With NASA now planning future sustained manned lunar outpost missions, the need is paramount for a reliable, robust, lightweight, and compact EVA software radio capable of achieving enhanced performance and efficiency on any of the following frequency bands of interest: UHF (401 - 402 Mhz, 25khz bandwidth), S-band (2.4 - 2.483 GHz), and Ka-band (22.55 - 23.55 GHz). Assume multi-point RF communications and simultaneous links to suit/vehicles at 10 km range and RF contingency voices at UHF half-duplex.

Due to menacing dust storms, frequency agility will be necessary during periods of disruptions. The programmable radio must support multiple bandwidths and data transmissions of telemetry, voice, and high-rate video. Assume bi-directional link and 20 Mbps maximum data rate. Solutions should include adaptive techniques to accommodate changing propagation and interference.

Small volume and low mass are always sought for human missions to enhance astronaut mobility on planetary surface. Operational scenarios dictate that EVA radios transmit audio, telemetry, and high-rate video to surface rovers, lander, and habitats, and other astronauts. Proposers must address EVA radio relay communications to surmount obscurations or poor line-of-sight to any surface nodes described above.

Pioneering astronauts exploring the surface of the Moon will also require a network enabling not only communications but precision relative navigation to keep these explorers abreast of their position relative to each other and lunar assets out to a maximum of 10 km.

NASA needs systems and technologies to provide an EVA crewmember with real-time navigation and position.
information while traversing on foot or in a rover. This system will be apt when the suited crewmember is traversing on foot and cannot rely on the rover system and markers for walk-back navigation. Because EVA radio is battery operated, power consumption should be minimized.

This solicitation seeks to develop a highly integrated multi-band multi-mode EVA adaptive intelligent programmable radio, a network that enables navigation between mobile and fixed communicating nodes, and required middleware technologies. Assume a stand-alone overlay or perhaps an embedded layer in a pre-existing, CDMA, OCDMA, ODFM, VOFDM or TDMA packet communication environment. In addition, EVA radio must dynamically and adaptively conserve power consumption on the fly packet-by-packet while maintaining interoperability among nodes.

Both communication and navigation functions of the network must assure 3D tracking and navigation accuracy, a BER of $10^{-8}$ or better, and graceful degradation. As a minimum, the proposed communications network concept must be capable of stand alone operation, independent of any other communication or navigation asset, and be capable of delivering high data rate or variable data rate digital communication ranging from voice to imagery transmissions while continually delivering bearing and pseudo-ranges between nodes within the network.

With ever-increasing versatility of the emerging programmable radios, NASA also needs a more potent approach to energy conservation - one that matches the QoS requirement, channel condition, and the interference environment to the most energy efficient operating point of the EVA radio. This requires an intelligent and/or cognitive middleware to draw QoS information from the application, plus channel and interference information from the PHY. Thus, the middleware identifies the unique PHY and MAC combinations that results in minimal energy operation.

As the number of modes delivered on the QoS increases, choosing the mode with the least energy profile must lead to substantial energy savings and battery life extension. The evolutionary use of Software Defined Radios and the emergence of technologies such as multi-antenna have resulted in radio systems that can easily support 1000s of unique modes. Coupled with the presence of heavy interference like dust storms and channel impairments, the minimal energy mode of operation must be identified. Proposed solutions must achieve energy consumption of 5x to 10x reduction in total power consumption, depending upon the richness of and diversity of modes available on the target radio. All software must be portable to any radio platform.

**Phase 1 Deliverables:**

Propose a robust multi-band miniaturized frequency-agile EVA software defined radio suitable for applications and bands. Address all technical MEMS challenges, pitfalls, and tradeoffs of EVA radio size, weight, 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. Special interests include single-chip design/packaging and RF MEMs technologies to realize compact radios under 5 lbs.

Develop suitable communication and navigation 3D tracking network system and algorithms capable of demonstrating the feasibility of the approach. Integrated communication and navigation solutions must include tracking, locating, identifying tagging assets with multiple routes over an operational range of 10 km - even if they descend in craters. Based on a minimum of three nodes, simulate the performance of the proposed integrated communications and navigation network architecture and conduct sensitivity analysis for the selected implementation strategy.

Develop the required middleware to properly characterize it in simulation. Achieve minimal power consumption by proper mode selection and perform demonstrated with five unique radio models including EVA. Conduct trades and identify the right set of required parameters for the ideal radio for such middleware. Quantify performance in terms of energy savings and the ability of the middleware to maximize connectivity and throughput in a mobile ad hoc network.

Phase 2 Deliverables:

Develop a EVA multi-band compact, lightweight, reconfigurable radio hardware prototype unit 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 with a minimum of 3 nodes using an active multi-node integrated communication and navigation network. Simulate and refine navigation and/or power software algorithms for real time robust operations and characterize system performance in compliance with the design goals outlined in Phase 1.