NASA’s Space Communications and Navigation Program (SCaN) is integrating its current agency networks: Deep Space Network (DSN), Space Network (SN), TDRSS spacecraft, Near Earth Network (NEN), and future Exploration Destination networks into a single Integrated Architecture circa 2018. Technologies must be adaptable to a variety of network operating environments ranging from the long-latency limited bandwidths of deep space communications to near Earth environments with traffic flow over global partner assets and the future internet. It is also important to note that NASA systems include ground-to-ground segments in addition to space-to-ground links. Solutions must keep in mind the “big picture” and be capable of seamlessly integrating with future ground systems.

Emerging space communications environments are expected to be shaped in various ways: small mobile mission clusters; traditional large spacecraft and launch vehicles; complexities of commercial and international partnering on the network and user sides; increasing threats to US space communications and navigation assets; and NASA’s need for 40% reduction in network operating costs.

NASA seeks space-networking technologies, which add network intelligence and learning capabilities to increase network efficiency; provide tailored user services; reduce network operating costs through automation; and increase security and resiliency.

Several technologies with promise to meet some of these challenges are listed below with their purpose current state-of–art, and performance metrics desired. Proposals should focus on one or two of these technologies, or for the more complex topics, single implementation aspects.

- **Dynamic traffic prioritization** provides a means to quickly isolate different types of traffic schemes across the space network. Current technologies allow for such features in the ground environment and the study should leverage those techniques as appropriate. The proposed approach should identify what is necessary for prioritization to be leveraged across multiple space organizations. It should also identify how decisions may impact the performance of different types of data streams.

- **Adaptive autonomous network management** is to enable smart network elements to make decisions within a predetermined playbook based upon awareness of local network conditions, policies and network end-to-end-objectives. Examples such as automated uplink/downlink scheduling have been demonstrated and are in operational use in limited circumstances. The concept is to shorten the time between a particular network anomaly and the resulting response by mission control allowing for more efficient utilization of the network. Studies must show how the shortened control loop yields better efficiency and how both conditions and automated responses are relayed back to a human operator.

- **Cognitive networking with learning** is to enable intelligent network elements to reason about reconfiguration decisions [at any layer in the protocol stack] even in unexpected conditions [whether to make decisions autonomously or to offer quantitative support to human operators] based upon situational awareness of
network conditions and statistical learning about network behavior and consequences of prior interventions. Software defined and cognitive radios have been demonstrated for terrestrial use and are progressing towards broader cognitive network applications with limited and specific terrestrial demonstrations. Cognitive networking with learning is currently at the forefront of the state-of-the-art, with a multiplicity of approaches being developed for diverse applications such as Future Internet, mobile wireless, and tactical communications. Bidders are encouraged to narrow their focus to specific implementation issues in the domain and focus on adaptation for SCaN space networks. Desired performance metrics are relevant analytical estimates of potential benefits and feature cost-benefit.

- Enhanced security and trust management services for missions that have limited computational and power resources. Contact should not be assumed to be continuous and approaches should leverage proven security techniques where appropriate and provide a means to authenticate between assets and to provide a means to securely update network information (i.e. route injection). It will be important to identify how the proposed approach mitigates particular security risks while also remaining efficient in the space environment.

- Novel techniques for position determination, timing, and route computation are to provide essential services for missions that venture beyond GPS coverage and SCaN infrastructure particularly for missions limited in equipage they can carry or in the face of intentional service disruption. Human missions develop positional uncertainty at a rate of 10 km/hr due to random accelerations. Early lunar missions like LRO are without timing service. Route computation requirements emerge with formation flight, delta-V sensitive libration point and planetary highway orbits, and robotic surface exploration. [Metrics: convergence time, overhead (number of bytes used by routing algorithm to reach steady state)].

For more information on NASA's future space communication plans, please see the Space Communications and Navigation website at https://www.spacecomm.nasa.gov/

Performance metrics are listed by technology above.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path towards Phase II hardware/software demonstration with delivery of a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Phase I report will analytically demonstrate technical feasibility of one or more space networking technologies identified above by characterizing:

- Technical requirements flow-down from generic objectives and summary of state-of-the-art to SCaN network-specific requirements on key performance metrics
- Identification of specific technical challenges to implementation for SCaN networks.
- Analysis of at least three alternative approaches to obtain this performance for SCaN networks.
- Assessment of cost-benefit of each (e.g. risk, complexity, added overhead)
- Selection of software or hardware concept and emphasis topics for further investigation.
- Plan for Phase II resolution of issues or uncertainties and hardware and software demonstration.
- Target TRL 3 at the end of Phase I efforts.

Phase II Deliverables: Phase II report will document:

- Updates to the technical requirements flow-down, identified technical challenges, and selected hardware or software concept based upon further investigation in Phase II.
- Analytical or experimental investigations undertaken to resolve issues and further definition of the selected approach.
- Design and test approach selected for hardware or software demonstration with detailed description of assumptions and parameters.
- Conclusions based upon test results and recommendations for further investigation including any plans for commercialization or further development.
- Target TRL of 5 at the end of Phase II efforts.