Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Tyvak Nano-Satellite Systems Inc.	)	
	)	
Application for Authority for Ground	)	
Testing, Launch, and Operation of	)	File No. 0987-EX-PL-2018
Experimental Non-Geostationary	)	
Low Earth Orbit Satellites	)	

NARRATIVE EXHIBIT

Table of Contents

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Tyvak Nano-Satellite Systems Inc.	)	
	)	File No. 0987-EX-PL-2018
Application for Authority for Ground Testing, Launch, and Operation of Experimental Non-Geostationary Low Earth Orbit Satellites	))))	

NARRATIVE EXHIBIT

Tyvak Nano-Satellite Systems Inc. ("Tyvak") provides nano-satellite, micro-satellite, and CubeSat space vehicle products and services that target advanced state-of-the-art capabilities for government and commercial customers to support operationally and scientifically relevant missions. With this Application, Tyvak requests two-year authority for operation of an experimental non-geostationary ("NGSO") low earth orbit ("LEO") CubeSat satellite referred to as Tyvak-0129. The RF communications links for the satellite will be two-way telemetry monitoring and command ("T&C") transmissions in the 400 MHz UHF range and space-to-Earth downlink transmissions in the 2 GHz S-band range.

I. NARRATIVE INFORMATION REQUIRED BY FCC FORM 442

Question 6A. Description of the Nature of the Research Project Being Conducted

Through the Tyvak-0129 satellite, Tyvak validates the spacecraft bus technologies needed to support the development of the Pathfinder experimental flight vehicle being built by Tyvak in cooperation with NASA. The NASA Pathfinder program leverages the inherent low costs of

CubeSat vehicle manufacture and launch capabilities to host experimental payloads (from payload vendors selected by NASA) for testing, flight training and on-orbit demonstrations.

Tyvak-0129 seeks to gather in-flight data for the bus hardware platform as a risk reduction prior to the NASA Pathfinder mission. The Tyvak-0129 bus platform includes the next generation of Tyvak power, communication, GNC and on-board processing subsystems and will be identical in form, fit and function to the bus used on NASA Pathfinder. Subsequently, Tyvak-0129 will serve as a flight demonstration to reduce risk and provide flight heritage to the bus platform prior to the launch of the NASA Pathfinder experimental missions later in 2019.

The NASA Pathfinder spectrum application has already been filed and an NTIA Certification of Spectrum Support has already been granted (NTIA Document 43771/1 SPS-23289/1). As such, Tyvak-0129 seeks to use the same UHF/S-band spacecraft configuration and the same UHF/S-band ground assets to enrich the level of risk-reduction provided to NASA Pathfinder.

In addition, Tyvak-0129 will host two experimental payloads to increase their technology readiness level and gather valuable flight test data. The two payloads are an electric propulsion system developed by Accion Systems Inc ("Accion") and a receive-only radio system developed by the Lockheed Martin Corporation ("LM"). Both payloads are only powered by Tyvak-0129 and rely on the spacecraft bus to downlink all flight telemetry to ground assets.

The satellites will adhere to a design specification co-developed by California State University, San Luis Obispo ("Cal Poly") and Stanford University ("Stanford") referred to as the CubeSat Standard. Additional information regarding the CubeSat Standard can be found at the CubeSat Community website, http://www.CubeSat.org/.

The spacecrafts will be fabricated, tested, launched, and operated by Tyvak using its Mission Operations Center ("MOC") in Irvine, California, and using affiliated Earth stations in the Continental United States (CONUS) and internationally. T&C for the satellites will be carried out by Tyvak via a two-way link in the UHF band with Telemetry between 400.15-401 MHz and Command between 401 to 402MHz. Both payloads will relay test instrument data via the spacecraft bus communication system to Tyvak-affiliated Earth stations using spectrum in the S-band between 2200-2290 MHz. Additionally, the LM payload will have receive-only communications capability separate from the T&C communications system to gather experimental operations data. LM has separately filed for ground station licensing under FCC File No. 0843-EX-CN-2018 to communicate from LM ground assets to their payload hosted on Tyvak-0129.

The Tyvak-0129 satellite will be launched into orbit on April 2018 on a PSLV from Sriharikota, India. The satellite is anticipated to perform operations for approximately 2 years. The Tyvak-0129 satellite requests authority through the FCC to grant ground communication authority to the satellite through CONUS ground stations.

Question 6B. Showing that the Communications Facilities Requested are Necessary for the Research Project

The primary purpose of Tyvak's CubeSat program is to test and demonstrate new satellite capabilities or subsystems. On-orbit operation is the only effective way of collecting functional and performance data in the relevant operational environment and cannot be adequately substituted by ground testing or computer simulation.

With the proliferation of the CubeSat Standard and the availability of low-cost space access for those adhering to that standard, the cost to test miniature components on-orbit has become relatively inexpensive compared to equivalent ground testing and simulation. This is largely due to the availability of low-cost secondary payload launch options and cost sharing among multiple CubeSat developers.

In addition, on-orbit data provides confidence to customers that future systems will operate successfully on-orbit through maneuvers. The evaluation of hardware and software in an environment similar to that found in space is not easily replicated on Earth. On-orbit component failures are often attributed to unforeseen conditions or coupling of effects that cannot be tested adequately until on-orbit. Consequently, the use of an on-orbit test bed provides significant direct and indirect financial benefits, as well as risk reduction for future satellite programs.

Question 6C. Showing that Existing Communications Facilities are Inadequate

The ground stations that would be used for operations are established for T&C operations within the 400-402 MHz UHF band.

For the payload downlink in the 2,200-2,290 MHz S-band, the payload data must be downlinked directly from the satellites to pre-existing KSAT Earth stations using these frequencies and thus no alternative existing facilities will be adequate.

Question 10. Transmitting Equipment to be Installed, Including Manufacturer, Model Number and Whether the Equipment is Experimental in Nature

Each of the CubeSats has capabilities for T&C and payload downlink. Spacecraft telemetry downlink is carried out in the UHF band between 400.15-401 MHz and uplink commands are handled in the UHF band between 401-402MHz. Payload downlink is carried out through an S-band transmitter in the range of 2200-2900 MHz. The following graphic provides an overview of the transmitting and receiving components of each element. The specific model numbers are subject to change based on product availability and system upgrades.

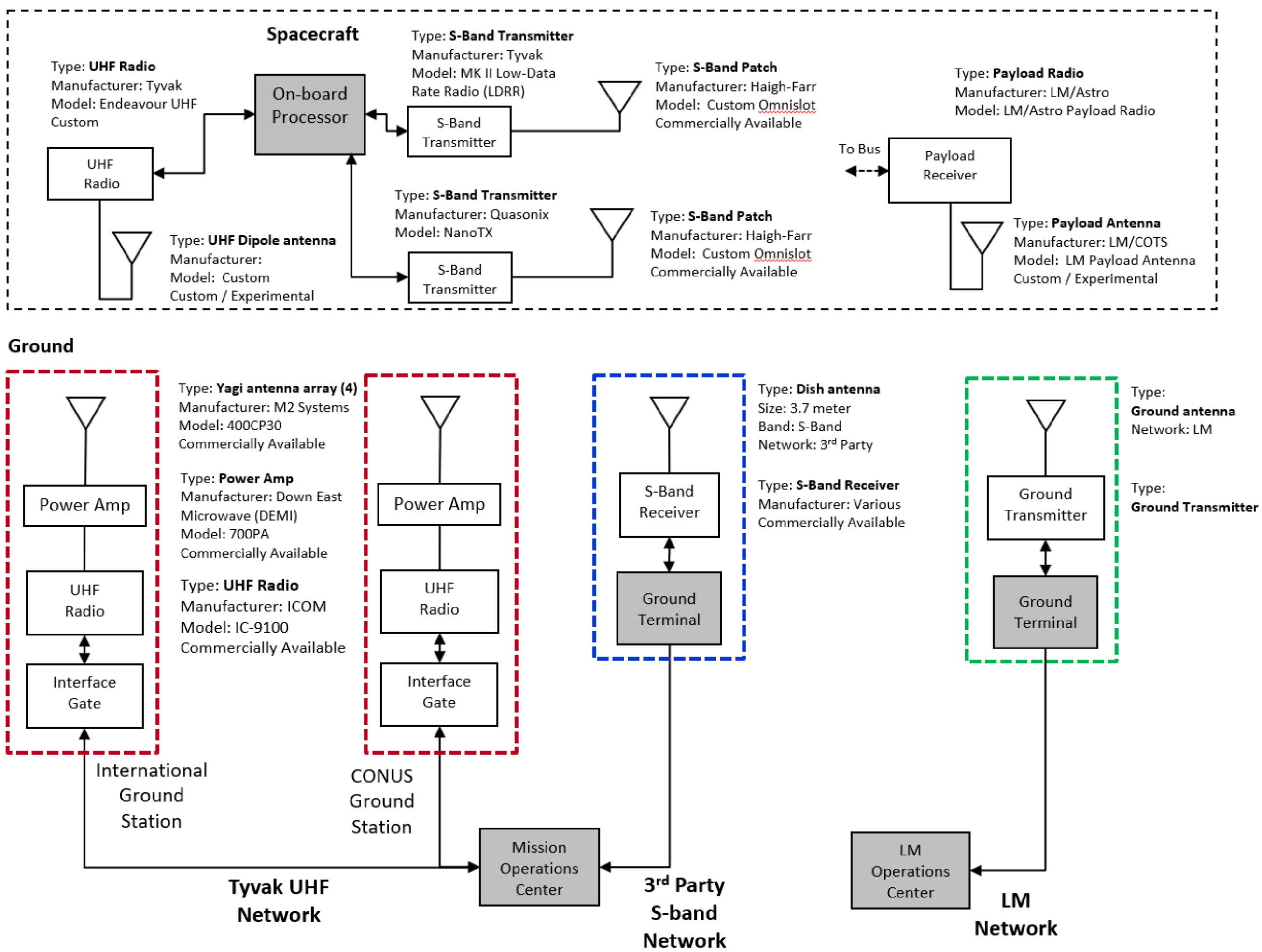

Figure 1: Mission Communication Systems Components

The transmitting components aboard the CubeSats are controlled by a dedicated on-board processor, which processes data for transmission, sends and receives data from the modem, and activates the appropriate radio systems depending on the state of operations. Each vehicle possesses a UHF system for vehicle command and telemetry retrieval and an S-band system for payload data download.

The T&C communications system uses a Tyvak-developed UHF radio derived from commercially-available UHF communications systems. The radio operates at 19,200 baud using GMSK. Tyvak-0129 will be the first flight experimental demonstration of the Tyvak-developed

UHF radio and will be baselined for use in many of Tyvak's future programs. The UHF system will use a custom designed half-wave dipole antenna.

The payload downlink S-band system utilizes an experimental Tyvak-developed S-band radio and a patch antenna developed by Haigh-Farr. Similar to the UHF radio, Tyvak-0129 will be the maiden flight of the Tyvak-developed S-band radio and serve as an on-orbit experimental demonstration of its performance. In addition, a commercial off-the-shelf Quasonix transmitter will also be used as a secondary S-band downlink and use an identical but independent Haigh-Farr patch antenna. As both S-band radios use the same center frequency and bandwidth allocation, they are not intended to be operated simultaneously.

S-Band transmissions are completed with blind downlinks and the vehicle does not transmit S-Band unless commanded by the ground to enable based on the ground station's GPS location or via absolute time. A 2 Mbps BPSK data rate is supported between the S-Band patch antenna to a 3.7m dish on the ground with a transmit power of 2W. The antenna is RHCP with a gain greater than 5dBic at the boresight with a VSWR < 2:1. The Tyvak S-band radio is also capable of operating in GMSK modulation.

Question 11A. Is the Equipment Listed in Item 10 Capable of Station Identification Pursuant to Section 5.115

Each transmitting component of the system is capable of station identification at the end of each complete transmission. The station identification process is incorporated into the mission operations procedure. The ground component will broadcast in clear voice the assigned call sign at the end of each data transmission by ground station operators.

Question 4: Antenna Registration Form; Operation of Directional Antenna

Tyvak-0129 will be a low earth orbit ("LEO") satellite in a 500km sun-synchronous orbit with an orbit period of approximately 1.6 hours. The satellite will pass over the Earth station roughly one to twelve times per day depending on its location with an average access time of five to nine minutes for each Earth station location. The UHF Earth station will use a computer-controlled tracking antenna to point the Earth station's antenna in the direction of the moving satellites. The antenna has a maximum gain of +20.2dBi along the bore-sight of the antenna and a half-power beam-width (*i.e.*, -3dB) of approximately 30 degrees. The antenna array uses four off-the-shelf, Yagi-type antennae developed by M2 Antenna Systems, Inc.

Tyvak-0129 is a NGSO satellite, thus the range of antenna azimuth and elevation will vary based on the relative motion of the satellite with respect to the ground station. It will also differ for each satellite pass. The Earth station will only transmit above the horizon. Consequently, the range of antenna elevation angles for all satellite passes will be between 0 and 180 degrees. The azimuth can vary between 0 degrees and 360 degrees.

In addition to on-orbit operations, the satellite components will undergo developmental testing at Tyvak's Irvine, CA facility beginning in December of 2018. Testing for the UHF TT&C link will be conducted in carrier current (*i.e.*, closed-loop) configuration and will produce only unintentional emissions. Under the Commission's rules, unintentional radiators operating in the frequency range between 9 kHz to 30 MHz must comply with the radiated emission limits for intentional radiators as provided in 47 C.F.R. § 15.209.[1] As Tyvak's test program may marginally exceed these limits, Tyvak seeks experimental authority for emissions in the appropriate ranges at the Tyvak facility. These developmental tests are expected to begin in December 2018.

[1] 47 C.F.R. § 15.109(e).

II. RELEVANT INFORMATION ADDRESSED IN SECTION 25.114 OF THE COMMISSION'S RULES

Section 25.114(c)(4)(i) Radio Frequency Plan

<u>UHF Communications System</u>

Tyvak-0129's UHF communications system will operate using half-duplex communications within the 401-402 MHz frequency band for telecommand (*i.e.*, earth-to-space) and 400.15-401 MHz frequency band for telemetry (*i.e.*, space-to-earth) communications. Tyvak-0129 is performing Earth Exploration payload technology demonstrations and thus the use/categorization of the telecommand (*i.e.*, earth-to-space) communications as an earth exploration satellite is justified in both the US and international allocation for the 401-402 MHz range. Similarly, Tyvak-0129 is utilizing UHF for vehicle telemetry downlink and thus the use/categorization of the telemetry (*i.e.*, space-to-earth) communications as space operation (space-to-earth) is justified in both the US and international allocation for the 400.15-401 MHz range. The space vehicle UHF communication system is half-duplex and, as such, the similar UHF center frequency for both telecommand and telemetry poses no operational concern.

Space-to-Earth and Earth-to-Space UHF Communications

Tyvak-0129 have been designed to include several precautions to prevent harmful interference to other services from space-to-Earth transmissions. First, as noted above, space-to-Earth satellite transmissions will be controlled from the Earth station and the spacecraft will not transmit until it receives a request from the Earth station.

Second, the satellite uplink and downlink will use the same 28.8 kHz bandwidth in half-duplex mode to send digital data using standard GMSK modulation with maximum data rates up to 19,200 baud.

The satellite transmitter can be adjusted to provide up to two watts of power output when communicating with the Earth station. Transmission power on the Earth station transmitter can be adjusted to provide up to 200 watts of power output. The communications parameters for the UHF communications system for the space-to-Earth and Earth-to-space links are shown in the following tables.

CubeSat Communications Parameters	**Value**
Emission Designator	28K8G1D
Service	Digital Data
Center Frequency	400.74 MHz
Requested Bandwidth (includes Doppler)	28.8 kHz
Modulation	GMSK
Data Rate	19,200 bps
Polarization	Linear (Results in RHCP)
Antenna Type	Dipole
Antenna Gain	0 dBi (Max)
RF Power Output	2W
Line/Misc Losses	-2dB
EIRP	1.0 dBW

Table 1: Tyvak-0129 UHF Communications Space-to-Ground Parameters

Earth Station Communications Parameters	**Value**
Emission Designator	28K8G1D
Service	Digital Data
Center Frequency	401.205 MHz
Requested Bandwidth (includes Doppler)	28.8 kHz
Modulation	GMSK
Data Rate	19,200 bps
Polarization	Linear (H, V) or Circular
Antenna Type	Yagi array
Antenna Gain	+20.2 dBi (Max)
RF Power Output	200 W
Line Losses	-3dB
EIRP	40.2 dBW

Table 2: Tyvak Earth Station UHF Communications Parameters

Earth Station	Frequency Range	Geographic Coordinates
San Diego, CA, USA	UHF	32.897°Lat, -117.201°Long
Bardufoss, Norway	UHF	69.05°Lat, 18.48°Long
Benevento, Italy	UHF	41.115°Lat, 14.826°Long
Fairbanks, AK, USA	UHF	64.85°Lat, -147.68°Long

Table 3: Tyvak Earth Stations UHF

S-Band Communications System

The spacecraft's S-band communications system will operate using simplex communications within the 2200-2290 MHz frequency band to downlink recorded payload data to Tyvak-affiliated S-band Earth stations. The Tyvak UHF Earth station at the Irvine MOC or Tyvak-affiliated UHF stations at other locations will issue commands in the UHF-band to trigger the satellite to transmit payload data in the S-band when over an S-Band KSAT site. The Tyvak MOC will have no transmission or reception capabilities in the S-band.

CubeSat Communications Parameters	Value
Emission Designator	2M80G1D
Service	Digital Data
Center Frequency	2235 MHz
Requested Bandwidth	2.8 MHz
Modulation	BPSK (Capable of GMSK)
Data Rate	2 Mbps
Polarization	RHCP
Antenna Type	Patch
Antenna Gain	+2 dBic (Max)
RF Power Output	2W
Line Losses	-2dB
EIRP	3 dBW

Table 4: Tyvak CubeSat S-Band Communications Parameters

Earth Station	Frequency Range	Geographic Coordinates
Svalbard, Norway	S-Band	78.23°Lat, 15.39°Long

Table 5: Tyvak Earth Stations S-Band

The CubeSats will communicate with the UHF ground stations and S-band ground stations only when they are within line-of-sight of the Earth stations and have received a communication from the Earth station directing the spacecraft to initiate transmissions. Consequently, the spacecrafts will utilize the 401-402 MHz and 2200-2290 MHz band only when in contact with specified Earth stations and potentially conflicting uses of the band in other regions of the world are not relevant to this application.

Spectrum Sharing and Interference Mitigation Techniques

The S-band communications system employs multiple design considerations that make it highly unlikely that harmful interference could result to any other satellite network. These include low-altitude, near-polar orbits and the use of short-duration, narrow bandwidth transmissions.

Sharing With Low Earth Orbit Satellite Networks: The Tyvak network is highly unlikely to cause unacceptable interference to other low-altitude satellite networks. First, transmissions from Tyvak spacecraft will be infrequent and of short duration, triggered only by affirmative command from the Tyvak MOC. Second, conjunction events in which a Tyvak satellite and another low-altitude satellite are relatively close to each other will occur very infrequently. When such rare conjunction events do occur, there will still be no potential for interference unless both satellite systems are transmitting at the same time, which would only happen when a Tyvak-affiliated earth station is in close geographic proximity to the earth station of another network. Given the international allocation for EESS across the entire 2200-2290 MHz band, other NGSO satellites operating in proximity to any Tyvak satellites are highly likely to follow similar interference mitigation procedures as those outlined above, resulting in high confidence that Tyvak operations will not cause unacceptable interference to other low-altitude satellite networks.

Sharing With Geostationary Satellite Networks: The Tyvak network is highly unlikely to cause unacceptable interference with geostationary ("GSO") or other high-altitude satellite networks. The 2200-2290 MHz band is not significantly used by GSO satellite networks. Further, the Tyvak network will utilize the 2200-2290 MHz band only in the space-to-Earth direction, preventing any potential interference toward the geostationary arc. With respect to space-to-Earth transmissions from GSO spacecraft using the 2200-2290 MHz band, these will be protected from harmful interference from the Tyvak satellite transmissions in the same manner as Tyvak will protect space-to-Earth transmissions from low Earth orbit NGSO networks, as discussed above.

Sharing With Fixed Service Networks: The Tyvak network operates in compliance with the ITU power limits specified to protect the Fixed Service operating in the 2200-2290 MHz band. Table 21-4 of ITU Radio Regulation number 21.16 specifies the following PFD limits at the Earth's surface for emissions from EESS space stations operating in the 2200-2290 MHz band for all conditions and for all methods of modulation.

Frequency band	**Service***	**Limit in dB(W/m²) for angles of arrival (δ) above the horizontal plane**			**Reference bandwidth**
		0°-5°	**5°-25°**	**25°-90°**	
2 200- 2 300 MHz	Earth exploration-satellite (space-to-Earth)	−154	$-154 + 0.5(\delta - 5)$	−144	4 kHz

When calculated at the minimum anticipated operating orbital altitude for the Tyvak-0129 of 450 kilometers, the PFD levels at the Earth's surface produced by the Tyvak satellite data and telemetry downlink transmissions will comply with these limits.

Section 25.114(c)(5)(i) Orbital Locations

Tyvak-0129 will be operating in LEO with the orbit parameters shown in Table 6. Each satellite will have an orbit period of roughly 1.6 hours with typical ground access times of five to seven minutes per pass. The orbit parameters are presented in the following table:

Spacecraft	Parameter	Units	Value
Tyvak-0129	Orbit Period	hrs	1.6 hrs
	Orbit Altitude	km	500 km (circular)
	Inclination	deg	98 degrees

Table 6: CubeSat Orbit Parameters

Section 25.114(c)(10) Physical Characteristics of Satellites

The Tyvak-0129 space vehicle is a nano-class satellite (< 14 kg), in which each element conforms to the CubeSat Standard. CubeSats can be designed in different sizes as long as they are multiples of the basic CubeSat standard unit, which is 10×10×10 centimeters, generally referred to as a 1U CubeSat, meaning one unit in size. Tyvak-0129 is 6U in size, which means each CubeSat will have the dimensions of approximately 30×20×10 centimeters or 30 x 20 x 10cm. The CubeSat dispenser limits the total vehicle mass of a 6U CubeSat to less than 14 kg respectively. The Tyvak-0129 vehicle has been designed primarily as a single-string system using commercial off-the-shelf parts with a mission lifetime of approximately two years on-orbit. The mass budget is identical for each satellite and is provided in the following table:

Component / Subsystem	Mass [g] 6U
Payload	3000
Spacecraft (Subtotal)	9200
Structure	2500
Electrical Power System	3150
ADCS	2000
C&DH	700
Communication	450
Harnessing	300

Component / Subsystem	Mass [g] 6U
Thermal	100
TOTAL	12200

Table 8: Spacecraft Mass Budget per Element

For power generation, Tyvak-0129 is equipped with a single-axis sun-tracking drive assembly securing two deployable solar array wings that generate approximately 61 watts of power during a typical orbit. Because of the short operational lifetime of the satellite (*i.e.*, approximately two years), the difference between the beginning-of-life ("BOL") and end-of-life ("EOL") power generation is negligible. To permit operations during eclipse, energy is stored on-board using Li-ion batteries, with power being distributed to subsystems and components through the electrical power subsystem circuitry. The EOL power budget is provided in the following table:

Component / Subsystem	EOL Power [mW] Orbit Averaged (6U)
LM Payload	20000
Accion Payload	12000
Spacecraft (Subtotal)	23000
Power Subsystem	1000
ADCS	7000
C&DH	7000
Communication	7500
Thermal/Sensors	500
TOTAL	55000

Table 9: Power Budget per Space Vehicle

Section 25.114(c)(12) Schedule

The project timeline and major milestones for the launch and operation of the Tyvak-0129 are provided in the following table. The dates are approximate and contingent upon the exact launch date ("Time of Launch" or "ToL"), orbit parameters, and unforeseen events during on-orbit operations.

Milestone	Date	Notes

Launch	February 2019	ToL + 0
Release from launch adapter	February 2019	ToL + 0hr 30min
On-orbit check	February 2019	ToL + 24 hours
Start of experiments	March 2019	ToL + 4 weeks
Decommissioning	February 2021	ToL + 24 months
Re-entry	February 2022	ToL + 3 years

Table 10: Tyvak-0129 Major Milestones

Section 25.114(d)(1) General Description of Overall System Facilities, Operations and Services

The Tyvak-0129 space vehicle provides a platform for flight performance evaluation of the bus avionics suite and on-orbit technology demonstration of the two experimental payloads: the low-thrust electric propulsion system from Accion and the RF receiver system from LM. The onboard systems on each space vehicle provide nominal attitude, electrical power, data storage, and command function for both mission payloads. The space vehicles communicate with the Earth stations through a low-rate (19.2 kbps) half-duplex communications link operating in the UHF band.

The spacecraft will be supported by a UHF Earth station at the Irvine MOC and several additional Earth stations operated by Tyvak affiliates at sites in Deadhorse, Alaska; Bardufoss, Norway; Benevento, Italy; and San Diego, California. S-band Earth stations will be located in Svalbard, Norway. The S-band Earth stations will be operated under contract by third-party S-band network providers.

The primary responsibilities of the Irvine MOC will be to command the space vehicles to initiate the experiments, recover spacecraft engineering telemetry, and manage the function of the spacecraft. The Earth station equipment comprises a UHF yagi antenna array and UHF transceiver. The MOC will also have vehicle control workstations and a mission data archive server.[2]

[2] T&C data will be received directly from the spacecraft via UHF link; payload data will be downlinked via S-band to third-party Earth stations and securely transmitted to the MOC via a VPN over the Internet.

Section 25.114(d)(3) Predicted Spacecraft Antenna Gain Contours

The spacecraft UHF antenna is a half wavelength L-dipole antenna, which is essentially omni-directional when mounted on the corner of a CubeSat structure. A simulation of the antenna design is shown in Figure 3.

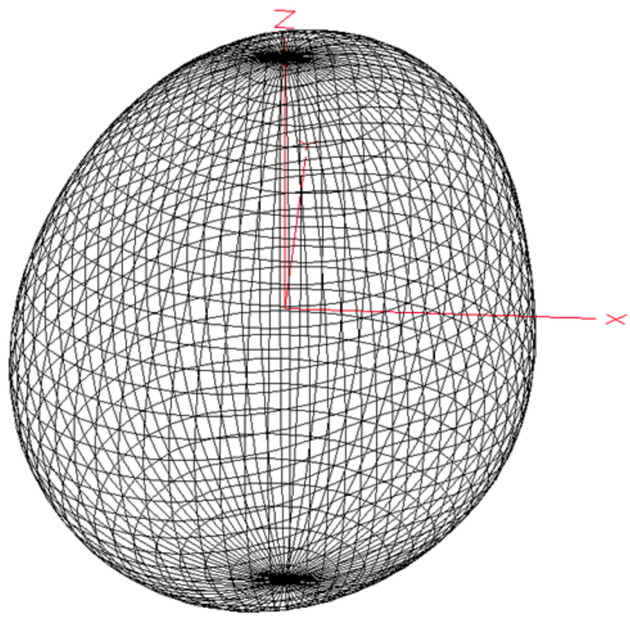

Figure 3: Tyvak-0129 L-Dipole UHF Antenna Gain Plot

The spacecraft S-band antennas are microstrip patch antennas possessing a maximum gain perpendicular to the surface normal to the patch. A representative antenna gain pattern cut is provided below for the S-band patch.

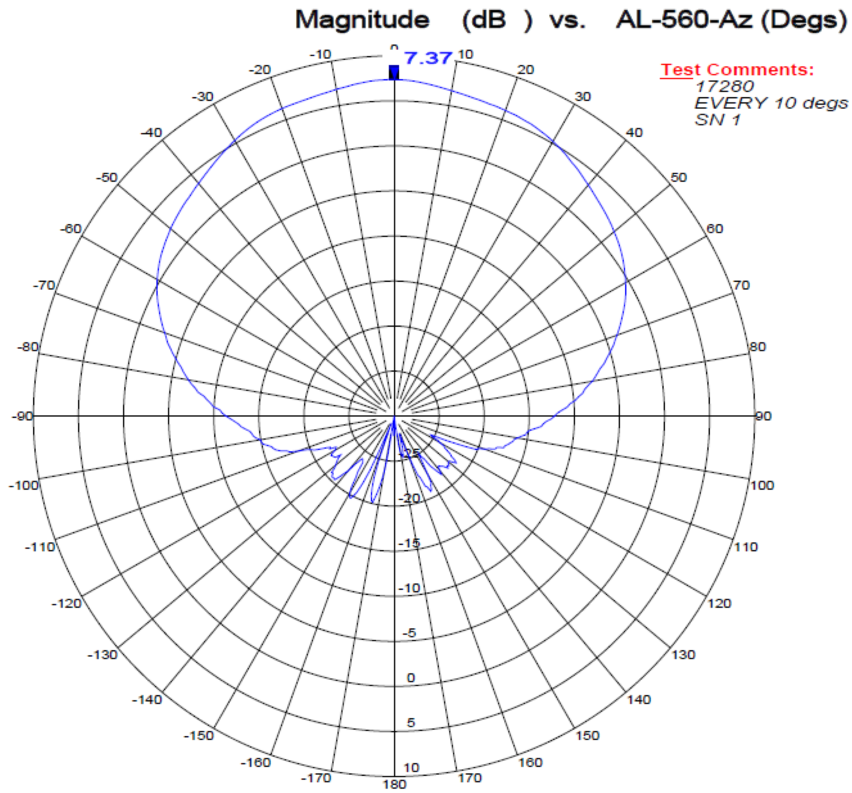

Figure 4: CubeSat S-band Antenna Gain Plot

Section 25.114(d)(14) Orbital Debris Mitigation

The CubeSat spacecraft will mitigate orbital debris by the following means:

Section 25.114(d)(14)(i) Limiting the amount of debris released during normal operations and the probability of the satellite becoming a source of debris by collisions with small debris or meteoroids that could cause loss of control and prevent post-mission disposal

In order to limit the amount of debris generated during normal operations, the CubeSats have been designed so that all parts will remain attached to the satellite during launch, ejection, and normal operations. This requirement is intrinsic to all satellites conforming to the CubeSat Standard and compliance is required for launch using the Poly-Picosatellite Orbital Deployer ("P-POD") system.

The basic geometry of Tyvak-0129 is a monolithic cubic structure (*i.e.*, 30cm x 20cm x 10cm) with two pairs of 30cm x 70cm triple-deploy panel wings. Based on an orbital debris model (ref. NASA DAS v2.0.2), the probability of a single particle impact with a size of 1 millimeter or larger over the mission lifetime is very low (*i.e.*, roughly 1.0×10^{-6}). This low probability of impact for the mission is a result of the small effective area of the space vehicle (*i.e.*, effective area ~ 0.221 m^2) and the relatively short mission duration (*i.e.*, mission life less than two years).

Catastrophic system failure due to orbital debris or micrometeoroid impact will not affect the vehicle's ability to de-orbit within the guidelines for vehicles operating in LEO (*i.e.*, less than 25 years). Based on the 500km mission orbit, the space vehicle is anticipated to re-enter the atmosphere within 3 years based on lifetime prediction simulations for the current mission epoch (*i.e.*, launch in CY2019).

Section 25.114(d)(14)(ii) Limiting the probability of accidental explosions during and after completion of the mission operations

The vehicles possess energy storage devices (*i.e.*, Li-ion batteries), which will be left in a nearly discharged state as part of the decommissioning procedure.

Section 25.114(d)(14)(iii) Limiting the probability of the satellite becoming a source of debris by collisions with large debris or other operational space stations

Based on a simple orbital debris model (ref. NASA DAS v2.0.2), the probability of the CubeSats colliding with large debris or other space systems of sizes one centimeter or greater at the mission orbit altitude and inclination is negligible (*i.e.*, roughly 1×10^{-6}).

The launch provider has instituted deployment procedures in order to place the co-manifested satellites in the launch vehicle into slightly different orbits in order to reduce the risk of collision. One of these procedures is to stagger deployment times. In addition, the deployable solar arrays will be inhibited from deploying for a pre-determined amount of time in order to minimize the surface area profile of the vehicle and further reduce chance of collision with another co-manifested satellite.

Section 25.114(d)(14)(iv) Post-mission disposal plans for the space station at end of life

The post-mission disposal plan for the spacecraft includes the transition of all vehicle systems to a dormant state, which includes the cessation of all radio operations (*i.e.*, transmit and receive). Energy storage devices will be held at a minimal charge state at the end of the life of the vehicles. Anticipated atmospheric re-entry of the satellites is within 3 years of mission completion based on the mission orbits, vehicle masses, geometry and mission epochs (*i.e.*, launch in CY2018). No active de-orbit maneuvers are required to meet the 25-year re-entry guidelines.

Re-entry debris and probability of human casualty will be negligible. The materials used on the vehicles include aluminum and PCB material, which have a relatively low melting temperature as compared to other materials such as Ti or stainless steel, and are not expected to survive reentry.

III. CONCLUSION

The Experimental Licensing Branch should grant Tyvak's application for a standard two-year experimental authority to launch and operate the Tyvak-0129 NGSO LEO satellite, which will permit Tyvak to demonstrate and evaluate operations and systems for government and non-government customers, adding valuable on-orbit performance data for future CubeSat Standard satellites. Tyvak's operation will not cause harmful interference to any licensed service. Tyvak will operate using the 400.15-402 MHz UHF band and the 2200-2290 MHz portion of the S-band allocated for EESS operations. Further, the Tyvak operation will meet the Commission's orbital debris mitigation requirements. Therefore, Tyvak's application should be granted at the soonest practicable time.