

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) seeks experimental license authority to operate a 2U experimental cubesat for up to one year.¹ The cubesat is named the Thomas Jefferson Research and Education Vehicle for the Evaluation of Radio Broadcasts or “TJ REVERB.”

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

The TJ REVERB project is creating a “best practices” document for building nanosatellites while actually building and operating a 2U cubesat. Additionally, TJ REVERB serves as an educational vehicle for teaching students the principles of systems engineering. Beyond the rich learning experience designing and constructing a satellite provides the students at TJHS, the 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.

¹ TJHSPF may potentially request and extension of experimental authority if additional operational life remains at the end of the initial license term.

² A separate request for experimental authority will be filed by Iridium to permit communications from the Iridium system to TJ REVERB.

I. DISCUSSION

TJHSPF seeks a one-year 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

The launch date for the satellite is expected to be April 17, 2019. However, the satellite must be delivered to Nanoracks for launch vehicle integration by February 15, 2019. Therefore, TJHS respectfully requests that the Commission consider and authorize the proposed experimental satellite operations (as appropriately conditioned) as soon as practicable.

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 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 TJHS will be conducted intermittently over a one-year period commencing shortly after deployment of the TJ REVERB satellite from the International Space Station (ISS). The satellite TT&C and payload communications frequencies, ground station location, and operational constraints 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.

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.

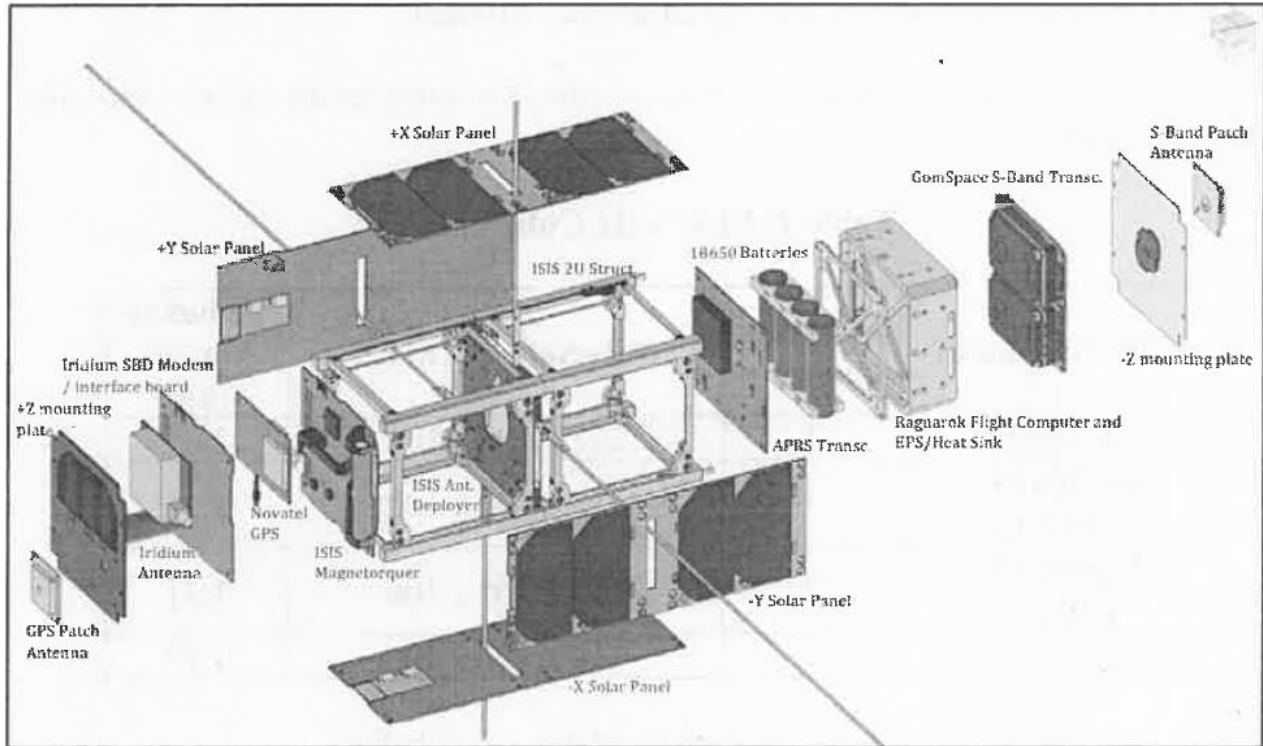


Figure 1 TJ REVERB Satellite Configuration⁴

Orbits. The TJ REVERB satellite will be launched to the ISS on the Cygnus NG-11 mission currently scheduled for April 17, 2019. The satellite will be 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 previously scheduled launch to the ISS and other cubesats that were also scheduled to be on that launch. Notwithstanding launch rescheduling, the ODAR analysis remains valid because the TJ REVERB satellite will still be deployed from the ISS.

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

⁵ See Orbital Debris Assessment Report (ODAR) (attached). Please note that the ODAR also mentions an S-band transponder on the TJ REVERB satellite; however, that radio has been removed.

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. Specific 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 (38.817871, -77.168268). Downlink operations will take place 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
- US Naval Academy SATT4 transceiver
- Tx (downlink) at 145.825 MHz (16 kHz bandwidth)
- LHCP polarized, AFSK modulation
- 1200 bps

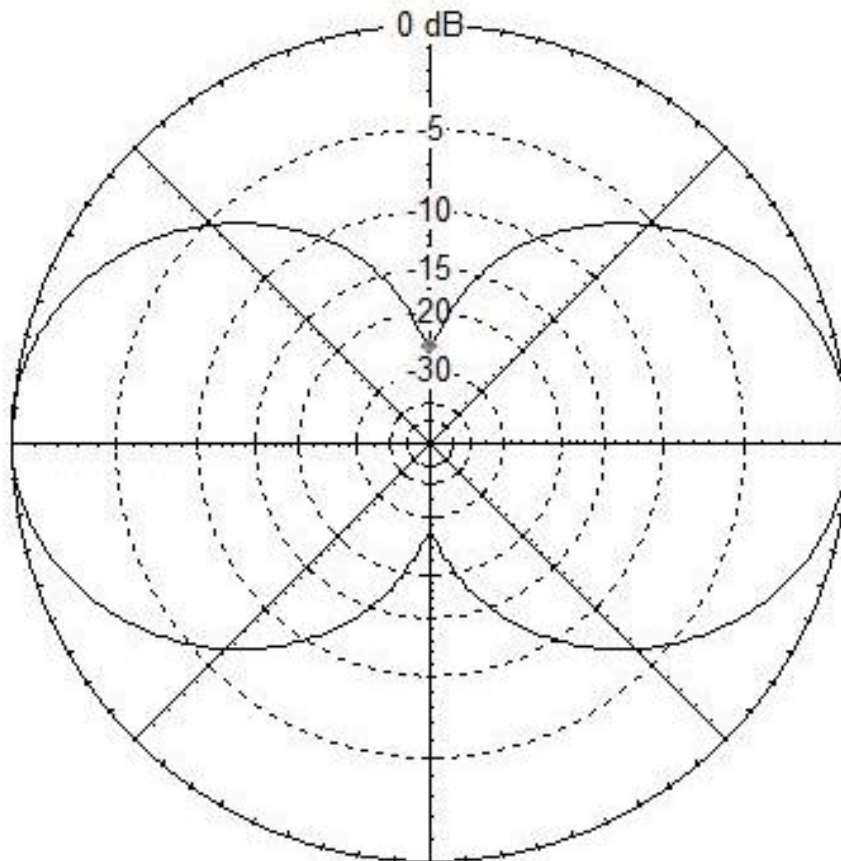
Command Uplink. Command uplink of the TJ REVERB satellite will be conducted in the VHF band from the TJHS facility in Alexandria, VA. Particulars of the command uplink operations include:

- 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.



146 MHz

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.

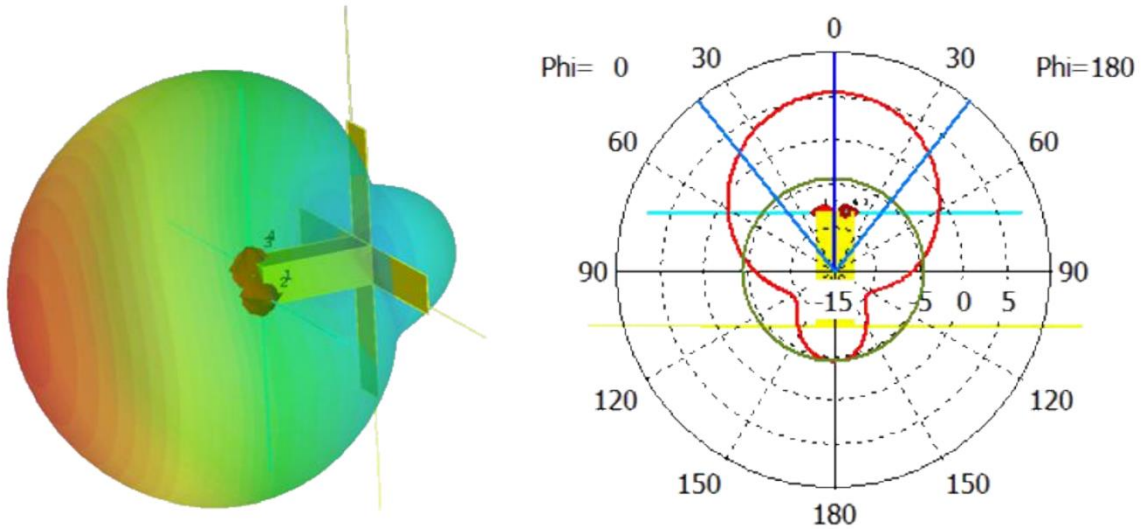


Figure 3 VHF TX/RX Antenna Pattern

Satellite Iridium Antenna Patterns

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

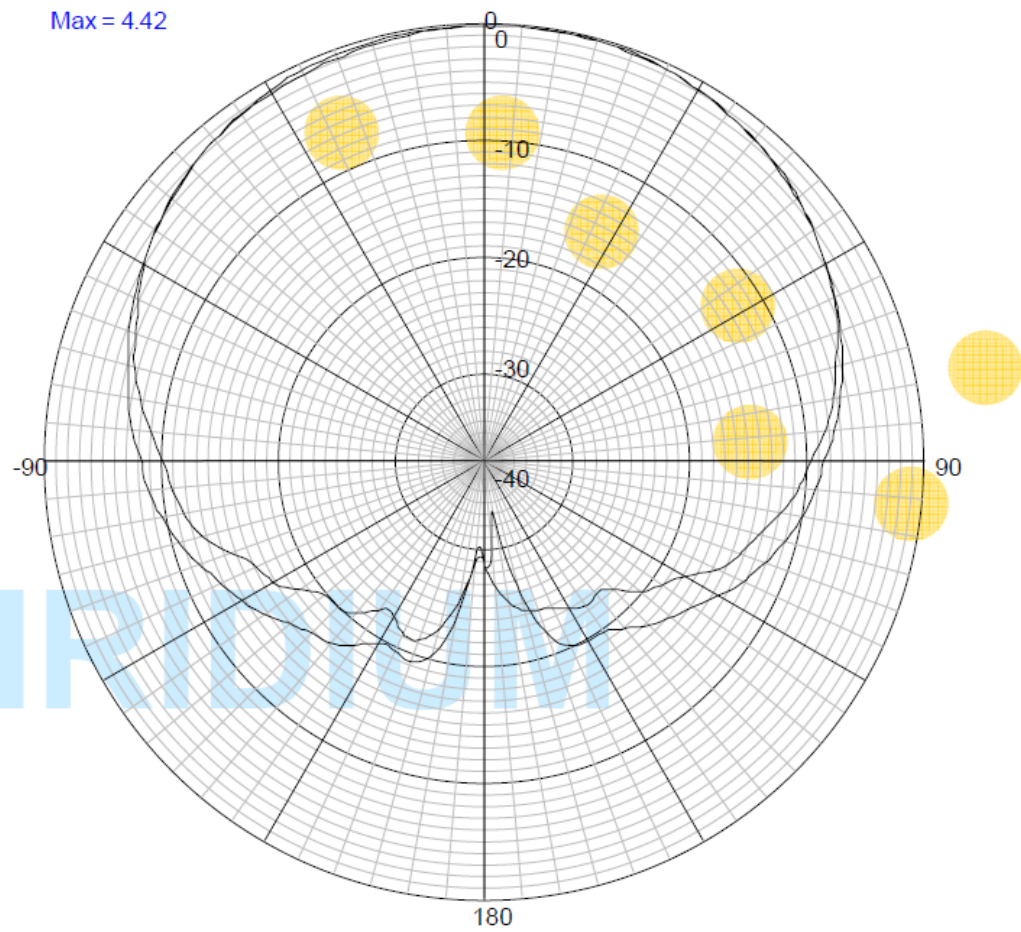


Figure 4 Iridium L-band TX/RX Antenna Pattern

TT&C Link Budgets

The following figures 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.

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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

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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	dB	-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