NASA SBIR 2009 Phase I Solicitation

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.