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Funding and Strategic Alignment Guidance for Infusing Small Business Innovation Research Technology Into Human Exploration and Operations Mission Directorate Projects for 2016

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Funding and Strategic Alignment Guidance for Infusing Small Business Innovation Research Technology Into Human Exploration and Operations Mission Directorate Projects for 2016

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Abstract

This report is intended to help NASA program and project managers incorporate Small Business Innovation Research (SBIR) technologies into NASA Human Exploration and Operations Mission Directorate (HEOMD) projects. Other Government and commercial project managers interested in HEOMD funding opportunities through NASA's SBIR program will find this report useful as well.

Introduction

Incorporating Small Business Innovation Research (SBIR)-developed technology into NASA projects is important, especially given the Agency's limited resources for technology development. Understanding the SBIR solicitation process can help small businesses and Human Exploration and Operations Mission Directorate (HEOMD) project managers form partnerships to incorporate SBIR technologies into NASA programs and projects. For example, when HEOMD program managers identify specific SBIR subtopics that are likely to generate technologies that could apply to their programs or projects, the SBIR office can provide information about previously developed technologies that could be incorporated into their work. Principal investigators (PIs) for small businesses can also benefit from understanding NASA program and project needs, increasing the likelihood that technologies developed by their small businesses will be integrated into HEOMD projects. SBIR solicitations for the current fiscal year are posted at <http://sbir.gsfc.nasa.gov/solicitations>.

The SBIR program's original intent was for technologies that had completed Phase II to be ready for integration into NASA programs. In many cases, however, there was a gap between Technology Readiness Levels (TRLs) 5 and 6 that needed to be closed. Now the SBIR program supports its small business partners with three post Phase II options that focus on creating opportunities for commercialization as well as technology integration. The Phase II Enhancement (Phase II-E), Phase II Expanded (Phase II-X), and Commercialization Readiness Pilot (CRP) options also provide opportunities for Phase II technologies to be integrated and tested in the NASA system platform or in the space environment. Details on post Phase II initiatives and opportunities, including funding options, may be found at <http://sbir.gsfc.nasa.gov/content/post-phase-ii-initiatives>.

Fiscal Year 2016 SBIR Subtopics and Subtopic Summaries

Figure 1 shows HEOMD topics and subtopics for fiscal year 2016; SBIR descriptions for each HEOMD subtopic follow. Research topics and subtopics for all directorates are listed in Chapter 9 of the Phase I SBIR/STTR Program Solicitation for fiscal year 2016, available at <https://sbir.nasa.gov/solicit/56329/detail?data=ch9&s=56316>

Topics and Subtopics

H1 In Situ Resource Utilization

H1.01 In Situ Resource Utilization: Production of Feedstock for Manufacturing and Construction

H2 Space Transportation

H2.01 LOX/Methane In-Space Propulsion
H2.02 Nuclear Thermal Propulsion
H2.03 High Power Electric Propulsion
H2.04 Cryogenic Fluid Management for In-Space Transportation

H3 Life Support and Habitation Systems

H3.01 Environmental Monitoring
H3.02 Environmental Control and Life Support for Spacecraft and Habitats

H4 Extra-Vehicular Activity

H4.03 Extra-Vehicular Activity Space Suit Power, Avionics, and Software Systems

H5 Lightweight Structures and Materials

H5.01 Large Deployable Structures for Smallsats
H5.03 Multifunctional Materials and Structures: Integrated Structural Health Monitoring for Long Duration Habitats

H7 Entry, Descent, and Landing

H7.01 Ablative Thermal Protection Systems Technologies

H8 High Efficiency Space Power

H8.01 Thermal Energy Conversion
H8.02 Solid Oxide Fuel Cells and Electrolyzers
H8.03 Advanced Photovoltaic Systems
H8.04 Advanced Next Generation Batteries

H9 Space Communications and Navigation

H9.01 Long Range Optical Telecommunications
H9.02 Advanced Space Communication Systems
H9.03 Flight Dynamics and Navigation Systems

H12 Human Research and Health Maintenance

H12.03 Novel Imaging Technologies for Space Medicine

H13 Non-Destructive Evaluation

H13.02 Non-Destructive Evaluation Sensors

H14 International Space Station (ISS) Demonstration and Development of Improved Exploration Technologies and Increased ISS Utilization

H14.01 International Space Station Utilization

Figure 1.—Fiscal year 2016 Small Business Innovation Research (SBIR) Human Exploration and Operations Mission Directorate (HEOMD) topics and subtopics.

H1.01 In Situ Resource Utilization: Production of Feedstock for Manufacturing and Construction

The overall goal of in situ resource utilization (ISRU) is to transform available resources, both natural and man-made, on extraterrestrial surfaces into usable materials and products that assist in sustaining and growing human exploration capabilities. ISRU involves all the steps associated with identifying, collecting, and converting local resources into products that can reduce mission mass, cost, and/or risk. It is imperative that novel technologies be developed to effectively utilize these resources for mission-critical consumables and to produce feedstock for additive manufacturing of replacement parts, construction for habitat, and infrastructure expansion.

H2.01 LOX/Methane In-Space Propulsion

NASA is developing high-thrust in-space chemical propulsion capabilities to enable human and robotic missions into the proving ground (Mars and beyond). Successful proposals are sought for focused investments in key technologies and design concepts that may transform the path for future exploration of Mars while providing component and system-level cost and mass savings. In-space propulsion is defined as the development and demonstration of technologies for ascent, orbit transfer, pulsing attitude/reaction control, and descent engines. The goal of this subtopic is to examine novel technology options that include the use of additive manufacturing or other low-cost processes that save mass and/or cost compared with current state-of-the-art technologies and fabrication methods.

H2.02 Nuclear Thermal Propulsion

Solid core nuclear thermal propulsion (NTP) has been identified as a high priority technology for future human exploration of Mars. This solicitation will examine a range of modern technologies associated with NTP. Specific technologies of interest include reactor fuel element designs with high-temperature, high-power density to maximize hydrogen propellant heating; concepts to cool down reactor decay heat after shutdown to minimize the amount of open cycle propellant used; low-risk reactor design features that allow more flexible criticality control during burns beyond the reactor circumferential rotating control drums and/or provide nuclear safety for ground processing, launch, and possible aborts; and ground test engine effluent processing technologies for efficient containment and/or filtering of radioactive particles and noble gases and management of high-temperature, high-flow hydrogen exhausts.

H2.03 High Power Electric Propulsion

The goal of this subtopic is to develop innovative, high-power (>100 kW) electric propulsion systems. High-power solar or nuclear electric propulsion may enable dramatic mass and cost savings for lunar and Mars cargo missions, including Earth escape and near-Earth space maneuvers, at power levels that enable a wide range of exploration missions. Innovations and advancements leading to improvements in the end-to-end performance of high-power electric propulsion systems are of interest. Methods are sought to increase overall system efficiency; improve system and/or component life or durability; reduce system and/or component mass, complexity, and development issues; or provide other definable benefits.

H2.04 Cryogenic Fluid Management for In-Space Transportation

This subtopic solicits technologies that support NASA's exploration goals by addressing the storage and transfer of cryogenic propellants such as hydrogen, oxygen, and methane. This effort includes a wide range of applications, scales, and environments consistent with future NASA missions. Such missions include (but are not limited to) the Exploration Upper Stage, In Situ Resource Utilization in cooperation with Mars Landers, and the Evolvable Mars Campaign.

H3.01 Environmental Monitoring

Environmental monitoring comprises the following four monitoring disciplines: air, water, microbial, and acoustics. These functional needs are required to address identified risks to crew health during Exploration-class missions. The International Space Station has employed a wide variety of analytical instruments to deal with critical items. Limitations to current approaches for missions beyond low Earth orbit include a reliance on return sample and ground analysis; too much crew time required; constraints on size, mass, and power; lack of portability; and insufficient calibration life. A concerted effort is underway to address these gaps, determine the most promising solutions, and mature those solutions to ground and flight technology demonstrations. Technologies that show improvements in miniaturization, reliability, lifetime, self-calibration, and reduction of expendables are of interest.

H3.02 Environmental Control and Life Support for Spacecraft and Habitats

Solutions and innovations are needed for technology that supports the mass- and energy-efficient maintenance of closed air, water, and waste systems in spacecraft habitats that operate on planetary surfaces such as Mars and in the microgravity environment of space. Three specific focus areas have been identified: (1) new applications of the heat melt compactor for contaminant control and waste management, (2) cleaning agents and physicochemical treatments for habitat housekeeping and laundering clothes, and (3) surface treatments that limit biofilm and scaling within water processing system plumbing lines.

H4.03 Extra-Vehicular Activity Space Suit Power, Avionics, and Software Systems

Spacesuit power, avionics, and software (PAS) advancements are needed to extend extravehicular activity (EVA) capability on the International Space Station beyond 2020 and in future human space exploration missions. NASA is presently developing a spacesuit system called the Advanced Extravehicular Mobility Unit (AEMU). The AEMU PAS system is responsible for power supply and distribution for the overall EVA system; collecting and transferring several types of data to and from other mission assets; providing avionics hardware to perform numerous data display and in-suit processing functions; and furnishing information systems to supply data to enable crewmembers to perform their tasks with autonomy and efficiency. NASA is seeking flight-rated electronic devices to complement the existing inventory of flight-rated parts so as to enable the creation of an advanced avionics suite for spacesuits.

H5.01 Large Deployable Structures for Smallsats

This subtopic seeks deployable structures innovations in two areas for proposed lunar and deep space missions: (1) large solar sails with at least 85 m² of deployed surface area for 6U cubesats and (2) large solar arrays with at least 200 W of power for 6U to 12U cubesats, or 600 W for 50 to 100 kg microsats. Design solutions must demonstrate high deployment reliability and predictability with minimum mass and launch volume and maximum strength, stiffness, stability, and durability.

H5.03 Multifunctional Materials and Structures: Integrated Structural Health Monitoring for Long Duration Habitats

For fiscal year 2016, this SBIR subtopic sought innovative, multifunctional approaches to integrating structural health monitoring into materials for long-duration deep space habitats, including (but not limited to) state-of-the art thin-ply composites and soft-goods materials for expandable habitat structural concepts, during or after fabrication, to enable evaluation of structural properties and failure prediction over the duration of the habitat's operational life. The goal for long-duration space habitat design is fail-safe operation, providing monitoring and early prediction of failure onset via structural health monitoring and a benign, progressive failure architecture that allows for safe evacuation even at or after the first failure point.

H7.01 Ablative Thermal Protection Systems Technologies

This subtopic calls for the development, modeling, testing, and monitoring of ablative thermal protection materials, high char yield adhesives, and/or systems that will support planetary entry. Ablative thermal protection systems (TPS) technologies support the goal of developing advancements in polymers for bonding and/or gap-filling ablative materials, instrumentation systems, and analytical modeling for the higher performance TPS materials currently in development for future Exploration missions. These ablative TPS materials include felt or woven material precursors impregnated with polymers and/or additives to improve ablation and insulative performance.

H8.01 Thermal Energy Conversion

NASA needs innovative technologies that convert thermal energy into electricity for space power generation on orbiting platforms, extraterrestrial surfaces, and space transportation vehicles. The thermal energy could be supplied by nuclear reactors, radioisotope heat sources, solar concentrators, chemical reactions, or as waste heat from other space systems. The focus of this subtopic is the energy conversion subsystem. Proposals are requested on thermal energy conversion approaches that offer high efficiency, low mass, high reliability, long life, and low cost. Candidate technologies include thermodynamic heat engines such as Stirling, Brayton, and Rankine as well as thermoelectric and thermionic devices. Ancillary components used to deliver heat (e.g., heat transport loops and heat pipes) to the energy conversion and reject waste heat (e.g., heat pipes and radiators) are also of interest.

H8.02 Solid Oxide Fuel Cells and Electrolyzers

Technologies are sought that improve the durability, efficiency, and reliability of solid oxide systems. Of particular interest are those technologies that address challenges common to fuel cells fed by oxygen and methane and electrolyzers fed by carbon dioxide and/or water. Hydrocarbon fuels of interest include methane and fuels generated by processing lunar and Mars soils.

H8.03 Advanced Photovoltaic Systems

Advanced photovoltaic (PV) power generation and enabling power system technologies are sought with improvements in power system performance (conversion efficiency, mass, stowed volume, etc.), mission operation capability, and reliability for PV power systems supporting NASA human exploration missions. The technologies being sought should enable or enhance the ability to provide low cost, low mass, and higher efficiency solar power systems that support high-power solar electric propulsion, high radiation and extreme environments, and Mars surface NASA missions.

H8.04 Advanced Next Generation Batteries

Breakthrough battery cell technologies that far exceed the specific energy and energy density or temperature performance of state-of-the-art lithium-based cell technologies are required to achieve far-term energy storage goals for human and robotic missions to the Moon, near-Earth orbit, Venus, and Mars. NASA is seeking innovative, advanced electrochemical cell and battery technologies that can aggressively address requirements for these future missions. Proposed chemistries and components must meet performance goals while simultaneously delivering a high level of safety. Components and systems are specifically sought for Extravehicular Activities, Human Lunar and Mars Landers and Rovers, and the Mars Ascent Vehicle.

H9.01 Long Range Optical Telecommunications

The Long Range Optical Telecommunications subtopic seeks innovative technologies in free-space optical communications for increased data volume returns from space missions in multiple domains. Proposals are sought in the following specific areas (TRL3 Phase I, to mature to TRL4–TRL5 in Phase II): (1) low-mass large apertures for high effective isotropic radiated power (EIRP) laser transceivers, (2) high-gigabit laser transmitter and receiver optical-electronic subsystems, (3) waveform signal processing, (4) large-aperture ground receiver subsystem technologies, (5) superconducting magnesium diboride (MgB₂) thin films for ground receiver detectors, (6) cryogenic readout electronics for large-format superconducting nanowire arrays, (7) beaconless pointing subsystems, and (8) low mass/low power/cold-survivable optical transceivers for planetary-lander-to-orbiter links.

H9.03 Flight Dynamics and Navigation Systems

NASA is investing in the advancement of systems, devices, and software algorithms and tools to enhance and extend its capabilities for providing spacecraft position, attitude, and velocity estimates and to improve spacecraft navigation, guidance, and control functions. Efforts must demonstrate significant risk reduction, cost reduction, performance benefit, or enabling capability. Proposals can support mission engineering activities at any stage of development, from the concept phase or pre-formulation through operations and disposal. Applications in low Earth orbit, lunar, and deep space are in scope for this

subtopic. Proposals that could lead to the replacement of the Goddard Trajectory Determination System or leverage state-of-the-art capabilities already developed by NASA, such as the General Mission Analysis Tool, are especially encouraged. Proposers who contemplate licensing NASA technologies are highly encouraged to coordinate with the appropriate NASA technology transfer offices prior to submission of their proposals.

H12.03 Novel Imaging Technologies for Space Medicine

NASA is seeking novel medical imaging techniques in two areas: (1) software-based ultrasound and (2) portable x ray.

(1) Software-based ultrasound's smaller footprint, lower power consumption, and lower emissions across the electromagnetic spectrum make it particularly well suited for space medicine. Ultrasound also provides medically useful capabilities outside the realm of imaging, such as quantitative ultrasound diagnostic techniques and therapeutic techniques that utilize the energy in the ultrasound signal itself.

(2) Portable x-ray technology can fill the gaps in ultrasound's ability to diagnose certain medical conditions that might arise during space flight, particularly space flight to deep space destinations. Limitations include the relatively higher volumetric footprint, higher power requirements, and higher electromagnetic emissions (particularly ionizing radiation, both in terms of dosage delivered to the crew and stray emissions) of x-ray devices and other imaging devices. NASA needs new technology developments to overcome these limitations and ensure on-orbit diagnosis of certain dental and musculoskeletal conditions.

H13.02 Non-Destructive Evaluation Sensors

Technologies sought under this SBIR program include advanced sensors, sensor systems, sensor techniques, and software applications that will enhance or expand NASA's current sensor capability. Targeting of structural components of space flight hardware (e.g., lightweight structural materials such as composites and thin metals) is desirable, though not required. Technologies sought include modular, smart, advanced nondestructive evaluation sensor systems and associated capture and analysis software. It is advantageous for techniques to include the development of quantum sensor, metasensor, and nanosensor technologies for deployment. Technologies that enable the inspection of large, complex structures are encouraged. Technologies should provide reliable assessments of the location and extent of damage.

H14.01 International Space Station Utilization

NASA continues to invest in the near- and mid-term development of highly desirable systems and technologies that provide innovative ways to leverage existing International Space Station (ISS) facilities for new scientific payloads and to provide on-orbit analysis to enhance capabilities. Additionally, NASA is supporting commercial science, engineering, and technology to provide low Earth orbit commercial opportunities utilizing the ISS. Utilization of the ISS is limited by available up-mass, down-mass, and crew time as well as by the capabilities of the interfaces and hardware already developed and in use. Innovative interfaces between existing hardware and systems that are common to ground research could facilitate increased and faster payload development and subsequent utilization. Technologies that are portable and able to be matured rapidly for flight demonstration on the ISS are of particular interest.

Phase I Contract Awards

Figure 2 indicates the number of HEOMD-associated Phase I contracts awarded in fiscal year 2016.

SBIR HEOMD Topics and Subtopics ^a	2016 Awards
H1 In Situ Resource Utilization	
H1.01 In Situ Resource Utilization: Production of Feedstock for Manufacturing and Construction	7
H2 Space Transportation	
H2.01 LOX/Methane In-Space Propulsion	3
H2.02 Nuclear Thermal Propulsion	3
H2.03 High Power Electric Propulsion	1
H2.04 Cryogenic Fluid Management for In-Space Transportation	6
H3 Life Support and Habitation Systems	
H3.01 Environmental Monitoring	7
H3.02 Environmental Control and Life Support for Spacecraft and Habitats	4
H4 Extra-Vehicular Activity	
H4.03 Extra-Vehicular Activity Space Suit Power, Avionics, and Software Systems	1
H5 Lightweight Structures and Materials	
H5.01 Large Deployable Structures for Smallsats	6
H5.03 Multifunctional Materials and Structures: Integrated Structural Health Monitoring for Long Duration Habitats	4
H7 Entry, Descent, and Landing	
H7.01 Ablative Thermal Protection Systems Technologies	5
H8 High Efficiency Space Power	
H8.01 Thermal Energy Conversion	5
H8.02 Solid Oxide Fuel Cells and Electrolyzers	3
H8.03 Advanced Photovoltaic Systems	3
H8.04 Advanced Next Generation Batteries	3
H9 Space Communications and Navigation	
H9.01 Long Range Optical Telecommunications	4
H9.02 Advanced Space Communication Systems	3
H9.03 Flight Dynamics and Navigation Systems	3
H12 Human Research and Health Maintenance	
H12.03 Novel Imaging Technologies for Space Medicine	1
H13 Non-Destructive Evaluation	
H13.02 Non-Destructive Evaluation Sensors	5
H14 International Space Station (ISS) Demonstration and Development of Improved Exploration Technologies and Increased ISS Utilization	
H14.01 International Space Station Utilization	5

^aSee Appendix A for contract titles.

Figure 2.—Fiscal year 2016 Phase I contract awards associated with the Human Exploration and Operations Mission Directorate (HEOMD).

HEOMD Program and Project Summaries

HEOMD topics and subtopics strategically align with HEOMD programs and projects and support the Directorate’s current needs and objectives. Figure 3 illustrates how SBIR subtopics are mapped to HEOMD programs and projects for fiscal year 2016. This is followed by descriptions of each HEOMD program and project (arranged alphabetically). Understanding how HEOMD topics and subtopics are being addressed in HEOMD programs and projects will be useful for small business principal investigators (PIs) and HEOMD project managers.

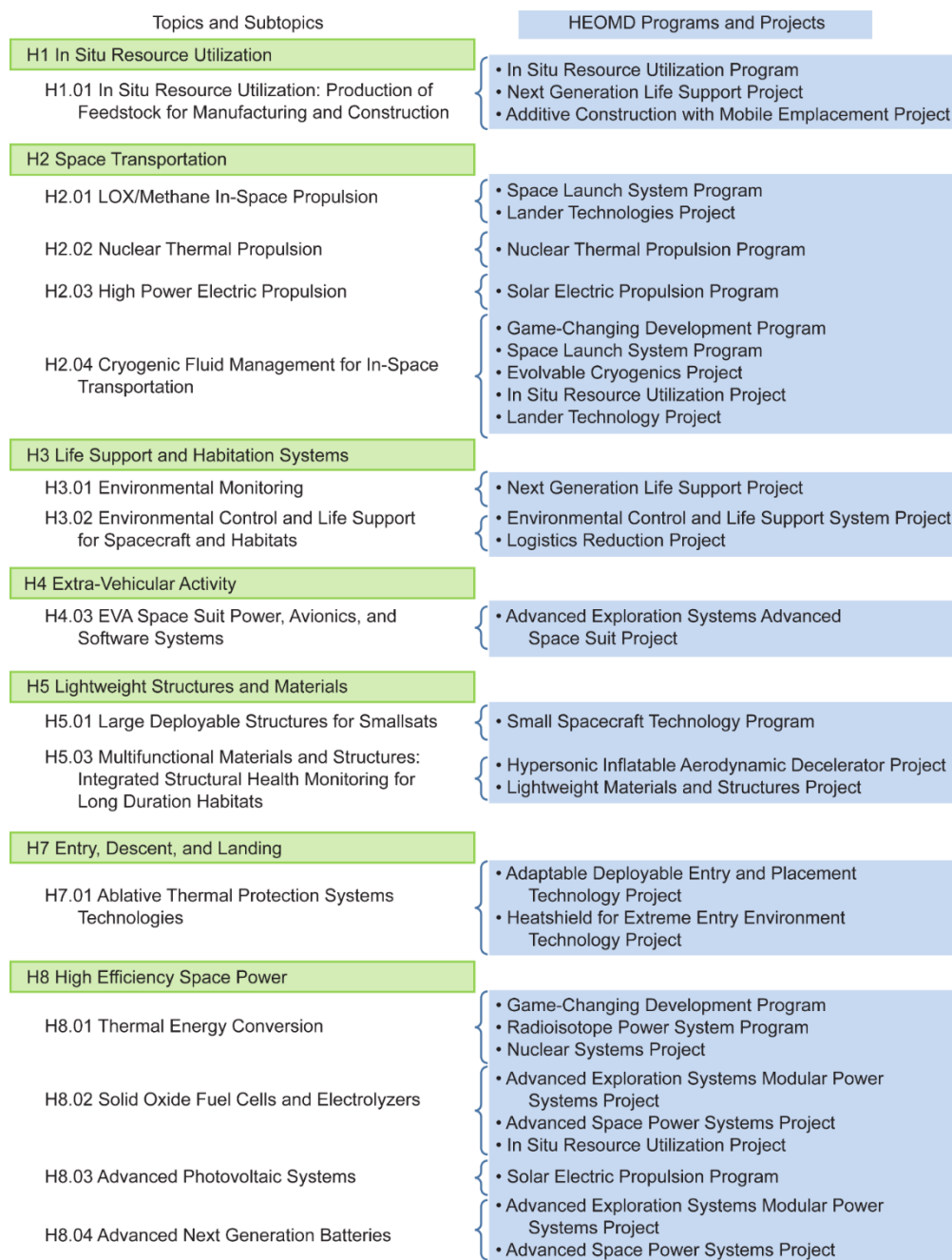


Figure 3.—Fiscal year 2016 Small Business Innovation Research (SBIR) Human Exploration and Operations Mission Directorate (HEOMD) subtopics mapped to HEOMD programs and projects.

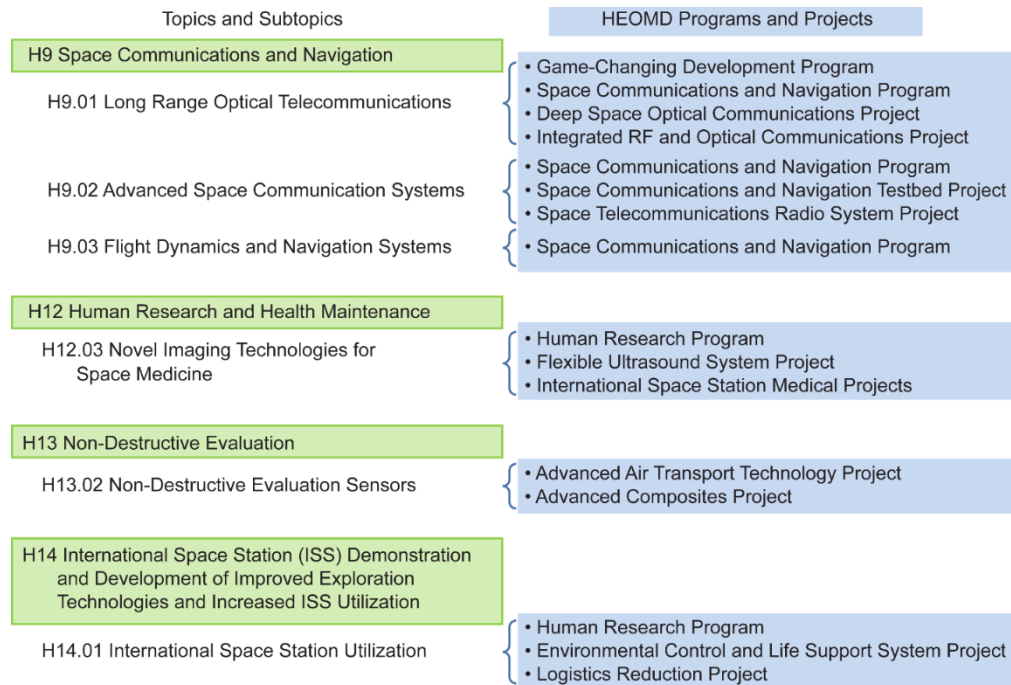


Figure 3.—Concluded.

Adaptable Deployable Entry and Placement Technology Project

The Adaptable Deployable Entry and Placement Technology (ADEPT) Project is a game-changing technology development project to develop, test, and demonstrate a deployable aeroshell concept as a viable thermal protection system for entry, descent, and landing of science and exploration class payload missions.

Additive Construction with Mobile Emplacement Project

The Additive Construction with Mobile Emplacement (ACME) Project is developing technology to build structures on planetary surfaces using in situ resources. The project focuses on the construction of infrastructure for planetary surface missions, both two-dimensional (landing pads, roads, and structure foundations) and three-dimensional (habitats, garages, radiation shelters, and other structures).

Advanced Air Transport Technology Project

The Advanced Air Transport Technology (AATT) Project explores and develops technologies for advanced fixed-wing transport aircraft with revolutionary energy efficiency. These technologies are critical to reduce the environmental impact of aviation as the industry continues to grow. AATT studies focus on the future, targeting vehicles that are three generations beyond the current state of the art that require mature technology solutions in the 2035 to 2045 timeframe.

Advanced Composites Project

The Advanced Composites (AC) Project addresses improved methods, tools, and protocols to reduce the development and certification timeline for composite materials and structures. The project focuses on the development and use of high fidelity and rigorous computational methods, improved test protocols, standardized inspection techniques, and manufacturing process simulation to shorten the timeline to bring innovative composite materials and structures to market.

Advanced Exploration Systems Advanced Space Suit Project

The Advanced Exploration Systems (AES) Advanced Space Suit Project develops component technologies for advanced spacesuits to enable humans to conduct “hands-on” surface exploration and in-space operations outside habitats and vehicles. Technology development includes portable life support systems; thermal control; power systems; communications, avionics, and information systems; and space suit materials.

Advanced Exploration Systems Modular Power Systems Project

The Advanced Exploration Systems (AES) Modular Power Systems (AMPS) project will infuse and demonstrate modular power electronics, batteries, fuel cells, and autonomous control for exploration ground system demonstrations; assess and provide recommendations for improvements of proposed power systems for other AES projects and Human Exploration and Operations Mission Directorate (HEOMD) demonstration systems; and develop modular power design concepts that will guide the ground system demonstrations and modular component and assembly development for the duration of this project.

Advanced Space Power Systems Project

The Advanced Space Power Systems (ASPS) Project addresses three project elements: advanced regenerative fuel cells, which include fuel cells and electrolyzers and balance-of-plant subsystems using an innovative passive fluid management technology; advanced high specific energy and energy density lithium-ion batteries with flame retardant electrolytes; and next-generation low-cost, high-power, space-tolerant solar power arrays that integrate advances in cell and manufacturing processing to achieve the end goals.

Deep Space Optical Communications Project

The objective of the Deep Space Optical Communications (DSOC) Project is to develop key technologies for the implementation of a deep space optical transceiver and ground receiver that will enable greater than 10× the data rate of a state-of-the-art deep space RF system (Ka-band) for similar spacecraft mass and power. Although a 10× RF deep space optical transceiver could be built with existing technologies, the mass and power performance for the data rate provided would not be competitive with existing RF telecommunications systems.

Environmental Control and Life Support System Project

The Environmental Control and Life Support System (ECLSS) Project performs several functions for the International Space Station (ISS): (1) provides oxygen for metabolic consumption; (2) provides potable water for consumption, food preparation, and hygiene uses; (3) removes carbon dioxide from the cabin air; (4) filters particulates and microorganisms from the cabin air; (5) removes volatile organic trace gases from the cabin air; (6) monitors and controls cabin air partial pressures of nitrogen, oxygen, carbon dioxide, methane, hydrogen, and water vapor; (7) maintains total cabin pressure; (8) maintains cabin temperature and humidity levels; and (9) distributes cabin air between connected modules.

Evolvable Cryogenics Project

The Evolvable Cryogenics (eCryo) Project is developing, validating, and integrating cryogenic fluid management technologies with the potential to benefit a variety of future space vehicles and space systems. To ensure the maturation of cryogenic fluid management technologies that can enable the capabilities needed for NASA's near-term missions, eCryo is addressing four focus areas: (1) analysis tools, (2) multi-layer insulation (MLI) characterization, (3) vapor-based heat intercept, and (4) radio frequency mass gauging (RFMG).

Flexible Ultrasound System Project

The Flexible Ultrasound System (FUS) Project is a technology development project that looks at the noninvasive diagnostic capability for imaging of internal body parts on future exploration missions. Ultrasound will be the “workhorse” for internal imaging modality on these missions due to its portability, low power consumption, and avoidance of the use of ionizing radiation. State-of-the-art clinical ultrasound units offer excellent and ever-expanding diagnostic capabilities, but they are difficult to adapt toward accommodating novel custom scans and therapeutic algorithms developed by NASA and its research partners.

Game-Changing Development Program

The Game-Changing Development Program seeks to identify and rapidly mature innovative and high-impact capabilities and technologies that may lead to entirely new approaches for the Agency's future space missions. The program will investigate novel ideas and approaches that have the potential to revolutionize future space missions. The most promising ideas will be advanced through significant ground-based testing and/or laboratory experimentation, typically by multiple performing teams using varied approaches.

Heatshield for Extreme Entry Environment Technology Project

The Heatshield for Extreme Entry Environment Technology (HEEET) Project seeks to mature a game-changing woven thermal protection system technology to enable in situ robotic science missions recommended by the NASA Research Council Planetary Science Decadal Survey committee.

Human Research Program

The Human Research Program (HRP) delivers products and strategies to protect the health and safety of space flight crews and increase their productivity while living and working in space. The project investigates and mitigates the highest risks to human health and performance, providing essential countermeasures and technologies for human space exploration. Risks include physiological and performance effects from hazards such as radiation, altered gravity, and hostile environments, as well as unique challenges in medical support, human factors, and behavioral health support.

Hypersonic Inflatable Aerodynamic Decelerator Project

The Hypersonic Inflatable Aerodynamic Decelerator (HIAD) project is a disruptive technology that will accommodate the atmospheric entry of heavy payloads to planetary bodies such as Mars. HIAD overcomes size and weight limitations of current rigid systems by utilizing inflatable soft-goods materials that can be packed into a small volume and deployed to form a large aeroshell before atmospheric entry.

In Situ Resource Utilization Program

The In Situ Resource Utilization (ISRU) Program works to assess the in situ resources available on the moon and Mars in addition to developing technologies needed to utilize these resources. The research will focus on technologies necessary to extract consumables (O₂, H₂O, N₂, He, etc.) for human life support system replenishment. The consumables will also be used as source materials (feedstock) for in situ fabrication and repair technologies as well as feedstock for radiation shielding and shelters.

Integrated RF and Optical Communications Project

The Integrated RF and Optical Communications (iROC) Project combines the best features of select deep space radio frequency (RF) and optical communication elements into an integrated system. The project is working on increasing Technology Readiness Levels (TRLs), leading to integrated hybrid communications system demonstration. These new systems offer potential 40× (optical) and 16× (RF) data rates with comparable Mars Reconnaissance Orbiter payload mass. Additionally, the deep space mission risk involved with transition to optical communication technology will be reduced by integrating highly capable and robust RF systems (extensible design beyond Mars).

International Space Station Medical Projects

The International Space Station Medical Projects (ISSMP) element provides planning, integration, and implementation services for Human Research Program research tasks. The objectives of the ISSMP are to maximize the utilization of the ISS for research to assess the effects of long-duration space flight on human systems; to develop and verify strategies to ensure optimal crew performance; and to enable development and validation of an integrated suite of physical, pharmacologic, and nutritional countermeasures to protect the health and performance of crewmembers.

Lander Technology Project

NASA's Lander Technology Project develops robotic lander capabilities for future lunar and Mars exploration through industry and international partnerships and through investments in critical risk-reducing technologies.

Lightweight Materials and Structures Project

The Lightweight Materials and Structures (LMS) Project will mature high-payoff structures and materials technologies that have direct application to NASA's future space exploration needs. One of the first objectives for LMS will be to demonstrate the significant weight savings afforded by the incorporation of composite cryogenic oxygen and methane propellant tanks.

Logistics Reduction Project

The Logistics Reduction Project enables a largely mission-independent, cradle-to-grave-to-cradle approach to minimize logistics contributions to total mission architecture mass. The goals are to engineer logistics materials, common crew consumables, and container configurations to meet five basic goals. When these five goals are integrated across a mission, they will reduce ISS-equivalent packaging volume by 50 percent.

Next Generation Life Support Project

The Next Generation Life Support (NGLS) Project is developing key technologies to enable critical capabilities in Extravehicular Activity (EVA) Portable Life Support Systems (PLSSs), life support oxygen recovery, and life support water recovery required to extend human presence beyond low Earth orbit into the solar system. The selected technologies within each of these areas are focused on increasing affordability, reliability, and vehicle self-sufficiency while decreasing mass and enabling long-duration exploration.

Nuclear Systems Project

The Nuclear Systems Project initiates the development of a low-cost, small fission terrestrial demonstration. The 3-year development effort will result in the demonstration of a fission power system using a prototype U235 reactor core coupled to flight-like Stirling converters. The small fission reactor and Stirling power converter technology will enable more capable outer planetary science missions as well as surface power systems for human missions to Mars. In addition to this new development effort, the project will complete the nonnuclear, thermal vacuum testing of a medium power (40 to 100 kW) in-space fission power system that will advance the component technologies to Technology Readiness Level (TRL) 5.

Nuclear Thermal Propulsion Program

The Nuclear Thermal Propulsion (NTP) Program is developing system concepts, ground-test approaches, and reactor fuel elements for nuclear thermal propulsion. A key goal of the program is to address critical, long-term NTP technology challenges and issues through development, analysis, and testing of NTP hardware so that NTP systems can be an affordable and viable in-space propulsion candidate for future Human Exploration and Operations missions.

Radioisotope Power System Program

The Radioisotope Power Systems (RPS) Program is a technology development effort managed by NASA that is strategically investing in nuclear power technologies that would maintain NASA's current space science capabilities and enable future space exploration missions. NASA, working in collaboration with the U.S. Department of Energy (DOE), invests in research and development efforts on the Advanced Stirling Radioisotope Generator. NASA also works with the DOE to maintain the capability to produce the Multi-Mission Radioisotope Thermoelectric Generator, which serves as the power source for Curiosity, the Mars Science Laboratory rover.

Small Spacecraft Technology Program

The Small Spacecraft Technology Program, one of the nine programs in the Space Technology Mission Directorate, has three primary objectives: (1) identify and support the development of new subsystem technologies to enhance or expand the capabilities of small spacecraft; (2) support flight demonstrations of new technologies, capabilities, and applications for small spacecraft; and (3) use small spacecraft as platforms for testing and demonstrating technologies and capabilities that might have more general applications in larger-scale spacecraft and systems.

Solar Electric Propulsion Program

The Solar Electric Propulsion (SEP) Program seeks to develop and fly a 50-kW spacecraft that uses flexible blanket solar arrays for power generation and electric propulsion for primary propulsion and is capable of delivering payloads from low Earth orbit to higher orbits and into deep space.

Space Communications and Navigation Program

The Space Communications and Navigation (SCaN) Program serves as the Program Office for all of NASA's space communications activities. SCaN manages and directs the ground-based facilities and services provided by the Deep Space Network (DSN), Near Earth Network (NEN), and Space Network (SN).

Space Communications and Navigation Testbed Project

The Space Communications and Navigation (SCaN) Testbed is an advanced integrated communications system and laboratory facility to be installed on the International Space Station (ISS). Using a new generation of Software Defined Radio technologies, this ISS facility will allow researchers to develop, test, and demonstrate new communications, networking, and navigation capabilities in the actual environment of space. The SCaN Testbed will thus advance space communication technologies in support of future NASA missions and other U.S. space endeavors.

Space Launch System Program

NASA's Space Launch System (SLS) is an advanced launch vehicle for a new era of exploration beyond Earth's orbit into deep space. SLS, the world's most powerful rocket, will launch astronauts in the Agency's Orion spacecraft on missions to an asteroid and eventually to Mars, while opening new possibilities for other payloads, including robotic scientific missions to places like Mars, Saturn, and Jupiter.

Space Telecommunications Radio System Project

Space Telecommunications Radio System (STRS) Project addresses future space communications and navigation system needs by defining an open architecture for NASA space and ground software-defined radios. The STRS Project is currently developing the standard to provide a common, consistent framework to abstract the application software from the radio platform hardware to reduce the cost and risk of using complex reconfigurable and reprogrammable radio systems across NASA missions.

NASA Glenn Facilities Associated With HEOMD Topics and Subtopics for Fiscal Year 2016

A number of HEOMD topics and subtopics for fiscal year 2016 can be aligned with facility capabilities at NASA Glenn Research Center, as illustrated in Figure 4. Descriptions of each facility follow.

Customers interested in using these facilities should contact the appropriate facility managers at <https://facilities.grc.nasa.gov/contact.html> and submit a brief online test request form at https://facilities.grc.nasa.gov/using_request.html. Appropriate NASA Glenn personnel will review each test request and provide a detailed cost estimate before preparing a formal test agreement, which must be signed by both parties.

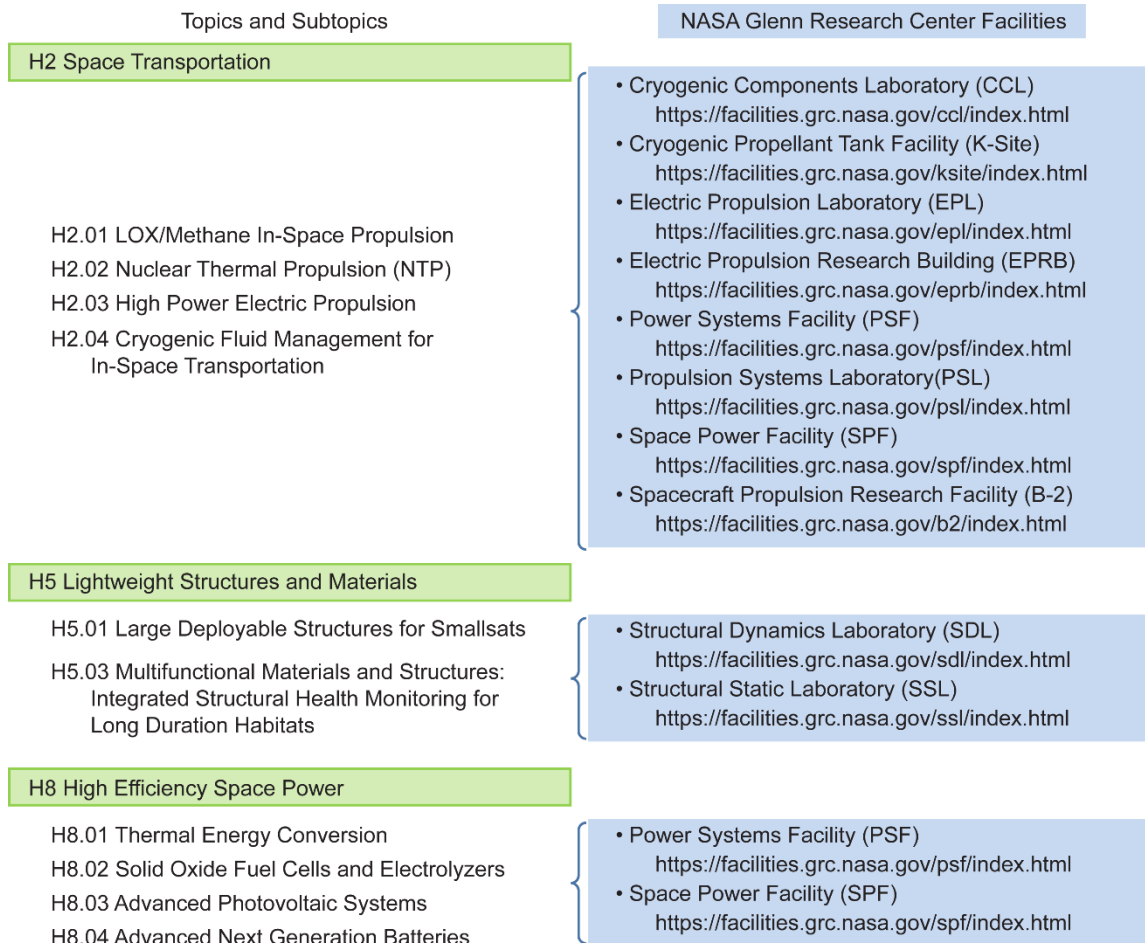


Figure 4.—Fiscal year 2016 Human Exploration and Operations Mission Directorate (HEOMD) subtopics mapped to NASA Glenn Research Center facilities.

Cryogenic Components Laboratory (CCL)

The Cryogenic Components Laboratory (CCL) is a new, state-of-the-art facility for research, development, and qualification of cryogenic materials, components, and systems. CCL specializes in cryogenic research utilizing liquid hydrogen, oxygen, and nitrogen. The CCL is a complex of buildings and systems that is ideally suited for high-energy, high-risk development of cryogenic systems.

Cryogenic Propellant Tank Facility (K-Site)

The Cryogenic Propellant Tank Facility (K-Site) is a space-environment test chamber 25 ft in diameter with a 20-ft-diameter door. The design and construction of this facility allows large-scale liquid hydrogen (LH₂) experiments to be conducted safely. Control and data systems are located in a separate, remote building, and electrical control systems include explosion-proof hardware.

Electric Propulsion Laboratory (EPL)

The Electric Propulsion Laboratory (EPL) supports research and development of spacecraft power and electric propulsion systems. EPL features two very large space environment chambers, intermediate and smaller environment simulation chambers for testing small engines or components, bell jars used for small-scale development and component testing, and support areas.

Electric Propulsion Research Building (EPRB)

The Electric Propulsion Research Building (EPRB) capability centers on its suite of vacuum chambers, which are configured to meet the unique requirements related to electric propulsion, spacecraft power, and space environmental effects. EPRB chambers range in size from benchtop bell jars to 3 m in diameter and are equipped with a variety of pumping systems (cryopumps, diffusion pumps, oil-free pumping trains, and high-throughput roots blowers). In addition to the vacuum chambers, EPRB provides over 20,000 sq ft of specialty labs, clean rooms, and assembly rooms.

Power Systems Facility (PSF)

The Power Systems Facility (PSF) developed, tested, and validated the electrical power systems for the International Space Station. PSF houses testbeds where scientists and engineers verify critical design concepts, test prototype hardware and software, and perform system validation in real-time simulations and under actual loading and operating conditions.

Propulsion Systems Laboratory (PSL)

The Propulsion Systems Laboratory (PSL) is NASA's only ground-based test facility that can provide true flight simulation for experimental research on air-breathing propulsion systems. Altitudes to 90,000 ft and Mach numbers to 3.0 in one cell and 6.0 in the other can be simulated continuously.

Space Power Facility (SPF)

The Space Power Facility (SPF) houses the world's largest space environment simulation chamber, measuring 100 ft in diameter by 122 ft high. In this chamber, large space-bound hardware can be tested in a severe environment similar to that encountered in space. The facility can sustain a high vacuum and can simulate solar radiation via a 4-MW quartz heat lamp array, solar spectrum via a 400-kW arc lamp, and cold environments with a variable geometry cryogenic cold shroud.

Spacecraft Propulsion Research Facility (B-2)

NASA's Spacecraft Propulsion Research Facility (B-2) is the world's only high-altitude test facility capable of full-scale rocket engine and launch vehicle system level tests. The facility supports mission profile thermal vacuum simulation and engine firing. The engine or vehicle can be exposed for indefinite periods to low ambient pressures, low-background temperatures, and dynamic solar heating, simulating the environment the hardware will encounter during orbital or interplanetary travel.

Structural Dynamics Laboratory (SDL)

Structural dynamic testing is performed to verify the survivability of a component or assembly when exposed to vibration stress screening or a controlled simulation of the actual flight or service vibration environment. Environmental stress screening, or workmanship vibration, is used to identify latent manufacturing defects of components prior to being incorporated into larger assemblies. Vibration testing is also used to verify design margins of assemblies and characterize the internal dynamic responses of a test article.

Structural Static Laboratory (SSL)

Structural testing is performed to verify the structural integrity of space-flight and ground-test hardware. Testing is also performed to verify the finite element analysis by measuring stiffness and induced stress at points in a test article. A structural test can be used to verify the modes of failure of a design when exposed to simulated service loads.

Appendix A.—Fiscal Year 2016 Phase I Contract Titles

Abstracts of these Phase I contracts are posted at <http://sbir.gsfc.nasa.gov/SBIR/abstracts/16-1.html>

H1.01-7789	Extruded Clay-Based Regoliths for Construction on Mars, Phobos, and NEAs
H1.01-7981	In-Situ Generation of Polymer Concrete Construction Materials
H1.01-8046	Polyethylene Production from In-Situ Resources in Microchannel Reactors
H1.01-8072	Extraterrestrial Metals Processing
H1.01-8191	Compact In-Situ Polyethylene Production from Carbon Dioxide
H1.01-8380	Micro-Channel Reactor for Processing Carbon Dioxide to Ethylene
H1.01-8453	ISP3: In-Situ Printing Plastic Production System for Space Additive Manufacturing
H2.01-7120	Additive Manufacturing Technology for a 25,000 lbf LOX/Methane Mars Ascent Engine
H2.01-7193	Diamond–Copper Materials Based Solution for Improved Engine Performance
H2.01-8108	Ultrasonic Additive Manufacturing for High Performance Combustion Chambers
H2.02-7384	Electrolytic Method for Tungsten Coating of Uranium Oxide Spheres
H2.02-7555	Joining of Tungsten Cermet Nuclear Fuel
H2.02-8468	Accident Tolerant Reactor Shutdown for NTP Systems
H2.03-7641	Long Life Cathode Heaters for Hollow Cathodes
H2.04-7581	Bubble Free Cryogenic Liquid Acquisition Device
H2.04-7766	A High Efficiency Cryocooler for In-Space Cryogenic Propellant Storage
H2.04-7770	Innovative Stirling-Cycle Cryocooler for Long Term In-Space Storage of Cryogenic Liquid Propellants
H2.04-8027	Microcapillary Recuperative Heat Exchanger (MRHX)
H2.04-8412	Thermally Insulative Structural Connection for Cryogenic Propellant Tanks
H2.04-8454	Lightweight, High-Flow, Low Connection-Force, In-Space Cryogenic Propellant Coupling
H3.01-7134	Devices and Methods for Collection and Concentration of Air and Surface Samples for Improved Detection
H3.01-7294	Silver Biocide Analysis & Control Device
H3.01-7659	Miniaturized Sensor Array Platform for Monitoring Calcium, Conductivity, and pH in Urine Brine
H3.01-7755	Compact Chemical Monitor for Spacecraft Water Recovery Systems
H3.01-7869	Real-Time Ethylene Sensor Based on Chemical Anisotropic Nanochannel Impedance Spectroscopy
H3.01-8321	Polymer Nanowire-Based Reversible, and Quasi Real-Time, Ethylene Analyzer
H3.01-8576	Innovative Microbial Surface Sampler
H3.02-7349	Multipurpose Waste Disposal Bags for Heat Melt Compactor Application
H3.02-7564	A Novel Cleaning Technology for Spacecraft Habitat
H3.02-8381	Nano-Scale ZnO Coating for Reduction of Biofilm Formation
H3.02-8508	Electrochemical Peroxide Generation
H4.01-7875	Dust Mitigation Strategies for High Pressure Oxygen QDs
H4.01-7953	Dust-Tolerant, High Pressure Oxygen Quick Disconnect for Advanced Spacesuit and Airlock Applications
H4.02-7354	Fiber-Based Adsorbents Tailored for PLSS Ammonia and Formaldehyde Removal
H4.02-8047	Advanced TCCS for Spacesuit Applications

H4.02-8142 Advanced Supported Liquid Membranes for Ammonia and Formaldehyde Control in Spacesuits

H4.02-8157 Novel, Vacuum-Regenerable Trace Contaminant Control System for Advanced Spacesuit Applications

H4.03-7597 Speaker Driver and Wireless Transceiver ASIC

H5.01-7616 200W Deep Space CubeSat Composite Beam Roll-Up Solar Array (COBRA)

H5.01-7702 High Performance TRAC Boom for Solar Sails

H5.01-7830 Simulating CubeSat Structure Deployment Dynamics

H5.01-8115 Electrically Activated Shape Memory Composite Deployable Boom

H5.01-8169 Structural Origami Array (SOAR)

H5.01-8430 Solar Cube 2U: A Heliogyro Propulsion System for CubeSats

H5.02-7100 Extreme Temperature Stitched Structures

H5.02-7447 Novel, Functionally Graded Coating System for Reusable, Very High Temperature Applications

H5.03-7392 Flexible Multifunctional Structural Health Monitoring Systems

H5.03-7485 A Low-Cost, Multi-Functional Sensor Network System for Intelligent Vehicle Health Assessments

H5.03-7546 Non-Invasive Environmental Sensing System for Lifecycle Management (NIEL)

H5.03-7999 Integrated Structural Health Sensors for Inflatable Space Habitats

H5.04-7952 Strut Attachment System for In-Space Robotic Assembly

H5.04-8148 Reclaimable Thermally Reversible Polymers for AM Feedstock

H6.01-7276 Fail-Safe, Controllable Liquid Spring/Damper System for Improved Rover Space Vehicle Mobility

H6.01-7532 The Stinger: A Geotechnical Sensing Package for Robotic Scouting on a Small Planetary Rover

H6.01-7743 Modular Advanced Networked Telerobotic Interface System (MANTIS)

H6.01-7882 Retractable Robotic Anchor for Hard Rock and Granular Soils

H6.01-8135 Liquid Cooled Viscoelastic Actuation for Robust Legged Robot Locomotion

H6.02-8297 cFS-Based Autonomous Requirements Testing Tool

H6.03-7501 Integrating Standard Operating Procedures with Spacecraft Automation

H6.03-8394 An Intelligent Consumables Management System Development Framework based on Artificial Intelligence Techniques

H6.04-8219 Integrating ISHM with Flight Avionics Architectures for Cyber-Physical Space Systems

H6.04-8395 Multiple Failure Response Procedure System

H7.01-7145 Evaluation of Alternative Carbon Fibers to Improve Joint Performance in 3D Woven Heatshields

H7.01-7553 Through-Thickness Health Monitoring of Thermal Protection Systems

H7.01-7929 High Char Flexible Polymers

H7.01-8143 Flexible Gap Filler for Ablative Thermal Protection Systems

H7.01-8243 Flexible, High Char Yield Hybridsil Adhesive Materials for Next Generation Ablative Thermal Protection

H7.02-8111 High Sensitivity, High Frequency Sensors for Hypervelocity Testing and Analysis

H7.02-8293 Laser Scattering Diagnostic for Shock Front Arrival and Electron Number Density

H8.01-7293 High Speed Closed Brayton Cycle Turboalternator

H8.01-7513 Thermal Energy Conversion
 H8.01-7742 Multi-Layer Radiation Shields
 H8.01-7759 Liquid Interface Diffusion Bonding of FPS Heat Pipes to Core
 H8.01-7787 A Novel Electrode Material for Thermionic Power Generation
 H8.02-8130 An Advanced Anode Electrocatalysis Concept for Direct Methane SOFC Systems
 H8.02-8156 Advanced Solid Oxide Cell Architecture and Materials for Durable, Regenerative Operation at Pressure
 H8.02-8171 Methane-Oxygen Solid Oxide Fuel Cell System
 H8.03-7723 Foldable Compactly Stowable Extremely High Power Solar Array System
 H8.03-8031 Affordable, Lightweight, Compactly Stowable, High Strength/Stiffness Lander Solar Array
 H8.03-8153 38% Efficient Low-Cost Six-Junction GaAs/InP Solar Cells Using Double Epitaxial Lift-Off
 H8.04-7232 Aerogel-Ionic Liquid Hybrid Electrolytes
 H8.04-8147 Advanced Lithium Sulfur Battery
 H8.04-8164 High Energy Density Li-Ion Batteries Enabled by a New Class of Cathode Materials
 H9.01-7254 Low-Power-Consumption Integrated PPM Laser Transmitter
 H9.01-7422 200Gb/s WDM Optical Transceiver Chip Modules with RF Transmission, Quadrature Modulation, and Fail-Safe Capabilities
 H9.01-8402 Superconducting Magnesium Diboride Thin Films for Ground Receiver Detectors
 H9.01-8407 High Speed Lasercom Signal Processing and Ground Station
 H9.02-7192 Plug-In Architecture for Software-Defined Radios
 H9.02-7583 OpenSWIFT-SDR for STRS
 H9.02-7669 Ka-Band Electronically Steered CubeSat Antenna
 H9.03-7096 Robust Trajectory Design in Highly Perturbed Environments Leveraging Continuation Methods
 H9.03-7387 Time Inter-Comparison Using Transportable Optical Combs
 H9.03-8310 NonLinear Parallel OPTimization Tool
 H10.01-7772 Improved Test and Launch Operations
 H10.01-7839 mREST:Flexible Open Interface Standard for Test and Launch Operations
 H10.02-7439 Fast Fiber-Coupled Imaging of X-Rays Events
 H10.02-7667 Robust Cryogenic Cavitation Modeling for Propulsion Systems Ground Test Facilities
 H10.02-8152 Elimination of Rocket Ignition Side Loads
 H10.02-8292 Plume Velocimetry Diagnostic for Large Rocket Engines
 H10.02-8302 Color-XHDR—A Compact High-Speed Color Extreme High Dynamic Range Video Capability for Rocket Engine Testing
 H11.01-7730 Process and Tool Innovation for CAD Integration with OLTARIS
 H12.01-7378 Task Analysis Data Processing and Enhanced Representations (TAPER)
 H12.01-7824 5D Task Analysis Visualization Tool
 H12.02-8240 SpaceDoc-Intelligent Health Management System for Astronauts
 H12.03-7975 Novel Methods for the Flexible Ultrasound System utilizing Augmented Reality Just-In-Time Procedural Guidance
 H12.03-8207 Multi-Purpose X-ray System
 H13.01-7712 Algorithms for Structural Dynamics Based Fiber Optic Strain Gage Health Monitoring

H13.01-8360 Fault-Tolerant NDE Data Reduction Framework
H13.01-8500 Electromagnetic Models and Software for the Nondestructive Evaluation of Carbon Nanotube Based Composites
H13.02-7099 Differential Terahertz Imaging Methods for Enhanced Detection of Subsurface Features, Flaws, and Damage
H13.02-7477 Printed Ultra-High Temperature NDE Sensors for Complex Structures
H13.02-7827 Precision Eddy Current Sensor for Nondestructive Evaluation of Spacecraft Structures
H13.02-8093 Active Metamaterial Based Ultrasonic Guided Wave Transducer System
H13.02-8257 Penetrating Backscatter X-Ray Imaging System
H14.01-7508 Space Facility for Orbital Remote Manufacturing (SPACEFORM)
H14.01-7565 Sintered Inductive Metal Printer with Laser Exposure
H14.01-8013 ERASMUS: Food Contact Safe Plastics Recycler and 3D Printer System
H14.01-8181 MEMS-Based Sensor for Monitoring Cabin Air Quality on the ISS
H14.01-8449 Orbital Fiber Optic Production Module

