A.1 NASA Centers Areas of Interest

Examples of Center research interest areas include these specific areas from the following Centers. If no POC is listed in the Center write-up and contact information is needed, please contact the POC listed in Appendix D for that Center and request contacts for the research area of interest.

A.5.1 Ames Research Center (ARC), POC: Brenda Collins (brenda.j.collins@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; entry decent and landing systems; supercomputing; robotics and autonomous systems; life Sciences and environmental controls; and air traffic management.

- Entry systems: *Safely delivering spacecraft to Earth & other celestial bodies*
- Supercomputing: *Enabling NASA's advanced modeling and simulation*
- NextGen air transportation: *Transforming the way we fly*
- Airborne science: *Examining our own world & beyond from the sky*
- Low-cost missions: *Enabling high value science to low Earth orbit, the moon and the solar system*
- Biology & astrobiology: *Understanding life on Earth and in space*
- Exoplanets: *Finding worlds beyond our own*
- Autonomy & robotics: *Complementing humans in space*
- Lunar science: *Rediscovering our moon*
- Human factors: *Advancing human-technology interaction for NASA missions*
- Wind tunnels**:** *Testing on the ground before you take to the sky*

Additional Center core competencies include:

- Space Sciences
- Applied Aerospace and Information Technology
- Biotechnology
- Synthetic biology.
- Biological Sciences
- Earth Sciences
- High Performance Computing,
- Intelligent Systems
- Quantum Computing
- Nanotechnology-electronics and sensors.
- Small Spacecraft and Cubesats
- Airspace Systems
- Augmented Reality
- Digital materials

A.5.2 Armstrong Flight Research Center (AFRC), POC: Dave Berger, dave.e.berger@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)

A.5.3 Glenn Research Center (GRC), POC: Mark David Kankam, Ph.D.
mark.d.kankam@nasa.gov

Research and technology, and engineering engagements comprise including:

- Acoustics / Propulsion Acoustics
- Advanced Energy (Renewable Wind and Solar, Coal Energy and Alternative Energy)
- Advanced Microwave Communications
- Aeronautical and Space Systems Analysis
- Electrified Aircraft
- Computer Systems and Networks
- Electric (Ion) Propulsion
- Icing and Cryogenic Systems/Engine and Airframe Icing
- 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
- Urban Air Mobility (UAM)
- Systems Engineering

The above engagement areas relate to the following key Glenn Areas of Expertise:

- Aircraft Propulsion
- Communications Technology and Development
- Space Propulsion and Cryogenic Fluids Management
- Power, Energy Storage and Conversion
- Materials and Structures for Extreme Environment
- Physical Sciences and Biomedical Technologies in Space

A.5.4 Goddard Space Flight Center (GSFC), POC: James Harrington
james.l.harrington@nasa.gov

Applied Engineering and Technology Directorate: POC: Danielle Margiotta,
Danielle.V.Margiotta@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 and Instruments** - 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
    - Formation Flying
- **Automated Rendezvous and Docking (AR&D) techniques**
    - Algorithm development
    - Pose estimation for satellite servicing missions
    - Sensors (e.g., LiDARs, natural feature recognition)
    - Actuation (e.g., micro propulsion, electromagnetic formation flying)
- **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/Smallsat components, technologies and systems to support NASA technology demonstration and risk reduction efforts. Student teams will develop miniature CubeSat/Smallsat systems for: power generation and distribution, navigation, communication, on-board computing, structures

(fixed and deployable), orbital stabilization, pointing, and de-orbiting. These components, technologies and systems shall be made available for use by NASA for integration into NASA Cubesat/Smallsats. They may be integrated into complete off-the-shelf "CubeSat/Smallsat 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 (Thomas.P.Flatley@nasa.gov).

- **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: Alan Cudmore (Alan.p.cudmore@nasa.gov).
- **Integrated Photonic components and systems** - Integrated photonic components and systems for Sensors, Spectrometers, Chemical/biological sensors, Microwave, Sub-millimeter and Long-Wave Infra-Red photonics, Telecom- inter and intra satellite communications.
- **Radiation Effects and Analysis**
  - Flight validation of advanced event rate prediction techniques
  - New approaches for testing and evaluating 3-D integrated microcircuits and other advanced microelectronic devices
  - End-to-end system (e.g., integrated component level or higher) modeling of radiation effects
  - Statistical approaches to tackle radiation hardness assurance (i.e., total dose, displacement damage, and/or single-event effects) for high-risk, low-cost missions.

Sciences and Exploration Directorate POC: Blanche Meeson, Blanche.W.Meeson@nasa.gov

The Sciences and Exploration Directorate at NASA Goddard Space Flight Center (http://science.gsfc.nasa.gov) is the largest Earth and space science research organization in the world. Its scientists advance understanding of the Earth and its life-sustaining environment, the Sun, the solar system, and the wider universe beyond. All are engaged in the full life cycle of satellite missions and instruments from concept development to implementation, analysis and application of the scientific information, and community access and services.

- The **Earth Sciences Division** plans, organizes, evaluates, and implements a broad program of research on our planet's natural systems and processes. Major focus areas include climate change, severe weather, the atmosphere, the oceans, sea ice and glaciers, and the land surface. To study the planet from the unique perspective of space, the Earth Science Division develops and operates remote-sensing satellites and instruments. We analyze observational data from these spacecraft and make it available to the world's scientists and policy makers. The Division conducts extensive field campaigns to gather data from the surface and airborne platforms. The Division also develops, uses, and assimilates observations into models that simulate planetary processes involving the water, energy, and carbon cycles at multiple scales up to global. POC: Eric Brown de Colstoun (eric.c.browndecolsto@nasa.gov).

- The **Astrophysics Science Division** conducts a broad program of research in astronomy, astrophysics, and fundamental physics. Individual investigations address issues such as the nature of dark matter and dark energy, which planets outside our solar system may harbor life, and the nature of space, time, and matter at the edges of black holes. Observing photons, particles, and gravitational waves enables researchers to probe astrophysical objects and processes. Researchers develop theoretical models, design experiments and hardware to test theories, and interpret and evaluate observational data. POC: Amber Straughn (Amber.n.Straughn@nasa.gov).

- The **Heliophysics Science Division** conducts research on the Sun, its extended solar-system environment (the heliosphere), and interactions of Earth, other planets, small bodies, and interstellar gas with the heliosphere. Division research also encompasses Geospace, Earth's magnetosphere and its outer atmosphere, and Space Weather—the important effects that heliospheric disturbances have on spacecraft and terrestrial systems. Division scientists develop spacecraft missions and instruments, systems to manage and disseminate heliophysical data, and theoretical and computational models to interpret the data. Possible heliophysics-related research include: advanced software environments and data-mining strategies to collect, collate and analyze data relevant to the Sun and its effects on the solar system and the Earth ("space weather"); and advanced computational techniques, including but not limited to parallel architectures and the effective use of graphics processing units, for the simulation of magnetized and highly dynamic plasmas and neutral gases in the heliosphere. POC: Doug Rabin (Douglas.Rabin@nasa.gov).

- The **Solar System Exploration Division** builds science instruments and conducts theoretical and experimental research to explore the solar system and understand the formation and evolution of planetary systems. Laboratories within the division investigate areas as diverse as astrochemistry, planetary atmospheres, extrasolar planetary systems, earth science, planetary geodynamics, space geodesy, and comparative planetary studies. To study how planetary systems form and evolve, division scientists develop theoretical models as well as the investigations and space instruments to test them. The researchers participate in planetary and Earth science missions, and collect, interpret, and evaluate measurements. POC: Lora Bleacher (Lora.V.Bleacher@nasa.gov).

- **Quantum computing:** Quantum computing is based on quantum bits or qubits. Unlike traditional computers, in which bits must have a value of either zero or one, a qubit can represent a zero, a one, or both values simultaneously. Representing information in qubits allows the information to be processed in ways that have no equivalent in classical computing, taking advantage of phenomena such as quantum tunneling and quantum entanglement. As such, quantum computers may theoretically be able to solve certain problems in a few days that would take millions of years on a classical computer..

- **Artificial intelligence and machine learning**: Artificial Intelligence (AI) is a collection of advanced technologies that allows machines to think and act, both humanly and rationally, through sensing, comprehending, acting and learning. AI's foundations lie at the intersection of several traditional fields - Philosophy, Mathematics, Economics, Neuroscience, Psychology and Computer Science. Current AI applications include big data analytics, robotics, intelligent sensing, assisted decision making, and speech recognition just to name a few

- **(Big) data analytics:** Data Analytics, including Data Mining and Pattern Recognition for Science applications and with special emphasis on:
  - Quantification of uncertainty in inference from big data
  - Experiment design to create data that is AI/ML ready and robust against misleading correlations
  - Methods for prediction of new discovery spaces
  - Strength of evidence and reproducibility in inference from big data

Scientists in all four divisions publish research results in the peer-reviewed literature, participate in the archiving and pubic dissemination of scientific data, and provide expert user support.

A.5.5 Jet Propulsion Laboratory (JPL)

POC: Linda Rodgers, linda.l.rodgers@jpl.nasa.gov
Petra Kneissl, petra.a.kneissl-milanian@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

- **<u>Communication and Navigation</u>**
  Optical communications & navigation technology
  Radio frequency communications
  Internetworking
  Position, navigation and timing
  Integrated technologies
  Revolutionary concepts
- **<u>Human Exploration Destination Systems</u>**
  In-situ resource utilization and Cross-cutting systems
- **<u>Science Instruments, Observatories and Sensor Systems</u>**
  Science Mission Directorate Technology Needs
  Remote Sensing instruments/sensors
  Observatory technology
  In-situ instruments/sensor technologies
- **<u>Entry, Descent and Landing Systems</u>**
  Aerobraking, aerocapture, and entry systems
  Descent
  Landing
  Vehicle system technology
- **<u>Nanotechnology</u>**
  Engineered materials
  Energy generation and storage
  Propulsion
  Electronics, devices and sensors
- **<u>Modeling, Simulation, Information Technology and Processing</u>**
  Flight and ground computing
  Modeling
  Simulation
  Information processing
- **<u>Materials, Structures, Mechanical Systems and Manufacturing</u>**
  Materials
  Structures
  Mechanical systems
  Cross cutting
- **<u>Thermal Management Systems</u>**
  Cryogenic systems
  Thermal control systems (near room temperature)
  Thermal protection systems

A.5.6 Johnson Space Center (JSC), POC: Kamlesh Lulla, kamlesh.p.lulla@nasa.gov

- In-space propulsion technologies
  - Energy Storage technologies-Batteries, Fuel cells
  - Robotics and TeleRobotics
  - Crew decision support systems
  - Immersive Visualization

- Virtual windows leading to immersive environments and telepresence systems
  - Human Robotic interface
  - Flight and Ground communication systems

- Audio
  - Adaptive-environment Array Microphone Systems and processing
  - Large bandwidth (audio to ultra-sonic) MEMs Microphones
  - Front end audio noise cancellation algorithms implementable in FPGAs-example Independent Component Analysis
  - Audio Compression algorithms implementable in FPGAs.
  - COMSOL Acoustic modeling
  - Sonification Algorithms implementable in DSPs/FPGAs

- Video
  - Ultra High Video Compressions
  - H265 Video Compression
  - Rad-Tolerant Imagers
  - Lightweight/low power/radiation tolerant displays

- Advanced habitat systems
  - GN&C for descent systems
  - Large body GN&C
  - Human-in-the-loop system data acquisition and performance modeling
  - Imaging and information processing

- Lightweight/Low power Display Technology
  - Scalable software-implementable graphics processing unit

- Simulation and modeling
  - Materials and structures
  - Lightweight structure
  - Human Spaceflight Challenges
  - http://humanresearchroadmap.nasa.gov/explore

- Human System Interfaces
  - OLED Technology Evaluation for Space Applications
  - Far-Field Speech Recognition in Noisy Environments
  - Radiation-Tolerant/ Hardened Graphics Processing
  - Machine-Learning human interfaces and methods
  - Human Computer Interaction design methods (Multi-modal and Intelligent Interaction) and apparatuses
  - Human Systems Integration, Human Factors Engineering: state of the art in Usability and performance assessment methods and apparatus.
  - Humans Systems Integration Inclusion in Systems Engineering

- ECLSS
  - Air Revitalization
  - Advanced water, O2 and CO2 monitoring and sensors
  - Advance thermally regenerated ionic fluids for CO2 and Humidity Control
  - Water Recovery and Management

- Brine water recovery systems and wastewater treatment chemical recover for reuse or repurpose
- Waste Management
- Advance wastewater treatment systems (lower toxicity, recoverable)
- Advanced trace contaminant monitoring and control technology
- Quiet fan technologies

- Active Thermal Control
  - Lightweight heat exchangers and cold plates
  - Condensing heat exchanger coatings with robust hydrophilic, antimicrobial properties
  - Development and demonstration of wax and water-based phase change material heat exchangers

- EVA
  - Pressure Garment
  - Portable Life Support System
  - Power, Avionics and Software

- Autonomous Rendezvous and Docking
  - Crew Exercise

- Small form Equipment
  - Biomechanics

- EDL (thermal)
  - Wireless and Comm Systems
  - Wireless Energy Harvesting Sensor Technologies
  - Robust, Dynamic Ad hoc Wireless Mesh Communication Networks
  - Radiation Hardened EPCglobal Radio Frequency Identification (RFID) Readers
  - Computational Electromagnetics (CEM) Fast and Multi-Scale Methods/Algorithms
  - EPCglobal-type RFID ICs at frequencies above 2 G

- Radiation and EEE Parts
  - Monitoring
  - Mitigation and Biological countermeasures
  - Protection systems
  - Space weather prediction
  - Risk assessment modeling

- Wearable Tech
  - Wearable Sensors and Controls
  - Wearable far-field Audio Communicator
  - Wearable sensing and hands-free control
  - Tattooed Electronic Sensors

- In-Situ Resource Utilization
  - Mars atmosphere processing
  - CO_2 collection, dust filtering, Solid Oxide CO_2 electrolysis, Sabatier
  - Reverse water gas shift
  - Lunar/Mars regolith processing

- Regolith collection and drying
- Water collection and processing, water electrolysis (PEM and Solid Oxide)
- Carbothermal reduction of regolith
- Solar concentrator heat collection
- Methane/Oxygen liquefaction and storage

A.5.7 Kennedy Space Center (KSC), by Roadmap Technical Area (TA), POC Jose Nunez, jose.l.nunez@nasa.gov

- HEOMD – Commercial Crew systems development and ISS payload and flight experiments
- Environmental and Green Technologies
- Health and Safety Systems for Operations
- Communications and Tracking Technologies
- Robotic, automated and autonomous systems and operations
- Payload Processing & Integration Technologies (all class payloads)
- R&T Technologies on In-Space Platforms (e.g., ISS, Gateway, Human Habitats)
- Damage-resistant and self-healing materials
- Plant Research and Production
- Water/nutrient recovery and management
- Plant habitats and Flight Systems
- Food production and waste management
- Robotic, automated and autonomous food production
- Robotic, automated and autonomous food production
- Damage-resistant and self-healing materials
- Automated and autonomous detection and repair
- Propulsion: Chemical Propulsion flight integration (human transportation)
- Space Environments Test: Right/West Altitude Chamber

NOTE:

The above R&T Focus Areas are described in the KSC R&T Portfolio Data Dictionary

A.5.8 Langley Research Center (LaRC), POC: Dr. Kimberly Brush, kimberly.m.brush@nasa.gov

- Intelligent Flight Systems – Revolutionary Air Vehicles
(POC: Guy Kemmerly 757-864-5070) – retired, awaiting new POC
- Atmospheric Characterization – Active Remote Sensing
(POC: Allen Larar 757.864.5328)
- Systems Analysis and Concepts - Air Transportation System Architectures & Vehicle Concepts (POC: Phil Arcara 757.864.5978)
- Advanced Materials & Structural System – Advanced Manufacturing
(POC: David Dress 757-864-5126)
- Aerosciences - Trusted Autonomy
(POC: Sharon Graves 757-864-5018) –retired, awaiting new POC
- Entry, Decent & Landing - Robotic Mission Entry Vehicles
(POC: Jeff Herath or Ron Merski)
- Measurement Systems - Advanced Sensors and Optical Measurement
(POC: Tom Jones 757-864-4903)

A.5.9 Marshall Space Flight Center (MSFC), POC: Frank Six, frank.six@nasa.gov

Propulsion Systems

- Launch Propulsion Systems, Solid & Liquid
- In Space Propulsion (Cryogenics, Green Propellants, Nuclear, Fuel Elements, Solar-Thermal, Solar Sails, Tethers)
- Propulsion Testbeds and Demonstrators (Pressure Systems)
- Combustion Physics
- Cryogenic Fluid Management
- Turbomachinery
- Rotordynamics
- Solid Propellant Chemistry
- Solid Ballistics
- Rapid Affordable Manufacturing of Propulsion Components
- Materials Research (Nano Crystalline Metallics, Diamond Film Coatings)
- Materials Compatibility
- Computational Fluid Dynamics
- Unsteady Flow Environments
- Acoustics and Stability
- Low Leakage Valves

Space Systems

- In Space Habitation (Life Support Systems and Nodes, 3D Printing)
- Mechanical Design & Fabrication
- Small Payloads (For International Space Station, Space Launch System)
- In-Space Asset Management (Automated Rendezvous & Capture, De-Orbit, Orbital Debris Mitigation, Proximity Operations)
- Radiation Shielding
- Thermal Protection
- Electromagnetic Interference
- Advanced Communications
- Small Satellite Systems (CubeSats)
- Structural Modeling and Analysis
- Spacecraft Design (CAD)

Space Transportation

- Mission and Architecture Analysis
- Advanced Manufacturing
- Space Environmental Effects and Space Weather
- Lander Systems and Technologies
- Small Spacecraft and Enabling Technologies (Nanolaunch Systems)

- 3D Printing/Additive Manufacturing/Rapid Prototyping
- Meteoroid Environment
- Friction Stir and Ultrasonic Welding
- Advanced Closed-Loop Life Support Systems
- Composites and Composites Manufacturing
- Wireless Data & Comm. Systems
- Ionic Liquids
- Guidance, Navigation and Control (Autonomous, Small Launch Vehicle)
- Systems Health Management
- Martian Navigation Architecture/Systems
- Planetary Environment Modeling
- Autonomous Systems (reconfiguration, Mission Planning)
- Digital Thread / Product Lifecycle Management (for AM and/or Composites)
- Material Failure Diagnostics

Science

- Replicated Optics
- Large Optics (IR, visible, UV, X-Ray)
- High Energy Astrophysics (X-Ray, Gamma Ray, Cosmic Ray)
- Radiation Mitigation/Shielding
- Gravitational Waves and their Electromagnetic Counterparts
- Solar, Magnetospheric and Ionospheric Physics
- Planetary Geology and Seismology
- Planetary Dust, Space Physics and Remote Sensing
- Surface, Atmospheres and Interior of Planetary Bodies
- Earth Science Applications
- Convective and Severe Storms Research
- Lightning Research
- Data Informatics
- Disaster Monitoring
- Energy and Water Cycle Research
- Remote Sensing of Precipitation

A.5.9 Stennis Space Center (SSC), POC: Dr. Mitch Krell, email: mitch.krell@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.