NASA SBIR 2008 Phase I Solicitation

O1 Space Communications

NASA's communications capability is based on the premise that communications shall enable and not constrain missions. Communications must be robust to support the numerous missions for space science, Earth science and exploration of the universe. Technologies such as optical communications, RF including antennas and ground based Earth stations, surface networks, access links, reprogrammable communications systems, communications systems for EVAs, advanced antenna technology, transmit array concepts and communications in support of launch services including space based assets are very important to the future of exploration and science activities of the Agency. Emphasis is placed on size, weight and power improvements. Even greater emphasis is placed on these attributes as small satellites (e.g., micro and nano satellite) technology matures. Innovative solutions centered around operational issues associated with the communications capability are needed. Communications that enable the range safety data from sensitive instruments is imperative. These technologies are to be aligned with the Space Communications and Navigation Architecture as being developed by the Agency. See https://www.spacecomm.nasa.gov/spacecomm/ for more details. A typical approach for flight hardware would include: Phase 1 - Research to identify and evaluate candidate telecommunications technology applications to demonstrate the technical feasibility and show a path towards a hardware/software demonstration. Bench or lab-level demonstrations are required. Phase 2 - Emphasis should be placed on developing and demonstrating the technology under simulated flight conditions. The proposal shall outline a path showing how the technology could be developed into space-worthy systems. The contract should deliver a demonstration unit for functional and environmental testing at the completion of the Phase 2 contract. Some of the subtopics in this topic could result in products that may be included in a future small satellite flight opportunity. Please see the SMD Topic S4 for more details as to the requirements for flight opportunities.Â

Subtopics

O1.01 Coding, Modulation, and Compression

Lead Center: JPL

Participating Center(s): ARC, GRC, GSFC

This subtopic aims to develop components in digital communication systems that offer both spectrum and power efficient solutions to NASA's future near-Earth, deep-space science and exploration applications. This area comprises technology in three key areas: forward error-correction (FEC) coding, data compression, and modulation. The state-of-the-art in flight for coding is (1) Reed-Solomon code concatenated with a convolutional codes, (2) turbo codes, and just emerging, (3) Low Density Parity Check (LDPC) codes. The first two have flown many times, and the initial designs for (3) are just being begun now. The state-of-the-art in compression is the CCSDS standard http://public.ccsds.org/publications/archive/122x0b1c1_e1.pdf. The state-of-the-art for modulation is BPSK and QPSK for deep space, and BPSK, QPSK, SQPSK, and 8-PSK for near Earth (TDRS) applications. Technology development is needed and required in the following areas:

Coding

The need is to handle signal degradation due to weather impact in Ka-band, RFI interference, and multi-path fading in NASA's future missions. A major challenge is developing coding schemes to handle long bursts of errors, up to 100,000 symbols long, at high processing rate. FEC coding technology to protect against long bursts of erasures due to radio frequency interference (RFI), weather conditions, fading, etc. An entirely new protection mechanism is needed for this long-outage scenario -- existing FEC codes of up to 16,000 are insufficient for this purpose. This technology would be needed in time for a first Ka-band-only mission in the 2015 time-frame. The target is a finished product at TRL 5.

Data Compression

The need is for a real-time high-speed hardware decoder for CCSDS 122.0-B-1 (http://public.ccsds.org/publications/archive/122x0b1c1_e1.pdf). (A CCSDS 122.0-B-1 compliant encoder is already inserted into NASA's mission.) This hardware development effort would be a reference implementation of this standard, that could be used either as the basis for a flight unit, or as an independent validation test module for a flight unit or engineering model. The target is a finished product at TRL 6.

Modulation

Bandwidth efficiency is becoming increasingly important; missions desire simultaneous telemetry and ranging. Modulations and multiple access schemes for multiple spacecraft downlinking to a single antenna; expansion of SNIP code library â€“ find more good PN spreading codes compatible with SNIP library; bandwidth efficient ranging â€“ how to combine ranging with higher order modulations. Technology target is a demonstration at TRL 5.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware and software demonstration and deliver a demonstration unit or software package for NASA 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.

O1.02 Antenna Technology

Lead Center: GRC

Participating Center(s): ARC, GSFC, JPL, JSC, LaRC

NASA seeks advanced antenna systems in the following areas: phased array antennas; ground-based uplink antenna array designs; high-efficiency, miniature antennas; smart, reconfigurable antennas; large aperture inflatable/deployable antennas; and antenna adaptive beam correction with pointing control.

Phased Array Antennas

Low cost phased array antennas are needed to enable communication capabilities in the following areas: lunar and planetary exploration, including links between astronauts, landers, habitats, probes, orbiters, suborbital vehicles such as sounding rockets, balloons, unmanned aerial vehicles (UAV's), and expendable launch vehicles (ELV's). The frequencies of interest are S-, X-, Ku-, and Ka-band.

The arrays are required to be aerodynamic or conformal in shape for sounding rockets, UAV's, and expendable platforms. They must also be able to withstand the launch environment. The balloon vehicles communicate primarily with TDRS and can tolerate a wide range of mechanical dimensions. The main challenges to be addressed are low mass, low cost, high power efficiency (i.e., > 40%), and coverage area (i.e., highly steerable). A significant cost reduction for MMIC based arrays is highly desirable. (Typical NRE is ~ $1000.00/element.) Advances in digital beam-forming techniques, including those based on superconducting digital signal processing methods, are also desirable. The expected exit technology readiness level (TRL) is 4.

Ground-based Uplink Antenna Array Designs

NASA is considering arrays of ground-based antennas to increase capacity and system flexibility, to reduce reliance on large antennas and high operating costs, and eliminate single point of failure of large antennas. A large number of smaller antennas arrayed together results in a scalable, evolvable system which enables a flexible schedule and support for more simultaneous missions. Some concepts currently under consideration are the development of medium-size (12-m class) antennas (hundreds of them are expected to be required) for transmit/receive (Tx/Rx) ground-based arrays. A significant challenge is the implementation of an array for transmitting (uplinking), which may or may not use the same antennas that are used for receiving. The uplink frequency will be in the 7.1-8.6 GHz range (X-band) in the near term, and may be higher frequencies in in the future; it will likely carry digital modulation at rates from 10 kbps to 30 Mbps. An EIRP of at least 500 GW is required, and some applications contemplate an EIRP as high as 10 TW. A major challenges in the uplink array design is minimizing the life-cycle cost of an array.

Other challenges for ground-based antennas include the development of low cost, reliable components for critical antenna systems; advanced, ultra-phase-stable electronics, and phase calibration techniques; improved understanding of atmospheric effects on signal coherence; and integrated low-noise receiver-transmitter technology. Phase calibration techniques needed to ensure coherent addition of the signals from individual antennas at the spacecraft are also required. It is important to understand whether space-based techniques are required or ground-based techniques are adequate. In general, a target spacecraft in deep space cannot be used for calibration because of the long round-trip communication delay.

Design of ultra-phase-stable electronics to maintain the relative phase among antennas is also needed . These will minimize the need for continuous, extensive and/or disruptive calibrations. A primary related effort currently underway is understanding the effect of the medium (primarily the Earth's troposphere) on the coherence of the signals at the target spacecraft. Generally, turbulence in the medium tends to disrupt the coherence in a way that is time-dependent and site-dependent. A quantitative understanding of these effects is needed. Consequently, techniques for integrating a very low-noise, cryogenically cooled receiver with a medium power (1-200 W) transmitter, are desired . If transmitters and receivers are combined on the same antenna, the performance of each should be compromised as little as possible, and the low cost and high reliability should be maintained.

Under the ground-based antenna area, the exit TRL should be greater than or equal to 4.

High-Efficiency, Miniature Antennas

High efficiency, low-cost, low-weight, miniaturized antennas that are wearable antennas or can be highly integrated into the structure. Example of EVA's space suits made with textile antennas or visor mounted antennas. The antennas may be fractal antennas but also multi-directional to support astronaut mobility, multiband operation and/or broad bandwidth. Antennas should be low/self-powered, small, and efficient, and compatible with communication equipment that can provide high data rate coverage at short ranges (~1.5-3 km, horizon for the Moon for EVA). In-situ low-gain antenna (UHF or X-band) that provide circular polarization with full hemispherical coverage (zenith as well as over the horizon) are desirable.

Smart, Reconfigurable Antennas

NASA is interested in smart, reconfigurable antennas for applications in lunar and planetary operations. The characteristics to consider include the frequency, polarization, and the radiation pattern. Low-cost approaches are encouraged to reduce the number of antenna apertures needed to meet the requirements associated with lunar and planetary surface exploration (e.g., rovers, pressurized surface vehicles, habitats, etc.). Desirable features include multibeam operation to support connectivity to different communication nodes on lunar and planetary surfaces or in support of communication links for satellite relays around planetary orbits. Also the antenna shall be highly directive, multi-frequency and compatible with Multiple Input Multiple Output (MIMO) concept.

The exit TRL should be 4.

Large Aperture Inflatable/Deployable Antennas

Large deployable or inflatable membrane antennas to significantly reduce stowage volume (packaging efficiencies as high as 50:1), provide high deployment reliability, and significantly reduced mass density (i.e., < 1kg/square meter) are needed. These large Gossamer-like antennas are required to provide high-capacity communication links with low fabrication costs from the Moon/Mars surface to relay satellites or Earth. These membrane antennas are deployed from a small package via some inflation mechanism. Techniques for rigidizing these membrane antennas without the use of gases (e.g., ultraviolet curing), as well as thin-membrane tensioning and support techniques to achieve precision and wrinkle-free surfaces, in particular for applications at Ka-band or higher frequencies is desirable.

Novel materials (including memory matrix materials), low fabrication costs and deployment and construction methods using low emissivity materials to enable passive microwave instrument application are also beneficial. Structural health monitoring systems, needed to support pre-flight integration / test activities and determine health of system in-flight, are of interest. The challenge is to generate designs incorporating structural considerations (e.g., aero-braking for deep space planetary missions).

Antenna Adaptive Beam Correction with Pointing Control

Antenna adaptive beam correction with pointing control that can provide spacecraft knowledge with fine beam pointing with sub-milliradian precision (e.g., < 250 micro-radians) in order to point large spacecraft antennas (e.g., 10-m diameter) in Mars' vicinity is also desirable under this subtopic. The challenges include reduced antenna reflector surface distortions in a space environment; compensation techniques to optimize antenna beam patterns; ground- and space-based methods to monitor spacecraft antenna distortions; and advanced technologies that enable antenna pointing accuracies in the sub-milliradian range for Ka-band spacecraft applications. Methods of dealing with extreme latency (e.g., 20 minutes) in beacon and monopulse systems are of interest. Advances would lead to enhanced space communication links. The resulting developments should be at TRL 4. Size weight and power requirements are of concern.

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

Development Timeline: After a possible Phase 3 development activity, these technologies are expected to ready for insertion at TRL 6 by 2014. Therefore a TRL progression from an entry TRL of 1-2 for Phase 1 in January 2009 followed by an exit TRL of 3 - 4 after Phase 2 is reasonable.

Phase 1 Deliverables:Â 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 3 funding from other government agencies (OGA).

Phase 2 Deliverables:Â A working proof-of-concept demonstrated and delivered to NASA for testing and verification.

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.

O1.03 Reconfigurable/Reprogrammable Communication Systems

Lead Center: GRC

Participating Center(s): ARC, GSFC, JPL, JSC

NASA seeks novel approaches in reconfigurable, reprogrammable communication systems to enable the vision of Space, Exploration, Science, and Aeronautical Systems. Exploration of Martian and Lunar environments will require advancements in communication systems to manage the demands of the harsh space environment on space electronics, maintain flexibility and adaptability to changing needs and requirements, and provide flexibility and survivability due to increased mission durations. NASA missions can have vastly different transceiver requirements (e.g., 1â€™s to 10â€™s Mbps at UHF and S-band frequency bands up to 10â€™s to 1000â€™s Mbps at X, and Ka-band frequency bands.) and available resources depending on the science objective, operating environment, and spacecraft resources. For example, deep space missions are often power constrained; operating over large distances, and subsequently have lower data transmission rates when compared to near-Earth or near planetary satellites. These requirements and resource limitations are known prior to launch; therefore, the scalability feature can be used to maximize transceiver efficiency while minimizing resources consumed. Larger platforms such as vehicles or relay spacecraft may provide more resources but may also be expected to perform more complex functions or support multiple and simultaneous communication links to a diverse set of assets.

This solicitation seeks advancements in reconfigurable transceiver and associated component technology. The goal of the subtopic is to provide flexible, reconfigurable communications capability while minimizing on-board resources and cost. Topics of interest include the development of software defined radios or radio subsystems which demonstrate reconfigurability, flexibility, reduced power consumption of digital signal processing systems, increased performance and bandwidth, reduced software qualification cost, and error detection and mitigation technologies. Complex reconfigurable systems will provide multiple channel and multiple and simultaneous waveforms. Areas of interest to develop and/or demonstrate are as follows:

- Advancements in bandwidth capacity, reduced resource consumption, or adherence to the Space Telecommunications Radio System (STRS) standard and open hardware and software interfaces. Techniques should include fault tolerant, reliable software execution, reprogrammable digital signal processing devices.
- Reconfigurable software and firmware which provide access control, authentication, and data integrity checks of the reconfiguration process including partial reconfiguration which allows simultaneous operation and upload of new waveforms or functions.
- Operator or automated reconfiguration or waveform load detection failure and the ability to provide access back to a known, reliable operational state. An automated restore capability ensures the system can revert to a baseline configuration, thereby avoiding permanent communications loss do to an errant reconfiguration process or logic upset.
- Dynamic or distributed on-board processing architectures to provide reconfigurability and processing capacity. For example, demonstrate technologies to enable a common processing system capacity for communications, science, and health monitoring.
- Adaptive modulation and waveform recognition techniques are desired to enable transceivers to exchange waveforms with other assets automatically or through ground control.
- Low overhead, low complexity hardware and software architectures to enable hardware or software component or design reuse (e.g., software portability) that demonstrates cost or time savings. Emphasis should be on the application of open standards architecture to facilitate interoperability among different vendors to minimize the operational impact of upgrading hardware and software components.
- Software tools or tool chain methodologies to enable both design and software modeling and code reuse and advancements in optimized code generation for digital signal processing systems.
- The use of reconfigurable logic devices in software defined radios is expected to increase in the future to provide reconfigurability and on-orbit flexibility for waveforms and applications. As the densities of these devices continue to increase and feature size decreases, the susceptibility of the electronics to single event effects also increases. Novel approaches to mitigate single event effects in reconfigurable logic caused by charged particles are sought to improve reliability. New methods should show advancements in reduced cost, power consumption or complexity compared to traditional approaches (i.e., voting schemes and constant updates (i.e., scrubbing)).
- Techniques and implementations to provide a core capability within the software defined radio in the event of failure or disruption of the primary waveform and/or system hardware. Communication loss should be detected and core capability (e.g., â€œgoldâ€ waveform code) automatically executed to provide access control and restore operation.
- Innovative solutions to software defined radio implementations that reduce power consumption and mass.

Solutions should enable future hardware scalability among different mission classes (e.g., low rate deep space to moderate or high rate near planetary, or relay spacecraft) and should promote modularity and common, open interfaces.

- In component technology, advancements in analog-to-digital converters or digital-to-analog converters to increase sampling and resolution capabilities, novel techniques to increase memory densities, and advancements in processing and reconfigurable logic technology each reducing power consumption and improving performance in harsh environments.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA 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.

O1.04 Miniaturized Digital EVA Radio

Lead Center: JSC

Participating Center(s): GRC

Lunar outpost surface operations pose unique challenges that demand a compact, power-efficient, and adaptive S-band EVA digital radio with built-in navigation capability. High-performance criteria, tight power constraints, and multi-mode functionality are making mobile terminals increasingly complex. Therefore, NASA needs to advance next-generation digital radio technologies to meet the stringent demands of ultra low power, high reliability, and small form factor. More than a conventional system, the EVA radio infrastructure supports relative navigation, high resolution image processing, voice encoding, networked based IP communications, and dynamic quality of service. By leveraging RF micro-electromechanical system (MEM) components, intelligent middleware, and location aided networking, this solicitation aims to reach TRL 5 by 2012 with breakthrough radio metrics- less than four watts of total power consumption and cell-phone sized form factor.

Operating at 2.4-2.483 GHz (S-band), the digital radio must support multiple bandwidth and data transmissions of voice, telemetry, and video- standard as well as high definition- to fixed and mobile assets, including lunar base station, landers, habitat, rovers, and other astronauts.

To extend battery life, the EVA digital radio must incorporate middleware that optimizes power needed to maintain link quality. Under harsh lunar environmental conditions, the cognitive middleware must optimally match the QoS requirement, the channel condition, and the interference environment as well as select the mode with the least energy profile for power efficiency. As a result, this EVA radio must dynamically and adaptively conserve power on a packet-by-packet basis.

During contingency mode, EVA digital radio will transmit voice and data in half-duplex mode. With novel wireless communication network concepts, the offeror should propose solutions to enable position determination and relative navigation out to a distance of 10km with accuracy of 100 meters (3 sigma).

The Phase 1 effort defines an ultra low-power, high-performance, compact digital radio that incorporates innovative components and novel approaches to meet the above requirements for a single fault tolerant architecture. To achieve dramatic reductions in power and volume, solutions must exploit MEMS for cell phones and handheld (e.g., MEM filters, tunable matching elements, etc.) and other advanced analog/digital components, advanced digital signal processing, as well as next-generation processing elements such as FPGAs and multi-core processors.

Moreover, one must select a promising modular candidate architecture for the above requirements, exploiting emerging commercial wireless network technologies such as WLAN and WWAN. This encompasses identifying transceiver hardware, firmware, and all platform integration issues.

For this solicitation, one can assume EVA digital radio will be part of a mobile ad hoc network infrastructure that is self-configuring, self-discovering, and self-healing. Where all nodes can act as routers for other low power mobile nodes and network coverage has no limit for wireless communications. In other words, the diameter of the network can be increased by adding more nodes.

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

Phase 1 Deliverables:

Conduct design tradeoffs between power, performance, and flexibility. Estimate mass, volume, power, max/min range, and data rates for dynamic quality of service (voice, telemetry, video) standard and high definition TV at S-band (2.4 - 2.483 GHz), backed with analyses including lunar propagation effects and comprehensive simulations to ensure achievable performance and power goals. Consider IP voice as an optional feature.

As a prerequisite to Phase 2, one must select a promising architecture that balances ultra low power, mass, size, performance, functionality, and reliability. In fact, the offeror must demonstrate the ability to achieve significant advantages in compactness over a non-MEMS approach and address power efficiency and reliability. Special interests include single-chip design/packaging and integrated circuit-level implemenation of RF MEMS.

Propose a preliminary design approach for the next-generation digital EVA radio, leveraging commercial multimedia cellular and WLAN technology. Operating at S-band (2.4- 2.483 GHz), MEM filters should be considered to achieve low power consumption and compact, cell-phone sized form factor. Determine the suitability and usage of ultra low power digital devices, compact RF systems, and novel configurations when recommending candidate architectures.

For the middleware, conduct trade-offs and identify the set of required parameters for the ideal radio. Quantify performance in terms of energy savings and the ability to maximize connectivity and throughput in an ad hoc network.

Develop communications and 3D navigation tracking ad hoc network concepts and algorithms that validate the feasibility of the approach. Without GPS, integrated low-power communication and navigation surface assets must track, locate, and identify tagging assets with multiple routes over an operational range of 10 km, even if astronauts descend into craters. Assume the availability of digital terrain maps. Consider low-power approaches that exploit bread crumbs, active/passive RFID systems for ID, position, sensing, etc and expand investigation to modulated retroreflectors based upon MEMS technology or solar-powered beacons.

Simulate the performance of a robust integrated communications and navigation network architecture and conduct preliminary sensitivity analysis for parameterization of the selected implementation strategy. Specifically, describe the division of functionalities between the various components (fixed and mobile) as well as segments (inter-vehicle and mobile-to-fixed node on planetary surface as well as surface-to-orbit (lunar relay satellites).

Phase 2 Deliverables:

Demonstrate RF performance and total power consumption of less than four watts, delivering voice, telemetry, and standard and high-definition video motion imagery at 2.4- 2.483 GHz (S-band). Within power budget allocation, verify performance and reliability for multiple bandwidth and data transmissions of telemetry, voice, and high-rate video.

Develop a reliable, intelligent, and power-efficient EVA digital radio prototype unit and demonstrate robust power management and optimization feasibility of the Phase 2 middleware and ad hoc network approach.

Explore radiometric tracking techniques and benefits from location-aided networking to support (limited) relative navigation using an ad hoc network infrastructure during EVA walkback. Moreover, a simulation capability must demonstrate node discovery, location awareness, and route re-configurability as nodes enter and leave the network. Testing will be conducted at an approved site and should comprise of a variety of nodes (fixed and mobile) as well as a suite of applications (non-real time data as well as real-time voice and video).

Develop and demonstrate a working ad hoc network prototype that allows characterization of the following metrics in a static deployment: a) network range, b) aggregate throughput and throughput per user, and c) node and network lifetime.

Deliver open middleware and supporting IP solutions.

Where costs preclude full implementation of all component technologies, provide analysis to extrapolate the performance of a complete design.

Commercial Potential:

Adaptive radios potentially offer significant cost savings to a wide spectrum of commercial markets including telecommunications and consumer electronics. They also provide for enhanced interoperability and spectrum reuse for Homeland Security applications. New component technologies and radio infrastructures are needed to extend the programmable capabilities into long battery life handsets.

O1.05 Communication for Space-Based Range

Lead Center: GSFC

Participating Center(s): ARC, GRC

Space-Based Telemetry Transceivers may replace Line-of-Sight (LOS) and RADAR based Tracking, Telemetry, and Command (TT&C) flight and ground systems for sub-orbital platforms and orbit-insertion launch vehicles. In order to do so, the transceivers must be capable of providing real-time or near real-time return (data) and forward (command) links of varying bandwidths with industry accepted Quality of Service (QoS) levels. Some applications require the coupling of embedded GPS receivers and attitude determination units, while others require high bandwidth links with common interfaces (i.e., Ethernet). In all cases it is desired to utilize an existing commercial satellite provider with fee-for-service to reduce operating and overhead expenses.

Note: The proposer should be aware of subtopic O4.01, which seeks advancements in GPS metric tracking. This proposal primarily focuses on space-based transceivers. However, advancements made under O4.01 could be incorporated with space-based transceivers in the future.

Purpose

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. It is desired to reduce or eliminate the need for redundant range assets and deployed down-range assets that are currently used to provide for LOS TT&C with sub-orbital platforms and orbit-insertion launch vehicles. This solicitation seeks to achieve this by focusing on specific needed advancements in TT&C.

There are varying applications for space-based transceivers, each necessitating a different set of requirements. Low data rate and very low cost transceivers coupled with highly accurate GPS receivers may be used to measure wind velocities to determine flight conditions and accurate trajectory predictions. These could also be used to track low risk payload or vehicle components for recovery purposes. Higher dynamic vehicles require a more robust transceiver with embedded position and attitude determination units to track vehicle trajectories through space insertion or for recovery purposes. High data rate transceivers with a commonly used interface could be used across multiple platforms for primary or redundant data dispersion and command control.

The proposer should address one of the following three need areas below:

Low Cost and Low SWAP Transceiver with Integrated GPS Receiver

Core Capabilities should include:

- Utilize existing commercial satellite provider with fee for service. Limit the user burden to provide adequate effective isotropic radiated power (EIRP) for providing acceptable link margins.
- Low Cost: several hundred dollars or less (throw-away).
- Low size, weight, and power (SWAP): 10 cubic inches or less, weigh less than 0.25 lbs, consume less than 1W (on avg).
- Ability to operate up to +/- 70 deg latitude (all latitudes preferred).
- Ability to sample time, position (x, y, z), and velocity (x., y., z.) solutions at a min of 10Hz.
- Ability to downlink the 10Hz or better sampled data with low latency (several seconds or better) and little to no loss (not to include ground infrastructure latency, i.e., internet latency).
- Ability to receive data and send commands from one location anywhere in the world via IP. However, an RF link could be used as a backup for remote locations.
- Ability to accept near real-time commands (latency of several seconds or better) and provide firmware level actions/responses (e.g.: to select alternate downlink data format).
- Highly accurate GPS solutions. Commercial-off-the-Shelf (COTS) embedded units may be utilized but repackaging may be needed to provide a single, integrated Over-the-Horizon (OTH) tracker. Independent Kalman Filtering techniques may need to be developed. Velocity jitter is highly undesirable. The ability to lift altitude and velocity (COCOM) restrictions is needed.
- Environmental considerations: Operability from sea level to 160,000 ft with operating temperatures ofÂ -20Â°C to +60Â°C. Vehicle dynamics are relatively benign. Duration of mission operation is several hours.
- Ground Software to view the telemetered data.

Optional Capabilities: The ability to operate at all latitudes. The ability to interface a small number of sensors (TTL, Analog-to-Digital, and/or serial interfaces) for sampling and transmit. Operating temperatures of -40Â°C to +85Â°C. The ability to allow uplink commands to change the state of on-board TTL level outputs. Ability to receive data and send commands from multiple locations via IP. Open source or factory customizable firmware.

Highly Dynamic Transceiver with Integrated GPS Receiver and Attitude Determination

Core Capabilities should include:

- Utilize existing commercial satellite provider with fee for service. Limit the user burden to provide adequate EIRP for providing acceptable link margins.
- Low cost, size and weight commensurate with materials and techniques used. Power consumption less than 5W (on avg).
- Ability to operate up to +/- 70 deg latitude (all latitudes preferred).
- Ability to sample time, position (x, y, z), velocity (x., y., z.), and vehicle dynamics (accelerations, pitch, and roll) at a min of 20Hz.
- Ability to downlink the 20Hz or better sampled data with very low latency (preferably sub-second) and little to no loss (not to include internet latency).
- Ability to accept commands on a real-time basis (preferably sub-second latency) and provide firmware level responses to those commands.
- Ability to receive data and send commands from one location anywhere in the world via IP. However, an RF link could be used as a backup for remote locations.
- Highly accurate integrated position and solid-state attitude solutions. COTS units may be utilized but repackaging may be needed to provide a single integrated OTH tracker. The ability to lift altitude and velocity (COCOM) restrictions is needed.
- Environmental considerations: Operability from sea level up to space insertion is desired (note that radiation hardening is not required). Operating temperatures of -20Â°C to +60Â°C are needed. Ability to operate on spin stabilized rockets (up to 7 rps), under sudden acceleration, and under high jerk environments (e.g., launch conditions and separation / jettison events). Duration of mission operation is several hours.
- Ground Software to view the telemetered data.

Optional Capabilities: The ability to operate at all latitudes. The ability to interface a small number of sensors (TTL, A to D, and/or serial interfaces) for sampling and transmit. Operating temperatures of -40Â°C to +85Â°C. The ability to allow uplink commands to change the state of on-board TTL level outputs. Ability to receive data and send commands from multiple locations via IP. Open source or factory customizable firmware.

High Data Rate Transceiver

Core Capabilities should include:

- Utilize existing commercial satellite provider with fee for service. Limit the user burden to provide adequate EIRP for providing acceptable link margins.
- Cost and SWAP commensurate with performance, but all should be kept minimal.
- Ability to operate up to +/- 70 deg latitude (all latitudes preferred).
- The minimum return bandwidth (data) is 50 kbps but several hundred kbps is desired. The minimum forward bandwidth (command) is 1 kbps but several kbps is desired.
- Ability to downlink data with very low latency (preferably sub-second) and little to no loss (not to include ground infrastructure latency, i.e., internet latency).
- Ability to receive commands with very low latency (preferably sub-second) and little to no loss from an IP based ground terminal.
- Ability to receive data and send commands from one location anywhere in the world via IP. However, an RF link could be used as a backup for remote locations.
- The transceiver I/O interface should allow for easy interfacing to multiple platforms. An Ethernet interface is preferred, but lower data rates may allow for an asynchronous serial interface. Depending on the satellite platform chosen, the proposer may have to provide internal buffering and clocking mechanisms to smooth an asynchronous input for proper ground receipt.
- Environmental considerations: Operability from sea level up to space insertion is desired (note that radiation hardening is not required). Operating temperatures of -20Â°C to +60Â°C are needed. The initial prototype could be tested on low dynamics vehicles, thereby concentrating the focus on performance. However, the ultimate goal is the ability to operate on spin stabilized rockets (up to 7 rps), under sudden acceleration, and under high jerk environments (e.g., launch conditions and separation / jettison events). Duration of mission operation is several minutes to several months.
- Ground Software to view the telemetered data.

Optional Capabilities: The ability to operate at all latitudes. Operating temperatures of -40Â°C to +85Â°C. Ability to receive data at multiple locations simultaneously via IP. Open source or factory customizable firmware.

In all cases, research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA 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.

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O1.06 Long Range Optical Telecommunications

Lead Center: JPL

Participating Center(s): ARC, GRC, GSFC

This subtopic seeks innovative technologies for long range Optical Telecommunications supporting the needs of space missions. Proposals are sought in the following areas:

- Systems and technologies relating to acquisition, tracking and sub-microradian pointing of the optical communications beam under typical deep-space ranges (to 40 AU) and spacecraft micro-vibration environments.
- Small lightweight (< 1-Kg), 2-axis gimbals with < 30-Î¼rad rms error and blind-pointing accuracy of < 35-Î¼rad. Must be able to actuate payload mass of approximately 6-Kg at rates up to 5-deg/sec. Assume that the payload is shaped as an 8-cm diameter cylinder, 30-cm long, with uniformly distributed mass. Proposals should come up with innovative pragmatic designs that can be flown in space.
- Light-weighted afocal optical telescopes with diameters varying from 10-50-cm diameter with an average areal density of < 45 Kg/m2 (Areal density is average over large and small optics used to gather and focus light on to sensors/detectors). The telescopes should be capable of operating in the near-infrared spectral range (1.0 â€“ 1.6 micrometers) with less than a tenth wave root-sum squared wavefront error.
- Uncooled photon counting imagers with >1024 x 1024 formats, ultra low dark count rates and 400 - 2000 nm sensitivity.
- Ultra-low (<0.1%) fixed pattern non-uniformity NIR imagers with large format (1024 x 1024), low noise (<1 e- read, <1ke/pix/sec dark) and high QE (>0.7).
- Nutating fiber pointing mechanisms with high precision (<0.01 urad) and high bandwidth (> 3 kHz).
- Compact, lightweight, low power, broad bandwidth (0 - 3 kHz) disturbance rejection and/or isolation platforms.
- Space-qualifiable, > 20% wall plug efficiency, lightweight, 20-500 psec pulse-width (10 to > 100 MHz PRF), tunable (Â± 0.1 nm) pulsed 1064-nm or 1550-nm laser transmitter fiber MOPA sources with >1 kW of peak power per pulse (over the entire pulse-repetition rate), with Stimulated Brillouin Scattering (SBS) suppression and > 10 W of average power, near transform limited spectral width, and <10 psec pulse rise and fall times. Also of interest for the laser transmitter are: robust and compact packaging with radiation tolerant electronics inherent in the design, and high speed electrical interface to support output of pulse position modulation encoding of sub nanosecond pulses and inputs such as Spacewire, Firewire or Gigabit Ethernet.Description of approaches to achieve the stated efficiency is a must.
- > 2-m diameter, <30-nm bandpass optical filters on a membrane substrate to pass center. Wavelengths in the 1000 to 1600 nm band with >90% transmission.
- > 2-m diameter f/1.1 primary mirror and Cassegrain focus of ~f/6 optical communication receiver telescopes. Maximum RMS surface figure error of 1-wave at 1000 nm wavelength. Telescope is positioned with a 2-axis gimbal capable of 0.25 mrad pointing. Combined telescope and gimbal shall be manufacturable in quantity (tens) for <$400k each.
- Daytime atmospheric compensation techniques capable of removing all significant atmospheric turbulence distortions (tilt and higher-order components) on an uplink laser beam; and/or for a 2-m diameter downlink receiver telescope. Also of interest are technologies to compensate for the static and dynamic (gravity sag and thermal) aberrations of 2-m diameter telescopes with a surface figure of 10â€™s of waves.
- Ground-based, relatively low-cost diode-pumped laser technology capable of reaching 100 kW average power levels in a TEM00 mode, for uplink to spacecraft.
- Photon counting Si, InGaAs, and HgCdTe detectors and arrays for the 1000 to 1600 nm wavelength range with single photon detection efficiencies > 60% and output jitters less than 20 psec, active areas > 20 microns/pixel, and 1 dB saturation rates of at least 100 megaphotons (detected) per pixel and dark count rates of < 1 MHz / mm^2.
- Radiation hard (100 Mrad level) photon counting detectors and arrays for the 1000 to 1600 nm wavelength range with single photon detection efficiencies > 40% and 1 dB saturation rates of at least 30 megaphotons/pixel and operational temperatures above 220 K and dark count rates of < 10 MHz / mm.
- Single-photon-sensitive, high-bandwidth (1 GHz), linear mode, high gain (> 1000), low-noise (< 1 kcps), large diameter (200 micron), HgCdTe avalanche photodiode and/or (small diameter) arrays for optical detection at 1060 nm or 1550 nm.

Research should be conducted to convincingly prove technical feasibility during Phase 1, with clear pathways to demonstrating and delivering functional hardware, meeting all objectives and specifications, in Phase 2.

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.

O1.07 Long Range Space RF Telecommunications

Lead Center: JPL

Participating Center(s): ARC, GRC

This solicitation seeks to develop innovative technologies for long-range RF telecommunications supporting the needs of space missions.

Purpose (based on NASA needs) and current state-of-the-art: Future spacecraft with increasingly capable instruments producing large quantities of data will be visiting the Moon and the planets. To support the communication needs of these missions and maximize the data return to Earth innovative telecommunications technologies that maximize power efficiency, transmitted power density and data rate, while minimizing size, mass and power are required.

The current state-of-the-art in long-range RF communications is about 2 Mbps from Mars using microwave communications systems (X-Band and Ka-Band) with output power levels in the low tens of Watts end DC-to-RF efficiencies in the range of 10-25%.

Specifications and Requirements:

- Ultra-small, light-weight, low-cost, low-power, modular deep-space transceivers, transponders, and components, incorporating MMICs and Bi-CMOS circuits;
- MMIC modulators with drivers to provide large linear phase modulation (above 2.5 rad), high-data rate (10 - 200 Mbps), BPSK/QPSK modulation at X-band (8.4 GHz), and Ka-band (26 GHz, 32 GHz and 38 GHz);
- High-efficiency (> 60%) Solid-State Power Amplifiers (SSPAs), of both medium output power (10 W - 50 W) and high-output power (150 W - 1 KW), using power combining techniques and/or wide band-gap semiconductor devices at X-band (8.4 GHz) and Ka-band (26 GHz, 32 GHz and 38 GHz);
- Epitaxial GaN films with threading dislocations less than 106 per cm2 for use in wide band-gap semiconductor devices at X- and Ka-Band;
- Utilization of nano-materials and/or other novel materials and techniques for improving the power efficiency or reducing the cost of reliable vacuum electronics amplifier components (e.g., TWTAs and Klystrons);
- SSPAs, modulators and MMICs for 26 GHz Ka-band (lunar communication);
- TWTAs operating at millimeter wave frequencies (e.g., W-Band) and at data rates of 10 Gbps or higher;
- Ultra low-noise amplifiers (MMICs or hybrid) for RF front-ends (< 50 K noise temperature); and
- MEMS-based RF switches and photonic control devices needed for use in reconfigurable antennas, phase shifters, amplifiers, oscillators, and in-flight reconfigurable filters. Frequencies of interest include VHF, UHF, L-, S-, X-, Ka-, V-band (60 GHz) and W-band (94 GHz). Of particular interest is Ka-band from 25.5 - 27 GHz and 31.5 - 34 GHz.

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

Phase 1 Deliverables: Feasibility study, including simulations and measurements, proving the proposed approach to develop a given product. Verification matrix of measurements to be performed at the end of Phase 2, along with specific quantitative pass-fail ranges for each quantity listed.

Phase 2 Deliverables: Working engineering model of proposed product, along with full report of on development and measurements, including populated verification matrix from Phase 1.

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.

O1.08 Lunar Surface Communication Networks and Orbit Access Links

Lead Center: GRC

Participating Center(s): ARC, GSFC, JPL, JSC

This solicitation seeks to develop a highly robust, bidirectional, and disruption-tolerant communications network for the lunar surface and lunar orbital access links. Exploration of lunar and planetary surfaces will require short-range (~1.6 km line-of sight, ~5.6 km non-line-of-sight) bi-directional, and robust multiple point links to provide on-demand, disruption and delay-tolerant, and autonomous interconnection among surface-based assets. Some of the nodes will be fixed, such as base stations and relays to orbital assets, and some transportable, such as rovers and humans. The ability to meet the demanding environment presented by lunar and planetary surfaces will encompass the development and integration of a number of communication and networking technologies and protocols. NASA lunar surface networks will be dynamic in nature, and required to deliver multiple data flows with different priorities (operational voice, command/control, telemetry, various qualities of video flows, and others). Bandwidth and power efficient approaches to mobile ad hoc networks are desired. Quality of Service (QoS) algorithms in a Mobile Ad hoc NETwork (MANET) setting will need to be developed and tailored to NASA mission specific needs and for the lunar surface environment.

These lunar and planetary surface networks will need to seamlessly interface with communications access terminals and orbiting relays that also can provide autonomous connectivity to Earth based assets. The access link communications system will encompass the development and integration of a number of communications and networking technologies and protocols to meet the stringent demands of continuous interoperable communications. Human exploration, therefore, requires the development of innovative communication protocols that exploit persistent storage on mobile and stationary nodes to ensure timely and reliable delivery of data even when no stable end-to-end paths exist. Solutions must exploit stability when it exists to nearly approximate the performance of conventional MANET protocols. The lunar surface communications network must support 15 simultaneous users with aggregate bandwidth of 80 Mbps. It must also support minimum data rates of 16 kbps and maximum data rates of 20 Mbps and be IP compatible with a BER of 10e-8 or less, and graceful degradation. Frequency bands of interest are UHF (401 - 402 MHz, 25 kHz bandwidth), S-band (2.4 - 2.483 GHz), and Ka-band (22.55 - 23.55 GHz).

Core capabilities:

- Short range access point, base stations, and wireless router bridges for extending surface network coverage;
- Non-line-of-sight communication between stationary and moving assets, outside or inside lunar craters without using orbiting assets;
- Analog voice-only radio service to the lunar outpost and the lunar relay satellite at the highest network priority for HF, UHF, or S-band for reliability;
- Support multiple bandwidths for telemetry, voice, and high-rate video;
- Ability to determine the QoS, channel, and interference information;
- Autonomously reconfigurable receivers capable of automatic link configuration and management;

Proposals should address the following areas:

- Disruptive and delay-tolerant networking (DTN);
- Networking algorithms and adaptive routing;
- Extra-Vehicular Activity (EVA) radio.

The following technologies are addressed under other SBIR Subtopic solicitations:

- Antennas for surface and orbital access communications required for the aforementioned goals shall be developed under subtopic O1.02;

- Radios for surface and orbital communications required for the aforementioned goals shall be developed under subtopic O1.03;
- Optical transceivers required for the aforementioned goals shall be developed under subtopic O1.06;
- Any high rate, low power, efficient amplifiers or transponders required for the aforementioned goals shall be developed under subtopic O1.07.

Development Timeline: After a possible Phase 3 development activity, these technologies are expected to ready for insertion at TRL 6 by 2014. To meet the schedule for NASAâ€™s Vision for Space Exploration (VSE), a TRL progression from an entry TRL of 1-2 for Phase 1 in January 2009 followed by an exit TRL of 3 - 4 after Phase 2 is required.

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

Phase 1 Deliverables:

Propose a robust lunar surface and orbit access communications network suitable for the applications and environment. Address all technical challenges, pitfalls, and tradeoffs of the network size, assets, and power as well as reliability, complexity, and performance. Solutions should encompass a notional architecture, functional requirements, and building block concepts, demonstrating a reliable and simultaneous voice, telemetry, and video transmission as well as reconfigurability across multiple applications and frequency bands.

Develop suitable communication algorithms capable of demonstrating the feasibility of the approach. Based on a minimum of three (3) nodes, simulate the performance of the proposed integrated communications network architecture and analyze the selected implementation strategy. Identify required parameters for the network architecture and quantify performance in terms of energy savings, connectivity, and throughput in a mobile ad hoc network.

Phase 2 Deliverables:Â

Develop a communications network with multi-functional capabilities described in above. Further enhance the concepts investigated in Phase 1 and demonstrate the feasibility of the approach on an actual platform.

Fabricate and test a prototype communications network with a minimum of three (3) nodes using an active integrated communication network. Simulate and refine power software algorithms for real time robust operations and characterize system performance in compliance with the design goals outlined in Phase 1.

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.

O1.09 Software for Space Communications Infrastructure Operations

Lead Center: JPL

Participating Center(s): ARC, GRC, GSFC

New technology is sought to improve resource optimization and the user interface of planning and scheduling tools for NASA's Space Communications Infrastructure. The software created should have a commercialization approach with the new modules fitting into an existing or in development planning and scheduling tool.

Purpose (based on NASA needs) and the current state of the art: The current infrastructure for NASA Space

Communications provides services for near-Earth spacecraft and deep space planetary missions. The infrastructure assets include the Deep Space Network (DSN), the Ground Network (GN), and the Space Network (SN). Recent planning for the Vision for Space Exploration (VSE) for human exploration to the Moon and beyond as well as maintaining vibrant space and Earth science programs resulted in a new concept of the communications architecture. The future communications architecture will evolve from the present legacy assets and with addition of new assets.

NASA seeks automation technologies that will facilitate scheduling of oversubscribed communications resources to support: (1) Increased numbers of missions and customers; (2) Increased number and complexity of constraints (as required by new antenna types); and (3) decreased operations budgets (both core communications network operations and mission side operations budgets.

Core Capabilities:

Intelligent Assistants

In order to automate the user's provision of requirements and refinement of the schedule, "intelligent assistant" software should manage the user interface. Assistants should streamline access and modification of requirement and schedule information. By modeling the user, this software can adjust the level of autonomy enabling decisions to be made by the user or the automated system. Assistants should try to minimize user involvement without making decisions the user would prefer to make. The assistants should adapt to the user by learning their control preferences. This technology should apply to local/centralized and collaborative scheduling.

In a conflict-aware scheduling system (especially in a collaborative scheduling environment), conflicts are prevalent. With the concept of one big schedule from the beginning of time, real time, to the end of time, resolving conflicts become a difficult task especially since resolving conflicts in a local sense may affect the global schedule. Therefore, an intelligent assistant may provide decision support to the system or the users to assist conflict resolution. This may involve a set of rules combining with certain local/global optimization to generate a list of options for the system or users to choose from.

Resource Optimization

The goal of schedule optimization is to produce allocations that yield the best objectives. These may include maximizing DSN utilization, minimizing loss of desired tracking time, and optimizing project satisfaction. Each project may have their own definition of satisfaction such as maximal science data returned, maximal tracking time,

best allocation of the day/week, etc. The difficulty is that we may not satisfy all of these objectives during the optimization process. Obviously, optimal solution for one objective may produce worse results for the other objectives. One possible solution is to map all of these objectives to an overall system goal. This mapping is normally non-linear. Technology needs to be developed for this non-linear mapping for scoring in addition to regular optimization approaches.

Optional Capabilities:

Multiple Agents

In an environment where all system variables can be controlled by a single controller, an optimal solution for the objective function can be achieved by finding the right set of variables. In a collaborative environment with multiple decision makers where each decision maker can only control a subset of the variables, modeling and optimization become a very complex issue. In the proposed collaborative scheduling approach, there are many users/agents that will control their own allocations with interaction with the others. How we model their interactions and define system policy so the interaction can achieve the overall system goal is an important topic. The approach for multiple decision-maker collaboration has been studied in the area of Game Theory. The applications cover many areas including economics and engineering. The major solutions include Pareto, Nash, and Stackelberg. There are many new research areas including incentive control, collaborative control, Ordinal Games, etc. Note that intelligent assistants and multiple agents represent different points on the spectrum of automation. Current operations utilize primarily manual collaborative scheduling, intelligent assistants would enhance users ability to participate in this process and intelligent agents could more automate individual customers scheduling. Ideally, proposed intelligent assistants and distributed agents would also be able to represent customers who do not wish to expose their general preferences and constraints.

A start for reference material on this subtopic may be found at the following:

http://ai.jpl.nasa.gov in the publications area;

http://scp.gsfc.nasa.gov/gn/gnusersguide3.pdf,

NASA Ground Network Userâ€™s Guide, Chapter 9 Scheduling;

and http://scp.gsfc.nasa.gov/tdrss/guide.html, Space Network User's Guide, SpaceOps Conference Proceedings.

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

Phase 1 Deliverables: Propose demonstration of Intelligent Assistants, Resource Optimization, or Multiple Agents on a number of communication asset allocation problem sets (involving dozens of missions, communications assets, and operational constraints). End Phase deliverable would include a detailed rationale for ROI in usage of said technology to communications asset allocation based on knowledge of current and future operations flows.

Phase 2 Deliverables: Demonstrate Intelligent Assistants, Resource Optimization, or Multiple Agents on actual or surrogate communication asset scheduling datasets. Deliverables would include use cases and some evidence of utility of deployment of developed technology.

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.