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Spacecraft and Platform Subsystems

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Spacecraft and Platform Subsystems Overview

- The Science Mission Directorate will carry out the scientific exploration of our Earth, the planets, moons, comets, and asteroids of our solar system and the universe beyond. SMD's future direction will include more detailed exploration missions that are at or near the surface (landers, rovers, and sample returns) or at more optimal observation points in space.
- A major objective of the NASA science spacecraft and platform subsystems development efforts are ***to enable science measurement capabilities using smaller and lower cost spacecraft*** to meet multiple mission requirements thus making the best use of our limited resources. To accomplish this objective, NASA is seeking innovations to significantly improve spacecraft and platform subsystem capabilities while reducing the mass and cost, that would in turn enable increased scientific return for future NASA missions.
- A spacecraft bus is made up of many subsystems like: ***propulsion; thermal control; power and power distribution; attitude control; telemetry command and control; transmitters/antenna; computers/on-board processing/software; and structural elements.*** Science platforms of interest could include ***unmanned aerial vehicles, sounding rockets, balloons, or station (ISS) payload*** that carry scientific instruments/payloads, to planetary ascent vehicles or Earth return vehicles that bring samples back to Earth for analysis.

S3.05 Guidance, Navigation and Control Overview

- **GSFC**, JPL, and ARC
- NASA seeks innovative, ground breaking, and high impact developments in spacecraft guidance, navigation, and control technologies in support of future science and exploration mission requirements. This subtopic covers the technologies enabling significant performance improvements over the state of the art in the areas of spacecraft attitude determination and control, spacecraft absolute and relative orbit and attitude navigation, pointing control, and SmallSat/CubeSat technologies.
- Component technology developments are sought for the range of flight sensors, actuators, and associated algorithms and software required to provide these improved capabilities. Technologies that apply to all spacecraft platform sizes will be considered. Special considerations will be given to emerging technologies applicable to SmallSat/CubeSat class spacecraft if they are technology leaps and mission enabling.
- Advances in the following areas are sought:
  - *Spacecraft Attitude Determination and Control Systems*
  - *Absolute and Relative Navigation Systems*
  - *Pointing Control Systems*
  - *SmallSat/CubeSat Technologies*
  - *Rad-hard GNC hardware*

S3.07 Thermal Control Systems

- **GSFC**, LaRC, MSFC, and JPL
- Advanced thermal devices capable of maintaining components of small spacecraft within their specified temperature ranges are needed. Some examples are: a) phase change systems; b) high performance, low cost insulation systems for diverse environments; c) high flux heat acquisition and transport devices; d) thermal coatings with low absorptance, high emmittance, and good electrical conductivity; e) radiator heat rejection turndown devices. and f) miniature pumped fluid loop systems with passive valve.
- Additive manufacturing technology is sought to simplify the processes of wick insertion and ensure good sealing for capillary two-phase devices, and to produce integrated heat exchangers to increase heat transfer performance while reducing mass, labor and cost.
- Current Structural-Thermal-Optical (STOP) analysis has several codes that do some form of integrated analysis for science, but none that have the capability to do a full end-to-end analysis. An improvement of existing code is needed in order to yield software that can integrate with commonly used programs at NASA for mechanical, structural, thermal and optical analysis.
- Thermoelectric converts (TEC) have been used on many science instruments requiring dedicated/localized cooling. Research and development in areas of advanced materials, processes, and designs are needed in order to improve its efficiency, and extend its low temperature (<90K) capability for space science application.
- Water has been used in two-phase thermal control devices such as heat pipes. However, water expands upon freezing which may cause the rupture of the heat pipe, and may be difficult to start from an initially frozen state. Water-containing azeotropes, which behave as a single-component working fluid, can offer substantial benefits as alternatives to use of pure water. High-performance water azeotropes with a freezing point below -40 ^{o}C are needed.
- An embedded heat transfer device, which facilitates in-situ cooling of three-dimensional integrated circuit chip stack is needed. Such a cooling device must accommodate high heat fluxes and minimize the thermal resistance between the heat source and sink.

S3.09 Command, Data Handling, and Electronics Overview

- **GSFC**, LaRC, and JPL
- Advances in technologies relevant to command and data handling and instrument electronics are sought to support NASA's goals and several missions and projects under development.
- The subtopic goals are to develop platforms for the implementation of miniaturized highly integrated avionics and instrument electronics that:
  - Are consistent with the performance requirements for NASA science missions.
  - Minimize required mass/volume/power as well as development cost/schedule resources.
  - Can operate reliably in the expected thermal and radiation environments.
- The technology priorities sought are listed below:
  - *System-In-Package integrated assemblies* - Technologies enabling highly integrated System-In-Package (SIP) assemblies integrating multiple die from different processes and foundries, enabling implementation of miniaturized, highly-reliable embedded processing or sensor readout modules.
  - *Printed Wiring Board Miniaturization* - Technologies enabling miniaturization of highly reliable printed wiring board assemblies and interconnect.
  - *COTS micropower/ultra-low power computing* - Technologies enabling the use of COTS micropower/ultra-low power computing devices in highly reliable spacecraft avionics systems .
  - *Radiation Shielding* - Innovative additive manufacturing and/or deposition technologies to create integral one-piece surface claddings of graded atomic number (Z) materials for use as radiation shielding for electronics.
- Proposals developing hardware should indicate an understanding of the intended operating environment, including temperature and radiation (which can vary significantly from mission to mission).
  - For example, some low earth orbit missions have a total ionizing dose (TID) radiation requirement of less than 10 krad(Si), while some planetary missions can have requirements well in excess of 1 Mrad(Si).
  - For descriptions of radiation effects in electronics, the proposer may visit (**http://radhome.gsfc.nasa.gov/radhome/overview.htm).**

T11.02 Distributed Spacecraft Mission (DSM) Technology Framework Overview

- **GSFC** and ARC
- A Distributed Spacecraft Mission (DSM) is a mission that involves multiple spacecraft to achieve one or more common goals; some DSM Instances include Constellations, Formation Flying missions, or Fractionated missions. Apart from Science goals that can only be attained with DSM, distributed missions are usually motivated by several goals, among which: increasing data resolution in one or several dimensions (e.g., temporal, spatial, spectral or angular), decreasing launch costs, increasing data bandwidths, as well as ensuring data continuity and inter-mission validation and complementarity. For the purpose of this subtopic, we do not assume the spacecraft to be of any specific sizes, i.e., we do not restrict this study to cubesats or smallsats.
- The goal of this subtopic is to mature NASA capabilities to formulate and implement novel science missions based on distributed platforms. Technologies solicited in this call are the following:
  - Technologies for high-bandwidth and efficient inter-satellite communication;
  - Metrology systems capable of sensing and controlling relative position and/or orientation of multi -element DSMs to sub-milli-arcsecond angular resolution and sub-micro-meter positional accuracy.
  - Autonomous and scalable ground-based constellation operations approaches including science operations and data management, and compatible with the Goddard Mission Services Evolution Center (GMSEC) (open source software developed at NASA Goddard).
  - Software components compatible with the Core Flight System (CFS) (open source software developed at NASA Goddard), enabling to control and navigate DSM formations and constellations; for example, discrete event supervisors offering a means to autonomously control systems based on selected mission metrics
  - Technologies for onboard collaborative processing and intelligence, including but not limited to, inter-spacecraft collaboration for collecting, storing and downloading data as well as multi-platform Science observation coordination and event targeting.
- Research proposed to this subtopic should demonstrate technical feasibility and should discuss how it relates to NASA programs and projects. Proposed work is expected to be at an entry Technology Readiness Level (TRL) between 2 and 5.

Recent Past Awards: S3.05 GN&C

- In the last 5 years
  - 11 Phase 1 Awards
  - 4 Phase 2 Awards

2011-2016 Guidance, Navigation and Control Awards			
Year	**Phase**	**Proposal Title**	**Firm**
2016	1	RF Crosslink for Relative Navigation and Time/Frequency Distribution	M42 Technologies, LLC
2016	1	DRG-Based CubeSat Inertial Reference Unit (DCIRU)	Applied Technology Associates
2016	1	Arcsecond Pointing Stability on a CubeSat Platform	Tyvak Nano-Satellite System Inc
2015	1	Miniature HD6D Navigation and Rendezvous LIDAR & Software	Systems & Processes Engineering Corp
2015	1	Compact Ultrasensitive Erbium-doped Waveguide Optical Gyros	Freedom Photonics, LLC
2015	2	Innovative Fiber-Optic Gyroscopes (FOGs) for High Accuracy Space Applications	Intelligent Fiber Optic Systems Corporation
2014	1	Miniaturized High Performance Optical Gyroscope	Gener8, Inc.
2014	2	Interferometric Star Tracker - Phase II	Optical Physics Company
2014	2	Ultraprecision Pointing Accuracy for SmallSat/CubeSat Attitude Control Systems	QorTek, Inc.
2011	1	Millisecond X-ray Star Tracker	CrossTrac Engineering, inc.
2011	2	Integrated CubeSat ADACS with Reaction Wheels and Star Tracker	Maryland Aerospace, Inc

Recent Past Awards: S3.07 Thermal

- In the last 5 years
  - 19 Phase 1 Awards
  - 5 Phase 2 Awards

2011-2016 Thermal Control Systems Awards			
Year	**Phase**	**Proposal Title**	**Firm**
2016	1	Next Generation Thermal Management Materials: Boron Arsenide for Isotropic Diamond Like Thermal Conductivity - Affordable BAs Processing Innovations	Applied Material Systems Engineering, Inc. (AMSENG)
2016	1	Flexible Methane & Ethane Heat Pipes	Advanced Cooling Technologies, Inc.
2016	1	Lightweight Flexible Thermal Energy Management Panels for CubeSats	ROCCOR, LLC
2016	1	Advanced Reentry Aeroheating Simulation Framework	ATA Engineering, Inc.
2016	1	Loop Heat Pipe Manufacturing via DMLS for CubeSAT Applications	Advanced Cooling Technologies, Inc.
2016	1	An Efficient, Reliable, Vibration-Free Refrigerant Pump for Space Applications	Creare, LLC
2015	1	High heat flux Enhanced Acquisition and Transport system for Small spacecraft	LoadPath
2015	1	Silicon Cold Plate for CubeSat/SmallSat Thermal Control	EOTRON, LLC
2015	1	Coupling Existing Software Paradigms for Thermal Control System Analysis of Re-Entry Vehicles	Combustion Research and Flow Technology
2015	1	Modified Ionic Liquids for Thermal Properties in CubeSats	Innosense, LLC
2015	1	Flexible 2-Phase Thermal Strap for Small Sats	i2C Solutions
2015	1	Two-phase Pumped Loop for Spacecraft Thermal Control	Advanced Cooling Technologies, Inc.
2015	2	Innovations for the Affordable Conductive Thermal Control Material Systems for Space Applications	Applied Material Systems Engineering, Inc. (AMSENG)
2015	2	Ultrasonic Additive Manufacturing for Capillary Heat Transfer Devices and Integrated Heat Exchangers	Sheridan Solutions, LLC
2014	1	Advanced Thermal Interface Material Systems for Space Applications	Applied Material Systems Engineering, Inc. (AMSENG)
2014	1	Low Mass, Two-Phase Thermal Switch	Advanced Cooling Technologies, Inc.
2014	2	Spacecraft Thermal Control System Not Requiring Power	Triton Systems, Inc.
2014	2	Hybrid Heat Pipes for High Heat Flux Applications	Advanced Cooling Technologies, Inc.
2014	2	A Robust Two-Phase Pumped Loop With Multiple Evaporators and Multiple Radiators	Creare LLC

Recent Past Awards: S3.09 C&DH and Avionics

- In the last 5 years
  - 12 Phase 1 Awards

2011-2016 Command, Data Handling, and Electronics Awards			
Year	**Phase**	**Proposal Title**	**Firm**
2016	1	Innoflight Middleware System (IMS)	Innoflight, Inc.
2016	1	3D Printed Composite-Z and Graded-Z Radiation Shields (CoGZ-Rad)	Tethers Unlimited, Inc.
2016	1	Bringing 3D Memory Cubes to Space: a "Rad-Hard by Design Study" with an Open Architecture	Irvine Sensors Corporation
2016	1	Resilient Afforable Cubesat Processor	Advanced Materials Applications
2016	1	Microstructure Gradient-Z Composite for Additive Manufacture of Radiation Shielding	Powdermet, Inc.
2015	1	Radiation Hardened ARM Micro Controller Module	Silicon Space Technology Corporation
2015	1	Software Redundancy Framework for COTS SoC FPGAs	Innoflight, Inc.
2015	1	Miniaturized System-in-Package Motor Controller for Spacecraft and Orbital Instruments	Honeybee Robotics, Ltd.
2015	1	Non Invasive Instrumentation For Single Event Effects (NIISEE)	Adventium Enterprises, LLC
2012	1	Modular SiGe 130 nm Cell Library for Extreme Environments	Ridgetop Group, Inc.
2012	1	Space Qualified Heterogeneous Processing	Space Micro, Inc.
2011	1	A 45 nm Low Cost, Radiation Hardened, Platform Based Structured ASIC	American Semiconductor, Inc.

Recent Past Awards: Distributed Spacecraft Missions (DSM) Technology Framework

- New topic this year
  - 1 Phase 1 Award

2016 Distributed Spacecraft Missions (DSM) Technology Framework			
Year	**Phase**	**Proposal Title**	**Firm / Research Institute**
2016	1	An Intelligent Autonomous Executive for cFS Distributed Spacecraft Missions	Emergent Space Technologies, Inc. University of Florida

Role of Small Businesses in Solving Problems through Innovation and Technology

- SBIR has been used to find new ways of solving existing problems
  - Small businesses are great at infusing technologies across industries and applications
- SBIR has been used to improve system performance at component level
  - We recognize system level product can be very costly to develop
  - Small businesses are encouraged to propose at the component technology level
- SBIR has been used to fund technologies that would lower cost
- SBIR has been used to fund software, algorithms, and techniques
- SBIR has been used to fund mission enabling new technologies in TRL 5-6
  - We recognize technology maturation beyond TRL-4 can take a lot of resources
  - We encourage and help infusion with any flight demonstration opportunities
  - Small businesses need to shoulder the responsibilities of finding external investors

Success Story

- Space Micro SBIR, “Space Qualified, Radiation Hardened, Dense Monolithic Flash Memory”, developed a flash memory controller that is being infused into the image processor on the TESS mission.
- Ridgetop SBIR, “Modular SiGe 130 nm Cell Library for Extreme Environments”, led to development of an analog-to-digital converter that has been infused in Air Force programs.
- Ktech developed high conductivity annealed pyrolytic graphite (APG) has been used on LDCM/TIRS-1, LDCM/TIRS-2, ICESat-2, MSL/SAM, ELC ISS, and Chandra missions.
- TTH developed loop heat pipe analytical model has been used for the NASA/ST-8 and NRL/TACSAT missions.
- Maryland Aerospace SBIR, “Integrated CubeSat ADACS with Reaction Wheels and Star Tracker”, has resulted in numerous preorders and as well as attracting investors to order more than 100+ Cubesat units.
- Optical Physics Company SBIR, “Interferometric Star Tracker”, has recently secured a flight opportunity with AFRL’s program to take their system beyond TRL-7.
- Numerous Publications and Patents