NASA SBIR 2009 Phase I Solicitation

O4 Navigation

NASA is seeking innovative research in the areas of positioning, navigation, and timing (PNT) that have relevance to Space Communications and Navigation programs and goals, as described at http://www.spacecomm.nasa.gov. NASA's Space Communication and Navigation Office considers the three elements of PNT to represent distinct, constituent capabilities: (1) positioning, by which we mean accurate and precise determination of an asset's location and orientation referenced to a coordinate system; (2) navigation, by which we mean determining an asset's current and/or desired absolute or relative position and velocity state, and applying corrections to course, orientation, and velocity to attain achieve the desired state; and (3) timing, by which we mean an asset's acquiring from a standard, maintaining within user-defined parameters, and transferring where required, an accurate and precise representation of time. NASA has divided its PNT interests into six focus areas: (1) Global Positioning System (GPS) (2) Distress Alerting Satellite System (DASS) (3) Flight Dynamics (4) Tracking and Data Relay Satellite System (TDRSS) (5) TDRSS Augmentation Service for Satellites (TASS) (6) Geodesy. This year, NASA seeks technology in focus areas (1), (3), (4), and (5), and related areas that provides PNT support and services for NASA's current tracking and communications networks and systems-including tracking during launch and landing operations, and research and technology relevant to the planning and development of PNT support and services for NASA's Project Constellation, including lunar surface operations, and other Exploration and Science Programs that NASA may undertake over the next two decades. Some of the subtopics in this topic could result in products that may be included in future flight opportunities. Please see the Science MD Topic S4 for more details as to the requirements for small satellite flight opportunities, and the Facilitated Access to the Space Environment for Technology Development and Training (FAST) website at http://ipp.nasa.gov/ii_fast.htm.

Subtopics

O4.01 Metric Tracking of Launch Vehicles

Lead Center: KSC

Participating Center(s): GSFC, MSFC

Range Safety requires accurate and reliable tracking data for launch vehicles. Onboard GPS receivers must maintain lock, reacquire very quickly and operate securely in a highly-dynamic environment. GPS Course Acquisition Code (CA) does not require classified decryption codes and has an accuracy of better than 30 m and 1 m/s. Although this accuracy is good enough for most Range Safety needs, better accuracy is needed for antenna pointing, docking maneuvers and attitude determination. CA code also offers little protection against deliberately transmitted false signals or "spoofing".

This solicitation seeks proposals in the following areas:

- Innovative technologies to increase the accuracy of the L1 C/A navigation solution by combining the pseudo ranges and phases of the L1 C/A signals, and use of the L2 and L5 carrier. Factors that degrade the GPS signal can be obtained by differencing the available carrier phase and pseudo range measurements and then removing this difference from the navigation solution.
- Technologies that combine spatial processing of signals from multiple antennas with temporal processing techniques to mitigate interference signals received by the GPS receiver. The coordinated response of adaptive pattern control (beam and null steering) and digital excision of certain interfering signal components minimizes strong jamming signals. Adaptive nulling minimizes interfering signals by the optimal control of the GPS antenna pattern (null steering).

These technologies should be independent of any particular GPS receiver design.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware and software demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

O4.02 On-Orbit PNT (Positioning, Navigation, and Timing) Sensors and Components

Lead Center: GSFC

Participating Center(s): GRC, JPL, JSC

This solicitation seeks proposals that will serve NASA's ever-evolving set of near-Earth and interplanetary missions that require precise determination of spacecraft position and velocity in order to achieve mission success. While the definition of "precise" depends upon the mission context, typical scenarios have required meter-level or better position accuracies, and sub-millimeter-level or better velocity accuracies.

Research should be conducted to demonstrate technical feasibility during Phase 1, and show a path toward a Phase 2 hardware and/or software demonstration of a demonstration unit or software package that will be delivered to NASA for testing at the completion of the Phase 2 contract. The Small Spacecraft Build effort highlighted in Topic S4 (Low-cost Small Spacecraft and Technologies) of the solicitation participates in this subtopic. Offerors are encouraged to take this in consideration as a possible flight opportunity when proposing work to this subtopic.

Purpose: NASA Needs vs. Current State of the Art

This solicitation is primarily focused on NASA's needs in three focused areas: onboard near-Earth navigation systems; onboard deep-space navigation systems; technologies supporting improved TDRSS-based navigation. Proposals that leverage state-of-the-art capabilities already developed by NASA such as GEONS (http://techtransfer.gsfc.nasa.gov/ft-tech-GEONS.html), Navigator (http://techtransfer.gsfc.nasa.gov/ft-tech-GPS-NAVIGATOR.html), GIPSY, Electra, and Blackjack are especially encouraged. NASA is not interested in funding efforts that seek to "re-invent the wheel" by duplicating the many investments that NASA and others have already made in establishing the current state-of-the-art.

General Operational Specifications and Requirements:

Core Capabilities:

Onboard Near-Earth Navigation System

NASA seeks proposals that would develop a commercially viable transceiver with embedded orbit determination software that would provide enhanced accuracy and integrity for autonomous onboard GPS- and TDRSS-based navigation and time-transfer in near-Earth space via augmentation messages broadcast by TDRSS. The augmentation message should include information on the TDRS orbits, status, and health that could be provided by future TDRS, and should provide information on the GPS constellation that is based on NASA's TDRSS Augmentation for Satellites Signal (TASS). Proposers are advised that NASA's GEONS and GIPSY orbit determination software packages already support the capability to ingest TASS messages.

Onboard Deep-Space Navigation System

NASA seeks proposals that would develop an onboard autonomous navigation and time-transfer system that can reduce DSN tracking requirements. Such systems should provide accuracy comparable to delta differenced one-way ranging (DDOR) solutions anywhere in the inner solar system, and exceed DDOR solution accuracy beyond the orbit of Jupiter. Proposers are advised that NASA's GEONS and DS-1 navigation software packages already support the capability to ingest many one-way forward Doppler, optical sensor observation, and accelerometer data types.

Technologies Supporting Improved TDRSS-based Navigation

NASA seeks proposals that would provide improvements in TDRS orbit knowledge, TDRSS radiometric tracking, ground-based orbit determination, and Ground Terminal improvements that improve navigation accuracy for TDRS users. Methods for improving TDRS orbit knowledge should exploit the possible future availability of accelerometer data collected onboard future TDRS.

Optional Capabilities:

NASA may consider other proposals relevant to NASA's needs for precise spacecraft navigation and tracking that demonstrably advance the state-of-the-art.

Development Timeline Associated with NASA Needs:

Phase 1 deliverables should include documentation of technical feasibility, which should at minimum show a path toward hardware and/or software demonstration of a demonstration unit or software package in Phase 2.

Phase 2 deliverables should include a demonstration unit or software.

The proposer to this subtopic is advised that the products proposed may be included in a future small satellite flight opportunity. Please see the SMD Topic S4 on Small Satellites for details regarding those opportunities. If the proposer would like to have their proposal considered for flight in the small satellite program, the proposal should state such and recommend a pathway for that possibility.

O4.03 Lunar Surface Navigation

Lead Center: GRC

Participating Center(s): GSFC, JPL, JSC

In order to provide location awareness, precision position fixing, best heading and traverse path planning for planetary EVA, manned rovers and lunar surface mobility units NASA has established requirements for onboard navigation capabilities for surface-mobile elements of lunar missions. Proposals are specifically sought which address the following needs:

- Asset localization within a work area. Specifically, real-time relative location of vehicles and EVA crewmembers for safety and task efficiency.
- EVA crew localization for emergency walk back to a safe haven (lander, habitat, fixed reference point, etc.)
- Fixed asset localization with respect to global coordinates.
- Traverse-path planning systems and navigation-specific displays are also of interest.
- Novel navigation techniques that utilize repurposed flight vehicle sensors (INS, AHRS, low light imager, star trackers, etc.)

This topic will develop systems, technologies and analysis in support of the required capabilities of lunar surface mobility elements. Contemplated navigation systems could employ celestial references, passive or active optical information such as optical flow or range to local terrain features, inertial sensor information or other location-specific sensed data or combinations thereof. However, radiometric measurements are considered to be concomitant to the lunar communications network and the lunar network will likely be used to communicate state information between lunar mission elements. As such, the main emphasis of this topic is on systems that exploit radiometric measurements such as range, Doppler or Angle of Arrival. Radiometric measurements can be considered between lunar mission elements such as surface mobility units, elements of a lunar surface architecture (such as surface landers or habitation units or other surface mobility units) or elements of the lunar communications and navigation infrastructure such as surface communications towers or lunar communication/navigation orbiters. Note that the constellation of moon-orbiting communication/navigation satellites will support both polar outpost missions as well as short term sortie missions that can occur anywhere on the lunar surface. This constellation will likely consist of no more than six satellites and may be only be one or two satellites. Earth-based nodes are not excluded from consideration, nor are two-way radiometric measurements, nor are non-NASA-standard modulation schemes.

Emphasis of the development is on navigation accuracy, position estimate update rate (minimized correlation time), minimum Size Weight and Power (SWaP), systems that operate effectively with minimal communications/navigation infrastructure (such as towers or orbiters) or with complete autonomy, with minimal crew involvement or completely automatically. Unified concepts and systems that provide a range of hardware capabilities (possibly trading accuracy with SWaP) and/or support dual-use (e.g., navigation and communication) are of interest.

Mature system concepts and technologies including system demonstration with TRL 6 components and internalized (by NASA) standards are required at the end of a Phase 2. Candidates for technology infusion include developmental EVA space suits and prototype crew and robotic rovers. An example rover system is the Lunar Electric Rover (LER). The LER (http://www.nasa.gov/exploration/home/LER.html) is a sport utility sized, 12-wheeled, pressurized vehicle capable of supporting 14-day missions with two astronauts. Recent tests have included 140km treks across rugged terrain in Arizona. Future testing will extend the distance. Examples of a developmental EVA space suit include the Mark iii spacesuit and the REI suit (c.f. http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20080012574_2008010837.pdf). Demonstration opportunities occur several times a year at lunar analog exercises such as the Desert Research and Technology Studies (D-RATS, c.f. http://en.wikipedia.org/wiki/Desert_Research_and_Technology_Studies) and the Haughton Field test (c.f. http://ti.arc.nasa.gov/projects/haughton_field/).

O4.04 Flight Dynamics Technologies and Software

Lead Center: GRC

Participating Center(s): GSFC, JPL

NASA is beginning to invest in re-engineering its suite of tools and facilities that provide navigation and mission design services for design and operations of near-Earth and interplanetary missions. This solicitation seeks proposals that will develop flight dynamics technologies and software that support these efforts.

In the context of this solicitation, flight dynamics technologies and software are algorithms and software that may be used in ground support facilities, or onboard a spacecraft, so as to provide Position, Navigation, and Timing (PNT) services that reduce the need for ground tracking and ground navigation support. Flight dynamics technologies and software also provide critical support to pre-flight mission design, planning, and analysis activities.

This solicitation is primarily focused on NASA?s needs in the following focused areas:

- Applications of cutting-edge estimation techniques, such as sigma-point and particle filters, to spaceflight navigation problems.

- Applications of estimation techniques that have an expanded state vector (beyond position and velocity components) to monitor non-Gaussian noise processes to improve upon the overall system accuracy.
- Applications of creative estimation techniques that combine measurements from multiple sensor suites to improve upon the overall system accuracy.
- Applications of advanced dynamical theories to space mission design and analysis, especially in the context of unstable orbital trajectories in the vicinity of small bodies and libration points.
- Addition of novel measurement technologies to existing NASA onboard navigation software that is licensed by the proposer.
- Addition of orbit determination capabilities to existing NASA mission design software that is either freely available via NASA Open Source Agreements, or that is licensed by the proposer.

Proposals that leverage state-of-the-art capabilities already developed by NASA such as GPS-Enhanced Onboard Navigation Software (http://techtransfer.gsfc.nasa.gov/ft-tech-GEONS.html), General Mission Analysis Tool (http://sourceforge.net/projects/gmat/), GPS-Inferred Positioning System and Orbit Analysis Simulation Software, (http://gipsy.jpl.nasa.gov/orms/goa/), 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.

Technologies and software should support a broad range of spaceflight customers. Technologies and software specifically focused on a particular mission's or mission set's needs, for example rendezvous and docking, or formation flying, are the subject of other solicitations by the relevant sponsoring organizations and should not be submitted in response to this solicitation.

Research should be conducted to demonstrate technical feasibility during Phase 1, and show a path toward a Phase 2 demonstration of a software package that will be delivered to NASA for testing at the completion of the Phase 2 contract.

The proposer to this subtopic is advised that the products proposed may be included in a future small satellite flight opportunity. Please see the SMD Topic S4 on Small Satellites for details regarding those opportunities. If the proposer would like to have their proposal considered for flight in the small satellite program, the proposal should state such and recommend a pathway for that possibility.

O4.05 Space-Based Range Technologies

Lead Center: GSFC

Participating Center(s): AFRC, GRC

The vision of Space-Based Range architecture is to assure public safety, reduce the costs of launch operations, enable multiple simultaneous launch operations, decrease response time, and improve geographic and temporal flexibility. This sub-topic seeks to reduce or eliminate the need for redundant range assets and deployed down-range assets that are currently used to provide for Line-of-Sight (LOS) Tracking Telemetry and Control (TT&C) with sub-orbital platforms and orbit-insertion launch vehicles. In order to achieve this, specific advancements are needed in TT&C.

Position, Attitude, and Inertial Metrics

Realization of a Space-Based Range requires the development of highly accurate and stable integrated metric tracking and inertial measurement units. The focus is on technologies that enable and advance development of low Size, Weight, and Power (SWaP), tactical grade, integrated metric tracking units that provide highly accurate and stable positioning, attitude, and inertial measurements on high dynamic platforms.

Factors to address include:

- Easy coupling of IMUs, gyros, accelerometers, and/or attitude determining GPS receivers that will provide very high frequency integrated metric solutions;
- The ability to reliably function on spin-stabilized rockets (up to 7 rps), during sudden jerk and acceleration maneuvers, and in high vibration environments is critical;
- Advancements in MEMs-based IMUs and accelerometers, algorithm techniques and Kalman filtering, phased-based attitude determination, single aperture systems, quick Time to First Fix and reacquisition.

Space-Based Telemetry

There are varying applications for space-based transceivers, each necessitating a different set of requirements. The desired focus is very low SWaP, tactical grade, highly reliable, and easily reconfigurable transceivers capable of establishing and maintaining unbroken satellite communication links for telemetry and/or control. This technology will serve applications which include low-cost sub-orbital missions, secondary communications systems for orbit insertion vehicles, low cost and size orbital payloads (typically LEO), and flight test articles. Durations will range from minutes to several weeks and the ability to operate on highly dynamic platforms is critical. High data rate links are highly desired, thus the use of NASA's TDRSS is emphasized, although other commercial satellite systems which can provide nearly global and high data rate links can also be explored.

Factors to address include:

- Advancements in software based radios and coding techniques;
- Use of the latest semiconductor technologies (GaN or other);
- Advanced heat dissipation techniques (to allow small packaging and long duration operating times);
- Immunity to corona breakdown;

- Ease of data interfacing.

RF power output requirements range from a few watts to as high as 100 W. Special consideration should be given to transceiver capability vs. packaging that would allow for customizable configurations depending on the target application. That is, a modular or stacking design with a common bus architecture should be considered where the RF and digital sections are separated. This could allow for a base digital and DC power design that will support multiple RF slices (such as a low, medium, or high power slice). Also, to satisfy missions who require unidirectional communications, a modular design could allow for separate transmitter and receiver modules/slices.

Phase 1 Deliverables

A final report containing optimal design for the technology concept including feasibility of concept, a detailed path towards Phase 2 hardware and/or software demonstration. The report shall also provide options for potential Phase 2 funding from other government agencies (OGA).

Phase 2 Deliverables

A working proof-of-concept demonstrated and delivered to NASA for testing and verification.