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 Deep Space Network (DSN) using S-band.

Launching from Cape Canaveral in early 2018, the NASA Space Launch System mission SLS-EM1 is testing the Orion Manned Module as the primary mission and launching a number of 6U CubeSats as part of its secondary mission. The Team Miles craft is deployed from SLS when 411,900 km from Earth, at 7 days 0 hrs 16 minutes into the flight. Prior to this point, the craft has no electrical power and is incapable of transmission.

The craft performs system checks and orients itself favorably for solar power and communications. It remains in this mode until day 10 of the SLS mission, slightly less than 3 days from deployment. During this 3 day period, the craft transmits continuously at 6000 bits per second, executing a 0.7 degree/second roll that ensures its antenna is not continuously pointed at Earth.

At SLS day 10, or deployment +3d, the craft begins 60 days of orbit change maneuvers, ending at SLS day 70, or deployment +63d. During this phase of operations, the craft spends a continuous 4 hour block each day transmitting at 6000 bits per second, again executing at 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 (actually the same pose and logic used after deployment), where it remains communicating until SLS day 200, or deployment +193d. During this phase of operations, the craft transmits continuously at 210 baud 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 DSN to receive the data from the spacecraft. The following 3 DSN locations will be utilizing a 70m dish, at a minimum 30-degree elevation:

Ground Station Goldstone Station
Latitude: 35.60439774042807
Longitude: 243.112670216
Location: Mohave Desert, Barstow, California. USA

Ground Station Madrid Station
Latitude: 40.61895079468376
Longitude: 355.750833
Location: Madrid, Spain

Ground Station Canberra Station
Latitude: -35.58308544261114
Longitude: 148.981667
Location: Canberra, Australia

These 70m dishes receive data with 3dB link margin (at the edge of the craft's half power beam width) for the craft at 46 million km.

The same DSN locations can transmit to the spacecraft, using either 34m or 70m dishes at 200W transmit power, with a roughly 13dB link margin for craft commanding. The spacecraft accepts commands to temporarily or permanently halt transmissions.

A backup receive-only Ground Station is provided by ATLAS, located in Ghana. This Ground Station is part of their NOAA implementation.

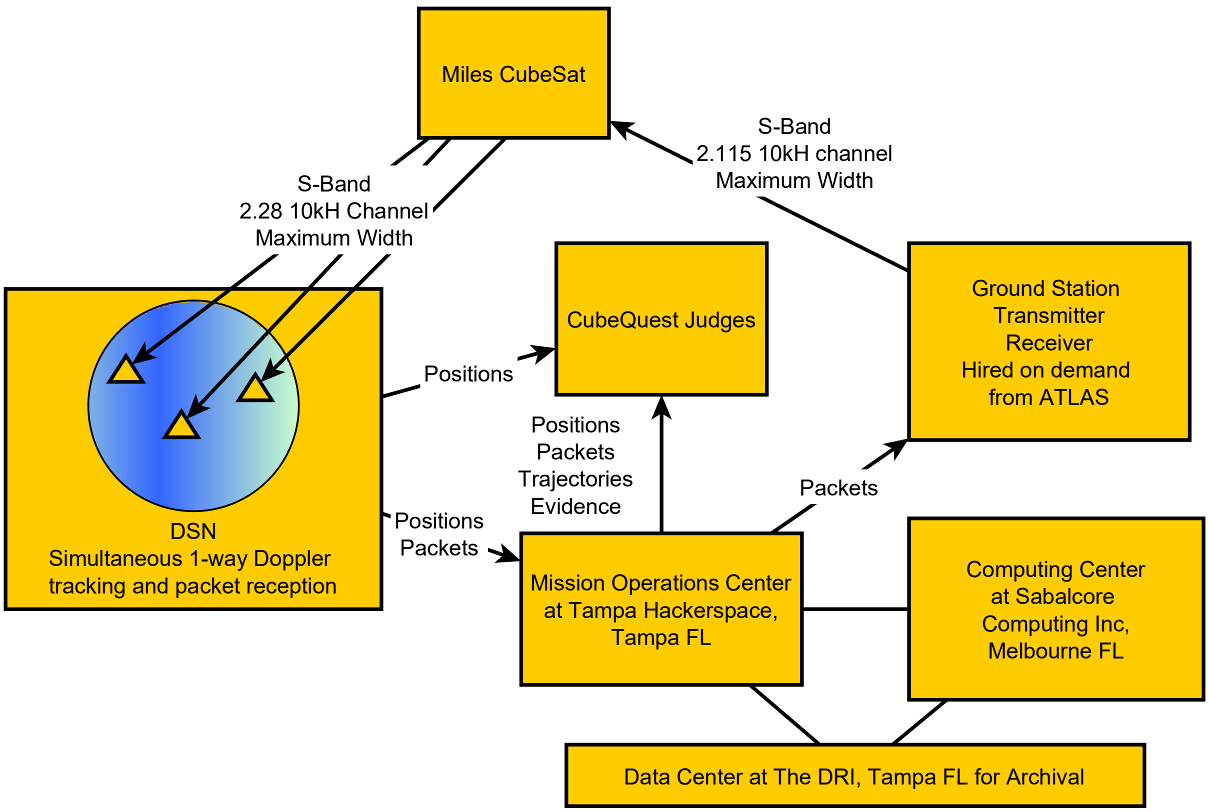

Table 2 Ground Systems Diagram

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.