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

In the future, spacecraft with increasingly capable instruments producing large quantities of data will be visiting the Moon and the planets. These spacecraft will also support long term missions, such as to the outer planets, or extended missions with new objectives. They will possess reconfigurable avionics and communication subsystems and will be designed to require less intervention from earth during periods of low activity. The communication needs of these missions motivate higher data rate capabilities on the uplink and downlink as well as more reliable RF and timing subsystems. Innovative long-range telecommunications technologies that maximize power efficiency, reliability, receiver capability, transmitted power and data rate, while minimizing size, mass and DC power consumption are required. The current state-of-the-art in long-range RF space telecommunications is 6 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%.

Technologies of interest:

This subtopic seeks innovative technologies in the following areas:

- Ultra-small, light-weight, low-cost, low-power, modular deep-space transceivers, transponders and components, incorporating MMICs, MEMs and Bi-CMOS circuits.

- MMIC modulators with drivers to provide a wide range of linear phase modulation (greater than 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 DC-to-RF-efficiency (> 60%), low mass 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 and/or wide band-gap semiconductors at X-band (8.4 GHz) and Ka-band (26 GHz, 32 GHz and 38 GHz).

- Utilization of nano-materials and/or other novel materials and techniques for improving the power efficiency or reducing the mass and cost of reliable vacuum electronics amplifier components (e.g., TWTAs and Klystrons).

- Ultra low-noise amplifiers (MMICs or hybrid, uncooled) for RF front-ends (High dynamic range (> 65 dB), data rate receivers (> 20 Mbps) supporting BPSK/QPSK modulations.
• MEMS-based integrated RF subsystems that reduce the size and mass of space transceivers and transponders. Frequencies of interest include UHF, X- and Ka-Band. Of particular interest is Ka-band from 25.5 - 27 GHz and 31.5 - 34 GHz.

• Novel approaches to mitigate RF component susceptibility to radiation and EMI effects.

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 - Feasibility study, including simulations and measurements, proving the proposed approach to develop a given product (TRL 3-4). Verification matrix of measurements to be performed at the end of Phase II, along with specific quantitative pass-fail ranges for each quantity listed.

Phase II Deliverables - Working engineering model of proposed product, along with full report of development and measurements, including populated verification matrix from Phase I (TRL 5-6). Opportunities and plans should also be identified and summarized for potential commercialization.

Potential NASA Customers include:

• Deep Space Planetary Missions such as Mars 2018, Mars Sample Return, Jupiter Outer Planet Missions.

• Human Space Exploration Missions such as missions to Asteroids, Mars or various Earth-Moon Libration Waypoints.