Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Tyvak Nano-Satellite Systems Inc.	)	
	)	
Application for Earth Station Authorization and Authority to Include Non-U.S. Authorized Satellite as Point of Communication	)	File No. SES-LIC-2022____-_____

NARRATIVE

The narrative addresses the following requirements for the authorization of an earth station operating with a non-U.S.-authorized satellite. First, information about the non-U.S. satellite is provided as required by Section 25.137 of the Commission's rules. Second, the Commission's waiver of certain rules is requested, including a waiver of the domestic frequency allocation table to permit the operation of the satellite and the earth station on a half-duplex basis using the same radio frequency for both earth-to-space and space-to-earth communications. Third, a spectrum sharing analysis is provided showing that the earth station can operate with the satellite without causing harmful interference to any other users of the relevant spectrum.

I. SECTION 25.137 REQUIREMENTS FOR COMMUNICATIONS WITH NON-U.S. AUTHORIZED SATELLITE

Tyvak Nano-Satellite Systems Inc. ("Tyvak"), hereby requests authority to identify the following non-U.S. authorized satellites as an authorized point of communication for the earth station covered by this application: Tyvak-0821, ITU notice ID number of 121545232.[1] Pursuant

[1] ITU notice ID number 121545232 actually covered two satellites, Tyvak-0821 and Tyvak-0820. This application, however, is only seeking market access to communicate with the Tyvak-0821 satellite.

to Section 25.137 of the Commission's rules, earth station applicants requesting authority to communicate with a non-U.S.-licensed space station must attach an exhibit with their FCC Form 312 addressing the legal and technical information for the non-U.S.-licensed space station required by Sections 25.114, 25.122 or 25.123, and 25.137 of the rules, each as applicable, including a complete Schedule S. This section provides the required information for the satellite.

§ 25.114(d)(1) System Facilities, Operations and Services and How Uplink Frequency Bands Connect to Downlink Frequency Bands

Spacecraft Orbit

Tyvak-0821 is a low earth orbit ("LEO") satellite in a 550 km circular orbit with an inclination of 97.6 degrees and an orbit period of approximately 96 minutes. 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 seven minutes for each Earth station location. The orbit parameters are presented in the following table:

Spacecraft	Parameter	Units	Value
Tyvak-0820	Orbit Period	Hrs	1.57 hrs
	Orbit Altitude	Km	550 km (circular)
	Inclination	Deg	97.6 degrees

Satellite Orbit Parameters

Satellite Tracking

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 of approximately 22 degrees. The antenna array uses four off-the-shelf, Yagi-type antennae developed by M2 Antenna Systems, Inc.

As an NGSO satellite, 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.

Radio Frequency Plan

The RF communications links for the Satellite uses use a 401.18 MHz center frequency for two-way telemetry monitoring, tracking, and command ("TT&C") transmissions and the 2235 MHz S-band for data downlinks. Tyvak is only requesting authority for operation in the UHF band listed above in the United States, not the S-band.

As noted above, the UHF communications system for the Tyvak-0821 satellite operates using half-duplex communications within a center frequency of 401.18 MHz for bi-directional TT&C (*i.e.*, earth-to-space & space-to-earth). The use of the same UHF center frequency for both telecommand and telemetry poses no operational concern. The communications parameters for the UHF communications system for the space-to-earth and earth-to-space links are shown in the following table.

CubeSat CommunicationsParameters	**Value**
Emission Designator	28K8G1D
Service	Digital Data
Center Frequency	401.18 MHz
Requested Bandwidth(includes Doppler)	28.8 kHz
Modulation	GMSK
Data Rate	19.2 kbps
Polarization	Linear (Results in RHCP)
Antenna Type	Dipole
Antenna Gain	2 dBi (Max)
RF Power Output	2 W
Line/Misc Losses	-2dB
ERP	1.22 W

Table 1: Tyvak-0821 UHF Communications Space-to-Ground Parameters

Earth Station CommunicationsParameters	**Value**
Emission Designator	28K8G1D
Service	Digital Data
Center Frequency	401.18 MHz
Requested Bandwidth(includes Doppler)	28.8 kHz
Modulation	GMSK
Data Rate	19.2 kbps
Polarization	Linear (H, V) or Circular
Antenna Type	Yagi array
Antenna Gain	+20.2 dBi (Max)
RF Power Output	200 W
Line Losses	-3dB
ERP	6400.1 W

Table 3: Tyvak Earth Station UHF Communications Parameters

Earth Station	**Frequency Range**	**Geographic Coordinates**
San Diego, CA, USA	UHF	32.897°Lat, -117.201°Long
Fairbanks, AK, USA	UHF	64.855°Lat, -147.686°Long

Table 4: Tyvak Earth Stations UHF

The transmitting components aboard the CubeSat 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. The satellite uses the UHF system for vehicle command and telemetry retrieval and the S-band system for data download outside the United States.

The TT&C communications system uses a Tyvak-developed UHF radio derived from commercially available UHF communications systems. The radio operates at a 19.2 kbps rate using GMSK modulation. The UHF system has an RF output power of 2 watts and uses a custom designed half-wave dipole antenna. The identical radio was previously used on the Tyvak-0129 satellite and has operated without problem.

The UHF band earth station facilities located in San Diego, California and Fairbanks, Alaska and each consists of a Yagi antenna array manufactured by M2 Systems, model number 400CP30.

The satellite payload S-band communications system (which will not be used to communicate with earth stations in the United States) operates at 2 watts using an off-the-shelf Quasonix NanoTX radio and patch antenna developed by Haigh-Farr for transmission. Similar to the UHF radio, the S-band radio has previously been used on-orbit several times without any problems including on Geostare SV2. 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. The S-band radio supports a 1 Mbps BPSK data rate using a transmit power of 2 watts. The antenna is RHCP with a gain of 7 dBic at the boresight with a VSWR < 2:1.

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 2.

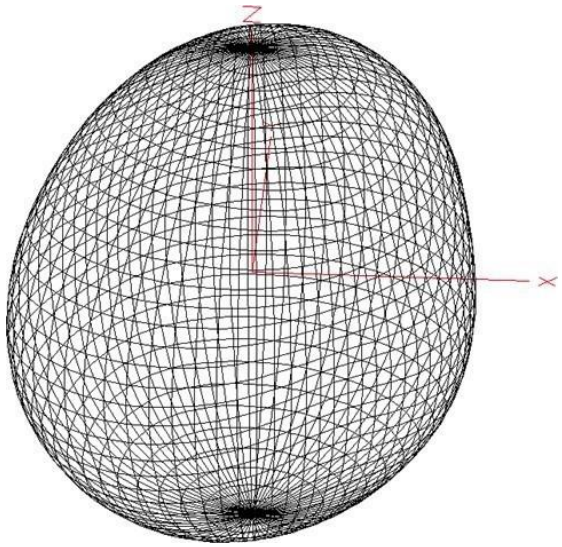

Figure 2: Tyvak-0821 L-Dipole UHF Antenna Gain Plot

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

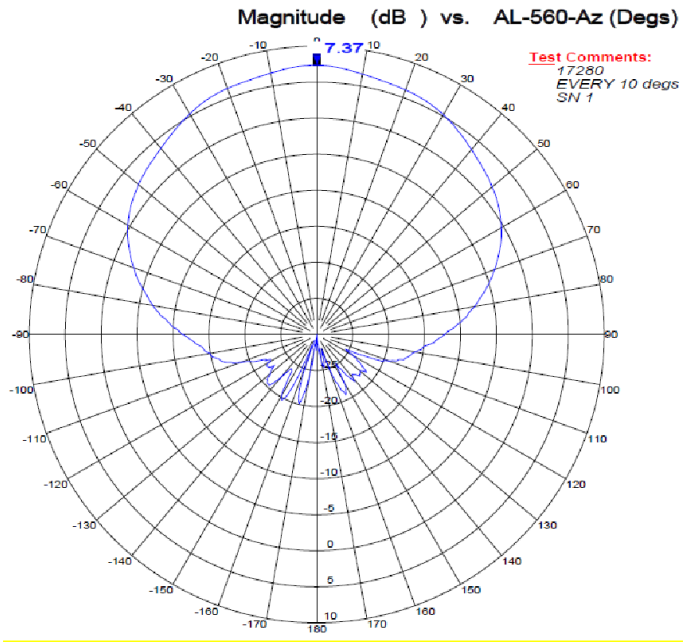

Figure 3: CubeSat S-band Antenna Gain Plot

§ 25.114(d)(6) Public Interest Considerations

Tyvak-0821 is the first of a second generation of Cicero satellites intended to collect on-orbit atmospheric radio occultation science data for the Cicero programs' customer GeoOptics. Radio occultation can be used for many beneficial research efforts including in the fields of weather forecasting, climate monitoring, climate model verification, and ionospheric research. Therefore, the grant of this application to permit the use of Tyvak's Fairbanks earth station to

communicate with the Tyvak-0821 satellite would serve the public interest even without consideration of the current state of the emergency involving the satellite.

As an additional public interest consideration, grant of this application is warranted to support Tyvak's efforts to recover control of the satellite and prevent it from becoming space debris. Following its launch on May 25, 2022, the Tyvak-0821 satellite has experienced lengthy periods of blackout in which Tyvak has been unable to communicate with or control the satellite using earth stations outside the United States. As Tyvak has indicated in correspondence with the Chief of the FCC Satellite Division, Tyvak has intermittently used its UHF earth station in Fairbanks to hail the satellite in an effort to secure a response. With this application, Tyvak seeks Commission authority to continue to use its UHF earth stations in Fairbanks in an effort to recover control of the satellite and to maintain control thereafter.

Tyvak is requesting authority to continue to communicate with the satellite for a period of six months in order to provide sufficient time to attempt the recovery of the control of the satellite, to ascertain the cause of the anomaly, and to correct it going forward so that its scientific mission can be initiated. During this six month recovery period, Tyvak will implement operational measures to use earth stations outside of the United States to maintain control over the satellite or Tyvak will request more permanent authorization from the FCC if deemed necessary or advisable.

§ 25.114(d)(14) Mitigation of Orbital Debris (including § 25.283)

The satellite will employ the following design and operational strategies to mitigate orbital debris. A technical analysis using NASA's Debris Assessment Software will be filed separately.

A. Control of Debris Released During Normal Operations

Tyvak has assessed and limited the amount of debris released in a planned manner during normal operations. By design, the Satellite limits debris released consistent with U.S. Government Orbital Debris Mitigation Standard Practice and there are no nominal jettisons of any equipment. All exterior surfaces are designed to avoid production of debris due to space exposure. In addition, Tyvak has assessed and limited 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. Standard environmental models and standard Tyvak design practices have been utilized to predict the environment and provide sufficient protection via bumper shields, *etc.* to limit the probability of the satellite from becoming a source of debris.

B. Minimizing Debris Generated by Accidental Explosions

Tyvak has assessed and limited the probability of accidental explosions during and after completion of mission operations for the satellite. The onboard energy sources are as follows:), reaction wheels and batteries. The reaction wheels (spin rate) and batteries (state of charge) are operated well within their safe operating limits. As mentioned above, all Satellite equipment is evaluated and protected from environmentally induced failure, *e.g.*, micrometeroids. After maneuvering to the disposal orbit stored energy will be removed from the satellite as follows: despinning of the reaction wheels, and discharge of the batteries preventing any recharging.

C. Selection of Safe Flight Profile and Operational Configuration

Tyvak has assessed and limited the probability of the satellite becoming a source of debris by collisions with large debris or other operational space stations by acquiring data from the Space

Surveillance Network ("SSN"), propagating the orbits, and if necessary (probability of collision greater than 10^{-4}), coordinating the potential close approach.

D. Post-Mission Disposal

Post mission at the end of life, the satellite is designed to be disposed of by atmospheric reentry. This reentry is realized by passive reentry resulting from drag. The total time is estimated to be 3 years, well within the 25 year NASA and international guideline.

The satellite is designed to employ demisable materials that limit the survivability of these materials upon reentry thereby minimizing the risk of human casualties. The risk is estimated to be less than 1 in 10,000, in accordance with NASA-STD 8719.14, requirement 4.7-1.

§ 25.137(a) Effective Competitive Opportunities

The satellite was authorized by the Norwegian Communications Authority ("NKOM"). Norway is a member of the World Trade Organization for services covered under the World Trade Organization Basic Telecommunications Agreement. Therefore, Tyvak is not required to demonstrate that no practical or legal constraints exist that limit or prevent access of U.S. licensed satellite systems in the relevant foreign market.

§ 25.137(d) Other Applicable Requirements

As required by Section 25.137(d)(2) and (3) of the Commission's rules, Tyvak will comply with all applicable reporting requirements and service rules for the satellite. As noted above, the satellite is already in orbit and therefore are not subject to Commission requirements addressing milestones, *see* 27.137(d)(1) or surety bonds, *see* 25.137(d)(4).

As noted above, the Tyvak-0821 is already in orbit. Prior to launch, NKOM submitted notification information for the satellite with the ITU. To assist the Commission in its review,

Tyvak has included with this application a copy of the AP4 submission for the Tyvak-0821 satellite. Please note that the AP4 actually addresses the ITU notification of two satellites, Tyvak-0820 and -0821. This application, however, only addresses the Tyvak-0821 satellite.

II. REQUESTED WAIVERS OF FCC RULES

The Commission's rules permit the FCC to grant waivers of its rules on a showing of "good cause."[2] The U. S. Supreme Court has indicated that the FCC not only has the legal right, but also an obligation to consider and grant waivers of its rules.[3] The Court indicated that the Commission's responsibility to consider waivers stems from its statutory obligation to serve the "public interest, convenience, or necessity."[4] The Court explained that "[i]f time and changing circumstances reveal that the 'public interest' is not served by application of the Regulations, it must be assumed that the Commission will act in accordance with its statutory obligations."[5]

Pursuant to this judicial instruction, the Commission maintains Section 1.3 of its rules, which indicates that the FCC will waive its rules "if good cause therefor is shown." In each circumstance discussed below, good cause is presented for the grant of each waiver requested and such grant would serve the public interest while not undermining any existing policy consideration that originally formed the basis for the rule in question.

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[2] 47 C.F.R. § 1.3 (1999).

[3] National Broadcasting Co. v. U.S., 319 U.S. 190 (1943) (upholding the Commission's "chain broadcasting regulations," which prohibit exclusive arrangements between networks and radio stations, in part because the Commission may still grant waivers of the rules); *see also* United States v. Storer Broadcasting Co., 351 U.S. 192, 205 (1956) (concluding that the Commission must grant a hearing to consider a justified request for waiver of its multiple ownership rules).

[4] *National Broadcasting Co.,* 319 U.S. at 225.

[5] *Id.*

§ 2.106 Waiver of Frequency Allocation Table

Tyvak's use of the 401.18 MHz range for TT&C is consistent with the Space Operation allocation that exists for both Federal and Non-Federal spectrum uses within the 401 to 402 MHz band.[6] The Space Operation service is allocated in the 401-402 MHz band solely in the space-to-Earth direction. In contrast, the Tyvak-0821 satellite operates using half-duplex communications, meaning that both uplink and downlink communications are carried out with a center frequency of 401.18 MHz. Tyvak therefore requests a waiver of the Commission's rules in order to permit the use of the 401-402 MHz band both in the space-to-earth and in the earth-to-space direction, the latter on a non-conforming, unprotected basis.

Such a waiver is warranted for several reasons. The use of a single frequency channel on a half-duplex basis is a highly efficient use of spectrum because it reduces the overall bandwidth that must be designated for use by the satellite and its associated earth station. The use of a half-duplex approach also reduces the size and complexity of the satellite communications system and therefore reduces the amount of mass that could contribute to orbital debris. Finally, a waiver to permit the use of a single frequency for both uplink and downlink communications is appropriate because Tyvak can operate its satellite and earth station in this manner without resulting in harmful interference to other spectrum users. The 401-402 MHz band is already available in the United States in the Earth-to-space direction for EESS uplinks. Thus, the spectrum sharing conditions for satellite uplink operations have already been considered and approved by the Commission in coordination with other U.S. government agencies. As for spectrum sharing with EESS and other

[6] The Space Operation Service is defined in the Commission's rules as being "concerned exclusively with the operation of spacecraft, in particular space tracking, space telemetry, and space telecommand." 47 C.F.R. § 2.1.

users of the 401-402 MHz band, Tyvak addresses its ability to share spectrum with other users of the 401-402 MHz band in the following section of this narrative. Finally, Tyvak is currently using this half-duplex operation with respect to other satellites that also operate within the 401-402 MHz band and these operations have been successfully without resulting in harmful interference to other parties.

For example, the Tyvak-0086 satellite is communicating with Tyvak earth stations in both Fairbanks and San Diego using half duplex bidirectional communications with a center frequency of 401.16 MHz.[7] The Tyvak-0087 satellite is communicating with both Tyvak's Fairbanks and San Diego earth stations using half duplex bidirectional communications with a center frequency of 401.12 MHz.[8] Finally, the Tyvak-0129 satellite is authorized to communicate with Tyvak's Fairbanks and San Diego earth stations using half duplex bidirectional communications with a center frequency of 401.205 MHz.[9] Therefore, a waiver of the frequency allocation table is justified and should be granted.

§ 25.137(c) Waiver of Application Processing Rounds

The satellite is (1) in orbit and operating, (2) been issued an authorization by NKOM, and (3) has been submitted for coordination to the ITU. Nevertheless, Tyvak herein requests a waiver of the application processing round requirements of Section 25.157 of the Commission's rules. Such a waiver is appropriate because the satellite can operate on a shared basis with other U.S.-authorized and non-U.S.-authorized satellite systems using the same spectrum and orbital

[7] *See* OET Call Sign WJ2XZG, File No. 0016-EX-TC-2022.

[8] *See* OET Call Sign WJ2XZK, File No. 0017-EX-TC-2022.

[9] *See* OET Call Sign WK2XAJ, File No. 0015-EX-TC-2022.

resources without resorting to band splitting or other measures intended to preserve access to scarce spectrum and orbital resources. Therefore, a waiver of the Section 25.157 application processing round requirements is appropriate and would serve the public interest by avoiding the delay and administrative burden imposed on the Commission of conducting an application processing round to address the Commission's consideration of this application.

III. SPECTRUM SHARING ANALYSIS

The Tyvak-0821 satellite has been designed to include several precautions to prevent harmful interference to other services. 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. Thus, transmissions from Tyvak spacecraft will be infrequent and of short duration, triggered only by affirmative command from the Tyvak Master Control Center.

Second, the satellite uplink and downlink will use the same 22 kHz bandwidth in half-duplex mode to send digital data using standard GMSK modulation with maximum data rates up to 19,200 baud. As a result, the actual transmissions will be minimal both in terms of bandwidth usage and duration.

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 earth station is in close geographic proximity to the Earth station of another network.

As noted previously in this narrative, the UHF communications system for the Tyvak-0821 satellite operates using a center frequency of 401.18 MHz (401.169-401.191 MHz), which is within the 401-402 MHz frequency band. The 401-402 MHz frequency band is allocated

internationally and in the United States for Meteorological Aids, Space Operation (space-to-Earth), Earth Exploration-Satellite (Earth-to-Space), Meteorological-Satellite (Earth-to-space). In the United States, these allocations are primary for Federal stations and, for non-Federal stations, the Meteorological Aids and Space Operation allocations are primary, while the remaining allocations are secondary.[10]

Earth Exploration Satellite Service

Planet Labs operates a fleet of Earth Exploration-Satellite Service ("EESS") NGSO satellites that is authorized to be as large as approximately 500 satellites, most of them at an orbit not exceeding 660 kilometers. The system is authorized to use portions of the 401-402 MHz (space-to-Earth) for TT&C operations. To support these operations, Planet Lab is authorized to operate a gateway earth station in Half Moon Bay, California, which is relatively close to Tyvak's San Diego earth station. Planet Lab's earth station, however, only uses the 401.27-401.33 MHz band for TT&C operations, which is sufficiently separate from Tyvak's frequency range of 401.169-401.191 MHz to prevent the need for coordination between the two systems.

On November 18, 2021, Kinéis was authorized by the Commission to use the EESS allocation to operate a Non-voice, Non-geostationary ("NVNG") constellation consisting of 25 nanosatellites operating at an altitude of 650 kilometers in a sun synchronous (98° inclination angle) orbit that would use the 401-403 MHz band for uplink communications.[11] Kinéis indicated that

[10] Pursuant to Footnote US64, the 401-406 MHz band is also available to Medical Device Radiocommunication Service (MedRadio) operations on the condition that harmful interference is not caused to stations in the meteorological aids, meteorological-satellite, and Earth exploration-satellite services, and that MedRadio stations accept interference from stations in the meteorological aids, meteorological-satellite, and Earth exploration-satellite services.

[11] *See Kinéis*, IBFS File No. SAT-PDR-20191011-00113 (Call sign S3054).

it will use the 401-403 MHz band to extend the provision of environmental ARGOS services in the U.S. and worldwide. Kinéis has not reported the launch of any satellites to the Commission and still has an application pending before the Commission to operate ground "beacons" in the United States that would transmit to its satellites using the 401-403 MHz band.[12]

Once Kinéis receives authority to operate terminal beacons and begins to launch its satellites, Tyvak will likely need to coordinate with it to ensure that Tyvak's brief bi-directional transmissions in the 401-402 MHz band, if they are still continuing by that point, do not interfere with its satellite network. As a non-conforming spectrum user in the earth-to-space direction, Tyvak recognizes that it would be solely responsible for ensuring that its uplink operations do not interfere with authorized satellite systems. However, given Tyvak's need to transmit signals to and from its satellites only for relatively brief periods and only within view of its associated earth stations, Tyvak is confident that its proposed spectrum use can easily be coordinated with these satellite systems as they are launched.

Federal Systems

The Department of Commerce's National Environmental Satellite, Data, and Information Service ("NESDIS") operates the Geostationary Operational Environmental Satellites ("GOES") and Polar Orbiting Satellite ("POES") systems, which receive environmental monitoring data from numerous ground stations that is transmitted in the Earth-to-space direction in the 401-402 MHz band. The GOES and POES systems as well as commercial satellites then re-transmit the

[12] *See Kinéis,* IBFS File No. SES-LIC-20220314-00271 (Call sign E220037).

information to a central processing center. In addition, NTIA reports that the Department of Defense operates radiosondes in the meteorological aids service "on a limited basis."[13]

Tyvak's space-to-Earth operations at 401.18 MHz should have no impact on these Federal operations. Tyvak's Earth-to-space operations at 401.18 MHz will be extremely limited, consisting of hailing signals and brief instructions to the Tyvak-0821 satellite when it is in view of Tyvak's San Diego and Fairbanks earth stations. As noted previously in this narrative, the 401-402 MHz band is already available in the United States in the Earth-to-space direction for non-Federal EESS uplinks, is currently being used for this purpose by Planet Labs, Inc., and the Commission has approved this same use by Kinéis. Further, as noted above, Tyvak is currently operating several other satellites using TT&C uplinks in the 401-402 MHz band without resulting in harmful interference to Federal systems, including Tyvak-0086 using a center frequency of 401.16 MHz,[14] Tyvak-0087 using a center frequency of 401.12 MHz.[15] and Tyvak-0129 using a center frequency of 401.205 MHz.[16] Therefore, Tyvak should be able to use its Fairbanks and San Diego earth stations to communicate with the Tyvak-0821 satellite without resulting in harmful interference to federal systems.

[13] Radiosondes are expendable free-floating balloons transmitting data to the global meteorological community as an essential input to weather models and by researchers for atmospheric and climatologic research.

[14] *See* OET Call Sign WJ2XZG, File No. 0016-EX-TC-2022.

[15] *See* OET Call Sign WJ2XZK, File No. 0017-EX-TC-2022.

[16] *See* OET Call Sign WK2XAJ, File No. 0015-EX-TC-2022.