NASA SBIR 2009 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 are needed which are centered on operational issues associated with the communication capability. Communication technologies enabling acquisition of range safety data from sensitive instruments is imperative. All technologies developed under this topic area to be aligned with the Architecture Definition Document and technical direction as established by the NASA Office of Space Communications and Navigation (SCaN). For more details, see:

https://www.spacecomm.nasa.gov/spacecomm/

https://www.spacecomm.nasa.gov/spacecomm/programs/default.cfm

https://www.spacecomm.nasa.gov/spacecomm/programs/technology/default.cfm

https://www.spacecomm.nasa.gov/spacecomm/programs/technology/sbir/default.cfm

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 desirable. 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 flight opportunity. Please see the following for more details:

1. SMD Topic S4 for more details concerning requirements for Small Satellite flight opportunities.

2. Facilitated Access to the Space Environment for Technology Development and Training (FAST): http://ipp.nasa.gov/ii_fast.htm

3. International Space Station payload opportunities:http://www.nasa.gov/mission_pages/station/science/experiements/Discipline.html
4. Terrestrial analogs (Desert Rats, Haughton Field): http://science.ksc.nasa.gov/d-rats/, http://ti.arc.nasa.gov/projects/haughton_field

NOTE: Communications technologies for space-based range must be highly integrated with required navigation components; hence, space-based range technologies are solicited in Navigation Subtopic O4.05.

Subtopics

O1.01 Coding, Modulation, and Compression

Lead Center: JPL

Participating Center(s): AFRC, ARC, GRC, GSFC

This subtopic aims to develop innovative technology in three key areas of space communications: modulation, forward error-correction (FEC) coding, and data compression. The objective is to provide the best possible trade-off of coding gain, bandwidth efficiency, complexity (mass or power), and rate-distortion, so that the total science/engineering value can be maximized while using the smallest amount of spacecraft energy possible. This will enable NASA to meet a wide range of requirements for its future space missions at near Earth, lunar, and deep space distances.

These future missions will use many link types (direct-to-Earth, TDRS relay, lander-to-orbiter relay, and short-proximity links), frequencies (S-, X-, and Ka-bands), and application-specific performance requirements (latency, complexity). The state-of-the-art in the three areas addressed by this subtopic is summarized here:

- Modulation: BPSK and QPSK for deep space, and BPSK, QPSK, SQPSK, and 8-PSK for near Earth (TDRS) applications; GMSK for bandwidth efficient applications

- Coding: CCSDS turbo codes and LDPC codes (See http://public.ccsds.org/publications/archive/131x0b1.pdf and http://public.ccsds.org/publications/archive/131x1o2e2.pdf)

- Compression: the CCSDS standard (http://public.ccsds.org/publications/archive/122x0b1c2.pdf)

Technology development is needed in the following areas:

Modulation

There is a need for the implementation and demonstration of ground receivers and flight receivers that exhibit very low implementation loss for 8-PSK and GMSK (in addition to BPSK, QPSK, and SQPSK) for operation ranges from 8 bps (emergency) through 100 Mbps (high rate Ka-band). Emphasis is placed on minimizing implementation loss (

Phase 1 tasks should target completion of a fixed-point design whose performance can be verified by simulation (in, e.g., Simulink or SPW). Phase 2 technology target is a hardware demonstration at TRL 5.

Coding

There is a need to interface a receiver as above with a high-performing LDPC decoder. Government licensing of LDPC decoding technology (Verilog source) is available. What is needed here is the development of the following:

- FPGA simulations of all 10 CCSDS LDPC codes down to a bit error rate of $1e^{-10}$ and a codeword error rate of $1e^{-9}$, and with a goal of identifying the "error floor" of each of the codes.
- Improved decoding algorithms that reduce the observed error floor. It is known that observed error floors for these codes are a characteristic of standard belief propagation (BP) decoding, and not because of the minimum distance properties of the codes. Variations of standard decoding may not be susceptible to the same trapping sets, thereby improving error floor performance. These methods include (a) optimally decoding the 4-cycles, (b) converting 4-cycles to equivalent trees, (c) BP decoding with damping, and (d) using min in place of min* in the later iterations of the decoder. These and other variations should be tested particularly on the k=1024, r=4/5 code, which is expected to exhibit the highest error floor.

The target is a finished product at TRL 5.

Data Compression

Development of a radiation-tolerant high-speed (over 100 Msamples/sec) lossless compression component conforming to CCSDS 121.0-B-1, "lossless data compression" (www.ccsds.org) allowing input dynamic range to over 24-bit/sample. Options should include user-supplied external predictor, as well as providing potential applications to hyper-spectral data by taking advantage of the spectral correlation in such data sets.

Development to TRL 5 is desired.

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): AFRC, 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; antenna adaptive beam correction with pointing control; parallelized numerical solvers for antenna modeling and design; and communication antennas with improved performance.

Phased Array Antennas

High performance phased array antennas are needed for (1) high-data rate communication and (2) remote sensing applications. The frequencies of interest are P-, L-, C-, S-, X-, Ku-, Ka-, and W-band. Potential communications applications include: lunar and planetary exploration, landers, probes, Lunar Relay Satellites, lunar rovers, lunar habitats, lunar surface EVA, suborbital vehicles, sounding rockets, balloons, unmanned aerial vehicles (UAV's), TDRSS communication, and expendable launch vehicles (ELV's). Potential remote sensing applications include: radiometers, passive radar interferometer platforms, and synthetic aperture radar (SAR) platforms for planetary science.

Multi-band phased array technology such as S- and Ka-band phased array antennas, which can dynamically reconfigure active element coupling in order to operate in either band as required in order to maximize flexibility, efficiency and minimize the mass of hardware delivered to the moon for lunar surface system operations, are of interest. The goal is to maximize flexibility and capability to share lunar communications infrastructure and therefore minimize mass of radio components that must to be delivered to the lunar surface.

There is also a high interest in developing phased array antennas for space-based range applications to accommodate dynamic maneuvers.

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/tradeoffs to be addressed are achieving low mass, low cost, high power efficiency, thermal stability of active array electronics, and coverage area (i.e., highly steerable arrays). Active arrays with features such as T/R module self-calibration for thermal stability, true time delay (TTD), low-cost highly-integrated MMIC-based T/R modules (e.g., SiGe/GaAs technology), multiple beam-forming capability, low-loss feeds for radiometer applications are also of interest. Advances in digital beam-forming techniques, including those based on superconducting digital signal processing methods, are also desirable.

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 at higher frequencies 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 challenge 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 if 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.

High-Efficiency, Miniature Antennas

High efficiency, low-cost, low-mass, broadband or dual-band miniaturized antennas (UHF or X-band) that radiate circular polarization with full hemispherical coverage are desirable. These antennas must be able to withstand launch and re-entry environments and must be low profile/conformal.

The emergence of frequency-agile radios increases emphasis of antenna capable of bidirectional communications across multiple bands. Accordingly, emphasis on small size, high efficiency and low cost of ownership is desirable. Miniaturization of L-, S-, and C- band for Micro Air Vehicles is also of interest.

Miniaturized antennas that are wearable or can be highly integrated into the host structure/entity, are also desirable. Examples include EVA's space suits made with textile antennas, fractal antennas, or visor mounted antennas. These miniaturized antennas should also be multi-directional to support astronaut mobility, support multi-band operation, and/or possess a 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).

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 multi-beam 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. The antenna shall also be highly directive, multi-frequency and compatible with the Multiple Input Multiple Output (MIMO) concept.

Large Aperture Inflatable/Deployable Antennas

Large aperture inflatable/deployable 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.,

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

Membrane materials for large inflatable membrane antennas for remote sensing applications for earth and planetary science missions are of particular interest to the Science Mission Directorate. The current state of the art for mechanical deployable antennas is reaching limits on packaging efficiencies. Reflectors manufactured from polymer films could enable greater packaging efficiencies due to their low mass, high packaging efficiencies, solar radiation resistance, and cryogenic flexibility. However, most polymer films, including polyimide polymer films, have many challenges that limit their usefulness in practical space applications. Active membrane control system concepts, developed to reduce shape errors, often add unwanted bulk and mass to the antenna system. While other concepts will be entertained, specific membrane material technology innovations of interest are listed below:

- Polymer membrane (0.5 mil to 2.0 mil) material exhibiting zero or near-zero Coefficient of Thermal Expansion (CTE).
- Polymer membrane material exhibiting durability to the space environment, including atomic oxygen, VUV, solar particulate radiation, and temperature extremes.
- Thin film deployment methods that deploy the antenna surface substantially free of wrinkles.
- Innovative intrinsically electroactive polymer membrane actuation mechanisms that can be used to shape-correct the antenna surface.

Additionally, composite materials for large deployable antenna reflector structures for remote sensing applications for earth and planetary science missions with high specific stiffness composite materials that can be packed compactly and deployed multiple times for ground evaluation of the antenna structure prior to launch and deployment in space are of interest. Investigators should consider materials that can be folded and deployed on the order of 5 to 10 times with up to 180 degree bends that retain their structural integrity and shape accuracy upon final deployment. The deployment of these materials should require low energy. Rigidizable materials (Shape Memory Polymers, Shape Memory Composites, UV Activated Composites, etc.) could be considered to obtain the appropriate structural stiffness and post-deployment precision.

Prospective proposers are advised to review Subtopic S1.02, Active Microwave Technologies, for additional remote sensing applications needs, and indicate applicability in their proposal(s).

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.,

Parallelized Numerical Solvers for Antenna Modeling/Design

Development of full 3-D electromagnetic (EM) solvers that take advantage of new software engineering approaches (e.g., object oriented programming) and parallel computing resources for fast and accurate modeling/design of antennas, antennas with feed structures, and antennas in multi-path environment are of interest. Numerical solvers offering fast and accurate synthesis via search algorithms (e.g., genetic algorithm) of patch arrays and waveguide slot arrays, to reduce design time, are also of interest. All solvers must aim toward experimental validation of actual antenna concept being simulated.

Communication Antennas with Improved Performance

High performance, low-cost antennas are needed for a variety of missions for communicating with TDRSS, GPS (L1, L2, and L5 bands), or the Deep Space Network (DSN). The frequency bands of interest are L-, S-, X-, Ku-, and Ka-band. Antenna concepts that offer significant improvement in cost and performance (e.g., mass, gain, efficiency, VSWR, axial ratio, bandwidth, power handling, vibration tolerance, etc.) over existing off-the-shelf antennas would be of interest. Novel isoflux antennas at S- and X-band would also be of interest. Antennas must be able to withstand launch environments.

Deliverables and Development Timeline

After a possible Phase 3 development activity, these technologies are expected to ready for insertion at TRL 6 by 2015. Therefore a TRL progression from an entry TRL of 1 - 2 for Phase 1 in January 2010 followed by an exit TRL of 3 - 4 after Phase 2 is reasonable.

For all above technologies, 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

A final report containing optimal design for the technology concept including feasibility of concept and 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

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

O1.03 Reconfigurable/Reprogrammable Communication Systems

Lead Center: GRC

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

NASA seeks novel approaches in reconfigurable, reprogrammable transceiver systems for Space Operations, Exploration, Science, and Aeronautics research. Exploration of Lunar and Mars environments will require advancements in radio 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., 1's to 10's Mbps at UHF- and S-band frequency bands up to 10's to 1000'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:

- Enable 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 due to an errant reconfiguration process or logic upset.
- Develop 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.

- 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 such as voting schemes and 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., "gold" 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 space environments.

- Development of radio technology that allows the incorporation of Space Network (SN) waveforms and candidate Lunar Surface System (LSS) wideband waveforms such as 802.11 and 802.16 into a single multimode radio capable of supporting simultaneous communications with space and lunar network assets. Development and implementation of direct RF to digital technologies that are currently emerging and can offer significant improvements in the flexibility of software or multi-mode radios. The goal is to maximize flexibility and capability to share lunar communications infrastructure and therefore minimize mass of radio components that must to be delivered to the lunar surface.

- Small, lightweight all-digital reconfigurable radios and transceivers that eliminate analog front ends that operate across multiple bands, are sought for applications that involve network enhanced telemetry, leading towards adaptive and cognitive radio applications. Application of reconfigurable systems in airborne and terrestrial systems is of interest.

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 hardware demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

O1.04 Miniaturized Digital EVA Radio

Lead Center: JSC

Participating Center(s): GRC

As NASA embarks upon deep space human exploration, the next-generation EVA radio will be a pivotal technology and integral part of lunar surface systems success. It will facilitate surface operations, enable crew mobility, and support point to multi-point communications across rovers, landers, habitat, and other astronauts. Driven by Communications, Command, Control, and Information (C3I) interoperability, tight power budgets, and extreme miniaturization, this mobile radio platform must be power efficient and highly adaptive. With a scant EVA radio power budget of less than four watts, the S-band (2.4 - 2.483 GHz) adaptive radio must deliver voice, telemetry, and high-definition motion imagery transmissions. To surmount interference, the radio must support frequency diversity over the specified S-band spectrum of 2.4 - 2.483 Ghz. During nominal operations, it is designed to operate with a mobile ad hoc network (MANET) so the coverage for communications can be extended indefinitely with node additions. It will communicate to fixed and mobile nodes, including lunar base stations, landers, habitats, rovers, and other astronauts. Therefore, it must support multiple bandwidths, waveforms, and energy profiles. To achieve the overarching communication goals of small form factor, ultra-power , and reconfigurability, NASA needs to extend the state-of-the art in two key areas:

Tunable RF Front End and Transceiver

The major impetus behind the MEMS technology stems from compactness which leads to lower power dissipation, higher levels of integration, lower weight, volume, and cost. To shrink form factor and enable efficient surface operations, one of the cornerstone radio components of this radio is the tunable filter. Recent advances in RF MEMs filters and resonator technology have permitted very high quality factors (>1000) at GHz frequencies. Achieving high and excellent tuning range (>2:1) to bandwidth ratio without cryogenic cooling is now viable for the S-band frequency. For reliability, the tunable filter should employ a contact-less tuning scheme.

Also, a new class of MEMS-based frequency synthesizers offers dramatic reduction in noise, power, and form factor. One should leverage emerging microscale resonator technologies to the maximum extent. Low phase noise synthesizers running at ultra low power levels are viable using high Q resonator technologies MEMS resonators-based phase lock loop offers compelling power and noise performance enhancements.

Power-Aware Processing

To support QoS of different applications, it's not enough to optimize power at design time, but dynamic power management must be employed to ensure power efficiency. To maximum power efficiency, it must be able to adjust power and update rates to suit diverse missions. Users should be able to specify Quality of Service (QoS) for different data streams. The radio must have the capability to scale power, select the optimum mode of operation, and minimum energy profile. During low-rate-processing intensive modes, including local processing and compression of telemetry data and voice, highly energy-efficient low-voltage, low-performance modes must be used. For high-rate-processing intensive modes, like advance signal encoding of high motion imagery, medium performance modes must be used; and during active communication modes (which may have a low duty-cycle), ultra-high-performance modes must be used. Accordingly, the digital platform must be highly agile and use-case aware to continuously minimize energy. Below are the desirable technology features.

Bear in mind, research should be conducted to demonstrate technical feasibility during Phase 1 and to show a path towards a hardware and software demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

Phase 1 Deliverables

Conduct design trade analyses 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 and simulation to ensure achievable performance and power goals.

Develop a promising MEMS-based system-on-chip radio design with the following features:

- **Variation-tolerant, performance-scalable architectures:** Hardware must sense its own limitation at a dynamically varying, performance-driven optimal energy operating point, and reconfigure accordingly. If variability is stressed at the low-voltage operating point, redundant hardware should be used to improve reliability; if throughput is stressed at the high-performance operating point, redundant hardware should be used to increase parallelism.
- **Highly agile platform components (SRAM and logic):** Circuits should use functionality assists, including selective biasing, leakage-control, routine resources, etc., that get engaged dynamically depending on the operating point.
- **Energy-aware algorithms for adaptive hardware:** Algorithms must be aware of the different hardware operating-points and associated architecture. For instance, during low-power modes targeting voice and data (for telemetry), occasional high through-put applications (like high motion imagery) should dynamically switch to algorithms employing extreme parallelism in order to support a minimum operating voltage.
- **Extreme power converters:** To minimize off-chip components, DC-DC converters should use a single reconfigurable architecture that efficiently delivers load powers ranging from micro-Watts, at low-voltages, to Watts, at high voltages.
- **High performance ultra-low power ADCs:** Exploit novel ADCs with sampling frequencies in tunable multi GHz range (preferable double digits). Variable resolution up to 20 bits or higher with ultra-low power jitters for finer resolutions at higher bits and comparators managed for higher bits with minimum power overheads.A high sampling rate is desirable. SNR optimizations and efficient signal recovery demonstration is a requirement for validating ADC capabilities.
- **Modularity and extensibility:** Enabling platform must support open architecture and accommodate rapid upgrades, multiple protocols, new technology advances, complete re-configurability of functionality, and evolution of lunar communications and network infrastructure.

One significant prerequisite to Phase 2 is the development of most promising MEMS-based transceiver system-on-chip (SoC) architecture The offeror must demonstrate the ability to achieve significant advantage in compactness and ensure power efficiency and reliability.

Phase 2 Deliverables

Develop a reliable, intelligent, and power-efficient MEMS-based EVA digital radio prototype unit, demonstrating robust and dynamic power management. The miniaturized radio technology must reach TRL=5 at the end of Phase 2.

Demonstrate RF performance and 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). With power constraints of under four watts, performance and reliability must be assured for multiple bandwidths and data transmissions of telemetry, voice, and high-rate video.

O1.05 Transformational Communications Technology

Lead Center: GRC

Participating Center(s): JSC

NASA seeks revolutionary, highly innovative, transformational communications technologies that have the potential to enable order of magnitude performance improvements for space operations, exploration systems, and science mission applications.

Research emphasizing both nearer-term and far-term technologies is focused (but not limited to) in the following areas:

Near-Term Focus Areas:

- Develop novel techniques to reduce the size, weight, and power (SWAP) of communications transceivers for space missions. Address SWAP challenges by addressing digital processing and logic implementation tradeoffs, static vs. dynamic power, voltage and frequency scaling, hardware and software partitioning such that operational modes are effectively managed. Great demands will be placed on these communication transceivers to assure crew safety and robustness in harsh deep-space environments for long duration missions. Investigate and demonstrate novel RF communication technologies to alleviate the demanding requirements on analog to digital converters (ADCs) and digital signal processors (DSPs). For software-defined radios, such requirements can result in high ADC power consumption, large form factor, and expensive components, which can pose problems for power and weight constrained deep space missions.
- Significant component-level technical advances are needed in the area of UHF/VHF filter technologies. Novel, smaller form factor, lower cost, higher performance, and lower weight than existing devices are to be demonstrated employing new technologies such as MEMS resonators (e.g., electrostatic, piezoelectric) and tunable dielectrics. Filter solutions that offer a bandwidth tunability or reconfigurability and filter banks are also sought. Fractional bandwidths of 0.1% to greater than 2% are of interest, where for narrower bandwidths, operating stability across temperature is necessary. At the conclusion of Phase 1, proposers should clearly delineate, through a combination of theoretical analysis and demonstrated prototypes, that the proposed solution can achieve better than 3 dB of insertion loss, better than 70 dB of rejection, less than 1 dB of ripple, small shape factors, power handling greater than +20 dBm, VSWR less than 2, and robust operation in a harsh space environment. Phase 2 will leverage the analysis and prototypes developed in Phase 1 to meet to the specifications for space-based communication links and will deliver a

demonstration unit of the proposed technology for testing. Phase 2 will also evaluate component reliability to ensure robust operation across the harsh temperature, vibration, shock, and other conditions encountered in space operation.

- NASA seeks to integrate RFID, antenna, flexible organic material (e.g., Liquid-crystal polymer with constant dielectric properties from 1-110 GHz) and energy-scavenging technologies to develop ultra-low-cost enhanced range sensor surface nodes. This new generation of conformal wireless nodes based on the utilization of UHF semi-passive RFIDs on beacons and astronaut suits would enable the development of robust communication links through the implementation of very-large-scale ad-hoc networks for rugged and/or emergency response environments. Many technical challenges are associated with the development and enhancement of localization and precise tracking of assets for long-duration missions. To leverage terrain-adaptive navigation solutions, inventory tracking, and astronaut body area network applications, several quantum leap technologies including semi-passive RFID-enabled wearable tags and multi-hopping inflatable beacons need to be advanced to demonstrate ranges in excess of 200 m. Astronauts wearing at least 4 miniaturized ultra-low-power inertial sensors at spacings below the operation wavelength of 2.4GHz (EVA) could enable RFID-enabled inflatable beacons for accurate tracking and navigation. The capability of state-of-the-art wireless systems to provide precise timing/time-tracking with nanosecond accuracy coupled with ultra-low-power wearable inertial sensors and low-power multi-hopping algorithms between beacon-mounted and astronaut-mounted RFIDs can enable true mobility location awareness in ranges in excess of 500/1000 meters. Low power beacons (assuming a duty cycle of 5-10 %) can be solar powered and fabricated in an inflatable triangular shape. It has already been already been proven that some solar-powered "semi-passive" RFID's with a single-hop range of 100+m consumes only 80 microwatts and can improved by a factor of 3 to 5. Yet, to have a practical ad-hoc beacon network with effective beacon-to-beacon and beacon-to-RFID ranges in excess of 1 km, with beacon power levels between 20 microwatts to 5 milliwatts, various technical challenges need to be addressed: solar panels should achieve efficiencies greater than 50% and should be easily printed as a substrate of the printed beacon antennas, the electronics should operate in sub-threshold domain, the IC power consumption should be below 20 microwatts, and the antenna should feature at least two different frequencies for redundancy. Solutions should consider employing power scavenging merging dynamic/kinetic energy from the astronaut motion (mounted on boots), solar energy (through thin-films on uniform), thermal/vibration energy (through inkjet-printed nanotube-based wearable textiles), thus minimizing the use of portable battery. Phase 1 effort should introduce an "ad-hoc" wearable network of 3-5 RFID-enabled wearable inertial sensors that could provide voice-level communication with inflatable beacons with total power consumption below 500 microwatts. Up to 5 hops with 300m + hop will be investigated for enhanced range wireless links for 433 MHz, 900MHz and integration. The prototype should include 5+ wearable tags and 5+ inflatable beacons and 3 test frequencies. Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 multi-tag, multi-scenario hardware demonstration prototype unit.

Far-Term Focus Areas:

- The promise of high-performance, multi-functional, nanostructured materials has led to intense interest in developing them for applications for human spaceflight and exploration. These materials (notably single wall carbon nanotubes) exhibit extraordinary mechanical, electrical, and thermal properties at the nanoscale and possess exceptionally high surface area. The development of nano-scale communication devices and systems including nano-antennas, nano-transceivers, etc. are of interest for nano-spacecraft applications.

- Quantum entanglement or innovative breakthroughs in quantum information physics has sparked interest to specifically address this phenomenon and the critical unknowns relevant to revolutionary improvements in communicating data, information or knowledge. Methods or techniques that demonstrate extremely novel means of effectively packaging, storing, encrypting, and/or transferring information are sought.

- Innovative approaches to use of medium to high frequency (300 KHz-30MHz) bands for applications benefiting future lunar missions. Concepts, studies, development of key technologies are needed to perform non-line-of-sight communication for potential use on the surface of the Moon. Modulation and coding techniques, antennas, solid-state amplifiers, digital baseband circuitry, etc. are required to be developed and/or validated to enable over the horizon communication and communications into craters for robotic and human missions. Range of communications on the order of 10-20 kilometers at a data rate of 128 kbps is envisioned to support many of these types of lunar surface links.

- Ultra-wideband (UWB) or impulse radio wireless communications, navigation and tracking for lunar applications. UWB has the capability of pervasive wireless transmission of data, video, etc., very fine time resolution, low power spectral density, and resistance to multipath. Device, component and/or subsystems that can enable use of UWB for space-based applications are sought, including but not limited to: transceivers, highly efficient antennas; array beamformers; space-time processing techniques; accurate timing generators for sub-nanosecond pulse widths; matched filters; channel estimators; low power, high bandwidth A/D converters with extended time sampling.

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:** Technologies relating to acquisition, tracking and sub-micro-radian pointing of the optical communications beam under typical deep-space ranges (to 40 AU) and spacecraft micro-vibration environments.

- **Small lightweight two-axis gimbals:** Approximately 1 kg in mass capable to actuating payload mass of approximately 6 kg at rates up to 5 degrees/second, with less than 30 micro-radian rms error and blind-pointing accuracy of less than 35 micro-radian. 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.

- **Photon counting Si, InGaAs, and HgCdTe detectors and arrays:** For the 1000 to 1600 nm wavelength range with single photon detection efficiencies greater than 60% and output jitters less than 20 pico-second, active area greater than 20 microns/pixel, and 1 dB saturation rates of at least 100 mega-photons (detected) per pixel and dark count rates of less than 1 MHz/square-mm.

- **Single-photon-sensitive, high-bandwidth, linear mode photo-detectors:** With high bandwidth (>1GHz), high gain (>1000), low-noise (

- **Uncooled photon counting imagers:** With >1024 x 1024 formats, ultra low dark count rates and visible to near-IR sensitivity.

- **Ultra-low fixed pattern non-uniformity NIR imagers:** With large format (1024x1024), non-uniformity of less than 0.1%, low noise (0.7) quantum efficiency.

- **Radiation hard photon counting detectors and arrays:** For the 1000 to 1600 nm wavelength range with single photon detection efficiencies greater than 40% and 1dB saturation rates of at least 30 mega-photons/pixel and operational temperatures above 220K and dark count rates of Radiation levels of at least 100 Mrad (unprotected).

- **Isolation platforms:** Compact, lightweight, low power, broad bandwidth (0.1 Hz -3 kHz) disturbance rejection.

- **Laser Transmitters:** Space-qualifiable, greater than 20% wall plug efficiency, lightweight, 20-500 pico-second pulse-width (10 to >100 MHz PRF), tunable (~0.2 nm) pulsed 1064-nm or 1550-nm laser transmitter fiber MOPA sources with greater than1 kW of peak power per pulse (over the entire pulse-repetition rate), with Stimulated Brillouin Scattering suppression and >10 W of average power, near transform limited spectral width, and less than 10 pico-second 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. Detailed description of approaches to achieve the stated efficiency is a must.

- **Low-cost ground-based telescope assembly:** With diameter greater than 2-m, primary mirror with f-number of ~1.1 and Cassegrain focus to be used as optical communication receiver optics. Maximum RMS surface figure error of 1-wave at 1000 nm wavelength.Telescope shall be positioned with a two-axis gimbal capable of 0.25mrad pointing. Combined telescope, gimbal and dome shall be manufacturable in quantity (tens) for ~$1.5M 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 10's of waves.

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.

O1.07 Long Range Space RF Telecommunications

Lead Center: JPL

Participating Center(s): ARC, GRC, GSFC

Solicitation Summary

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

Purpose (based on NASA needs) and current state-of-the-art

In the 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 long-range 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 space telecommunications 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 and 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 space qualified 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);

- Improved integrated non-linear amplifier/modulator designs that reduce crest-factor impacts and significantly enhance the efficiency of high peak-to-average power ratio waveforms, such as 802.11 and 802.16;

- 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 (
- 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.

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.

O1.08 Lunar Surface Communication Networks and Orbit Access Links

Lead Center: GRC

Participating Center(s): 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, often highly asymmetric, and robust multiple-point links to provide on-demand, disruption and delay-tolerant, and autonomous interconnection among surface-based assets. Minimization of communication asset scheduling, and other ground operation support, is highly desirable. 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. Exploitation of delay/disruption tolerant network (DTN) technology to maximize autonomy of the communication infrastructure and to minimize demands on channel capacity is of significant interest. Advantages and disadvantages associated with parallel DTN and IP networks, and a competing DTN-over-IP network architecture, should be considered. Possible associated considerations include routing, security, and QoS.

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 capability of the network to provide infrastructure-based position determination and navigation is of interest to NASA, especially when coverage issues arise and/or orbiter access links are unavailable. The extent to which the network can support localization of mobile nodes should be addressed, and network architecture options that could further support navigation should be identified.

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). Existing commercial standards for the PHY and MAC layers should be leveraged to the extent possible while meeting other requirements, with modifications considered when necessary. Results from NASA's Lunar Architecture Team, as well as technology trade studies performed for NASA's Constellation Systems, should be referenced for input regarding data flows, coverage, network requirements, etc. EVA study results can be found at:

EVA Technology Development path loss study: http://gltrs.grc.nasa.gov/reports/2007/TM-2007-214825.pdf

Specific Subtopic Capabilities to Address This Year

This year's call intends to focus innovations in 4 key areas. Participants should focus their proposed innovation in one or more of these key areas:

- Differentiated services and QoS support in dynamic wireless networks when safety-of-life and data flows critical to the mission are traversing the network.
- DTN prototype protocol development and demonstration in an emulated operational network.
- Secure data transfers over mobile, dynamic wireless networks with potential interferers and/or interceptors.
- Position determination and navigation based novel uses of the network infrastructure (e.g. utilizing radiometric information from the network signaling).

Proposal should address the following:

- Network traffic models
- Network architecture (both hardware and software)
- Spectrum usage
- Security plan (if the proposal deals with particular innovations in this area)
- Identification of software and/or hardware technologies common to networking components that will have the largest impact on size, weight, and power reduction while not compromising the goals of the network architecture as listed above.

Phase 1 Deliverables

A trade analysis identifying novel software and/or hardware technologies common to networking components that will have the largest impact on size, weight, and power reduction while not compromising the goals of the network architecture is the most important aspect of the Phase 1 deliverable. It is not reasonable to expect that all issues and technologies concerning the network architecture proposed will be developed under a Phase 2 contract. However, the proposer should identify and rank novel hardware/software components based on size/weight/power reduction that will enable the proposed network architecture. The proposer should also identify how they are uniquely qualified to develop the novel technologies to products beneficial to NASA, DoD, and perhaps commercial interests.

The Phase 1 proposal should clearly state the assumptions, proposed network architecture, and innovations regarding the 4 key areas mentioned above.

Phase 2 Deliverables

The novel software and/or hardware component identified in Phase 1 will be developed to a state in which it may be demonstrated and the feasibility of the approach on an actual platform may be quantitatively evaluated by NASA testing at the completion of the Phase 2 contract. (TRL 4 or better).

O1.09 Software for Space Communications Infrastructure Operations

Lead Center: JPL

Participating Center(s): 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 User'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.