NASA EPSCoR research priorities are defined by the Mission Directorates (Aeronautics Research, Human Exploration & Operations, Science, and Space Technology), and NASA's ten Centers. Each Mission Directorate and Center covers a major area of the Agency's research and technology development efforts. The below list will also be included in the FY 2015 EPSCoR Research CAN.

Research priorities for each of the Mission Directorates (followed by Centers) are summarized below;

Aeronautics Research Mission Directorate (ARMD), POC: Tony Springer, tony.springer@nasa.gov

Researchers responding to the ARMD should propose research that is aligned with one or more of the ARMD programs. Proposers are directed to the following:

- ARMD Programs: http://www.aeronautics.nasa.gov/programs.htm
- The National Aeronautics and Space Administration (NASA), Headquarters, Aeronautics Research Mission Directorate (ARMD) Current Year version of the NASA Research Announcement (NRA) entitled, "Research Opportunities in Aeronautics (ROA)" has been posted on the NSPIRES web site at http://nspires.nasaprs.com (select "Solicitations" and then "Open Solicitations").

Detailed requirements, including proposal due dates are stated in appendices that address individual thrust areas. These appendices will be posted as amendments to the ROA NRA and will be published as requirements materialize throughout the year.

Human Exploration & Operations Mission Directorate (HEOMD), POC: Bradley Carpenter, bcarpenter@nasa.gov

Human Research Program

The Human Research Program (HRP) is focused on investigating and mitigating the highest risks to human health and performance in order to enable safe, reliable, and productive human space exploration. The HRP budget enables NASA to resolve health risks in order for humans to safely live and work on missions in the inner solar system. HRP conducts research, develops countermeasures, and undertakes technology development to address human health risks in space and ensure compliance with NASA's health, medical, human performance, and environmental standards.

Space Life Sciences

The Space Life Sciences, Space Biology Program has three primary goals:

- To effectively use microgravity and the other characteristics of the space environment to enhance our understanding of fundamental biological processes;
- To develop the scientific and technological foundations for a safe, productive human presence in space for extended periods and in preparation for exploration;
- To apply this knowledge and technology to improve our nation's competitiveness, education, and the quality of life on Earth.

These goals will be achieved by soliciting research using its three program elements:

- Cell and Molecular Biology and Microbial Biology - studies of the effect of gravity and the space environment on cellular, microbial and molecular processes;
- Organismal & Comparative Biology - studies and comparisons of responses of whole organisms and their systems; and
- Developmental Biology – studies of how spaceflight affects reproduction, development, maturation and aging of multi-cellular organisms, as described in NASA's Fundamental Space Biology Science Plan (PDF, 7.4 MB).

Further details about ongoing activities specific to Space Biology are available at: [Space Biosciences website]

Physical Science Research

The Physical Science Research Program, along with its predecessors, has conducted significant fundamental and applied research, both which have led to improved space systems and produced new products offering benefits on Earth. NASA's experiments in various disciplines of physical science reveal how physical systems respond to the near absence of gravity. They also reveal how other forces that on Earth are small compared to gravity, can dominate system behavior in space.

The Physical Science Research Program also benefits from collaborations with several of the International Space Station international partners—Europe, Russia, Japan, and Canada—and foreign governments with space programs, such as France, Germany and Italy. The scale of this research enterprise promises new possibilities in the physical sciences, some of which are already being realized both in the form of innovations for space exploration and in new ways to improve the quality of life on Earth.

Research in physical sciences spans from basic and applied research in the areas of:

- Fluid physics: two-phase flow, phase change, boiling, condensation and capillary and interfacial phenomena;
- Combustion science: spacecraft fire safety, solids, liquids and gasses, supercritical reacting fluids, and soot formation;
- Materials science: solidification in metal and alloys, crystal growth, electronic materials, glasses and ceramics;
- Complex Fluids: colloidal systems, liquid crystals, polymer flows, foams and granular flows;
- Fundamental Physics: critical point phenomena, atom interferometry and atomic clocks in space

Implementing Centers: NASA's Physical Sciences Research Program is carried out at the Glenn Research Center (GRC), Jet Propulsion Laboratory (JPL) and Marshall Space Flight Center (MSFC). Further information on physical sciences research is available at http://issresearchproject.nasa.gov/

Engineering Research

- Spacecraft: Guidance, navigation and control; thermal; electrical; structures; software; avionics; displays; high speed re-entry; modeling; power systems; interoperability/commonality; advanced spacecraft materials; crew/vehicle health monitoring; life support.
- Propulsion: Propulsion methods that will utilize materials found on the moon or Mars, “green” propellants, on-orbit propellant storage, motors, testing, fuels, manufacturing, soft landing, throttle-able propellants, high performance, and descent.
- Robotic Systems for Precursor Near Earth Asteroid (NEA) Missions: Navigation and proximity operations systems; hazard detection; techniques for interacting and anchoring with Near Earth Asteroids; methods of remote and interactive characterization of Near Earth Asteroid (NEA) environments, composition and structural properties; robotics (specifically environmental scouting prior to human arrival and later to assist astronauts with NEA exploration); environmental analysis; radiation protection; spacecraft autonomy, enhanced methods of NEA characterization from earth-based observation.
- Robotic Systems for Lunar Precursor Missions: Precision landing and hazard avoidance hardware and software; high-bandwidth communication; in-situ resource utilization (ISRU) and prospecting; navigation systems; robotics (specifically environmental scouting prior to human arrival, and to assist astronaut with surface exploration); environmental analysis, radiation protection.

- Data and Visualization Systems for Exploration: Area focus on turning precursor mission data into meaningful engineering knowledge for system design and mission planning of lunar surface and NEAs. Visualization and data display; interactive data manipulation and sharing; mapping and data layering including coordinate transformations for irregular shaped NEAs; modeling of lighting and thermal environments; simulation of environmental interactions including proximity operations in irregular micro-G gravity fields and physical stability of weakly bound NEAs.
- Research and technology development areas in HEOMD support launch vehicles, space communications, and the International Space Station. Examples of research and technology development areas (and the associated lead NASA Center) with great potential include:
  - *Processing and Operations*
    - Crew Health and Safety Including Medical Operations (Johnson Space Center (JSC))
    - In-helmet Speech Audio Systems and Technologies (Glenn Research Center (GRC))
    - Vehicle Integration and Ground Processing (Kennedy Space Center (KSC))
    - Mission Operations (Ames Research Center (ARC))
    - Portable Life Support Systems (JSC)
    - Pressure Garments and Gloves (JSC)
    - Air Revitalization Technologies (ARC)
    - In-Space Waste Processing Technologies (JSC)
    - Cryogenic Fluids Management Systems (GRC)

  - *Space Communications and Navigation*
    - Coding, Modulation, and Compression (Goddard Spaceflight Center (GSFC))
    - Precision Spacecraft and Lunar/Planetary Surface Navigation and Tracking (GSFC)
    - Communication for Space-Based Range (GSFC)
    - Antenna Technology (Glenn Research Center (GRC))
    - Reconfigurable/Reprogrammable Communication Systems (GRC)
    - Miniaturized Digital EVA Radio (Johnson Space Center (JSC))
    - Transformational Communications Technology (GRC)
    - Long Range Optical Telecommunications (Jet Propulsion Laboratory (JPL))
    - Long Range Space RF Telecommunications (JPL)
    - Surface Networks and Orbit Access Links (GRC)
    - Software for Space Communications Infrastructure Operations (JPL)
    - TDRS transponders for launch vehicle applications that support space communication and launch services (GRC)

  - *Space Transportation*
    - Optical Tracking and Image Analysis (KSC)
    - Space Transportation Propulsion System and Test Facility Requirements and Instrumentation (Stennis Space Center (SSC)
    - Automated Collection and Transfer of Launch Range Surveillance/Intrusion Data (KSC)
    - Technology tools to assess secondary payload capability with launch vehicles (KSC)

- Spacecraft Charging/Plasma Interactions (Environment definition & arcing mitigation) (Marshall Space Flight Center (MSFC))

Science Mission Directorate (SMD), POC: Stephanie Stockman, stephanie.a.stockman@nasa.gov

Detailed information on SMD research priorities is available at the following URLs:

- NASA Science: http://science.nasa.gov
- NASA Science Plan 2010: http://science.hq.nasa.gov/strategy/ and http://science.nasa.gov/media/medialibrary/2010/08/10/2010SciencePlan.pdf.
- NASA's Plan for a Climate-Centric Architecture for Earth Observations and Applications from Space: http://science.nasa.gov/media/medialibrary/2010/07/01/Climate_Architecture_Final.pdf.
- Research Opportunities in Space and Earth Science (ROSES):
- http://nspires.nasaprs.com/external/. Select “Solicitations”, “Open Solicitations”, and then “Research Opportunities in Space and Earth Sciences (ROSES) – 2010”.
- In addition, proposers can visit the following URLs:
- http://nasascience.nasa.gov/big-questions which summarizes the research questions across all four SMD divisions and links to their respective 2007-2016 science strategy.
- http://science.nasa.gov/researchers/sara/advisory-committees/ which provides information on a new planetary decadal survey that was released in the spring of 2011.

Space Technology Mission Directorate (STMD), POC: Joseph Grant joseph.grant-1@nasa.gov

In addition to the key areas of: 1) ISS utilization, 2) MGI, 3) Advanced Manufacturing and 4) Robotics, the Space Technology Mission Directorate (STMD) is responsible for developing crosscutting, pioneering, and transformational new technologies and capabilities, needed by the Agency to achieve its current and future missions. STMD is divided into the following nine programs, representing all levels of technology readiness (TRL) from early stage innovations to mission-ready projects:

- NASA Innovative Advanced Concepts focuses on visionary aeronautics and space system concepts. TRL Range: 1-3
- Space Technology Research Grants focus on innovative research in advanced space technology via range of university grants involving senior researchers, early career faculty and graduate students. TRL Range: 1-3
- Center Innovation Fund stimulates creativity and innovation at the NASA field centers. TRL Range: 1-3
- Centennial Challenges offers incentive prizes to stimulate innovative solutions by citizen inventors and independent teams outside of the traditional aerospace community. TRL Range: 5-9
- Small Business Innovative Research (SBIR)/Small Business Technology Transfer (STTR) engage small businesses in aerospace research and development for infusion into NASA missions and the nation’s economy. TRL Range: 2-5
- Game Changing Development focuses on maturing advanced space technologies that may lead to entirely new approaches for the Agency's future space missions. TRL Range: 3-5
- Small Spacecraft Technology develops and demonstrates subsystem technologies and new mission capabilities for small spacecraft. TRL Range: 3-7

- Flight Opportunities facilitates low-cost access to suborbital environments for a broad range of innovators as a means of advancing space technology development and supporting the evolving entrepreneurial commercial space industry. TRL Range: 5-7
- Technology Demonstration Missions seeks to mature laboratory-proven technologies to flight-ready status. TRL Range: 5-7

In addition, Space Technology supports NASA's participation in the following cross-agency partnerships and National initiatives:

- The National Network for Manufacturing Innovation brings together government agencies to collaborate toward modernization of manufacturing, and supports direct investments in small businesses and training for the high-skilled manufacturing workforce. (http://manufacturing.gov/welcome.html)
- The National Nanotechnology Initiative brings government agencies together with a collective interest in understanding and controlling matter at the nanoscale, leading to a revolution in technology and industry that benefits society. (http://www.nano.gov/)
- The National Robotics Initiative brings together government agencies with interest in accelerating the development and use of robots in the United States that work beside, or cooperatively with, people and funds innovative robotics research and applications emphasizing the realization of such co-robots acting in direct support of and in a symbiotic relationship with human partners. (http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503641&org=CISE)
- Materials Genome Initiative is a multi-agency initiative designed to create a new era of policy, resources, and infrastructure that support U.S. institutions in the effort to discover, manufacture, and deploy advanced materials twice as fast, at a fraction of the cost.

Additional information about STMD programs is available at http://www.nasa.gov/directorates/spacetech/home/index.html.

By investing in high payoff, crosscutting and transformational technologies the broad space enterprise cannot tackle today, STMD matures these technologies required for NASA's future missions in science and exploration, while proving the capabilities and lowering the cost for other government agencies and commercial space activities. By pushing the boundaries of aerospace technology and seizing opportunities, investing in space technology allows NASA and our Nation to remain at the cutting edge. NASA's STMD:

- Advances technologies that are broadly applicable to multiple stakeholders
- Employs a portfolio approach to capture the entire spectrum of technology readiness
- Competitively selects research by academia, industry, NASA Centers, and other government organizations based on technical merit
- Coordinates with internal and external stakeholders and leverages the technology investments of our international, other government agency, academic and industrial partners
- Results in new inventions, new capabilities and the creation of a pipeline of innovators aimed at serving future NASA needs and National needs
- Grows the Nation's innovation economy and creates high-technology jobs

STMD programs intentionally push the boundaries of what is possible with a strong focus on innovation. No single effort is guaranteed to succeed and some will fail as novel approaches are attempted. While appropriate safety, design, and verification practices are followed, STMD programs employ a graduated technical risk tolerance approach. More resources, rigor, and greater risk avoidance apply to higher cost and higher technology readiness level (TRL) efforts, such as test articles destined for complex ground tests and/or space flight demonstrations. In all cases, a transparent, informed risk acceptance approach applies.

STMD programs described above fund projects aligned with the Agency's Space Technology Roadmaps (http://www.nasa.gov/offices/oct/home/roadmaps/index.html), which reflect the National Research Council's (NRC's) review and prioritization http://www.nap.edu/catalog.php?record_id=13354) of these roadmaps.

NASA developed the Space Technology Roadmaps in order to facilitate the development and demonstration of space technologies that address the needs of NASA's exploration systems, earth and space science, and space operations mission areas, as well as those that contribute to critical national and commercial needs in advanced space technologies. Each of the 14 roadmaps focuses on a Technology Area (TA). The roadmaps were initially drafted by NASA and subsequently independently reviewed by the NRC. The NRC's review (link provided above) resulted in findings, recommendations, and priorities – within and across the technology areas – intended to inform NASA's space technology investments. The NRC's final report (http://www.nap.edu/catalog.php?record_id=13354) was released early in 2012.

Applicants proposing Space Technology related content are strongly encouraged to familiarize themselves with the roadmap document most closely aligned with their space technology interests. Links to the individual roadmap documents are provided below along with the NRC's top 16 priorities within their corresponding technology area:

Technology Areas	**NRC Priorities within Technology Areas**
TA01 Launch Propulsion Systems http://www.nasa.gov/pdf/500393main_TA01-ID_rev6-NRC-wTASR.pdf	
TA02 In-Space Propulsion Technologies http://www.nasa.gov/pdf/501329main_TA02-ID_rev3-NRC-wTASR.pdf	(Nuclear) Thermal Propulsion Electric Propulsion (2.2.1)
TA03 Space Power and Energy Storage http://www.nasa.gov/pdf/501328main_TA03-ID_rev7_NRC_wTASR.pdf	Solar Power Generation (Photovoltaic and Thermal) (3.1.3) Fission Power Generation (3.1.5)
TA04 Robotics, Tele-Robotics, and Autonomous Systems http://www.nasa.gov/pdf/501622main_TA04-ID_rev6b_NRC_wTASR.pdf	Extreme Terrain Mobility (4.2.1)
TA05 Communication and Navigation http://www.nasa.gov/pdf/501623main_TA05-ID_rev6_NRC_wTASR.pdf	Guidance Navigation &Control
TA06 Human Health, Life Support, and Habitation Systems http://www.nasa.gov/pdf/500436main_TA06-ID_rev6a_NRC_wTASR.pdf	Radiation Mitigation for Human Spaceflight Long-Duration Crew Health Environmental Control and Life Support Systems

TA07 Human Exploration Destination Systems http://www.nasa.gov/pdf/501327main_TA07-ID_rev7_NRC-wTASR.pdf	
TA08 Science Instruments, Observatories, and Sensor Systems http://www.nasa.gov/pdf/501624main_TA08-ID_rev5_NRC_wTASR.pdf	In-Situ Instruments and Sensors (8.3.3) Optical Systems (Instruments and Sensors) (8.1.3)High Contrast Imaging and Spectroscopy Technologies (8.2.4) Detectors and Focal Planes (8.1.1)
TA09 Entry, Descent, and Landing Systems http://www.nasa.gov/pdf/501326main_TA09-ID_rev5_NRC_wTASR.pdf	Entry Descent and Landing and TPS (see also (TA14)
TA10 Nanotechnology http://www.nasa.gov/pdf/501325main_TA10-ID_rev8_NRC-wTASR.pdf	
TA11 Modeling, Simulation, Information Technology and Processing http://www.nasa.gov/pdf/501321main_TA11-ID_rev4_NRC-wTASR.pdf	
TA12 Materials, Structures, Mechanical Systems, and Manufacturing http://www.nasa.gov/pdf/501625main_TA12-ID_rev6_NRC-wTASR.pdf	Lightweight and Multifunctional Materials and Structures
TA13 Ground and Launch Systems Processing http://www.nasa.gov/pdf/501626main_TA13-ID_rev4_NRC-wTASR.pdf	
TA14 Thermal Management Systems http://www.nasa.gov/pdf/501320main_TA14-ID_rev6a-NRC-wTASR.pdf	EDL and Thermal Protection Systems (see also TA09) Active Thermal Control of Cryogenic Systems

NASA will balance investments across all levels of technology readiness. By investing in all TRLs for pioneering, crosscutting and transformational technologies, the Agency ensures a robust pipeline of new capabilities for future space exploration missions.

NASA Centers

Examples of Center research interest areas include these specific areas from the following Centers. If no POC is listed or contact information is needed, please contact the POC using contact information listed in Appendix D.

Goddard Space Flight Center (GSFC), POC: David J. Rosage, david.j.rosage@nasa.gov

- Advanced Manufacturing - facilitates the development, evaluation, and deployment of efficient and flexible additive manufacturing technologies. (ref: NAMII.org)

- Advanced Multi-functional Systems and Structures - novel approaches to increase spacecraft systems resource utilization
- Micro - and Nanotechnology - Based Detector Systems - research and application of these technologies to increase the efficiency of detector and optical systems
- Ultra-miniature Spaceflight Systems - miniaturization approaches from multiple disciplines - materials, mechanical, electrical, software, and optical - to achieve substantial resource reductions
- Systems Robust to Extreme Environments - materials and design approaches that will preserve designed system properties and operational parameters (e.g. mechanical, electrical, thermal), and enable reliable systems operations in hostile space environments.
- Spacecraft Navigation Technologies
    - Spacecraft GNSS receivers, ranging crosslink transceivers, and relative navigation sensors
    - Optical navigation and satellite laser ranging
    - Deep-space autonomous navigation techniques
    - Software tools for spacecraft navigation ground operations and navigation analysis
- Mission and Trajectory Design Technologies
    - Mission design tools that will enable new mission classes (e.g., low thrust planetary missions, precision formation flying missions)
    - Mission design tools that reduce the costs and risks of current mission design methodologies
    - Trajectory design techniques that enable integrated optimal designs across multiple orbital dynamic regimes (i.e. earth orbiting, earth-moon libration point, sun-earth libration point, interplanetary)
- Spacecraft Attitude Determination and Control Technologies
    - Modeling, simulation, and advanced estimation algorithms
    - Advanced spacecraft attitude sensor technologies (e.g., MEMS IMU's, precision optical trackers)
    - Advanced spacecraft actuator technologies (e.g. modular and scalable momentum control devices, 'green' propulsion, micropropulsion, low power electric propulsion)
- CubeSats - Participating institutions will develop CubeSat components, technologies and systems to support NASA technology demonstration and risk reduction efforts. Student teams will develop miniature CubeSat power, pointing, communication, command/telemetry, structure, deployable (etc.) sub-systems and/or integrate such components into complete off-the-shelf "CubeSat bus" systems, with a goal of minimizing "bus" weight/power/volume/cost and maximizing available "payload" weight/power/volume. NASA technologists will then use these components/systems to develop payloads that demonstrate key technologies to prove concepts and/or reduce risks for future Earth Science, Space Science and Exploration/Robotic Servicing missions. POC: Thomas P. Flatley
- On-Orbit Multicore Computing - High performance multicore processing for advanced automation and science data processing on spacecraft. There are multiple multicore processing platforms in development that are being targeted for the next generation of science and exploration missions, but there is little work in the area of software frameworks and architectures to utilize these platforms. It is proposed that research in the areas of efficient inter-core communications, software partitioning, fault detection, isolation & recovery, memory management, core power management, scheduling algorithms, and software frameworks be done to enable a transition to these newer platforms. Participating institutions can select areas

to research and work with NASA technologists to develop and prototype the resulting concepts. POC: Charles P Wildermann.

Ames Research Center (ARC), POC: Elizabeth Cartier, Elizabeth.A.Cartier@nasa.gov

Ames research Center enables exploration through selected development, innovative technologies, and interdisciplinary scientific discovery. Ames provides leadership in the following areas: Astrobiology; small satellites; supercomputing; robotic lunar exploration; and technologies for exploration. Additional Center core competencies include:

- Space Sciences
- Applied Aerospace and Information Technology
- Biotechnology
- Intelligent Systems
- Biological Sciences
- Earth Sciences
- High Performance Computing
- Advanced Aerospace Materials and Devices
- Space Transportation Technology/Thermal Protection Systems
- Human Systems Integration
- Small Spacecraft
- Airspace Systems

Glenn Research Center (GRC), POC: Mark David Kankam, mark.d.kankam@nasa.gov

Research and technology, and engineering engagements comprise including:

- Acoustics
- Advanced Energy (Renewable Wind and Solar, Coal Energy and Alternative Energy)
- Advanced Microwave Communications
- Aeronautical and Space Systems Analysis
- Computer Systems and Networks
- Electric (Ion) Propulsion
- Icing and Cryogenic Systems
- Instrumentation, Controls and Electronics
- Fluids, Computational Fluid Dynamics (CFD) and Turbomachinery
- Materials and Structures, including Mechanical Components and Lubrication
- Microgravity Fluid Physics, Combustion Phenomena and Bioengineering
- Nanotechnology
- Photovoltaics, Electrochemistry-Physics, and Thermal Energy Conversion
- Propulsion System Aerodynamics
- Space Power Generation, Storage, Distribution and Management
- Systems Engineering

The above engagement areas relate to the following key GRC competencies:

- Air-Breathing Propulsion
- Communications Technology and Development
- In-Space Propulsion & Cryogenic Fluids Management
- Power, Energy Storage and Conversion
- Materials and Structures for Extreme Environment

- Physical Sciences and Biomedical Technologies in Space

Armstrong Flight Research Center, (AFRC) POC: Oscar Murillo, Oscar.J.Murillo@nasa.gov

- Autonomy (Collision Avoidance, Separation assurance, formation flight, peak seeking control) (POC: Jack Ryan, AFRC-RC)
- Adaptive Control (POC: Curt Hanson, AFRC-RC)
- Hybrid Electric Propulsion (POC: Starr Ginn, AFRC-R)
- Control of Flexible Structures using distributed sensor feedback (POC: Marty Brenner, AFRC-RS; Peter Suh, AFRC-RC)
- Supersonic Research (Boom mitigation and measurement) (POC: Ed Haering, AFRC-RA)
- Supersonic Research (Laminar Flow) (POC: Dan Banks, AFRC-RA)
- Environmental Responsive Aviation (POC: Mark Mangelsdorf, AFRC-RS)
- Hypersonic Structures & Sensors (POC: Larry Hudson, AFRC-RS)
- Large Scale Technology Flight Demonstrations (Towed Glider) (POC: Steve Jacobson, AFRC-RC)
- Aerodynamics and Lift Distribution Optimization to Reduce Induced Drag (POC: Al Bowers, AFRC-R)

Marshall Space Flight Center (MSFC), POC: Frank Six, frank.six@nasa.gov

Propulsion Systems

- Launch Propulsion Systems
- In-Space Propulsion (Cryogenics, Green Propellants, High Pulse Power, Electric, Nuclear - Thermal, Solar Thermal, Solar Sails, Tethers
- Propulsion Test beds and Demonstrators
- Cryogenic Fluid Management
- Rapid Affordable Manufacturing of Propulsion Components
- Composite Structures
- Materials Research

Space Systems

- Fission Surface Power
- In-Space Habitation with Emphasis on Life Support Systems and Nodes/Elements
- In Situ Resource Utilization

- Mechanical Design & Fabrication
- Small Affordable ISS Payloads
- Robotics Platforms
- In-Space Asset Management (Automated Rendezvous & Capture, De-Orbit, Orbital Debris Mitigation)

Space Transportation

- Advanced Manufacturing with Emphasis on In-Space Fabrication & Repair
- Space Environmental Effects and Space Weather
- Lander Systems and Technologies
- Small Spacecraft and Enabling Technologies (Nanolaunch Systems)
- 3D Printing / Additive Manufacturing
- Meteoroid Environment

Science

- Replicated Optics
- High Energy Astrophysics (X-ray, gamma ray, cosmic ray)
- Heliophysics
- Interstellar & Planetary Dust
- Radiation Mitigation
- Next Generation Observatories
- Earth / Atmospheric Science
- Severe Storms Research
- Climate Dynamics
- Lightning Research
- Remote Sensing
- Planetary Geophysics/Atmospheres

Kennedy Space Center, POC Michael Lester, gregory.m.lester@nasa.gov

- Robotics, Tele-Robotics, and Autonomous Systems
- Human Health, Life Support and Habitation Systems
- Human Exploration Destination Systems
- Ground and Launch Systems
- Communication and Navigation Systems
- Modeling, Simulation, Information Technology & Processing
- Thermal Management Systems
- KSC Tech Transfer initiative to hand-off commercially viable KSC IP to universities for further development that will meet both NASA and commercial applications (i.e. Dual Use Technology):
    - Focus on low TRL-high commercial potential KSC IP that has lost NASA funding
    - Provide to university faculty and/or doctorate students for development toward commercialization and NASA use
    - Use educational/external funding sources (e.g. EPSCoR, Space Grant, etc.)
    - KSC oversight of university work provided by Tech Transfer and, possibly, KSC inventors.

- Ammonia Recovery System for Wastewater: *http://technology.ksc.nasa.gov/documents/Tops/TOPS_13681_Ammonia_Recovery_System_Wastewater.pdf*
- High Performance Polyimide Powder C*oatings:* *http://technology.ksc.nasa.gov/documents/Tops/TOPS_12777_Polyimide_Powder_Coatings.pdf*
- Wire Damage Detection and Rerouting System: *http://technology.ksc.nasa.gov/documents/Tops/TOPS_12866_13285_InSituWireDamage.pdf*

Jet Propulsion Laboratory (JPL), POC: Linda Rodgers, linda.l.rodgers@jpl.nasa.gov

- Solar System Science
  Planetary Atmospheres and Geology; Solar System characteristics and origin of life; Primitive solar systems bodies; Lunar science; Preparing for returned sample investigations
- Earth Science
  Atmospheric composition and dynamics; Land and solid earth processes; Water and carbon cycles; Ocean and ice; Earth analogs to planets; Climate Science
- Astronomy and Fundamental Physics
  Origin, evolution, and structure of the universe; Gravitational astrophysics and fundamental physics; Extra-solar planets and star and planetary formation; Solar and Space Physics; Formation and evolution of galaxies
- In-Space Propulsion Technologies
  Chemical propulsion; Non-chemical propulsion; Advanced propulsion technologies; Supporting technologies
- Space Power and Energy Storage
  Power generation; Energy storage; Power management & distribution; Cross-cutting technologies
- Robotics, Tele-Robotics and Autonomous Systems
  Sensing; Mobility; Manipulation technology; Human-systems interfaces; Autonomy; Autonomous rendezvous & docking; Systems engineering
- Communication and Navigation
  Optical communications & navigation technology; Radio frequency communications; Internetworking; Position, navigation and timing; Integrated technologies; Revolutionary concepts
- Human Exploration Destination Systems
  In-situ resource utilization and Cross-cutting systems
- Science Instruments, Observatories and Sensor Systems
  Science Mission Directorate Technology Needs; Remote Sensing instruments/sensors; Observatory technology; In-situ instruments/sensor technologies
- Entry, Descent and Landing Systems
  Aerobraking, aerocapture and entry systems; Descent; Landing; Vehicle system technology
- Nanotechnology
  Engineered materials; Energy generation and storage; Propulsion; Electronics, devices and sensors
- Modeling, Simulation, Information Technology and Processing
  Flight and ground computing; Modeling; Simulation; Information processing
- Materials, Structures, Mechanical Systems and Manufacturing
  Materials; Structures; Mechanical systems; Cross cutting

- Thermal Management Systems
  Cryogenic systems; Thermal control systems (near room temperature); Thermal protection systems

Johnson Space Center (JSC), POC: Kamlesh Lulla, kamlesh.p.lulla@nasa.goc

- Propulsion systems and Technologies
- In-space propulsion technologies
- Energy Storage technologies-Batteries, Regenerative Fuel cells
- Robotics and TeleRobotics
- Crew decision support systems
- Immersive Visualization
- Human Robotic interface
- Flight and Ground communication systems
- Advanced habitat systems
- GN&C for descent systems
- Large body GN&C
- Human system performance modeling
- Imaging and information processing
- Semantic Technologies
- Simulation and modeling
- Materials and structures
- Lightweight structure
- Smallsat and antennas

Langley Research Center (LaRC), POC: Gamaliel (Dan) Cherry, Gamaliel.R.Cherry@nasa.gov

- Intelligent Flight Systems – Revolutionary Air Vehicles (POC: Guy Kemmerly 757-864-5070)
- Atmospheric Characterization – Active Remote Sensing (POC: Malcolm Ko 757-864-8892)
- Systems Analysis and Concepts - Air Transportation System Architectures & Vehicle Concepts (POC: Michael Marcolini 757-864-3629)
- Advanced Materials & Structural System – Advanced Manufacturing (POC: David Dress 757-864-5126)
- Aerosciences - Trusted Autonomy (POC: Sharon Graves 757-864-5018)
- Entry, Decent & Landing - Robotic Mission Entry Vehicles (POC: Keith Woodman 757-864-7692)
- Measurement Systems - Advanced Sensors and Optical Measurement (POC: Tom Jones 757-864-4903)

Stennis Space Center, POC: Nathan Sovik, nathan.a.sovik@nasa.gov

- Active and Passive Nonintrusive Remote Sensing of Propulsion Test Parameters
- Intelligent Integrated System Health Management (ISHM) in Rocket Test-Stands
- Advanced Non-Destructive Evaluation Technologies
- Advanced Propulsion Systems Testing
- Cryogenic Instrumentation and Cryogenic, High Pressure, and Ultrahigh Pressure Fluid Systems
- Ground Test Facilities Technology
- Propulsion System Exhaust Plume Flow Field Definition and Associated Plume Induced Acoustic & Thermal Environments
- Vehicle Health Management/Rocket Exhaust Plume Diagnostics

PROPULSION TESTING

Active and Passive Nonintrusive Remote Sensing of Propulsion Test Parameters

The vast amount of propulsion system test data is collected via single channel, contact, intrusive sensors and instrumentation. Future propulsion system test techniques could employ passive nonintrusive remote sensors and active nonintrusive remote sensing test measurements over wide areas instead of at a few discrete points. Opportunities exist in temperature, pressure, stress, strain, position, vibration, shock, impact, and many other measured test parameters. The use of thermal infrared, ultraviolet, and multispectral sensors, imagers, and instruments is possible through the SSC sensor laboratory.

Intelligent Integrated System Health Management (ISHM) in Rocket Test-Stands

SHM is a capability to determine the condition of every element of a system continuously. ISHM includes detection of anomalies, diagnosis of causes, and prognosis of future anomalies; as well as making available (to elements of the system and the operator) data, information, and knowledge (DIaK) to achieve optimum operation. In this context, we are interested in methodologies to embed intelligence into the various elements of rocket engine test-stands, e.g., sensors, valves, pumps, tanks, etc. Of particular interest is the extraction of qualitative interpretations from sensor data in order to develop a qualitative assessment of the operation of the various components and processes in the system. The desired outcomes of the research are: (1) to develop intelligent sensor models that are self-calibrating, self- configuring, self- diagnosing, and self- evolving (2) to develop intelligent components such as valves, tanks, etc., (3) to implement intelligent sensor fusion schemes that allow assessment, at the qualitative level, of the condition of the components and processes, (4) to develop a monitoring and diagnostic system that uses the intelligent sensor models and fusion schemes to predict future events, to document the operation of the system, and to diagnose any malfunction quickly, (5) to develop architectures/taxonomies/ontologies for integrated system health management using distributed intelligent elements, and (6) to develop visualization and operator interfaces to effectively use the ISHM capability.

Advanced Non-Destructive Technologies

Advances in non-destructive evaluation (NDE) technologies are needed for fitness-for-service evaluation of pressure vessels used in rocket propulsion systems and test facilities. NDE of ultra- high pressure vessels with wall thicknesses exceeding 10 inches require advanced techniques for the detection of flaws that may affect the safe use of the vessels.

Advanced Propulsion Systems Testing

Innovative techniques will be required to test propulsion systems such as advanced chemical engines, single- stage-to-orbit rocket plane components, nuclear thermal, nuclear electric, and hybrids rockets. New and more cost- effective approaches must be developed to test future propulsion systems. The solution may be some combination of computational- analytical technique, advanced sensors and instrumentation, predictive methodologies, and possibly subscale tests of aspects of the proposed technology.

Cryogenic Instrumentation and Cryogenic, High Pressure, and Ultrahigh Pressure Fluid Systems
Over 40 tons of liquefied gases are used annually in the conduct of propulsion system testing at the Center. Instrumentation is needed to precisely measure mass flow of cryogens starting with very low flow rates and ranging to very high flow rates under pressures up to 15,000 psi. Research, technology, and development opportunities exist in developing instruments to measure fluid properties at cryogenic conditions during ground testing of space propulsion systems. Both intrusive and nonintrusive sensors, but especially nonintrusive sensors, are desired.

Ground Test Facilities Technology
SSC is interested in new, innovative ground-test techniques to conduct a variety of required developmental and certification tests for space systems, stages/vehicles, subsystems, and components. Examples include better coupling and integration of computational fluid dynamics and heat transfer modeling tools focused on cryogenic fluids for extreme conditions of pressure and flow; advanced control strategies for non- linear multi-variable systems; structural modeling tools for ground-test programs; low-cost, variable altitude simulation techniques; and uncertainty analysis modeling of test systems.

Propulsion System Exhaust Plume Flow Field Definition and Associated Plume Induced Acoustic & Thermal Environments
Background: An accurate definition of a propulsion system exhaust plume flow field and its associated plume induced environments (PIE) are required to support the design efforts necessary to safely and optimally accomplish many phases of any space flight mission from sea level or simulated altitude testing of a propulsion system to landing on and returning from the Moon or Mars. Accurately defined PIE result in increased safety, optimized design and minimized costs associated with: 1. propulsion system and/or component testing of both the test article and test facility; 2. any launch vehicle and associated launch facility during liftoff from the Earth, Moon or Mars; 3. any launch vehicle during the ascent portion of flight including staging, effects of separation motors and associated pitch maneuvers; 4. effects of orbital maneuverings systems (including contamination) on associated vehicles and/or payloads and their contribution to space environments; 5. any vehicle intended to land on and return from the surface of the Moon or Mars; and finally 6. the effects of a vehicle propulsion system on the surfaces of the Moon and Mars including the contaminations of those surfaces by plume constituents and associated propulsion system constituents. Current technology status and requirements to optimally accomplish NASA s mission: In general, the current plume technology used to define a propulsion system exhaust plume flow field and its associated plume induced environments is far superior to that used in support of the original Space Shuttle design. However, further improvements of this technology are required: 1. in an effort to reduce conservatism in the current technology allowing greater optimization of any vehicle and/or payload design keeping in mind crew safety through all mission phases; and 2. to support the efforts to fill current critical technology gaps discussed below. PIE areas of particular interest include: single engine and multi-engine plume flow field definition for all phases of any space flight mission, plume induced acoustic environments, plume induced radiative and convective ascent vehicle base heating, plume contamination, and direct and/or indirect plume impingement effects. Current critical technology gaps in needed PIE capabilities include: 1. An accurate analytical prediction tool to define convective ascent vehicle base heating for both single engine and multi- engine vehicle configurations. 2. An accurate analytical prediction tool to define plume induced environments associated with advanced chemical, electrical and nuclear propulsion systems. 3. A

validated, user friendly free molecular flow model for defining plumes and plume induced environments for low density external environments that exist on orbit, as well as interplanetary and other planets.

Vehicle Health Management/Rocket Exhaust Plume Diagnostics
A large body of UV-Visible emission spectrometry experimentation is being performed during the 30 or more tests conducted each year on the Space Shuttle Main Engine at SSC. Research opportunities are available to quantify failure and wear mechanisms, and related plume code validation. Related topics include combustion stability, mixture ratio, and thrust/power level. Exploratory studies have been done with emission/absorption spectroscopy, absorption resonance spectroscopy, and laser induced fluorescence. Only a relatively small portion of the electromagnetic spectrum has been investigated for use in propulsion system testing and exhaust plume diagnostics/vehicle health management.