term exposure to research through year-round opportunities for selected students at TAMU and UT-Brownsville and repeat summer experiences.

The University of Texas at Dallas (UT-Dallas)

The University of Texas at Dallas listed six active awards in aerospace technology for FY 2015, with a total award amount of $15,849,662. During that year, UT-Dallas' research expenditures for awards in aerospace technology were $4,696,031. Information for the identified active awards are provided.

Title: *COSMIC-2 Spacecraft Ion Velocity Meter (IVM) Support Project*
Principal Investigator(s): Roderick A. Heelis
Department, Center, or Institute: Department of Space Science
Institution: The University of Texas at Dallas
Discipline: Space Science
Funding Agency: University Corp for Atmospheric Research
Award Number: W14-16198/D16198-01
Award Amount: $903,000
Abstract: UT-Dallas shall be responsible for fabrication, testing, and delivery for seven sets of IVM grid stack assemblies from material and machined parts already procured under existing contract FA9453-11- C-0013. All requirements of contract number FA9453-11-C-0013 applicable to the grid stacks referenced above and the requirements detailed in the VIDI Technical Requirements Document (TRD) dated March 13, 2012, and the associated Manufacturing Cross Reference Matrix (MCRM) Design and Manufacturing Requirements.

Title: *Spatial and Temporal Characterization of Convection and Precipitation Boundaries in the Auroral Region Using DMSP Multi-Point Measurements*
Principal Investigator(s): Roderick A. Heelis
Department, Center, or Institute: Department of Space Science
Institution: The University of Texas at Dallas
Discipline: Space Science
Funding Agency: NASA
Award Number: NNX14AF33G
Award Amount: $373,176
Abstract: UT-Dallas proposes to determine the spatial and temporal characteristics of convection and precipitation boundaries at high latitudes and to relate those boundaries to the behavior of magnetically connected boundaries in the magnetosphere. Thus, the proposal primary science area is Magnetosphere-Ionosphere Coupling/Magnetotail. We will employ a unique data set gathered during the years 2003-2013 when there are three to five Defense Meteorological Satellite Program (DMSP) satellites in sun-synchronous, circular polar orbits in the ionosphere, configured with at least one pair of satellites in nearly identical orbits

with the others in different local time orientations. Consecutive passes across the high-latitude region allow boundaries in the energetic particle precipitation and the plasma flow to be identified and their motion to be compared with measurements of the plasma flow direction to determine the nature of the boundary. The offset between the geographic and geomagnetic poles produces a wide range of magnetic local times over which this information can be gathered.

Title: *SSIE-3 Pre-Launch Field Support/Launch-Readiness Assessment/Program Support*
Principal Investigator(s): Roderick A. Heelis
Department, Center, or Institute: Department of Physics
Institution: The University of Texas at Dallas
Discipline: Physics
Funding Agency: Northrop Grumman
Award Number: 8200134971
Award Amount: $1,933,122
Abstract: Maintain and sustain the hardware and software for the on-orbit operation of the Special Sensor Plasma Monitoring Ion, Electron Sensor (SSIES-2 and SSIES-3).

Title: *The Couple Ion Neutral Dynamics Investigation (CINDI) Extended Mission*
Principal Investigator(s): Roderick A. Heelis
Department, Center, or Institute: Department of Physics
Institution: The University of Texas at Dallas
Discipline: Physics
Funding Agency: NASA Goddard Space Flight Center
Award Number: NNX10AT02G
Award Amount: $4,180,003
Abstract: The Coupled Ion Neutral Dynamics Investigation (CINDI) instruments are designed to measure the ion and neutral motions and the ion composition, temperature and density in the earth's low latitude ionosphere/thermosphere where collisions between the ion and neutral particles affect the dynamics, energetics and chemistry of each species. CINDI measurements will address fundamental questions concerning: 1) how the daily variability in the upper atmosphere wind system is related to variability in the ionospheric electrodynamics; 2) how and why the ionosphere and thermosphere super-rotate; 3) how the electrodynamics of the ionosphere evolves with increasing solar extreme ultraviolet (EUV) flux and associated increases in magnetic activity; and 4) whether variations in the F-region neutral wind can be used to improve the specification of plasma irregularity occurrence and intensity.

Title: *Ion Velocity Metter (IVM) for Ion-Neutral Connection Explorer (ICON)*
Principal Investigator(s): Roderick A. Heelis
Department, Center, or Institute: Department of Space Science
Institution: The University of Texas at Dallas
Discipline: Space Science
Funding Agency: University of California Berkeley

Award Number: NNG12FA45C
Award Amount: $4,727,261
Abstract: Perform a Phase A Concept Study of the Ion-neutral Connection Explorer (ICON) under NASA. The IVM processes outputs from two sensors: a Retarding Potential Analyzer (RPA) and a Drift Meter (DM) to determine the total ion concentration, the major ion composition, the ion temperature, and the ion velocity in the spacecraft reference frame.

Title: *An Ion Velocity Meter (IVM) for Space Situational Awareness Environmental Monitoring*
Principal Investigator(s): Roderick A. Heelis
Department, Center, or Institute: Department of Physics
Institution: The University of Texas at Dallas
Discipline: Physics
Funding Agency: US Air Force Research Laboratory
Award Number: FA9453-11-C-0013
Award Amount: $3,733,100
Abstract: Design, fabrication and testing of the IVM. Two IVM instruments, a Design Qualification Unit (DQU) and a Flight Demonstration Unit (FDU) will be designed; fabricated; tested; and delivered, along with appropriate GSE.

The University of Texas at El Paso (UT-El Paso)

The University of Texas at El Paso listed 44 active awards in aerospace technology for FY 2015, with a total award amount of $20,864,236. During that year, UT-El Paso's research expenditures for awards in aerospace technology were $5,060,303. Information for the identified active awards are provided.

Title: *3D Printing Multifunctionality: Additive Manufacturing for Aerospace Applications*
Principal Investigator(s): Ryan Wicker
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering
Funding Agency: America Makes
Award Number: 4030
Award Amount: $1,000,000
Abstract: The next generation of manufacturing technology will require complete spatial control of material and functionality as structures are created layer-by-layer – providing fully customizable, high-value, multi-functional products for the consumer, biomedical, aerospace and defense industries. With contemporary Additive Manufacturing (AM, also known more popularly as 3D printing) providing the base fabrication process, a comprehensive manufacturing suite will be integrated seamlessly to include: 1) extrusion of a wide variety of robust thermoplastics/metals, 2) micromachining, 3) laser ablation, 4) embedding of wires and fine-pitch meshes submerged within the thermoplastics, and 5) robotic

component placement. Collectively, the integrated technologies will fabricate multi-material structures through the integration of a wide variety of integrated manufacturing systems (multi-technology) to provide multi-functional products (consumer wearable electronics, bio-medical devices, defense, space and energy systems, etc.). The system advocated under this proposal (Multi3D) will provide this solution. A prototype version of the proposed system has been created at the Keck Center and includes several sub-processes with a conveyance system to translate a device-under-construction between stages. The prototype is capable of embedding wires and components within a multi-material substrate to provide mechanical, electronic, thermal, and electromagnetic functionality. Although this technology is well suited for fabricating space hardware and, the harsh conditions of space provide a testament to the robustness of the resulting structures, the proposed Multi3D Manufacturing System can also be used to fabricate any 3D structural electronics, including those intended for use in biomedical, aerospace, defense, or consumer markets.

Title: *Synthesis of 3D Printable Polymer Matrix Composites*
Principal Investigator(s): David Roberson
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering
Funding Agency: Air Force Office of Scientific Research
Award Number: FA9550-14-1-0260
Award Amount: $360,000
Abstract: Material extrusion 3D printing is a manufacturing method that utilizes a polymeric monofilanment as a feedstock in the fabrication of 3D objects. The use of polymeric material is advantageous in that it can be used to fabricate low-density components; however, the inherent physical properties of polymers impose limitations on the applicability of this 3D printing method. To expand the functionality of material extrusion 3D printing to be able to fabricate a broad range of objects, novel materials must be developed with enhanced physical properties, while maintaining compatibility with material extrusion 3D printer technology. The strategy employed is the synthesis of polymer matrix composites and polymer blends in the creation of novel material systems, which can then be used by material extrusion 3D printers. Challenges that must be overcome for the research proposed here to be successful are as follows: 1) Adhesion between the particle and matrix material; 2) dispersion of the reinforce material within the polymer matrix; 3) the synthesis of a solid, void free monofilament; 4) the ability to maintain printability, despite drastic altering of the overall material properties of the composite; and 5) the ability to print a component with accurate dimensional stability, as compared to original CAD drawings.

Title: *Synthesis and Characterization of High Temperature Polymer Matrix Composites and Polymer Blends for the 3D Printing of Novel Low-Density Materials*

Principal Investigator(s): David Roberson
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering
Funding Agency: Air Force Office of Scientific Research
Award Number: FA9550-15-1-0312
Award Amount: $391,979

Abstract: The system described in this Defense University Research Instrumentation Program (DURIP) proposal will enable the synthesis and characterization of high-temperature, polymer-matrix composites and blends intended for the 3D printing of low-density materials. The key components of this system are: 1) a high-temperature, mini-polymer extruder; 2) a Fourier transform infrared spectrometer (FTIR); and 3) a low-voltage electron microscope. When used in conjunction, the proposed instrumentation will create a system that will have an immediate and profound effect on the fundamental knowledge produced by the AFOSR-funded project "Synthesis of 3D-printable Polymer Matrix Composites," which is currently limited in terms of materials characterization and a restriction of base materials to low-temperature polymers, such as acrylonitrile butadiene styrene (ABS).

Title: *STTR I: Additive Manufacturing (AM) Plastic Materials with Improved Dielectric Breakdown*

Principal Investigator(s): David Roberson
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering
Funding Agency: Air Force Office of Scientific Research
Award Number: FA9451-15M-0531
Award Amount: $139,027

Abstract: The use of materials with high dielectric breakdown properties is important in insulation applications because it allows better performance when used with high-power microwave sources. The goal of this project is to develop custom thermoplastic-based materials that meet dielectric breakdown requirements while remaining compatible (in terms of printability) with material extrusion AM processes. Development of materials (i.e., material identification, compounding, and producing filament) and printing of materials will be executed at UT-El Paso.

Title: *Investigation and Testing of Direct Manufacturing Technology for Aerospace Tooling*

Principal Investigator(s): Ryan Wicker
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering
Funding Agency: Lockheed Martin
Award Number: 20140262

Award Amount: $338,992

Abstract: The early use of direct manufacturing technologies by Lockheed Martin (LM) Aero has demonstrated the fabrication of tooling to aid in drilling, locating, and other production operation processes. Specifically, Fused Deposition Modeling (FDM) has been used to produce polycarbonate tooling. To fully take advantage of the benefits provided by direct manufacturing technologies, the proposed work will research the use of alternate materials and technologies to produce LM Aero tooling. In addition, mechanical components (e.g., bushings, router edges) will be intermittently inserted and incorporated within FDM-manufactured parts to improve LM Aero tooling. Lastly, post-processing (e.g., surface coatings, machining) and bonding (or joining) methods will be researched and implemented to identify their benefits to LM Aero tooling.

Title: *Development of Customized Fabrication Strategies Toward the Improvement of Parts Fabricated Using Electron Beam Melting (EBM) Additive Manufacturing Technology*

Principal Investigator(s): Ryan Wicker
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering
Funding Agency: Air Force Research Laboratory
Award Number: FA8650-11-D-5702
Award Amount: $186,000

Abstract: The University of Texas at El Paso (UT-El Paso) has gained experience in topology optimization and fatigue testing from work that has been performed in collaboration with General Dynamics Information Technology (GDIT) on a project titled "Additive Manufacturing Topology Optimization for Aerospace Components." A simple L-bracket design was chosen to develop topology optimization skills and gain an understanding of the fatigue properties of EBM-fabricated parts. As a result of the work, students at UT-El Paso have gained experience in topology optimization using Altair Optistruct. An outcome of this work was in the development of ideas to improve the fatigue properties of EBM-fabricated parts by implementing novel selective scanning strategies for known failure sites to locally improve mechanical performance. Results from the ongoing study have provided UT-El Paso faculty, staff, and students with expertise on the effects of processing variables on the effect of mechanical performance. The subject of this proposed research will be to develop customized fabrication strategies toward the improvement of parts fabricated using electron beam melting additive manufacturing technology.

Title: *Cooling Rate Correlation between Microstructural Phases and Geometry for electron beam melting (EBM)-Fabricated Parts*

Principal Investigator(s): Ryan Wicker
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering

Funding Agency: National Science Foundation
Award Number: N/A
Award Amount: $198,142

Abstract: Ti-6Al-4V components fabricated by EBM technology are widely used for biomedical implants and aerospace applications since complex and lightweight designs can be easily fabricated when compared to traditional manufacturing methods with less material waste. It is hypothesized here that faster cooling rates obtained from geometric part thickness below 2 mm provide an martensitic phase in its microstructure lowering the part's ductility. This phase could lower the yield strength obtained for the component in consideration, therefore playing an important role at the time of designing the part. It is further hypothesized that phase can be avoided in the microstructure of the thin wall-sections of the components if the cooling rate is controlled, therefore obtaining same yield strength regardless of part thickness. For this project, a pyrometer device has been implemented in an Arcam S12 system to obtain cooling rates for each step of the process, which will be correlated with final microstructure for sample thicknesses ranging from 0.2mm to 100mm in the XY plane and up to 40mm in the ZX plane. Microstructural analysis will consist of obtaining images from the specific location the cooling rate was measured. An image processing software will be developed to aid in the quantification of phase percentages, using thresholding techniques. The data will be correlated with yield strength obtained from Vickers micro-hardness measurement for each phase at different geometrical thicknesses. Finally, modifications to the standard recipe parameters and hardware modifications will be implemented to achieve uniform layer-by-layer cooling rates regardless of lateral and vertical dimensions. Verification of the modifications will take place by fabrication of acetabular cups.

Title: *A Cyber-Enabled Platform for Process Variable vs. Part Quality Relationships in Direct Metal Additive Manufacturing (AM)*
Principal Investigator(s): Ryan Wicker
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering
Funding Agency: Office of Naval Research
Award Number: through Carnegie Mellon University
Award Amount: $152,101

Abstract: There is currently a gap between sophisticated process models and direct metal AM processes that can benefit from them. The objective of this project is to bridge the gap by establishing a platform of process variable vs. part quality relationships, acting as a knowledge base for feedforward and feedback AM process control. The approach of this project is to use process mapping technologies as this knowledge base platform for powder bed direct metal AM processes.

Title: *Collaborative Research: Design of Negative Stiffness (NS) Metamaterials*
Principal Investigator(s): Eric MacDonald
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering
Funding Agency: National Science Foundation
Award Number: through University of Texas at Austin
Award Amount: $86,605
Abstract: Modern materials processing and additive manufacturing techniques enable unprecedented levels of control of material architecture. In fact, metamaterials rely on the engineered arrangement of their constituents, rather than the composition of the constituents themselves, to provide properties that are not achievable with conventional materials. Our goal is to combine modern additive manufacturing techniques with multi-level materials modeling and design exploration methods to architect metamaterials with unprecedented levels of structural performance. Our research approach is multi-faceted, with primary tasks devoted to modeling, designing, fabricating, and testing these NS metamaterials. We have assembled a team of experts in materials modeling, characterization, fabrication, and design, along with industrial partners who can help us identify suitable applications to drive our design process and transition the resulting designs into industrial applications. The proposed research effort will consist of the following tasks: 1) Multi-level modeling of negative stiffness metamaterials, 2) multi-level materials design with Bayesian network classifiers, 3) fabrication of negative stiffness metamaterials via microstereolithography and composite inclusion, 4) characterization of stiffness and damping characteristics of negative stiffness metamaterials, and 5) implementation of negative stiffness materials in structural applications.

Title: *Investigation of Additive Manufacturing (AM) toward Arbitrary Electromagnetic Structures*
Principal Investigator(s): David Roberson
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering
Funding Agency: National Science Foundation
Award Number: 20140274
Award Amount: $180,000
Abstract: Additive manufacturing, or AM technologies, often called 3D printing, have received much attention recently with impressive demonstrations ranging from musical instruments [1], to vehicles [2], to housing components [3] or even entire buildings [4]. Different structural materials, including metal [5], polymer [6], ceramics [7], concrete [9] and even biological tissues [8], have been incorporated in various 3D printing technologies. Although it has been argued that 3D printing could be the future of manufacturing, the potential and applicability of these methods for creating functional electronics, especially those operating at RF / microwave frequency, which are critical components for many applications including wireless communication, remote sensing, high speed computing, etc.,

remain largely unexplored. To achieve the ultimate program goal, the following innovative approaches will be carried out. First, materials that are suitable for 3D AM will be developed based on a novel polymer matrix compound technique to obtain improved electromagnetic properties such as large range of dielectric constant and magnetic response. Second, technique for additive manufacturing of high quality (i.e., good RF conductivity) conductors by ultrasonic embedding and laser welding metallic wires and fine-pitch meshes within dielectric materials such as thermoplastics will be developed and refined. Third, based upon these new techniques and our team's previous research in AM, a comprehensive manufacturing suite will be integrated seamlessly to include: 1) extrusion of a wide variety of robust thermoplastics/metals; 2) micromachining; 3) laser ablation; 4) embedding of wires and fine-pitch meshes submerged within the thermoplastics; and 5) robotic component placement. Fourth, practical microwave components (i.e., transmission line with vertical interconnects, wire and patch antennas, etc.) will be designed, printed and tested to validate the developed AM materials and processes. In addition, a 3D gradient index metamaterial-based device (i.e., flattened Luneburg lens imager) with superior performance will be designed, printed, and demonstrated.

Title: *A Low-Cost Industrial Multi3D System for 3D Electronics Manufacturing*
Principal Investigator(s): Ryan Wicker
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering
Funding Agency: America Makes
Award Number: 4055
Award Amount: $1,000,000
Abstract: This proposed system would integrate an existing thermoplastic extrusion system (to be identified during the execution of the grant and to include possibly both a high performance and low cost version) seamlessly within a gantry including a router and tool exchange system. Custom tooling will be included, optimized, and integrated with the control software for micro-machining, wire and conductive foil embedding. The custom tooling will be developed in such a way to be possible for retrofitting with an extrusion system that has a gantry system and head geometries that can accommodate the additional equipment. Consequently, this project will be applicable for a wide range of other additive manufacturing (AM) systems and potentially other AM technologies.

Title: *Metal 3D Printing of Low-NOX Fuel Injectors with Integrated Temperature Sensors*
Principal Investigator(s): Ryan Wicker
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering
Funding Agency: U.S. Department of Energy
Award Number: 20150297
Award Amount: $250,000

Abstract: This work necessitates the exploration of design and prototyping of a Low-NOX fuel injector with integrated temperature sensing capabilities using the Electron Beam Melting (EBM) additive manufacturing process. Over the past few years, EBM has proven itself as a viable method to rapidly fabricate complex shapes for custom-designed components. The lack of assembly requirements and the virtually unlimited geometrical complexity renders EBM process particularly attractive for fabricating complex energy system components.

Title: *STTR II: Development of nuclear quality components using metal additive manufacturing*

Principal Investigator(s): Ryan Wicker
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering
Funding Agency: U.S. Department of Energy
Award Number: 20140291
Award Amount: $350,000

Abstract: Nuclear fission energy is considered a reliable baseload source of clean and economical electrical energy. Approximately 20 percent of the electricity generated in the U.S. comes from nuclear power plants, where a total of 103 GW of electricity is produced at 65 operating sites with 104 licensed commercial reactors. Nuclear reactor cores can degrade materials at a high rate due to the combined environment of high stress, high temperature, radiation, and aggressive coolants. A major problem with nuclear fission reactors is the welding of components of dissimilar metals, where the filler is usually of an additional metal alloy that is not necessarily the same as the two parts to be joined. Welding of metals will often have a heat-affected zone (HAZ) and a thermo-mechanically affected zone (TMAZ), which needs to be post-weld heat-treated to minimize precipitation or segregation. It is proposed here to address a critical welded component to be enhanced by additive manufacturing. It is forth seen to obtain a considerable benefit not only in the nuclear industry, but also in every industry where material joining by welding or any other method creates a percentage of failure due to joining malfunctions after welding.

Title: *MIRO Center for Space Exploration and Technology Research (MIRO cSETR)*

Principal Investigator(s): Ahsan Choudhuri, John Chessa, Evgeny Shafirovich, Ryan Wicker, Norman Love
Department, Center, or Institute: cSETR
Institution: The University of Texas at El Paso
Discipline: Aerospace
Funding Agency: NASA
Award Number: 20150100
Award Amount: $5,000,000

Abstract: The MIRO cSETR supports NASA's vision of space exploration by focusing on advanced capabilities in the areas of nontoxic and green propulsion. The MIRO cSETR vision is to establish a sustainable minority university center of excellence in

advanced propulsion research through strategic partnerships and to educate a diverse future aerospace workforce. Goal 1-Research: Advanced research in nontoxic cryogenic and green propulsion technologies. Goal 2-Education: Increase the number of STEM degrees awarded to undergraduate and graduate students, especially those from underrepresented groups. Goal 3-Capcity Building: Build sustainable research capacity and infrastructure in aerospace engineering.

Title: *HAN-Based Advanced Hybrid Rocket Motor Tecnologies*
Principal Investigator(s): Norman Love, Ahsan Choudhuri, Evgeny Shafirovich
Department, Center, or Institute: cSETR
Institution: The University of Texas at El Paso
Discipline: Aerospace
Funding Agency: Missile Defense Agency
Award Number: 20150138
Award Amount: $589,795
Abstract: The research goal of this proposal is to measure and improve regression rates of Hydroxylammonium Nitrate (HAN) and Hydroxyl-Terminated Polybutadiene (HTPB) propellant combination. The study will use HAN-HTPB and: i) characterize the combustion products and efficiency of the fuel and oxidizer reaction; ii) measure fuel regression rates; iii) enhance combustion chamber mixing with the use of a novel coaxial swirl injection system; and iv) perform a parametric study to observe the effects of pressure, gas temperature, and oxidizer mass flow rate and injector characteristics. The hybrid engine will be tested at UT-El Paso and utilize various existing facilities including the altitude simulation system and multi-purpose Optically Accessible Combustor (MOAC) system. This research is of interest to the MDA since HAN-HTPB based advanced hybrid rocket motors have the potential to meet the demands of highly flexible and efficient axial and boost propulsion for Ballistic Missile Defense applications. The primary advantages of HAN-HTPB hybrid propulsion architectures include high mass fraction and specific impulse, restart and throttling capabilities, low development and production costs, and inherent safety of nontoxic and hybrid propellant formulation.

Title: *HBCU/MI: An Investigation on Structures of Premixed Flames in High Intensity Turbulent Flow*
Principal Investigator(s): Ahsan Choudhuri
Department, Center, or Institute: cSETR
Institution: The University of Texas at El Paso
Discipline: Aerospace
Funding Agency: ARMY RESEARCH OFFICE
Award Number: 20120535
Award Amount: $650,000
Abstract: A superior understanding of turbulent premixed combustion at conditions relevant to Air Force propulsion systems remains one of the high priority research areas of the Air Force Office of Scientific Research (AFSOR). Effective design and optimization of next generation turbines, scram/ramjet and rocket engines depend heavily upon a systemic study of flame structures at compressible and high

Reynolds number conditions. Using kHz level optical and laser diagnostics, the primary objective of the proposed effort will study structures of backward-facing, step stabilized premixed flames in high turbulence flow. The overarching goal of the project is to generate high quality experimental flame data at compressible and high Reynolds number conditions, as well as provide better understanding of turbulent flame structures under these conditions.

Title: *Development of 20N Class Ammonium Dinitramide (ADN) Thrusters for Fast-Response Time Divert and Attitude Control (DAC) Propulsion Systems*

Principal Investigator(s): Ahsan Choudhuri
Department, Center, or Institute: cSETR
Institution: The University of Texas at El Paso
Discipline: Aerospace
Funding Agency: Missile Defense Agency
Award Number: 20130319
Award Amount: $216,572

Abstract: Divert and Attitude Control, orDAC propulsion systems are required for next generation of highly maneuverable ballistic missile defense technology. Such systems will require fast response times, operation with environmentally and toxicologically benign propellants, high mass fractions, and low cost. Ammonium Dinitramide (ADN, NH3N(NO2)2) based propellants are an emerging class of nontoxic monopropellant that consist of a ternary blend of liquid fuel/oxidizer salt/and solvent that could potentially replace hydrazine with both increased performance (60% higher than monopropellant hydrazine) and decreased safety overhead cost. Major technical challenges persist, including reliable ignition and fast response times. The objectives of this proposal are threefold: The first is to develop novel ADN injection and catalysis schemes that provide for reliable ignition and fast response using catalytic, thermal, electrolytic, and mixed mode injectors. The second goal is to develop catalyst beds for ADN decomposition that are optimized for both length and decomposition efficiency. The concepts of heat regeneration will be utilized to combat heat losses at low-bed loads that lead to efficient catalyst beds over a wide flow regime. The final objective is to develop system level components (ignition hardware, thrust chambers, nozzles, and catalyst beds) and prototype fast response time ADN based DACS thrusters with steady state, pulsing, and restart capability. The results will satisfy MDA's goal of developing inexpensive, fast response time, high-mass fraction propulsion systems for next generation propulsion technology for ballistic missile defense systems.

Title: *I-DISCOVER: Collaborative Integration*

Principal Investigator(s): Juan C. Noveron
Department, Center, or Institute: USDA National Institute of Food and Agriculture
Institution: The University of Texas at El Paso
Discipline: Chemistry
Funding Agency: USDA-NIFA Grant
Award Number: 2014-38422-22078
Award Amount: $1,000,000

Abstract: Artificial-wood and its composites with applications to construction, automobile, and aircraft industries. Cellulose conversion into polycyclic aromatic 3D polymers can lead to a new generation of materials with the mechanical properties of wood and the moldable capabilities of plastics.

Title: *Investigation of Factors that May Increase Oxidation of Tin Powders*
Principal Investigator(s): Evgeny Shafirovich
Department, Center, or Institute: Department of Mechanical Engineering, cSETR
Institution: The University of Texas at El Paso
Discipline: Mechanical Engineering
Funding Agency: B/E Aerospace, Inc.
Award Number: 226821155A
Award Amount: $39,966
Abstract: The project investigated the kinetics of tin oxidation for chemical oxygen generator applications.

Title: *Energetic Materials Laboratory*
Principal Investigator(s): Evgeny Shafirovich
Department, Center, or Institute: Department of Mechanical Engineering, cSETR
Institution: The University of Texas at El Paso
Discipline: Mechanical Engineering
Funding Agency: DOD
Award Number: W911NF-14-1-0034
Award Amount: $499,930
Abstract: The University of Texas at El Paso requests the purchase of equipment and instrumentation for research and education on energetic materials that will enhance the university's capabilities in materials preparation, materials characterization, and combustion experiments. The proposed acquisition will also provide a new capability of conducting research on the enhancement of aluminum reactivity; nanoenergetics, such as nanoparticle-enhanced liquid fuels; and solid/gelled rocket propellants.

Title: *Efficient and Safe Chemical Gas Generators with Nanocomposite Reactive Materials*
Principal Investigator(s): Evgeny Shafirovich
Department, Center, or Institute: Department of Mechanical Engineering, cSETR
Institution: The University of Texas at El Paso
Discipline: Mechanical Engineering
Funding Agency: DOD
Award Number: W911NF-12-1-0056
Award Amount: $620,000
Abstract: The overarching goal of the reported project was to develop application-customized chemical gas generators based on novel energetic materials that will exhibit improved effectiveness, process stability, and fire safety. Chemical gas generators typically include a solid compound that decomposes at increased temperatures and various catalytic/heat-generating additives. The project objective

was to determine the characteristics and reaction mechanisms of gas-generating compositions involving novel nanocomposite and mechanically alloyed reactive materials, produced by arrested reactive milling, a technique developed recently at the New Jersey Institute of Technology (NJIT).

Title: *Mechanically Activated Combustion Synthesis of MoSi2-Based Composites*
Principal Investigator(s): Evgeny Shafirovich
Department, Center, or Institute: Department of Mechanical Engineering, cSETR
Institution: The University of Texas at El Paso
Discipline: Mechanical Engineering
Funding Agency: DOE NETL
Award Number: DE-FE0008470
Award Amount: $200,000
Abstract: The project is developing a novel and competitive processing route for manufacturing MoSi2-based composites, which are promising materials for structural applications under operating conditions that take place in advanced boilers, steam turbines, and gas turbines. Specifically the team is investigating mechanically activated self-propagating high-temperature synthesis (MASHS) followed by compaction. The objectives of the proposed research include: 1) determination of optimal MASHS conditions for production of MoSi2 reinforced with secondary phases; 2) development of an SHS compaction technique for densification and shaping of MoSi2-based composites obtained by MASHS; 3) and determination of mechanical and oxidation properties of MoSi2-based composites produced by MASHS-compaction.

Title: *Technology Management & Diminishing Manufacturing Sources (DMS) Analyses III*
Principal Investigator(s): Eric D. Smith and Bill Tseng
Department, Center, or Institute: IMSE Dept.
Institution: The University of Texas at El Paso
Discipline: Systems Engineering
Funding Agency: Lockheed Martin Aeronautics
Award Number: 20150456
Award Amount: $67,000
Abstract: Two graduate students from the University of Texas at El Paso will provide Lockheed Martin Aeronautics with an Integrated Technology Management User Guide, illustrating the processes in Lockheed Martin (LM) Technology Management Guide (TMG). The Integrated Technology Management User Guide, will detail how the integrated technology management processes in the appendices of the LM Technology Management Guide, as well as details in the body of the TMG are optimally executed using a virtually developed Represented System. The UT-El Paso team will illustrate in detail each step/analysis needed to execute the integrated technology management process.

Title: *Wires Centennial Ground Support Equipment (Gse) Development*
Principal Investigator(s): Ahsan Choudhuri
Department, Center, or Institute: Department of Mechanical Engineering, cSETR
Institution: The University of Texas at El Paso
Discipline: Mechanical Engineering
Funding Agency: Kyushu Institute Of Technology
Award Number: INTL, 20150202
Award Amount: $32,000
Abstract: Development of a facility for the test and evaluation of a joint research platform using winged rockets with navigation and control systems. Ground support equipment will be needed as a foundational and enabling infrastructure for long-term test platforms.

Title: *3D Formable RF Materials and Devices*
Principal Investigator(s): CHURCH, KENNETH H
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering
Funding Agency: Army Research Office
Award Number: N/A
Award Amount: $544,376
Abstract: To research and discover revolutionary science and technologies that will form the basis for conceptualizing, defining, and creating functional RF monolithic 3D devices incorporating multiple materials and multiple functions. Research will focus on 3D formable materials with exceptional RF properties enabling interactions with multi-material structures in order to provide the DOD with technologies that are potentially smaller, lighter, stronger, and higher performing than currently available.

Title: *A Novel Multiscale Design of Interfaces for Polymeric Composites and Bonded Joints Using Additive Manufacturing*
Principal Investigator(s): Pavana Prabhakar
Department, Center, or Institute: W.M. Keck Center for 3D Innovation
Institution: The University of Texas at El Paso
Discipline: Engineering
Funding Agency: Air Force Office of Scientific Research
Award Number: 20140560
Award Amount: $360,000
Abstract: Interface design is very critical for layered materials, like fiber reinforced composites, and a smart designing technique should be developed to minimize the damage and failure incurred by weak interfaces. Also, the same concept applies to joint design. Improving the material strength of the interfaces is not the only requirement for constructing better composites and joints, but the interfaces have to be engineered for specific types of loads acting and the geometry of the components. Trial-and-error experimental approaches with changing component geometry and load combinations will be very expensive. Therefore, a robust

computational model to drastically reduce the trial-and-error experiments for interface design will be beneficial for the designer. The interface strength and toughness can be improved significantly by structural nano-reinforcements using polymer additive manufacturing. The computational modeling package proposed above will be developed to upscale the influence of structural interface reinforcements for damage and failure resistance. This will further improve the strength of the composite, with negligible increase in the weight and cost associated.

Title: *Equality Measures in Stem: The Disabled and Females in the Future Aero-Workforce*
Principal Investigator(s): ROBINSON, NATHANIEL
Department, Center, or Institute: cSETR
Institution: The University of Texas at El Paso
Discipline: N/A
Funding Agency: Texas Space Grant Consortium
Award Number: 20130305
Award Amount: $30,775
Abstract: Given that society is increasingly knowledge driven and based in technological and global changes, the need for an increased engineering and science presence is large and broad reaching. To address this challenge, a larger, more diverse population must be reached to fill the talent needs of the future workforce. The proposal to be submitted will work toward that goal by researching engagement mechanisms for girls and the disabled in STEM activities specifically catered to their respective dynamics (learning style, interests, delivery methods, etc). The proposal will show the recruitment approach and management of the operations that will provide girls and the disabled with high quality STEM content and activities that lead toward their greater interest in aerospace engineering and science.

Title: *Coatings Based on Nitride and Oxynitride Nanostructures*
Principal Investigator(s): RAMANA, CHINTALAPALLE V
Department, Center, or Institute: Department of Mechanical Engineering, cSETR
Institution: The University of Texas at El Paso
Discipline: Mechanical Engineering
Funding Agency: Clarkson Aerospace Corporation
Award Number: 20130245
Award Amount: $351,419
Abstract: Goals of the project are to explore the effect of (a) growth temperature, (b) interfacial layers, and (c) controlled ternary (mutli-component) compounds to effectively promote the optical activity and enhance the quantum efficiency of MNx and MNxOy (M=Ti,Zr,Hf) coatings. The technical merit is to use: 1) plasma assisted surface/interface engineering approach to prepare MNx thin-films and nanostructures, 2) thermal energy induced surface wetting of the nitrides and 3) interfacial layers to restrict the undesired substrate effects at the interface.

Title: *Next Generation Multiferroic Nanostructures for Tunable Electronic And Electro-Mechanical Sensors and Actuators*
Principal Investigator(s): RAMANA, CHINTALAPALLE V
Department, Center, or Institute: Department of Mechanical Engineering, cSETR
Institution: The University of Texas at El Paso
Discipline: Mechanical Engineering
Funding Agency: Clarkson Aerospace Corporation
Award Number: 20160169
Award Amount: $255,000
Abstract: The Principal Investigator and his team at UT-El Paso propose the design and development of novel, multifunctional ceramics with controlled composition and phase, which are quite important for this new class of materials: Multiferroics, which are expected to revolutionize the present-day electro-mechanical systems and sensor device technologies and to open the new possibilities for developing efficient and powerful technologies for application in Air Force (AF), energy, defense, military and homeland security applications.

Title: *Migration of Se&I Requirements and Verification Tool*
Principal Investigator(s): USEVITCH, BRYAN E
Department, Center, or Institute: FAST
Institution: The University of Texas at El Paso
Discipline: Electrical and Computer Engineering
Funding Agency: The Boeing Company
Award Number: 20130089
Award Amount: $131,366
Abstract: This task involves design, development, testing, and enhancement of data tools, which will maintain requirements and verification data associated with the NASA Docking System/International Docking Adapter Project in the Teamcenter System Engineering (TcSE) application. Requirement specification data will be maintained in a Teamcenter database with a user interface enabling create/modify/delete capabilities. Capabilities will exist for data export to other applications. Overall application development must adhere to Object Oriented principles.

Title: *Jacobs-NASA JSC Engineering, Technology and Science (JETS) Subcontract (FY15-20)*
Principal Investigator(s): John D. Olivas, Darren M. Cone
Department, Center, or Institute: x
Institution: The University of Texas at El Paso
Discipline: Interdisciplinary
Funding Agency: Jacobs Engineering, NASA Flow Down
Award Number: EN41520TMS, SPN01191
Award Amount: $4,126,356
Abstract: Provide engineering, technical and scientific products, project management products and reviews as necessary to support Jacobs on the NASA Johnson Space Center (JSC) Engineering, Technology and Science (JETS) contract.

Title: *Jacobs-JETS Project Management and Administrative Support (FY15)*
Principal Investigator(s): John D. Olivas, Darren M. Cone
Department, Center, or Institute: x
Institution: The University of Texas at El Paso
Discipline: Interdisciplinary
Funding Agency: Jacobs Engineering, NASA Flow Down
Award Number: EN41520TMS-STO001, SPN01191
Award Amount: $51,644
Abstract: Provde project management oversight of UTEP resources for science, engineering and technical services provided as necessary to support Jacobs JETS contract at NASA Johnson Space Center.

Title: *Jacobs-NASA JSC Orbital Debris Astronomer (FY15)*
Principal Investigator(s): Darren M. Cone
Department, Center, or Institute: x
Institution: The University of Texas at El Paso
Discipline: Physics/Astronomy
Funding Agency: Jacobs Engineering, NASA Flow Down
Award Number: EN41520TMS-S24614, SPN01191
Award Amount: $155,500
Abstract: Provide support for full-time astronomical researcher to perform theoretical and experimental research in the field of orbital debris tracking and characterization.

Title: *Jacobs-NASA JSC Orbital Debris Astronomer (FY15)*
Principal Investigator(s): Darren M. Cone
Department, Center, or Institute: x
Institution: The University of Texas at El Paso
Discipline: Physics/Astronomy
Funding Agency: Jacobs Engineering, NASA Flow Down
Award Number: EN41520TMS-S24616, SPN01191
Award Amount: $148,400
Abstract: Provide support for full-time astronomical researcher to perform theoretical and experimental research in the field of orbital debris tracking and characterization.

Title: *Jacobs-NASA JSC Hypervelocity Impact Research Scientist (FY15)*
Principal Investigator(s): Darren M. Cone
Department, Center, or Institute: Center for the Advancement of Space Safety and Mission Assurance Research (CASSMAR)
Institution: The University of Texas at El Paso
Discipline: Materials Science/Physics
Funding Agency: Jacobs Engineering, NASA Flow Down
Award Number: EN41520TMS-S24615, SPN01191
Award Amount: $189,000

Abstract: Provide support for full-time researcher to perform theoretical and experimental research in the field of hypervelocity impact phenomena on spacecraft structures and shielding.

Title: *Jacobs-NASA JSC Orbital Debris Computational Scientist (FY15)*
Principal Investigator(s): Darren M. Cone
Department, Center, or Institute: Center for the Advancement of Space Safety and Mission Assurance Research (CASSMAR)
Institution: The University of Texas at El Paso
Discipline: Physics/Computational Sciences/Applied Mathematics
Funding Agency: Jacobs Engineering, NASA Flow Down
Award Number: EN41520TMS-S24617, SPN01191
Award Amount: $170,000
Abstract: Provide support for full-time researcher to perform computational modeling and assessment of Earth's orbital debris environment.

Title: *Jacobs-NASA JSC Astromaterials Research Scientist (FY15)*
Principal Investigator(s): Darren M. Cone
Department, Center, or Institute: Center for the Advancement of Space Safety and Mission Assurance Research (CASSMAR)
Institution: The University of Texas at El Paso
Discipline: Geology/Materials Science
Funding Agency: Jacobs Engineering, NASA Flow Down
Award Number: EN41520TMS-S24618, SPN01191
Award Amount: $136,300
Abstract: Provide support for full-time researcher in the field of astromaterials characterization of recovered orbital debris.

Title: *Jacobs-NASA JSC Hypervelocity Impact Internship (FY15)*
Principal Investigator(s): Darren M. Cone
Department, Center, or Institute: Center for the Advancement of Space Safety and Mission Assurance Research (CASSMAR)
Institution: The University of Texas at El Paso
Discipline: Materials Science/Physics
Funding Agency: Jacobs Engineering, NASA Flow Down
Award Number: EN41520TMS-S24622, SPN01191
Award Amount: $11,400
Abstract: Graduate student internship in the field of hypervelocity impact experimentation, and hydrodynamic simulation of shielding technology used for the International Space Station and Orion Program applications.

Title: *Jacobs-NASA JSC Orbital Debris Internship (FY15)*
Principal Investigator(s): Darren M. Cone
Department, Center, or Institute: Center for the Advancement of Space Safety and Mission Assurance Research (CASSMAR)
Institution: The University of Texas at El Paso
Discipline: Materials Science/Physics
Funding Agency: Jacobs Engineering, NASA Flow Down
Award Number: EN41520TMS-S24621, SPN01191
Award Amount: $11,400
Abstract: Graduate student internship in the field of measuring, modeling, and characterizing the manmade orbital debris environment in low Earth orbit.

Title: *Composite Time Span*
Principal Investigator(s): TSENG, TZU-LIANG B
Department, Center, or Institute: RES INST/MANUFACT/ENGR
Institution: The University of Texas at El Paso
Discipline: IND., MANFG. & SYSTEMS ENG.
Funding Agency: Lockheed Martin Aeronautics
Award Number: M7809011
Award Amount: $54,007
Abstract: Objective: The objective of this project is to perform analysis on composites manufacturing at Aero-FW. The results of the project should determine process steps in the overall process to be eliminate or changed that will reduce the span times currently being experienced. Congruent with the list of changes in process should be a roadmap for implementation. The analysis will consist of all direct and support process steps of the composites build process, and they all should be included in the value stream maps (VSM). The current state VSM should be used to identify the major factors that attribute to the current spans. Detailed scientific thinking analysis should be applied to those major factors. We will apply a lean approach and lean tools to generate the future state VSM that proves a reduced span time.

Title: *Foreign Object Debris (FOD) Elimination Research*
Principal Investigator(s): TSENG, TZU-LIANG B
Department, Center, or Institute: RES INST/MANUFACT/ENGR
Institution: The University of Texas at El Paso
Discipline: IND., MANFG. & SYSTEMS ENG.
Funding Agency: Lockheed Martin Aeronautics
Award Number: M7809005
Award Amount: $343,241
Abstract: UT-El Paso's Department of Industrial, Manufacturing & Systems Engineering will focus on characterizing/quantifying the problem of FOD for Lockheed Martin Aeronautics and development/implementation of a preventive/predictive algorithm for feasibility/viability trade studies of FOD-free operations. The research effort will produce classroom and practical learning tools for developing work definitions and

technology portfolios that result in FOD-free products for typical aerospace industry processing and operations.

Title: *Supply Chain Management*
Principal Investigator(s): TSENG, TZU-LIANG B
Department, Center, or Institute: RES INST/MANUFACT/ENGR
Institution: The University of Texas at El Paso
Discipline: IND., MANFG. & SYSTEMS ENG.
Funding Agency: Lockheed Martin Aeronautics (LM Aero)
Award Number: M7809012
Award Amount: $145,803
Abstract: Demonstrate effectiveness through reduced SDL count, reduced SDL-related SRR, and downward trend of SDL severity metric in 2015. Institutionalize use of this approach in LM Aero Supplier Quality Management (SQM) and drive proliferation through the defense aerospace supply base. Investigate use of regression modeling to use historical data on supplier disclosures to isolate a manageable number of variables as indicators of disclosure risk. Disclosures are distinguished from low-frequency escapes by the catastrophic failure of both manufacturing and product verification processes over an extended period of time. Design predictive model focused on SDL prevention using factors noted above. Source appropriate, reliable datasets to feed model. Identify and engage high-risk supplier population with the production part approval process (PPAP) and enhanced first article inspection (FAI) tools to proactively identify and correct process deficiencies. We will measure quality performance at target supplier population before and after.

Title: *Technology Management & Diminishing Manufacturing Sources (Dms) Framework*
Principal Investigator(s): SMITH, ERIC D
Department, Center, or Institute: RES INST/MANUFACT/ENGR
Institution: The University of Texas at El Paso
Discipline: IND., MANFG. & SYSTEMS ENG.
Funding Agency: Lockheed Martin Aeronautics
Award Number: M7809010
Award Amount: $49,997
Abstract: Two graduate students from the University of Texas at El Paso will provide Lockheed Martin Aero with a Technology Management & Diminishing Manufacturing Sources Framework and Data Set to be used in the development of an introductory Technology Management & Diminishing Manufacturing Sources (DMS) course to support TM/DMS Engineers conducting air system design, development, and operations. The TM/DMS Framework and Data Set Package will include the following sections.

Title: *Integrated Technology Management User Guide*
Principal Investigator(s): RES INST/MANUFACT/ENGR
Department, Center, or Institute: SMITH, ERIC D
Institution: The University of Texas at El Paso

Discipline: IND., MANFG. & SYSTEMS ENG.
Funding Agency: Lockheed Martin Aeronautics
Award Number: M7809013
Award Amount: $50,143
Abstract: Two graduate students from the University of Texas at El Paso will provide Lockheed Martin Aeronautics with an Integrated Technology Management User Guide, illustrating the processes in Lockheed Martin (LM) Technology Management Guide (TMG). The Integrated Technology Management User Guide will detail how the integrated technology management processes in the appendices of the LM Technology Management Guide, as well as details in the body of the TMG are optimally executed using a virtually developed Represented System. The UT-El Paso team will illustrate in detail each step/analysis needed to execute the integrated technology management process. The Representative System will be a theoretical navigation or communication system that could go into various types of aircraft, ships and/or land units – given that there are three programs (aircraft, ship, land unit) that are going to collaborate on the project and follow the TMG process to achieve a successful and cost-effective technology transition. The example will illustrate how the TMG processes would be best executed in this collaborative Technology Management environment.

The University of Texas at San Antonio (UT-San Antonio)

The University of Texas at San Antonio listed five active awards in aerospace technology for FY 2015, with a total award amount of $1,168,989. During that year, The University of Texas at San Antonio's research expenditures for awards in aerospace technology were $894,749. Information for the identified active awards are provided.

Title: *Minority Leaders Program, Materials and Manufacturing Nanotechnology Research*
Principal Investigator(s): Castillo Villar, Krystel
Department, Center, or Institute: Department of Mechanical Engineering
Institution: The University of Texas at San Antonio
Discipline: Engineering
Funding Agency: Clarkson Aerospace Corporation
Award Number: P5983
Award Amount: $139,189
Abstract: The quantification of dimensional variability in manufactured parts characterized by complex surface geometries (e.g., airfoils, turbine blades, among others) often requires the use of high-quantity, non-contact scanning systems (also known as 3D laser scanners), as well as big data analytics to elucidate the systematic and the random errors involved. 3D laser scanners have the potential to detect unforeseen failures in as-manufactured parts that cannot be captured by conventional Coordinate Measuring Machines (CMM). This is because CMMs measure a fixed number of predetermined dimensions, while 3D laser scanners acquire high-density point clouds of the complex geometries under consideration. A large variety of manufacturing companies are now acquiring 3D laser scanners to inspect complex parts and improve the overall quality of their products. Traditional

3D inspection involves separating bad parts from good parts; however, these activities often neglect part-to-part variation and shifts in manufacturing processes. As a fundamental part of the research agenda of these state-of-the-art measuring technologies, an efficient way is needed to: 1) quantify the uncertainty in the measurement process, and 2) develop novel Statistical Process Control (SPC) techniques so that 3D laser scanner measurement repeatability and reproducibility can be distinguished from the geometrical variation of production lots. The study of the effects that relevant factors have in the scanning process, as well as the identification of realistic statistical distributions that describe the geometric variations found in as-manufactured components, can serve as inputs to performance models (e.g., lifting models and strength models) and enable quantification of the impact of geometric variability on system performance. The overall objective is to investigate real-time big data analytics methods and techniques that provide decision makers with improved ability to process, visualize, and interact with big data generated from non-contact scanning systems.

Title: *Probing Cell Membranes through Multi-Responsive Nanoparticles*
Principal Investigator(s): Nash, Kelly
Department, Center, or Institute: Department of Physics and Astronomy
Institution: The University of Texas at San Antonio
Discipline: Nanoscience
Funding Agency: US Department of the Air Force
Award Number: P5300
Award Amount: $350,000
Abstract: The research proposed here will study the dynamics and composition of cell membranes through the use of heterogeneous nanoparticle platforms. This approach is based on acquiring synergistic optical signatures from nanoparticles in response to biological systems. The proposed nanostructures composed of luminescent lanthanide nanoparticles decorated with metallic nanoparticles will be utilized as optical imaging contrast by utilizing their ability to be excited in the near infrared (NIR) and to emit in the visible-to-NIR region. This will enable multi-wavelength detection without potentially interfering autoflourescence from biomolecules. The addition of metallic nanoparticles, such as gold or silver, will enable the use of surface enhanced Raman scattering (SERS) such that the molecular specificity from the vibrational spectra will not require potentially interfering molecular labels. Based on this approach, the luminescence and SERS will be applied to a range of samples, including proteins, simple model membranes, and live cell biomembranes. Molecular interactions with the nanoparticles will be studied for the determination of the detection limit of the both luminescence and SERS fingerprints of the model proteins. Through lipid bilayers assembled on the nanoparticle surfaces, we will investigate supramolecular organization of this organic – inorganic interface in an effort to provide an understanding of physical-chemical interactions. Finally, through studies on intact cell membranes, luminescence will be used as an imaging contrast for particle tracking as the nanoparticles interact with the biomembrane while SERS will provide a spectral map of the membranes to determine the heterogeneity associated with cell signaling. Additionally, electron microscopy techniques

including cryoelectron microscopy will provide insight into co-localization of nanoparticles with the biological systems, which can be compared to results from biospectroscopic investigations. The proposed research supports research interest Air Force Office of Scientific Research (AFOSR), such as enhancing imaging while elucidating basic biophysical function for future development of enhanced human performance.

Title: *Cooperative Control and Sensing for Multiple Unmanned Aerial Vehicles (UAVs) Working in GPS-denied Environments*

Principal Investigator(s): Pack, Daniel
Department, Center, or Institute: Department of Electrical Engineering
Institution: The University of Texas at San Antonio
Discipline: Engineering
Funding Agency: US Department of the Air Force
Award Number: P4694
Award Amount: $125,000

Abstract: In this project, we propose to develop distributed, cooperative 1) navigation algorithms, and 2) ground target tracking technologies for multiple small UAVs operating in GPS challenged/denied environments. UT-San Antonio currently has capabilities to localize stationary and mobile ground targets using multiple cooperative small UAVs. The technologies, however, rely on the availability of GPS signals, which cannot be guaranteed for a growing number of applications due to jamming signals and obstructions, such as buildings and mountains. Existing non-GPS navigation solutions employ inertial navigation systems (INS), which tend to be bulky and expensive, making them unsuitable for small UAVs. We plan to use range measurements obtained from communication radios onboard UAVs to self-locate UAVs in a distributed manner. The task is challenging since the UAV topology constantly changes and needs to be controlled. The self-location is performed individually using distributed estimation technique, including the Out-of-Order Sigma Point Kalman filters and distributed consensus filters. The range measurements will be complemented with the vision-aided navigation technology we are currently developing, to improve the localization accuracy. Using both the self-localization and vision-aided UAV navigation technologies, UAVs will be enabled to navigate when GPS is partially blocked or missing by observing the motions of neighboring UAVs and ad hoc (natural) landmarks on the ground. To track ground targets, a combination of virtual sensor field of views, generated by controlling the motions of UAVs, and distributed motion estimation filters will be used. Distributed networked filters and optimal cooperative control techniques will combine the information retrieved from virtual field of views, with camera constraints, platform and target motions, and measurements from both range sensor and camera sensor onboard UAVs to produce navigation and localization solutions for a team of UAVs.

Title: *Extending GPS Operation in GPS-denied Areas Through Cross-Correlation Jamming Cancellation*

Principal Investigator(s): Pack, Daniel and David Akopian
Department, Center, or Institute: Department of Electrical Engineering
Institution: The University of Texas at San Antonio
Discipline: Engineering
Funding Agency: US Department of the Air Force
Award Number: P5654
Award Amount: $194,800

Abstract: Through this project, we propose a joint project between the United States Air Force Academy (USAFA) and the UT-San Antonio to develop and demonstrate core technologies that enable GPS signal reception in GPS-denied environments through interference mitigation. GPS-denied environments are often interpreted as fundamentally inaccessible for GPS signals. While signal propagation environments can be very challenging for conventional receiver operations, advanced signal processing methods can significantly mitigate these phenomena. A common source of GPS signal impairments is intentional and unintentional interference signals generating undesirable cross-correlation. Examples include jamming of relatively weak GPS-satellite signals by stronger signals from other GPS-satellites, terrestrial GPS-like beacons called pseudolites, multipath reflections of the line-of-sight signals and various jammers. The proposed technology mitigates these interferences in real-time through a real-time adaptive, mathematically optimal, method, incorporating interference-rejection filters in signal acquiring correlators. The objectives of the proposed project are: 1) to implement the developed GPS jamming mitigation technology on a hardware system, and 2) to flight demonstrate real-time operations of the hardware system using an unmanned aerial vehicle, proving its theoretical superior performance that exceeds 20 folds improvement, compared to the ones using conventional GPS receivers in GPS-denied environments. By 20 folds, we mean that the proposed GPS signal receiver will operate normally until its proximity to a jammer is 1/20th of the relative distance where standard GPS receivers begin to malfunction.

Title: *Predictive Simulation of Material Failure Using Peridynamics - Advanced Constitutive Modeling, Verification, and Validation*

Principal Investigator(s): Foster, John
Department, Center, or Institute: Center for Simulation Visualization and Real Time Prediction (SiViRT)
Institution: The University of Texas at San Antonio
Discipline: Engineering
Funding Agency: Air Force Office of Scientific Research
Award Number: A1280
Award Amount: $360,000

Abstract: The proposed research will seek to advance the predictive simulation capabilities for the deformation and failure of engineering materials through development, verification, and validation of new constitutive models within the framework of the peridynamic theory of solid mechanics (peridynamics). Relaxed kinematic assumptions allow the peridynamic momentum balance to be satisfied even in the face of nondifferentiablity, discontinuities, shocks, voids, and other defects in an otherwise continuous body. This allows for a straightforward and mathematically consistent way to model material failure and other complex behavior. In the proposed research, new constitutive models that have no analogue in classical theory will be explored. Starting with the unique development of beam, plate, and shell theories, these models may lead to advancements that could describe material behavior not typically found in nature and, therefore, have implications toward advancements in macro-scale metamaterials modeling. These lower dimensional structures will be explored in an effort for the problems to remain tractable, such that analytic solutions can be developed for verification of numerical simulations. Finally, a validation effort will be undertaken to validate simulations against experiments involving material failure in the context of material uncertainty. Probabilistic techniques will be used to define convergence of computational simulations with respect to distributions of experimental data.

University of Houston (UH)

The University of Houston listed 49 active awards in aerospace technology for FY 2015, with a total award amount of $25,598,483. During that year, the University of Houston's research expenditures for awards in aerospace technology were $1,264,527. Information for the identified active awards are provided.

Title: *Houston-Louis Stokes Alliance for Minority Participation: Senior Alliance*
Principal Investigator(s): Renu Khator
Department, Center, or Institute: College of Natural Sciences and Mathematics
Institution: University of Houston
Discipline: Engineering
Funding Agency: National Science Foundation
Award Number: 0903948
Award Amount: $3,500,000
Abstract: Collaborative between UH, University of Houston-Downtown, Texas Southern University, Texas State University, Houston Community Collge (Houston CC), San Jacinto College, Rice University, and Houston ISD to recruit and enhance success of underrepresented STEM majors; increase Houston CC transfers and provide opportunities for international experiences.

Title: *Search for and Study of Novel Superconductor with Higher Tc and Jc*
Principal Investigator(s): Ching-Wu Chu
Department, Center, or Institute: Texas Center for Superconductivity at the University of Houston
Institution: University of Houston
Discipline: Physics
Funding Agency: U.S. Air Force Office of Scientific Research
Award Number: FA9550-09-1-0656
Award Amount: $2,800,000

Abstract: Multidisciplinary approach to synthesize and characterize single crystals of novel superconducting materials.

Title: *Integrated Remote Sensing and Shallow Geophysical Investigations on the Pelusiac River, an Ancient Branch of the Nile River*
Principal Investigator(s): Shuhab Khan
Department, Center, or Institute: Department of Earth & Atmospheric Sciences
Institution: University of Houston
Discipline: Earth & Atmospheric Sciences
Funding Agency: National Science Foundation
Award Number: OISE-1004168
Award Amount: $57,256
Abstract: Applications of remote sensing to image surface and subsurface features along the Nile River.

Title: *Isotopic Investigations of Planetary and Solar System Materials*
Principal Investigator(s): Alan Brandon
Department, Center, or Institute: Department of Earth & Atmospheric Sciences
Institution: University of Houston
Discipline: Earth & Atmospheric Sciences
Funding Agency: NASA - Headquarters
Award Number: NNX12AD06G
Award Amount: $546,000
Abstract: Investigation of isotope mixing in the solar nebula to reveal solar and pre-solar components involved in terrestrial planets.

Title: *Coupled Lu-Hf and Sm-Nd Isotopic Studies of Martian meteorites: Constraints on Crystallization Ages and Source Compositions*
Principal Investigator(s): Thomas Lapen
Department, Center, or Institute: Department of Earth & Atmospheric Sciences
Institution: University of Houston
Discipline: Earth & Atmospheric Sciences
Funding Agency: NASA - Headquarters
Award Number: NNX11AF52G
Award Amount: $201,364
Abstract: Investigation of Martian meteorites to understand source compositions and crystallization ages to understand magmatic processes in Mars.

Title: *Effects of Long-Term Exposure to Microgravity on Salivary Markers of Innate Immunity*
Principal Investigator(s): Richard Simpson
Department, Center, or Institute: Center for Neuromotor & Biomechanics Research
Institution: University of Houston
Discipline: Health and Human Performance

Funding Agency: NASA - Johnson Space Center
Award Number: NNX12AB48G
Award Amount: $712,411
Abstract: Studies of spaceflight-associated immune system dysregulation using multiple measures throughout phases during the six-month period on the International Space Station (ISS).

Title: *Control and Investigation of Microbes in the Space Environment*
Principal Investigator(s): James M. Briggs
Department, Center, or Institute: Department of Biology/Biochemistry
Institution: University of Houston
Discipline: Biology/Biochemistry
Funding Agency: Texas Southern University
Award Number: NNX108Q16A
Award Amount: $297,650
Abstract: Developing effective bacteria and fungi control applications for manned missions on the International Space Station (ISS).

Title: *Investigate the Recycling Rate of Moisture in the Atmosphere from Observation and Model*
Principal Investigator(s): Xun Jiang
Department, Center, or Institute: Institute for Climate and Atmospheric Science
Institution: University of Houston
Discipline: Earth & Atmospheric Sciences
Funding Agency: NASA - Headquarters
Award Number: NNX13AC04G
Award Amount: $255,792
Abstract: Studies of atmospheric moisture and modeling spatial and recycling patterns using observational data sets.

Title: *Enhancing the Speed and Quality of CO2 Retrievals from the OCO-2 Mission*
Principal Investigator(s): Xun Jiang
Department, Center, or Institute: Institute for Climate and Atmospheric Science
Institution: University of Houston
Discipline: Earth & Atmospheric Sciences
Funding Agency: California Institute of Technology
Award Number: 65P-1094260
Award Amount: $80,000
Abstract: Simulations of CO2 profile using several approaches and data from satellite CO2 data.

Title: *A High-Order, Multi-scale Numerical Approach for Kinetic Simulations*
Principal Investigator(s): Jingmei Qiu
Department, Center, or Institute: Mathematics
Institution: University of Houston
Discipline: Department of Mathematics
Funding Agency: U.S. Air Force Office of Scientific Research
Award Number: FA9550-12-1-0318
Award Amount: $359,760
Abstract: Development of a numerical algorithm for kinetic simulations with applications to plasma physics, astrophysics, and rarefied gas dynamics.

Title: *Medipix 3 Collaboration and Support for on Orbit Technology Development and Demonstration*
Principal Investigator(s): Lawrence S. Pinsky
Department, Center, or Institute: Department of Physics
Institution: University of Houston
Discipline: Physics
Funding Agency: Wyle Science Technology and Engineering Group
Award Number: T72203
Award Amount: $1,635,943
Abstract: Providing active radiation detectors in support of the Radiation Environment Monitor technology and orbit demonstration and data analysis.

Title: *Enhancement of Gravity Recovery and Climate Experiment (GRACE) Temporal Gravity Field Solutions to Study Terrestrial Water Dynamics in the Congo Basin*
Principal Investigator(s): Hyongki Lee
Department, Center, or Institute: Department of Civil Engineering
Institution: University of Houston
Discipline: Civil Engineering
Funding Agency: NASA - Goddard Space Flight Center
Award Number: NNX12AJ95G
Award Amount: $606,508
Abstract: NASA GRACE investigation to calibrate HRR model over the Congo Basin and produce hydrological model and wetland water storage with hydrologic/hydraulic interpretation.

Title: *Microfluidic Label-free Sensing for Rapid Multiplexed Pathogen Detection in Space Missions*
Principal Investigator(s): Wei-Chuan Shih
Department, Center, or Institute: Department of Electrical & Computer Engineering
Institution: University of Houston
Discipline: Electrical & Computer Engineering
Funding Agency: NASA - Stennis Space Center
Award Number: NNX12AQ44G
Award Amount: $600,000

Abstract: Space-friendly technology to identify and quantify unlabeled pathogens for use in monitoring and control during space missions.

Title: *University of Houston SLS Graduate Research Stipend (ST-II)*
Principal Investigator(s): Charles S. Layne
Department, Center, or Institute: Department of Health and Human Performance
Institution: University of Houston
Discipline: Health and Human Performance
Funding Agency: NASA - Johnson Space Center
Award Number: NNX12AO33G
Award Amount: $79,991
Abstract: Graduate student trainees in human spaceflight research.

Title: *Control of Electromagnetic Fields*
Principal Investigator(s): Daniel Onofrei
Department, Center, or Institute: Department of Mathematics
Institution: University of Houston
Discipline: Mathematics
Funding Agency: U.S. Air Force Office of Scientific Research
Award Number: FA9550-13-1-0078
Award Amount: $360,000
Abstract: Detect and control unknown electromagnetic fields using a unified physical mathematical approach and design of antennas with associated computational tools.

Title: *High Hydrogen Content Nanostructured Polymer Radiation Protection System*
Principal Investigator(s): Alex Ignatiev
Department, Center, or Institute: Center for Advanced Materials
Institution: University of Houston
Discipline: Physics
Funding Agency: NASA - Goddard Space Flight Center
Award Number: NNX13AC85G
Award Amount: $499,836
Abstract: Development of a new radiation protection system using polyaniline nanostructures.

Title: *An Advanced Learning Framework for High Dimensional Multi-Sensor Remote Sensing Data*
Principal Investigator(s): Saurabh Prasad
Department, Center, or Institute: Department of Electrical & Computer Engineering
Institution: University of Houston
Discipline: Electrical & Computer Engineering
Funding Agency: Purdue University
Award Number: 4103-51247

Award Amount: $224,553
Abstract: Develop a multi-kernal approach to spatial-spectral analysis of hyperspectral imagery.

Title: *Energy Balance of Saturn and Jupiter*
Principal Investigator(s): Liming Li
Department, Center, or Institute: Department of Physics
Institution: University of Houston
Discipline: Physics
Funding Agency: NASA - Headquarters
Award Number: NNX09AV77G
Award Amount: $319,920
Abstract: Investigation of energy balance on Saturn and Jupiter.

Title: *Enhanced Development of the Office of Scientific Data Review and Dissemination*
Principal Investigator(s): Charles S. Layne
Department, Center, or Institute: Department of Health and Human Performance
Institution: University of Houston
Discipline: Health and Human Performance
Funding Agency: WYLE Laboratories
Award Number: T72314
Award Amount: $3,886,343
Abstract: Work with the Office of Scientific Data Review.

Title: *The Mars Rover Model Celebration: Enhancing Formal and Informal STEM Education in Grades 3-8 and Improving Teacher Training Using the Excitement of NASA's Latest Mars Missions*
Principal Investigator(s): Edgar A. Bering
Department, Center, or Institute: Department of Physics
Institution: University of Houston
Discipline: Physics
Funding Agency: NASA - Headquarters
Award Number: NNX12AB56G
Award Amount: $414,428
Abstract: STEM education aimed at grades 3-8 focused on NASA's explorations of Mars.

Title: *NASA Intergovernmental Personnel Act (IPA) Agreement: Manager, Human Research Program (HRP)*
Principal Investigator(s): William Paloski
Department, Center, or Institute: Department of Health and Human Performance
Institution: University of Houston
Discipline: Health and Human Performance
Funding Agency: NASA - Johnson Space Center
Award Number: NNJ13ZA04P
Award Amount: $777,291

Abstract: HRP Manager.

Title: *Vibration Spectrometer for Detecting Single Atoms Using Carbon Nanotube Resonator Arrays*
Principal Investigator(s): Zhifeng Ren
Department, Center, or Institute: Texas Center for Superconductivity at the University of Houston
Institution: University of Houston
Discipline: Physics
Funding Agency: U.S. Air Force Academy
Award Number: FA7000-13-1-0001
Award Amount: $1,137,042
Abstract: Design and establish a new mass spectrometer using carbon nanotube arrays as detectors.

Title: *Improved Quantification of Global Mountain Glacier Mass Balance Estimate*
Principal Investigator(s): Hyongki Lee
Department, Center, or Institute: Department of Civil Engineering
Institution: University of Houston
Discipline: Civil Engineering
Funding Agency: Ohio State University
Award Number: 60039639
Award Amount: $105,225
Abstract: Retracking of radar altimetry data over mountain glaciers and ice caps.

Title: *Experimental Investigations on Reaction Pathways and Isotope Signatures of Abiotic Organic Synthesis in Hydrothermal Systems*
Principal Investigator(s): Qi Fu
Department, Center, or Institute: Department of Earth & Atmospheric Sciences
Institution: University of Houston
Discipline: Earth & Atmospheric Sciences
Funding Agency: NASA - Goddard Space Flight Center
Award Number: NNX13AH75G
Award Amount: $88,488
Abstract: Reaction pathways and isotope signatures of abiotic organic synthesis in hydrothermal systems.

Title: *Climate Change Adaptation Science at NASA and Johnson Space Center (JSC): Phase 2*
Principal Investigator(s): Ramesh Shrestha
Department, Center, or Institute: National Center for Airborne Laser Mapping
Institution: University of Houston
Discipline: Civil Engineering
Funding Agency: NASA - Johnson Space Center

Award Number: NNX14AP77G
Award Amount: $72,086
Abstract: Investigations of water-related hazards and inland flooding in the region surrounding JSC.

Title: *Research Opportunities in Complex Fluids and Macromolecular Biophysics-NRA-NNH13ZTT001N*
Principal Investigator(s): Peter Vekilov
Department, Center, or Institute: Department of Chemical Engineering
Institution: University of Houston
Discipline: Chemical Engineering
Funding Agency: NASA - Headquarters
Award Number: NNX14AD68G
Award Amount: $841,142
Abstract: Protein crystallization characterizations in microgravity conditions.

Title: *MURI: Cryogenic Peltier Cooling*
Principal Investigator(s): Zhifeng Ren
Department, Center, or Institute: Texas Center for Superconductivity at the University of Houston
Institution: University of Houston
Discipline: Physics
Funding Agency: Ohio State University
Award Number: RF01344603
Award Amount: $623,559
Abstract: Investigations of Peltier coolers using semiconducting and metallic materials to produce materials for cryogenic temperatures.

Title: *An Undergraduate Student Instrumentation Project to Develop New Instrument Technology to Study the Auroral Ionosphere and Stratospheric Ozone Layer Using Ultralight Balloon Payloads*
Principal Investigator(s): Edgar A. Bering
Department, Center, or Institute: Department of Physics
Institution: University of Houston
Discipline: Physics
Funding Agency: NASA - Headquarters
Award Number: NNX13AR57G
Award Amount: $50,000
Abstract: Student project using instrumented balloons to monitor ozone and nitrogen profiles for understanding magnetospheric and auroral physics.

Title: *The Mars Rover Model Celebration: Enhancing Formal and Informal STEM Education in Grades 3-8 and Improving Teacher Training Using the Excitement of NASA's Latest Mars Missions*
Principal Investigator(s): Bonnie Dunbar
Department, Center, or Institute: Department of Mechanical Engineering
Institution: University of Houston
Discipline: Mechanical Engineering
Funding Agency: University of Texas at Austin
Award Number: UTA13-000843
Award Amount: $15,000
Abstract: Science Mission Directorate (SMD) education resources with science and mission data from NASA Mars exploration to enhance curricula for grades 3-8.

Title: *SBIR: Spatiotemporal Dynamical System Analysis Tools for Very Large Data Sets*
Principal Investigator(s): Gemunu H. Gunaratne
Department, Center, or Institute: Department of Physics
Institution: University of Houston
Discipline: Physics
Funding Agency: Spectral Energies, LLC
Award Number: SB1317-001-1
Award Amount: $174,999
Abstract: Nonlinear analysis tools for analysis of engineering of the propulsion system using big data sets for modeling.

Title: *High-Bandwidth, Laser-Based Measurements and Modeling for Thermo-acoustic Instabilities in High-Pressure Combustors for Aerospace Fuels and Emerging Alternatives*
Principal Investigator(s): Gemunu H. Gunaratne
Department, Center, or Institute: Department of Physics
Institution: University of Houston
Discipline: Physics
Funding Agency: Spectral Energies, LLC
Award Number: SB1306-001-2
Award Amount: $69,764
Abstract: Modeling and diagnostic approaches for devising intelligent control strategies using high-bandwidth data from laser-based measurements.

Title: *Modeling and Experimental Studies on Gas-Liquid Two-Phase Flow through Packed Beds in Microgravity*
Principal Investigator(s): Vemuri Balakotaiah
Department, Center, or Institute: Department Chemical Engineering
Institution: University of Houston
Discipline: Chemical Engineering
Funding Agency: NASA - Glenn Research Center
Award Number: NNX14AD28G

Award Amount: $300,000

Abstract: Investigation of gas-liquid phase flows in microgravity on the International Space Station (ISS).

Title: *Solar System Exploration Research Virtual Institute (SSERVI)*
Principal Investigator(s): Thomas Lapen
Department, Center, or Institute: Department of Earth & Atmospheric Sciences
Institution: University of Houston
Discipline: Earth & Atmospheric Sciences
Funding Agency: Universities Space Research Association
Award Number: 02235-06
Award Amount: $185,177

Abstract: Petrologic and geochemical analyses of lunar and meteoritic samples for lunar and asteroid science.

Title: *Transitioning from an RNA World: The Origins of the Protein Synthesis Machinery*
Principal Investigator(s): George E. Fox
Department, Center, or Institute: Department of Biology/Biochemistry
Institution: University of Houston
Discipline: Biology/Biochemistry
Funding Agency: NASA - Headquarters
Award Number: NNX14AK16G
Award Amount: $421,039

Abstract: Investigation of the origins of the modern ribosome in the context of the amino acids in conserved functional biomolecules.

Title: *Development of Novel Integrated Antennas for CubeSats*
Principal Investigator(s): David R. Jackson
Department, Center, or Institute: Department of Electrical & Computer Engineering
Institution: University of Houston
Discipline: Electrical & Computer Engineering
Funding Agency: NASA - Johnson Space Center
Award Number: NNX13AR44A
Award Amount: $199,860

Abstract: Cubsat antenna for communications on space missions and in aerospace.

Title: *Composite Nanoshells for Enhanced Solar-to-Fuel Photocatalytic Conversion*
Principal Investigator(s): T. Randall Lee
Department, Center, or Institute: Department of Chemistry
Institution: University of Houston
Discipline: Chemistry
Funding Agency: National Central University
Award Number: 107097
Award Amount: $45,000

Abstract: Development of nanoshell materials to absorb light and inhibit photocorrosion and extend semiconductor lifetime.

Title: *Evolutionary History of the Translation Machinery*
Principal Investigator(s): George E. Fox
Department, Center, or Institute: Department of 'Biology/Biochemistry
Institution: University of Houston
Discipline: 'Biology/Biochemistry
Funding Agency: NASA - Goddard Space Flight Center
Award Number: NNX14AK36G
Award Amount: $422,732
Abstract: Investigation of conserved cellular translational processes in ribosomal function.

Title: *Generation of Mesendoderm Stem Cell Progenitors in the ISS-National Laboratory*
Principal Investigator(s): Robert Schwartz
Department, Center, or Institute: Department of 'Biology/Biochemistry
Institution: University of Houston
Discipline: 'Biology/Biochemistry
Funding Agency: Center for the Advancement of Science in Space
Award Number: GA-2014-128
Award Amount: $268,006
Abstract: Investigation of fibroblast stem cell reprogramming into cardiac progenitors in tissue culture in preparation for spaceflight study.

Title: *Novel Bayesian Image Analysis for Robust Multisensor Remote Sensing with Applications to Coastal Ecosystem Monitoring*
Principal Investigator(s): Saurabh Prasad
Department, Center, or Institute: Department of Electrical & Computer Engineering
Institution: University of Houston
Discipline: Electrical & Computer Engineering
Funding Agency: NASA - Goddard Space Flight Center
Award Number: NNX14AI47G
Award Amount: $261,105
Abstract: LiDAR data analyses to model environmental climate change.

Title: *Estimating Two-Dimensional Surface Water Depths in the Congo Wetlands using Multiple Remote Sensing Measurements*
Principal Investigator(s): Hyongki Lee
Department, Center, or Institute: Department of Civil Engineering
Institution: University of Houston
Discipline: Civil Engineering
Funding Agency: NASA - Goddard Space Flight Center
Award Number: NNX14AI01G
Award Amount: $256,165

Abstract: Modeling Congo Basin water and vegetative land cover through satellite radar altimetry.

Title: *Decomposing the Water Storage Signal from Basins in Varied Climate Settings with Remote Sensing and Modeling*
Principal Investigator(s): Hyongki Lee
Department, Center, or Institute: Department of Civil Engineering
Institution: University of Houston
Discipline: Civil Engineering
Funding Agency: Northeastern University
Award Number: 505015-78050
Award Amount: $46,875
Abstract: Radar altimetry applications for modeling and monitoring time related change in selected water bodies.

Title: *AFRL Collaboration Program-Materials and Manufacturing Research - Raman Microscopy Characterization and Computational Simulations of Refractory Matrices and Nanocrystalline Carbides*
Principal Investigator(s): Viktor Hadjiev
Department, Center, or Institute: Texas Center for Superconductivity at the University of Houston
Institution: University of Houston
Discipline: Chemistry
Funding Agency: Clarkson Aerospace Corporation
Award Number: UHH-13-S7700-01-C2
Award Amount: $85,000
Abstract: Applications of advanced optical spectroscopy and first-principles simulations to characterize nanocomposites for structural and thermal protection systems.

Title: *Air Force Research Lab (AFRL) Collaboration Program-Materials and Manufacturing Research*
Principal Investigator(s): James Meen
Department, Center, or Institute: Texas Center for Superconductivity at the University of Houston
Institution: University of Houston
Discipline: Physics
Funding Agency: Clarkson Aerospace Corporation
Award Number: UHM 13-S7700-01-C1
Award Amount: $175,000
Abstract: Development of high temperature electronics for application in aerospace in essential electronic circuits.

Title: *Tools to Study Interfaces for Superconducting, Thermoelectric, and Magnetic Materials at the University of Houston*
Principal Investigator(s): Ching-Wu Chu
Department, Center, or Institute: Texas Center for Superconductivity at the University of Houston
Institution: University of Houston
Discipline: Physics
Funding Agency: U.S. Air Force - Asian Office of Aerospace Research & Development
Award Number: FA2386-14-1-3007
Award Amount: $781,612
Abstract: Study of superconducting interfaces.

Title: *Formation Mechanisms of the Protein-Rich Clusters*
Principal Investigator(s): Peter Vekilov
Department, Center, or Institute: Department of Chemical Engineering
Institution: University of Houston
Discipline: Chemical Engineering
Funding Agency: NASA - Marshall Space Flight Center
Award Number: NNX14AE79G S01
Award Amount: $500,000
Abstract: Investigations of protein clusters.

Title: *Flexible and Stretchable Lithium Ion Batteries for Space Suits*
Principal Investigator(s): Haleh Ardebili
Department, Center, or Institute: Department of Mechanical Engineering
Institution: University of Houston
Discipline: Mechanical Engineering
Funding Agency: University of Texas-Texas Space Grant Consortium
Award Number: 14-000562
Award Amount: $10,000
Abstract: Development of thin film batteries for space suits.

Title: *Metal Nanoshells for Plasmonically Enhanced Solar-to-Fuel Photocatalytic Conversion*
Principal Investigator(s): T. Randall Lee
Department, Center, or Institute: Department of Chemistry
Institution: University of Houston
Discipline: Chemistry
Funding Agency: U.S. Air Force - Asian Office of Aerospace Research & Development
Award Number: FA2386-14-1-4074
Award Amount: $60,000
Abstract: Investigation of photonic nanoparticle structures for application in power conversion efficient fuel cell systems.

Title: *International Space Station (ISS) - Microbial Observatory*
Principal Investigator(s): George E. Fox
Department, Center, or Institute: Department of Biology/Biochemistry
Institution: University of Houston
Discipline: Biology/Biochemistry
Funding Agency: Jet Propulsion Laboratory
Award Number: 1506453
Award Amount: $90,000
Abstract: NextGen sequencing for bioinformatic study of samples from ISS.

Title: *High-Fidelity Sizing Model for Superconducting Rotating Machines for Turbo-Electric Propulsion Design - Year 4*
Principal Investigator(s): Philippe Masson
Department, Center, or Institute: Department of Mechanical Engineering
Institution: University of Houston
Discipline: Mechanical Engineering
Funding Agency: Advanced Magnet Lab
Award Number: 108653
Award Amount: $98,561
Abstract: Superconducting rotating machines in propulsion systems for aeronautic applications.

University of Houston-Clear Lake (UH-Clear Lake)

The University of Houston-Clear Lake listed three active awards in aerospace technology for FY 2015, with a total award amount of $267,346. During that year, UH-Clear Lake's research expenditures for the award were $184,784. Information for the identified active awards is provided.

Title: *Dependence of Radiation Quality on Charged Particle-Induced Chromosomes*
Principal Investigator(s): Larry Rohde
Department, Center, or Institute: Department of Biology
Institution: University of Houston-Clear Lake
Discipline: Biological Sciences
Funding Agency: NASA-Johnson Space Center (JSC)
Award Number: NNX12AD35A
Award Amount: $27,347
Abstract: Dependence of Radiation Quality on charged particle-induced early and late damages in chromosomes and investigation of intrachromosome rearrangement as a biodosimeter for radiation exposure.

Title: *NASA Phase 2 LED Smart Light*
Principal Investigator(s): Ahmed Abukmail
Department, Center, or Institute: Department of Computer Science
Institution: University of Houston-Clear Lake
Discipline: Math and Computer Science
Funding Agency: Innovative Imaging and Research Corp.
Award Number: N/A
Award Amount: $230,000
Abstract: Phase 2: Evaluate the potential of using a mobile device within an energy-efficient smart light system concept.

Title: *NASA Phase 2 LED Smart Light-Continuation*
Principal Investigator(s): Ahmed Abukmail
Department, Center, or Institute: Department of Computer Science
Institution: University of Houston-Clear Lake
Discipline: Math and Computer Science
Funding Agency: Innovative Imaging and Research Corp.
Award Number: N/A
Award Amount: $10,000
Abstract: Continuation of Phase 2: Evaluate the potential of using a mobile device within an energy efficient smart light system concept.

University of North Texas (North Texas)

The University of North Texas listed 10 active awards in aerospace technology for FY 2015, with a total award amount of $13,000,415. During that year, the University of North Texas' research expenditures for the awards were $712,557. Information for the identified active awards are provided.

Title: *Advanced Gas Sensing Technology for Space Suits*
Principal Investigator(s): M. Omary
Department, Center, or Institute: Department of Chemistry and AMMPI
Institution: University of North Texas
Discipline: Chemistry and Materials Science and Engineering
Funding Agency: NASA STTR (Agency Solicitation Topic: T6.01 - Gas Sensing Technologies Advancement for Space Suits)
Award Number: GN0007359
Award Amount: $31,238 (subcontract)
Abstract: Advanced space suits require lightweight, low-power, durable sensors for monitoring critical life support materials. No current compact sensors have the tolerance for liquid water that is specifically required for portable life support systems (PLSS). IOS and North Texas will develop a luminescence-based optical sensor probe to monitor carbon dioxide, oxygen, and humidity, and selected trace contaminants. Our monitor will incorporate robust CO2, O2, and H2O partial pressure sensors interrogated by a compact, low-power optoelectronic unit. The

sensors will not only tolerate liquid water but will actually operate while wet, and can be remotely connected to electronic circuitry by an optical fiber cable immune to electromagnetic interference. For space systems, these miniature sensor elements with remote optoelectronics give unmatched design flexibility for measurements in highly constrained volume systems such as PLSS. Our flow-through monitor design includes an optical sensor we have already developed for PLSS humidity monitoring, and an optical oxygen sensor – both of them based on a common IOS technology. In prior projects, IOS has demonstrated a CO_2 sensor capable of operating while wet that also met PLSS environmental and analytical requirements, but did not meet life requirements. A new generation of CO_2 sensors will be developed to advance this sensor technology and fully meet all NASA requirements, including sensor life. The totally novel approach will overcome the limitations of state-of-the-art luminescent sensors for CO_2. Additional sensors will be developed to monitor trace contaminants often found in the ventilation loop as result of material off-gassing or crew member metabolism. IOS has established collaboration with United Technologies (UTC) Aerospace Systems to produce prototypes for space qualification, and will conduct extensive testing under simulated space conditions, ensuring a smooth path to technology infusion.

Title: *Molecular Dynamics Simulations of Cerium Containing Glasses*
Principal Investigator(s): Jincheng Du
Department, Center, or Institute: Department of Materials Science and Engineering
Institution: University of North Texas
Discipline: Material Science and Engineering
Funding Agency: Air Force Research Lab (AFRL)
Award Number:
Award Amount: $89,000
Abstract: The local environments of cerium ions in phosphosilicate glasses have been studied using molecular dynamics simulations to understand the glass chemistry and optical absorption and radiation hardening behaviors.

Title: *Fundamental Studies on Precipitation and Transformation Temperatures in NiTiZr High-Temperature Shape Memory Alloy*
Principal Investigator(s): Marcus Young
Department, Center, or Institute: Department of Materials Science and Engineering
Institution: University of North Texas
Discipline: Material Science and Engineering
Funding Agency: ATI Specialty Alloys and Components
Award Number: GP6483
Award Amount: $59,948
Abstract: The program of research will cover a period of 12 months. The focus of this research program will be to study the effect of precipitation in NiTiZr high-temperature shape memory alloy (HTSMA) on transformation temperatures. Also, microstructural characterizations will be conducted on the supplied alloys to further the understanding of the evolution of the microstructure, as a result of thermomechanical processing. As-cast buttons or rolled NiTiZr alloy strip that

range from slightly Ni rich to slightly Ti rich will be supplied by ATI Specialty Alloys and Components. This research will impact the fundamental understanding of precipitation in NiTiZr and lead to improved shape memory effect and superelasticity at high temperature in NiTiZr HTSMA.

Title: *Institute for Science and Engineering Simulation (ISES)*
Principal Investigator(s): Rajarshi Banerjee
Department, Center, or Institute: Department of Materials Science and Engineering
Institution: University of North Texas
Discipline: N/A
Funding Agency: Air Force Research Laboratory (AFRL)
Award Number: FA8650-08-C-5226
Award Amount: $11,027,048
Abstract: N/A

Title: *Integration of ICME with Legacy and Novel TMP Processing for Assured Properties in Large Titanium Structure*
Principal Investigator(s): Rajarshi Banerjee
Department, Center, or Institute: Department of Materials Science and Engineering
Institution: University of North Texas
Discipline: N/A
Funding Agency: American Lightweight Materials Manufacturing Innovation Institute (ALMMII)
Award Number: TMP 3A-0003A-6
Award Amount: $450,000
Abstract: N/A

Title: *Titanium Surface Oxidation Characterization*
Principal Investigator(s): Rajarshi Banerjee
Department, Center, or Institute: Department of Materials Science and Engineering
Institution: University of North Texas
Discipline: N/A
Funding Agency: Lockheed Martin Aeronautics Company
Award Number: XH3583790E
Award Amount: $103,154
Abstract: N/A

Title: *DARPA Open Manufacturing: tiFAB Phase II*
Principal Investigator(s): Rajarshi Banerjee
Department, Center, or Institute: Department of Materials Science and Engineering
Institution: University of North Texas
Discipline: N/A
Funding Agency: Boeing

Award Number: HR0011-12-C-0035
Award Amount: $531,385
Abstract: N/A

Title: *Friction Stir Processing Industry/University Cooperative Research Center*
Principal Investigator(s): Rajiv Mishra
Department, Center, or Institute: Department of Materials Science and Engineering
Institution: University of North Texas
Discipline: Materials Science and Engineering
Funding Agency: National Science Foundation
Award Number: NSF-IIP-1067902
Award Amount: $193,741
Abstract: This is an industry-university cooperative research center to work on the science and technology of friction stir welding and processing.

Title: *NSF Friction Stir Processing*
Principal Investigator(s): Rajiv Mishra
Department, Center, or Institute: Department of Materials Science and Engineering
Institution: University of North Texas
Discipline: Materials Science and Engineering
Funding Agency: General Motors, Boeing, Pacific National Northwest Lab., ARL, Rolls-Royce
Award Number: *Membership Fee*
Award Amount: $175,000
Abstract: This is an industry-university cooperative research center to work on the science and technology of friction stir welding and processing.

Title: *Multiscale Fundamental Investigation of Micromechanisms of Fatigue in an Ultrafine Grained Aluminum Alloy*
Principal Investigator(s): PI-Zhiqiang Wang and Rajiv Mishra
Department, Center, or Institute: Department of Materials Science and Engineering
Institution: University of North Texas
Discipline: Materials Science and Engineering
Funding Agency: National Science Foundation
Award Number: NSF-1435810
Award Amount: $339,901
Abstract: This project investigates fatigue life in aerospace alloys.

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