Form 442 Question 7: Experimentation Description

If all the answers to Items 4, 5, 6 are "NO", include as an exhibit a narrative statement describing in detail the following items:
a. The complete program of research and experimentation proposed including description of equipment and theory of operation.
b. The specific objectives sought to be accomplished.
c. How the program of experimentation has a reasonable promise of contribution to the development, extension, expansion or utilization of the radio art, or is along a line not already investigated.

The team is engaged in the NASA CubeQuest Challenge, a NASA Centennial Challenge. The nature of this challenge is to prove navigation to either Lunar orbit or deep space (at least 4 million kilometers from Earth) and establish communications directly to Earth without the use of relays from a 6U CubeSat.

To accomplish this mission, the team intends to navigate to deep space while transmitting data packets from the onboard communications system to the NASA Near Earth Network (NEN) using S-band.

Launching from Cape Canaveral, the NASA Space Launch System mission SLS-EM1 is testing the Orion Manned Module as the primary mission and launching 6U CubeSats as part of its secondary mission.

The craft performs system checks and orients itself favorably for solar power and communications. It remains in this mode until day 4 of the SLS mission, slightly less than 3 days from deployment. During this 3 day period, the craft transmits continuously executing a 0.7 degree/second roll that ensures its antenna is not continuously pointed at Earth.

At SLS day 4, or deployment +3d, the craft begins 60 days of orbit change maneuvers, ending at SLS day 64, or deployment +63d. During this phase of operations, the craft spends a continuous 12 hour block each day transmitting while continuing to execute a 0.7 degree/second roll that ensures the antenna is not continuously pointed at Earth.

From that point forward, the craft orients itself favorably for solar power and communications (the same pose and logic used after deployment), where it remains communicating until SLS day 360, or deployment +359d. During this phase of operations, the craft transmits continuously with a 0.7 degree/second roll. At the end of this phase, the craft drains all potential energy from the electrical system and shuts down in a stable helio-centric orbit between Earth and Mars.

Communications will be accomplished using the following equipment.

Item Name	Item Description	Quantity	Manufacturer	Part/Model Nbr
S-Band Transceiver	Radio - Ettus USRP B200mini	1	Ettus	784415-01
Transceiver case	Steel thermal shroud	1	Ettus	785280-01
Receive Antenna	Antenna - PCL Nomex, 60 degree half power beam width	1	Printech Circuit Laboratories Ltd	Nomex
Transmit Antenna	Antenna - PCL Nomex, 60 degree half power beam width	1	Printech Circuit Laboratories Ltd	Nomex
Low Noise Amplifier	LNA - MiniCircuits	1	MiniCircuits	ZX60-P33ULN+
5W Power Amplifier	PA - WENTEQ	1	WENTEQ	AHP0230-09-3537
Reference	10 MHz Reference Oscillator, 25 ppb	1	Bliley	LP62AAAABA1M0

Table 1 CubeSat Transmitter Equipment

Onboard the spacecraft, a software defined radio (SDR) from Ettus transmits using a 5W amplifier from Wenteq and a 9dBi, 60 degree HPBW patch antenna from Printech Circuit Laboratories. The transmit frequency is stabilized by tying the SDR's external clock to a Bliley 10MHz reference oscillator with 25ppm frequency stability. The transmit power is fixed and cannot be varied, aside from ceasing transmission.

The craft uses a separate antenna for receiving commands. This is an 8dBi, 60 degree HPBW patch antenna from Printech. It is connected to a LNA amplifier from MiniCircuits. The Ettus SDR radio has an input for the received data, separate from the transmit circuit.

Team Miles will utilize the NASA NEN to receive the data from the spacecraft. The following two NEN antennas will be utilized.

NASA Near Earth Network
WG1 Dish
Wallops Island, VA

NASA Near Earth Network
WS1 Dish
White Sands, NM

This mission will demonstrate unprecedented communications ability from deep space for a craft of this size. NASA has, and continues to, communicate with probes at far greater distances. However, these probes (e.g. Voyager) mass about 1000 kg and broadcast at much higher power levels. The CubeSat we are testing measures merely 60x20x30 cm with a total mass of 14 kg. Demonstrating navigation and communications in this diminutive form factor opens the doors to space exploration and science payloads that cost substantially less than currently available options making such exploration cost effective and spurring new missions that were not previously practical.