Narrative and Technical Description

On behalf of Thomas Jefferson High School (TJHS), part of the Fairfax County Public School System in the Commonwealth of Virginia, the Thomas Jefferson High School Partnership Fund (TJHSPF) respectfully requests renewal of its conventional experimental authority to operate its 2U experimental cubesat, commencing on August 1, 2021 (which reflects the earliest possible launch date for the spacecraft) or as soon as practicable thereafter.[1]

The cubesat, named the Thomas Jefferson Research and Education Vehicle for the Evaluation of Radio Broadcasts or "TJ REVERB," was scheduled to deploy from the ISS on April 17, 2019. However, due to assembly and testing delays, and then complications caused by the Covid-19 pandemic, TJ REVERB was not able to meet its original launch date. Continued pandemic isolation protocols are further delaying completion of the TJ REVERB, and TJHSPF now estimates a launch date in the third quarter of 2021.

TJHSPF's proposed experimental operations, which are identical to those authorized under the *TJ License*, consist of a VHF automatic packet reporting system (APRS) transceiver operating at 145.825 MHz (VHF amateur band) that will also be used for telemetry, tracking, and control (TT&C). The satellite will also carry an Iridium short burst data (SBD) modem and patch antenna that will be used to demonstrate and evaluate communications between the Iridium constellation and TJ REVERB, and for backup TT&C services.[2] This experimental application

[1] *See* Thomas Jefferson High School Partnership Fund Inc., Call Sign WJ2XXB, File No. 0950-EX-CN-2018 ("*TJ License"*) (expires August 1, 2020). TJHSPF may request a further extension of experimental authority should the satellite remain operational at the end of this license term.

[2] A separate request for experimental authority was filed by Iridium to permit communications from the Iridium system to TJ REVERB, Call Sign WK2XKD, File No. 0553-EX-CN-2019 (expires February 1, 2021). *See* Iridium Experimental Grant here.

also includes a request for renewed authority to operate an earth station in the above-referenced VHF amateur band to communicate with TJ REVERB.

TJ REVERB serves as an educational vehicle for teaching students the principles of systems engineering. The TJ REVERB project is creating a "best practices" document for building nanosatellites while actually building and operating the 2U cubesat. Beyond benefiting from the rich learning experience that designing and constructing a satellite provides, the TJHS student team is committed to a robust local, national, and international outreach program. Additional background information regarding the program can be found at: https://activities.tjhsst.edu/cubesat/ and https://space.skyrocket.de/doc_sdat/tjreverb.htm.

TJHS respectfully requests consideration and grant of this application by August 1, 2021, or as soon as practicable thereafter. As described herein, grant of the requested experimental license renewal will continue to strongly serve the public interest. TJHSPF incorporates by reference all previously submitted information in its application for the *TJ License* to support this experimental license application, and reserves the right to update the record of this proceeding in order to provide the FCC with additional information if necessary.

I. DISCUSSION

TJHSPF seeks renewal of its experimental license to operate the TJ REVERB satellite and associated earth station. A comprehensive view of TJHSPF's proposed experimental operations is set forth herein. In addition, TJHSPF has prepared necessary ITU-related information (satellite system filings and cost-recovery documentation) in connection with this application.[3]

[3] TJHSPF commits to paying all ITU cost-recovery fees but it understands that its satellite system filing will be designated as "amateur" and therefore cost-recovery fees will not be imposed on its ITU filing.

Operation of the TJREVERB cubesat will enable the students, teachers, and supporting mentors at TJHS to gain valuable science, technology, engineering, and math (STEM) experience and to collect data on satellite and earth station operations, including the efficacy of using the Iridium SBD link to support low-Earth orbit (LEO) TT&C operations.

The tests and demonstrations planned by TJHSPF will be conducted intermittently over a period of at least a year, commencing shortly after launch. The satellite TT&C and payload communications frequencies, ground station location, and operational constraints are the same as previously authorized and have been carefully identified to avoid the potential for interference to other spectrum users.

A. TJ REVERB Satellite

The TJ REVERB satellite is a 2U cubesat (100 mm X 100 mm X 227 mm) in the stowed configuration with VHF deployable antennas, with a total mass of approximately 2.61 kg. The satellite employs two ISIS ISPA solar panels on each side panel of the satellite. Each solar panel is capable of generating 2.3 W. Therefore, the maximum solar power generation when the satellite is fully illuminated by the sun is approximately 4.6 W. The TJREVERB includes 40 Wh of electrical energy storage.

The maximum transmitter output RF power is approximately 3 dBW in VHF and 0 dBW in L-band. The communications payload uses a hemispherical patch antenna in L-band and the VHF radio uses an ISIS quad monopole tape spring antenna assembly, as indicated in Figure 1.

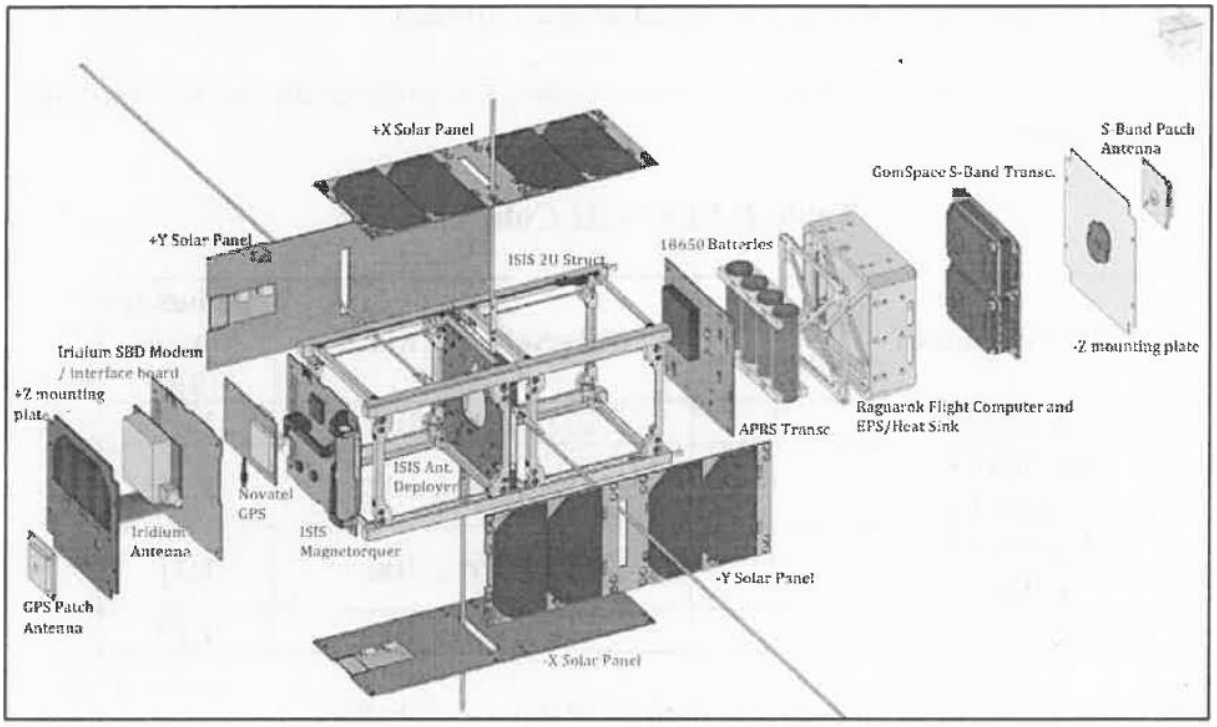

Figure 1. TJ REVERB Satellite Configuration[4]

Orbits. The TJ REVERB satellite will be launched to the ISS and deployed from the ISS by Nanoracks into a nominal circular orbit (at ~400 km apogee and ~400 km perigee) with an inclination from the equator of 51.3°. An orbital lifetime calculation for this orbit estimates that the satellite will remain in orbit for approximately 1.5 years (under worst-case conditions), well within the limits set by internationally accepted guidelines.[5]

Please note the attached ODAR includes references to TJ REVERB's originally scheduled launch to the ISS as well as to other cubesats that were also scheduled to be on that

[4] Please note that references to S-band radio and antenna equipment in the diagram of the TJ REVERB satellite should be disregarded. The satellite design previously included S-band communications capability, but that radio has been removed.

[5] NASA technical standards limit post-mission lifetime to 25 years. *See* NASA-STD-8719.14G requirement 4.6-1(a). *See also* Orbital Debris Assessment Report (ODAR) (attached). The ODAR was previously submitted to the Commission and has not changed.

launch.[6] Notwithstanding launch rescheduling, the ODAR analysis remains valid because the TJ REVERB satellite will still be deployed from the ISS.

Satellite Communications Payload. The TJ REVERB experimental communications payload consists of an NAL Research Corp. Iridium L-band 9602 Short Burst Data (SBD) modem and patch antenna for transmit/receive TDD operations. Technical parameters include:

- Experimental data downlink (TJ REVERB-to-Iridium return link)
  - L-band Transmit
  - 0.0 dBW spacecraft transmitter output power, 4.4 dBW Peak EIRP, 2.25 dBW ERP
  - Tx in 1618.725 – 1626.5 MHz, 31.5 kHz channel bandwidth, 41.667 kHz channel spacing
  - RHCP polarized, QPSK modulation
  - 25 ksps, 50 kbps

- Experimental data uplink (Iridium-to-TJ REVERB forward link)
  - L-band Receive
  - Rx in 1618.725 – 1626.5 MHz, 31.5 kHz channel bandwidth, 41.667 kHz channel spacing
  - RHCP polarized, QPSK modulation
  - 25ksps, 50 kbps

The L-band communications payload will operate intermittently and on an as-needed basis to test the performance of the Iridium SBD communications with a LEO satellite and as a possible TT&C backup.

Telemetry Downlink. Telemetry reception of the TJREVERB satellite downlink signal in the 145-146 MHz band will be conducted using a Byonics MTT4B VHF transceiver with a Spectral Isopole Jr monopole antenna at the TJHS facility, 6560 Braddock Rd, Alexandria, VA 22312 (coordinates: 38.817871°, -77.168268°). Downlink operations will take place

[6] The ODAR also mentions an S-band transponder on the TJ REVERB satellite; however, that radio has been removed.

intermittently when the satellite is in view of the VHF earth station site. TJHSPF will coordinate the TT&C operations to ensure compatibility with any other co-frequency operations in the area. Particulars of the telemetry and tracking downlink operations include:

- 2.0 W spacecraft transmitter output power, 3 dBW EIRP, 0.85 dBW ERP
- U.S. Naval Academy SATT4 transceiver
- Tx (downlink) at 145.825 MHz (16 kHz bandwidth)
- LHCP polarized, AFSK modulation
- 1200 bps

Command Uplink. Command uplink of the TJ REVERB satellite will be conducted in the VHF band from the TJHS facility in Alexandria, Virginia. Particulars of the command uplink operations include:

- 40 W ground station transmitter output power, 14 dBW EIRP, 11.85 dB ERP
- Tx (uplink) at 145.825 MHz (16 kHz bandwidth)
- Vertical polarized, AFSK modulation
- 1200 bps

Satellite telemetry, tracking and command communications will begin once the TJ REVERB spacecraft is deployed into its intended orbit.

B. VHF Earth Station

TJHSPF will utilize a Byonics 40W MTT4B VHF transceiver radio and associated equipment, including a Spectral Isopole Jr monopole antenna with 0 dBi peak gain, to conduct telemetry, tracking and command (TT&C) operations. The earth station will be located at the TJHS facility in Alexandria, VA. The earth station transmits and receives at 145.825 MHz band (16 kHz bandwidth). The antenna pattern for the VHF antenna is illustrated in Figure 2 below.

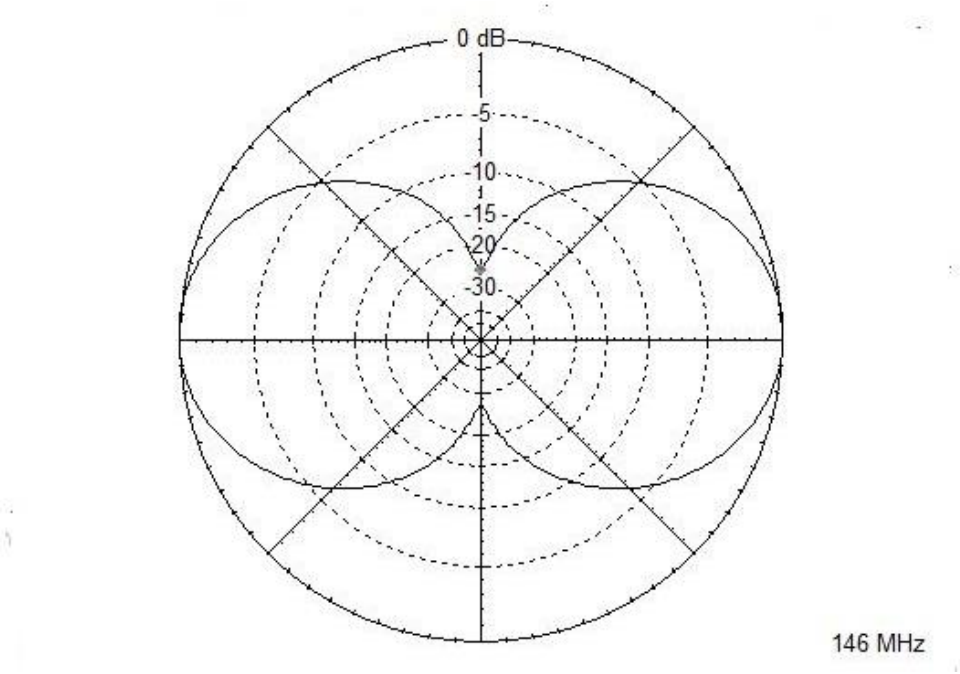

Figure 2. VHF Earth Station Antenna TX/RX Pattern

Satellite VHF Antenna Patterns. The antenna patterns for the VHF transmit/receive antenna are provided in Figure 3.

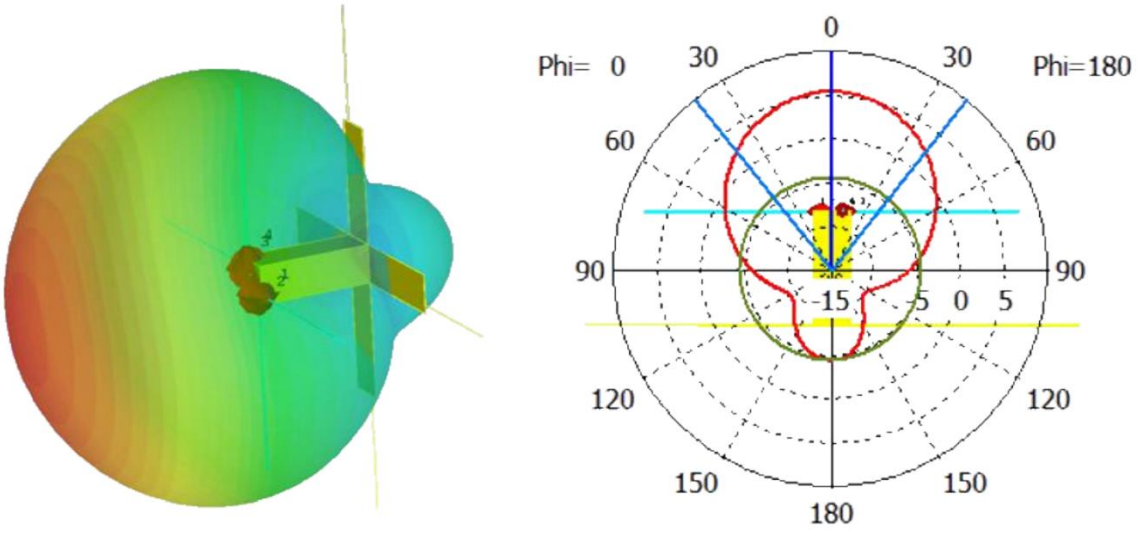

Figure 3. VHF TX/RX Antenna Pattern

Satellite Iridium Antenna Patterns. The antenna patterns for the L-band Iridium TX/RX antenna are provided in Figure 4.

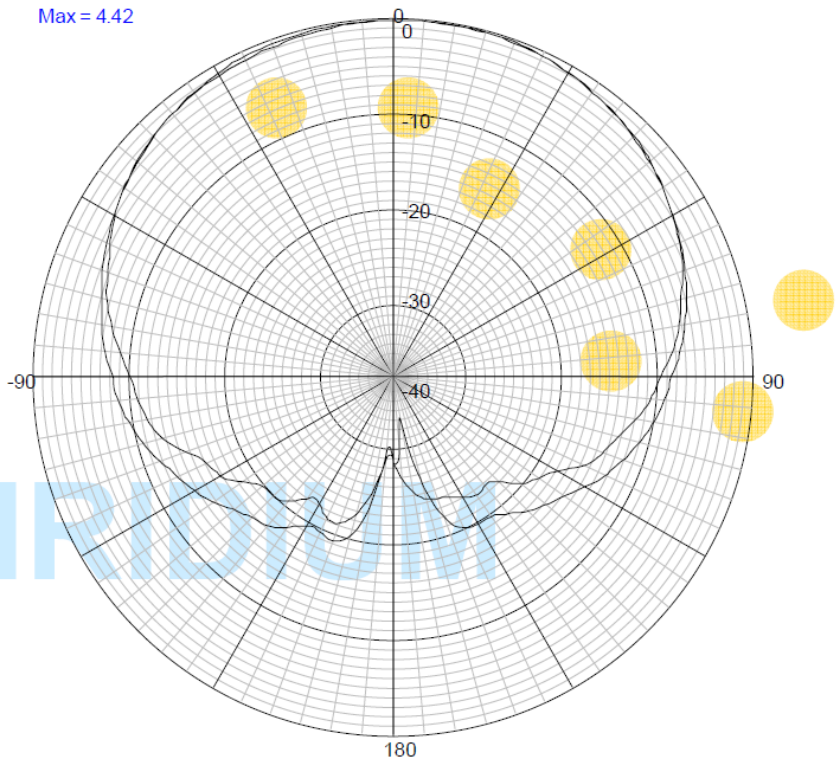

Figure 4. Iridium L-band TX/RX Antenna Pattern

TT&C Link Budgets. The following Figures 5 through 8 illustrate representative link budgets for the VHF-band TT&C downlink, VHF TT&C uplink, Iridium TT&C forward link, and Iridium TT&C return link, respectively.

Link parameters	**Unit**	**0**	**15**	**30**	**45**	**60**	**75**	**90**
Carrier Frequency	MHz	145.85	145.85	145.85	145.85	145.85	145.85	145.85
Carrier wavelength	m	2.06	2.06	2.06	2.06	2.06	2.06	2.06
Boltzmann constant	dBW/K/Hz	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6
BASIC PARAMETERS								
Orbit height	km	400	400	400	400	400	400	400
Earth radius	km	6371	6371	6371	6371	6371	6371	6371
Elevation Angle	°	0	15	30	45	60	75	90
Tx-Rx distance	**km**	**2293**	**1176**	**740**	**550**	**458**	**413**	**400**
Satellite Segment								
Tx antenna gain	dBi	0.0	1.0	2.0	2.5	3.0	4.0	5.0
Tx RF power	W	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Tx losses	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tx EIRP	**dBW**	**3.0**	**4.0**	**5.0**	**5.5**	**6.0**	**7.0**	**8.0**
PROPAGATION								
Satellite Antenna Pointing Loss	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polarization Loss	dB	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Free space losses	dB	142.9	137.1	133.1	130.5	128.9	128.0	127.8
Atmospheric Loss	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ionospheric Loss	dB	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Total Propagation Losses	**dB**	**146.3**	**140.5**	**136.5**	**133.9**	**132.3**	**131.4**	**131.2**
Receive Antenna Gain	dBm	0.0	-1.0	-3.0	-5.0	-8.0	-15.0	-25.0
Received Power	dBm	-113.3	-107.5	-104.5	-103.4	-104.3	-109.4	-118.2
Receiver Sensitivity	dBm	-117.0	-117.0	-117.0	-117.0	-117.0	-117.0	-117.0
Link Margin	dBm	3.7	9.5	12.5	13.6	12.7	7.6	-1.2

Figure 5. VHF-Band TT&C Downlink Link Budgets

Link parameters	**Unit**	**0**	**15**	**30**	**45**	**60**	**75**	**90**
Carrier Frequency	MHz	145.85	145.85	145.85	145.85	145.85	145.85	145.85
Carrier wavelength	m	2.06	2.06	2.06	2.06	2.06	2.06	2.06
Boltzmann constant	dBW/K/Hz	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6
BASIC PARAMETERS								
Orbit height	km	400	400	400	400	400	400	400
Earth radius	km	6371	6371	6371	6371	6371	6371	6371
Elevation Angle	°	0	15	30	45	60	75	90
Tx-Rx distance	**km**	**2293**	**1176**	**740**	**550**	**458**	**413**	**400**
Earth Segment								
Tx antenna gain	dBi	0.0	-1.0	-3.0	-5.0	-8.0	-15.0	-25.0
Tx RF power	W	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Tx losses	dB	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Tx EIRP	**dBW**	**14.0**	**13.0**	**11.0**	**9.0**	**6.0**	**-1.0**	**-11.0**
PROPAGATION								
Satellite Antenna Pointing Loss	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polarization Loss	dB	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Free space losses	dB	142.9	137.1	133.1	130.5	128.9	128.0	127.8
Atmospheric Loss	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ionospheric Loss	dB	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Total Propagation Losses	**dB**	**146.3**	**140.5**	**136.5**	**133.9**	**132.3**	**131.4**	**131.2**
Receive Antenna Gain	dBm	0.0	1.0	2.0	2.5	3.0	4.0	5.0
Received Power	dBm	-102.3	-96.5	-93.5	-92.4	-93.3	-98.4	-107.1
Receiver Sensitivity	dBm	-114.0	-114.0	-114.0	-114.0	-114.0	-114.0	-114.0
Link Margin	dBm	11.7	17.5	20.5	21.6	20.7	15.6	6.9

Figure 6. VHF-Band TT&C Uplink Link Budgets

Link parameters	**Unit**	**0**	**15**	**30**	**45**	**60**	**75**	**90**
Carrier Frequency	MHz	1620.00	1620.00	1620.00	1620.00	1620.00	1620.00	1620.00
Carrier wavelength	m	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Boltzmann constant	dBW/K/Hz	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6
BASIC PARAMETERS								
Orbit height	km	358	358	358	358	358	358	358
Earth radius	km	6371	6371	6371	6371	6371	6371	6371
Elevation Angle	°	0	15	30	45	60	75	90
Tx-Rx distance	**km**	**2164**	**1072**	**666**	**493**	**409**	**370**	**358**
Satellite Segment								
Tx EIRP	**dBW**	**27.6**	**30.6**	**26.5**	**23.9**	**22.3**	**21.4**	**21.1**
PROPAGATION								
Satellite Antenna Pointing Loss	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polarization Loss	dB	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Free space losses	dB	163.3	157.2	153.1	150.5	148.9	148.0	147.7
Atmospheric Loss	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ionospheric Loss	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Propagation Losses	**dB**	**164.3**	**158.2**	**154.1**	**151.5**	**149.9**	**149.0**	**148.7**
Receive Antenna Gain	dBm	-1.0	0.0	1.0	2.0	3.0	4.0	4.4
Received Power	dBm	-107.7	-97.6	-96.6	-95.6	-94.6	-93.6	-93.2
Receiver Sensitivity	dBm	-117.0	-117.0	-117.0	-117.0	-117.0	-117.0	-117.0
Link Margin	dBm	9.3	19.4	20.4	21.4	22.4	23.4	23.8

Figure 7. Iridium TT&C Forward Link Budgets

Link parameters	**Unit**	**0**	**15**	**30**	**45**	**60**	**75**	**90**
Carrier Frequency	MHz	1620.00	1620.00	1620.00	1620.00	1620.00	1620.00	1620.00
Carrier wavelength	m	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Boltzmann constant	dBW/K/Hz	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6
BASIC PARAMETERS								
Orbit height (delta orbits)	km	358	358	358	358	358	358	358
Earth radius	km	6371	6371	6371	6371	6371	6371	6371
Elevation Angle	°	0	15	30	45	60	75	90
Tx-Rx distance	**km**	**2164**	**1072**	**666**	**493**	**409**	**370**	**358**
Earth Segment								
Tx antenna gain	dBi	-1.0	0.0	1.0	2.0	3.0	4.0	4.4
Tx RF power	W	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Tx losses	dB	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Tx EIRP	**dBW**	**-1.0**	**0.0**	**1.0**	**2.0**	**3.0**	**4.0**	**4.5**
PROPAGATION								
Satellite Antenna Pointing Loss	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polarization Loss	dB	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Free space losses	dB	163.3	157.2	153.1	150.5	148.9	148.0	147.7
Atmospheric Loss	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ionospheric Loss	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Propagation Losses	**dB**	**164.3**	**158.2**	**154.1**	**151.5**	**149.9**	**149.0**	**148.7**
Receive Antenna Gain	dBm	17.0	16.0	15.0	14.0	13.0	12.0	11.0
Received Power	dBm	-118.3	-112.2	-108.1	-105.4	-103.8	-102.9	-103.2
Receiver Sensitivity	dBm	-117.0	-117.0	-117.0	-117.0	-117.0	-117.0	-117.0
Link Margin	dBm	-1.3	4.8	8.9	11.6	13.2	14.1	13.8

Figure 8. Iridium TT&C Return Link Budgets

II. CONCLUSION

Based on the foregoing, TJHSPF respectfully requests that the Commission grant this conventional experimental license renewal by August 1, 2021, or as soon as practicable thereafter, to allow operations of TJ REVERB to the benefit of TJHS students and the U.S. public generally.