Background Information on the Orbital Test Bed Mini-Satellite for the FCC

Background information for the FCC to allow assessment of experimental spacecraft licensing application

Document Number OTB-DOC-000639-03

Dated: June 2015

Tyler Murphy

Surrey Satellite Technology
345 Inverness Drive South, Suite 100
Englewood,
CO 80112

tmurphy@sst-us.com

Tel 720 255 0903

TABLE OF CONTENTS

APPROVALS

SST-US

Prepared by ……..…..Tyler Murphy, Systems Engineer Dated 7/1/15

Approved by …….Matt Yavorsky, Systems Engineer Dated 7/1/15

Authorised by ……..….William Thompson, Project Manager Dated 7/1/15

RECORD OF REVISIONS

Rev	Date	Author	Description of changes
1	Aug ‘13	M Brown	Initial issue for comment
2	Aug ‘13	M Brown	Incorporates updated spacecraft design information.
3	June ‘15	T Murphy	Incorporates change in frequency and update of critical dates

APPLICABLE DOCUMENTS

1) GUIDANCE ON OBTAINING LICENSES FOR SMALL SATELLITES DA: 13-445 Released: March 15, 2013. Federal Communications Commission 445 12th St., S.W. Washington, D.C. 20554.

2) Orbital Debris Assessment Report (ODAR) for the Orbital Test Bed (OTB) Minisatellite - ODAR Document Number OTB-DOC-000638-03 Dated: June 2015. Surrey Satellite Technology, US LLC. 345 Inverness Drive South, Suite 100, Englewood, CO 80112.

PREAMBLE

This document supports Surrey Satellite technology's application for an experimental license [1].

Further supporting information is provided in reference [2].

1. OVERVIEW

1.1 Mission Concept of Operations

1.1.1 The SST-US 'Orbital Test Bed' (OTB) mini-satellite is an internally funded small LEO experimental satellite that will provide an in-orbit test bed for the experimentation and demonstration of a variety of scientific, research and prototype payloads, subsystems and equipments. These 'hosted' payloads are detailed in section 2 of this document.

1.1.2 SST-US will make an experimental license application to the FCC to operate the OTB mini-satellite and are providing this document (together with the related Orbital Debris Assessment Report (ODAR) ref [2]) as supporting evidence.

1.1.3 The RF transmitter communications links required to operate the OTB mini satellite are reviewed in section 3 of this document.

1.1.4 **Launch Schedule & Critical Dates -** The OTB satellite is currently in development against the following launch schedule:

Preliminary Design Review	18th September 2013
Critical Design Review	January 2014
Flight Readiness Review	April 2016
Launch	September 2016

The spacecraft will operate in orbit for 5 years to allow data to be gathered on the effects of long term exposure to radiation on the experiments. Therefore SST-US will apply for a 5 year experimental license.

Critical date –April 2016. Requested Grant Date SST-US will be holding a flight readiness review with the launch services provider. SST-US proposes this date as the requested grant date.

1.1.5 **Launch Site** - The OTB satellite will be launched from Space Launch Complex 40 at Cape Canaveral AFS, 28° 24' 20" N / 80° 36' 18" W, using the SpaceX Falcon Heavy Launch Vehicle, designation STP-2 for the US Air Force. SST-US is not sponsoring the launch.

1.1.6 **Orbital Parameters** - The orbit will be a 720+/-18.5 km altitude LEO circular orbit of 24deg inclination. The OTB has no means of altering the orbit into which it is delivered as it has no propulsion.

1.2 Earth Stations

1.2.1 Surrey Satellite Technology has completed selection of an appropriate ground station, which will be used for TT&C (transmit and receive) and payload data download. The selected ground station is the NASA Johnson Space Center (JSC) Electronic Systems Test Laboratory (ESTL) S-Band 3m Dish. The ground station antenna information can be found below:

3.0m ESTL Antenna

Location: 29 33 39.19 N, 95 05 31.94 W
Site Elevation: 4.9 m
Antenna Height above Terrain: 10.7 m
Antenna Type: Parabolic Tracking Antenna
Azimuth Range: 000 – 360 degrees
Minimum Elevation Angle: 5 degrees
Antenna Polarization: Right or Left Hand Circular
Peak Gain: 32.0 dBi
Antenna Beamwidth: 3.3 degrees

Equivalent NTIA Data Fields:

RADxx 32G003B001-360A00005H011
RAZxx V05
RAPxx T
*where xx represents receiver instance number (receiver 1 -> 01, receiver 2 -> 02, etc)

1.2.2 SST-US will only require one 7 - 8 minute link session per day for satellite TT&C and to download platform status information and payload data. The OTB satellite will not radiate RF signals when out of control of the ground station. A separate FCC application will be made for ground station operations.

1.3 Contact(s) for interference issues

1.3.1 Primary

Tyler Murphy

Surrey Satellite Technology
345 Inverness Drive South, Suite 100
Englewood,
CO 80112
tmurphy@sst-us.com

Tel: 001 720 255 0903

1.3.2 Secondary

Brian Johnson

Surrey Satellite Technology
345 Inverness Drive South, Suite 100
Englewood,
CO 80112
bjohnson@surreysatellite.com

Tel: 001 720 545 0870

1.3.3 Secondary

Rebecca Yoder

Surrey Satellite Technology
345 Inverness Drive South, Suite 100
Englewood,
CO 80112
byoder@surreysatellite.com

Tel: 001 720 256 2590

.

2. SATELLITE DESCRIPTION; EXPERIMENTAL PAYLOADS & TESTING

2.1 Satellite Description

2.1.1 The OTB mini satellite is an evolution of the ESPA compatible SSTL-150 spacecraft, first flown in 2007 for LANL http://www.sst-us.com/downloads/datasheets/sstl_150-feb-09 . The total spacecraft mass is 180kg and has the deployed configuration as shown in figure 2-1.

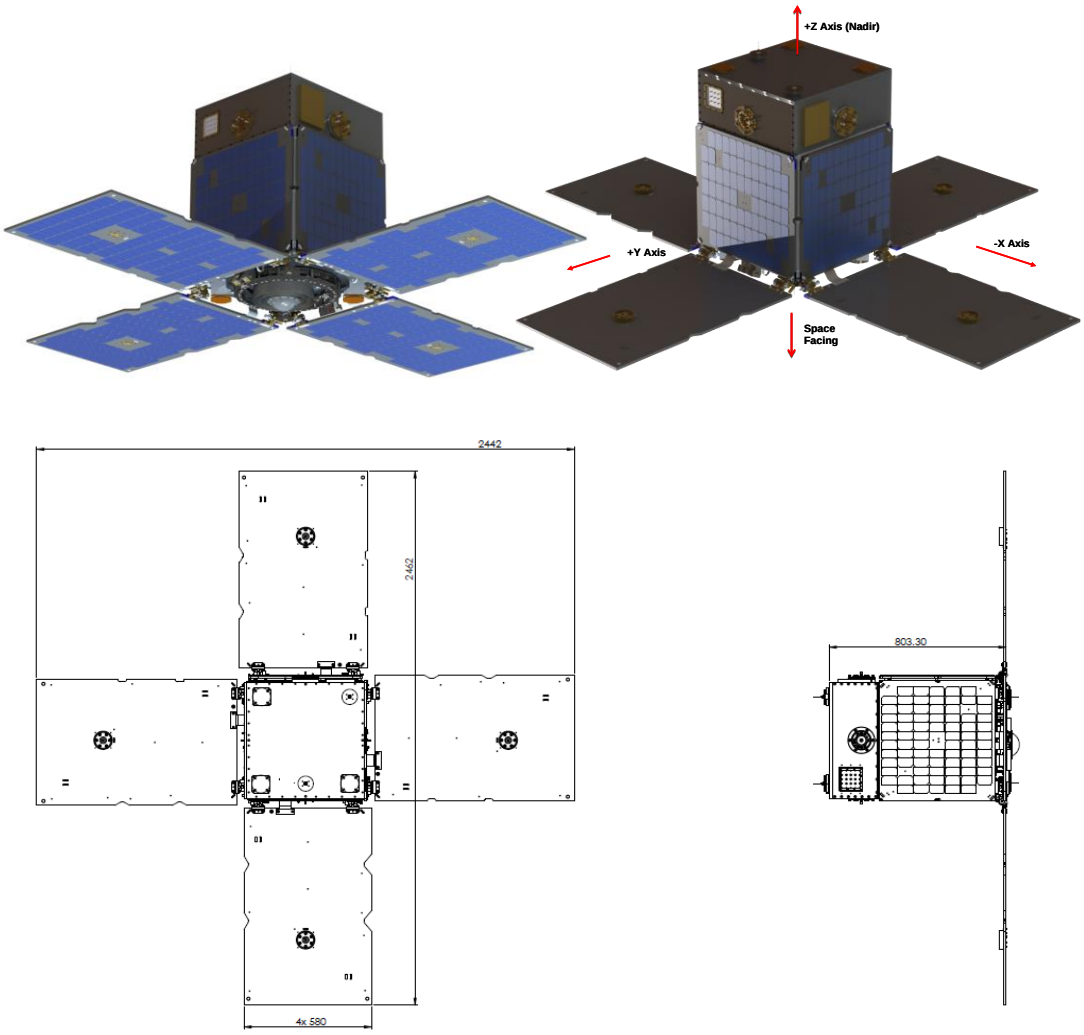


Figure 2-1 Outline of OTB mini satellite configuration (all dimensions in mm).

2.2 Experimental Payloads and Testing

2.2.1 The OTB satellite accommodates a number of 'hosted' payloads, provided either by SST-US or sponsored by external parties.

1. Deep Space Atomic Clock (DSAC) – sponsored by the Jet Propulsion Laboratory under JPL subcontract No 1468935. http://www.nasa.gov/mission_pages/tdm/clock/

2. iMESA-R – A space weather monitor built by the USAF Academy and sponsored through AFRL. http://www.usafa.edu/df/dfe/dfer/centers/sparc

3. Modular Solar Array (MSA) – built by Vanguard and sponsored through AFRL. http://www.vst-inc.com

4. SSC Electronics Test Bed – An experiment designed to monitor the effects of spaceflight on new electronics components, sponsored by the Surrey Space Centre at the University of Surrey www.surrey.ac.uk/ssc This experiment is designed to understand the effects of radiation on a variety of commercial-off-the-shelf components to assess whether they are suitable for spaceflight.

5. CUSP - A microprocessor and memory storage experiment from the University of Colorado Boulder www.colorado.edu

6. FlexRx – A new spacecraft RF receiver design sponsored by SST-US. The receiver will be tested to assess its RF reception characteristics in space. It does not radiate RF signals.

7. Radiation Monitor – A new spacecraft radiation monitor sponsored by SST-US. This experiment is designed to provide data on the long-term radiation environment experienced in LEO. It helps calibrate the effects of radiation on other payloads.

8. Custom Experimental Solar Panel – A new solar panel sponsored by SST-US.

2.2.2 All data generated from the various payloads are multiplexed within the OTB spacecraft and down linked via a single, high rate, S-band; 2.0352 Mbits/s data link to the ground station (section 3-3). None of the payloads separately radiate RF signals.

2.2.3 SST-US will require one 7 - 8 minute RF link session every day for satellite Telemetry & Tele-Command (TT&C) and to download satellite status information and payload data. This is the minimum practical to ensure spacecraft health and retrieve experimental data. The satellite will not radiate any RF signals at any other time.

2.2.4 The spacecraft will operate for 5 years, although a number of payloads will operate for a shorter time and will be switched off as required.

2.2.5 No testing of the payloads listed in section 2.2.1 will alter the orbital, physical or RF characteristics of the OTB mini-satellite from nominal during their testing, as such they should be regarded as 'passive' in operation.

3. RF COMMUNICATIONS

3.1 *Summary*

3.1.1 The OTB satellite RF transmitters, as referenced from the ground station, are:

1) A low rate; 38.4kbits/s; S-band transmitter to downlink platform status information to the ground station.

2) A high rate; 2.0352 Mbits/s; S-band transmitter to downlink payload data to the ground station *(NOTE: there are two S-band transmitters onboard although only one is operational, the other is a cold redundant spare)*

3.1.2 For information, the satellite Telemetry and Tele-Command (TT&C) is a low rate, 19.2kbits/s S-band uplink from the ground station. Figure 3-1 shows the relationship between the satellite and the ground station.

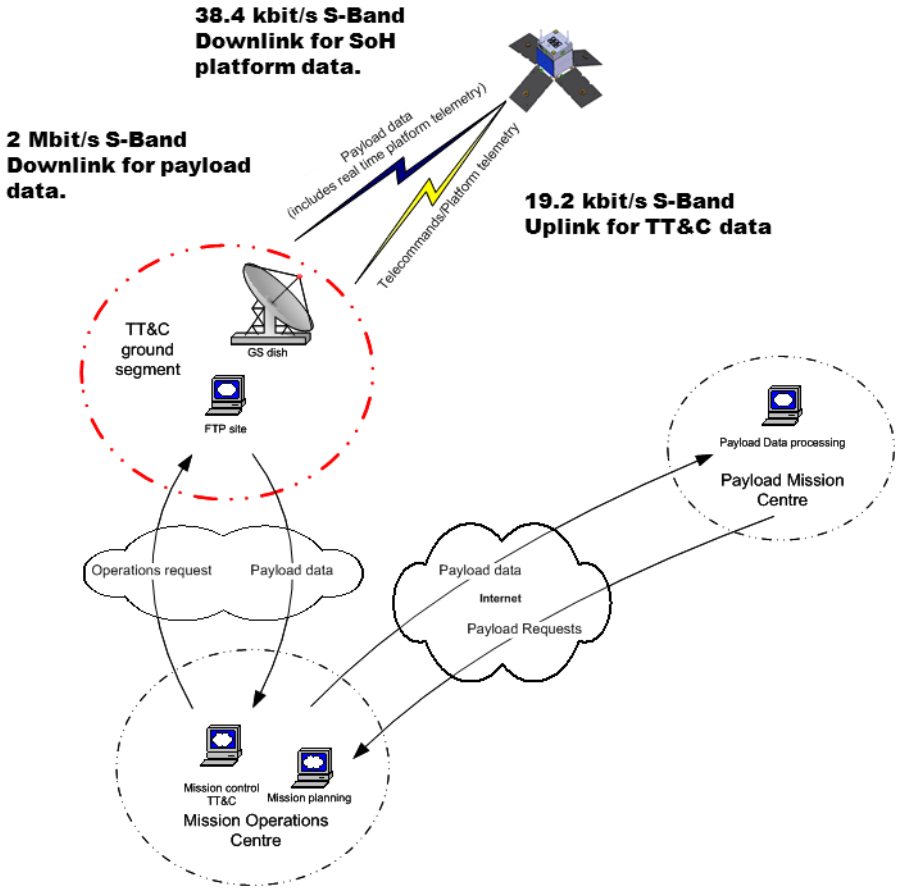
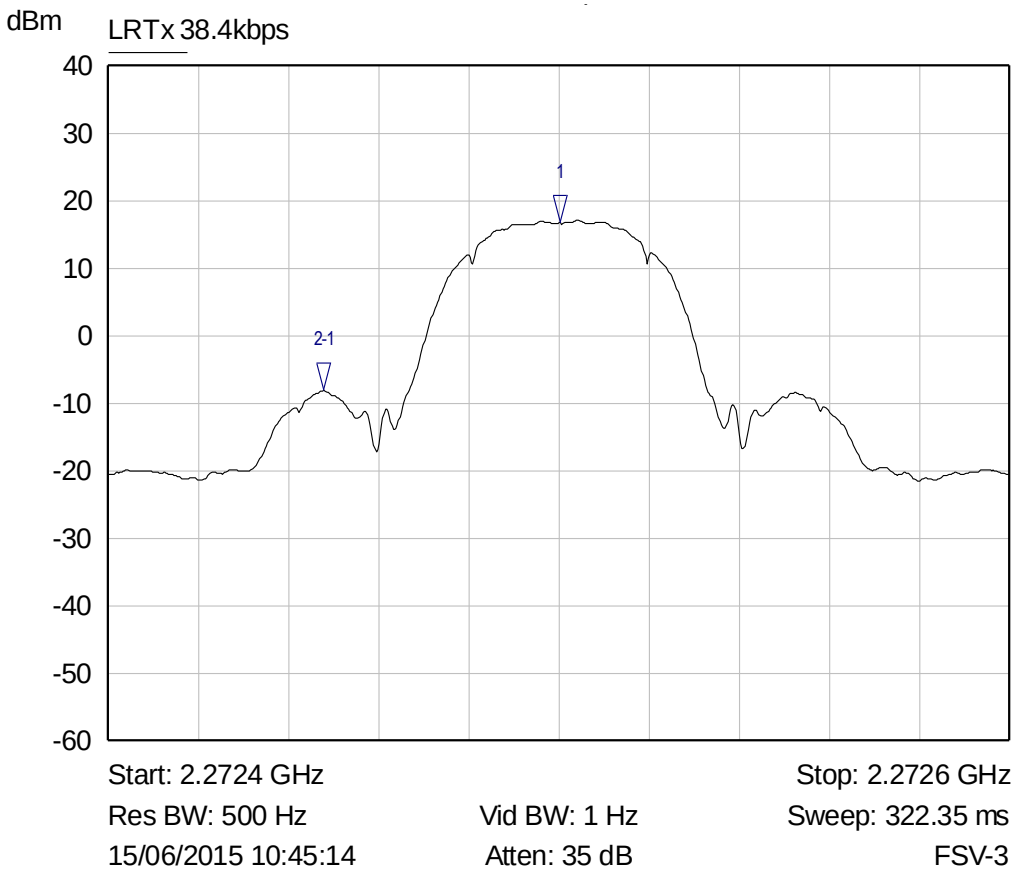


Figure 3-1 Ground Station - OTB satellite relationship

3.2 *S-band; Low-rate; 38.4 Kbits/s transmitter for downlink of satellite status information.*

3.2.1 The RF characteristics of the S band low rate downlink are as follows.

Identifier	S-Band Low Rate Tx	
Function:	Downlink of satellite state of health – 'platform data'.	
Necessary bandwidth:	70 kHz	
Operating Frequency:	2272.5 MHz	
Maximum Transmit Power:	24 dBm	(0.25W)
EIRP	-11.5 dBW	(70mW)
Antenna Gain in main pattern lobe	0 dBi	
Modulation type:	BPSK	
Polarization type:	Linear-V	
Data Rate:	38.4Kbits/sec	
Out of band emission	-29 dB relative to maximum, figure 3-2.	
Emission Designator	G-1-D	



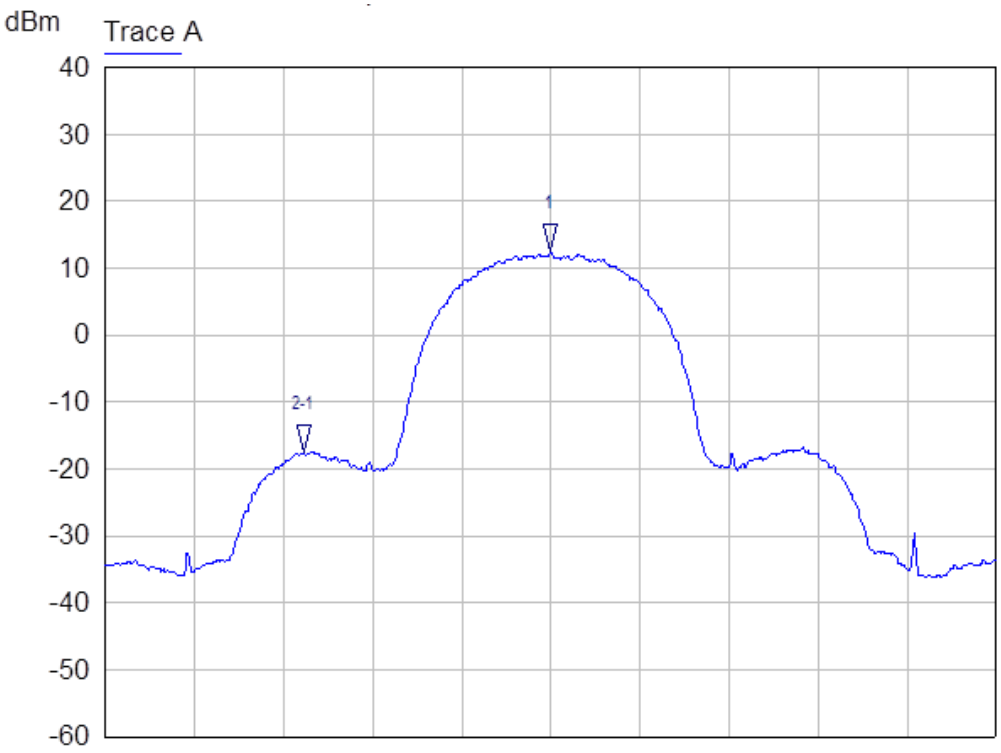
Mkr	Trace	X-Axis	Value	Notes
1	LRTx 38.4kbps	2.2725 GHz	16.81 dBm	
2-1	LRTx 38.4kbps	-52.4638 kHz	-24.87 dB	

Figure 3-2 Emission spectrum of S-Band Low Rate Tx

3.3 *S-band; High-rate; 2.0352 Mbits/s transmitter for downlink of satellite payload data.*

3.3.1 The RF characteristics of the S band high rate downlink are as follows.

Identifier	S-Band High Rate Tx	
Function:	Downlink of satellite payload data	
Necessary bandwidth:	3.26 MHz	
Operating Frequency:	2272.5 MHz	
Maximum Transmit Power:	37 dBm	(5W)
EIRP	7.8 dBW	(6W)
Antenna Gain in main pattern lobe	3 dBi	
Modulation type:	QPSK	
Polarization type:	Circular-RHC	
Data Rate:	2.0352 Mbits/sec	
Out of band emission	-27.8 dB relative to maximum, figure 3-2.	
Emission Designator	G-1-D	



Mkr	Trace	X-Axis	Value	Notes
1	Trace A	2.2725 GHz	12.55 dBm	
2-1	Trace A	-2.7681 MHz	-30.13 dB	

Figure 3-3 Emission spectrum of S-Band High Rate Tx

4. FURTHER INFORMATION

4.1 *Related frequency filing activity*

4.1.1 Surrey Satellite Technology Ltd (SSTL) in the UK (SST-US's parent company) has made previous frequency filings for operations in S band that may have some bearing on the experimental license application. This information can be provided on request should the FCC believe it to be relevant.

4.1.2 Sapphire is a Canadian DND space surveillance satellite which was launched in 2013. Sapphire was constructed by MacDonald, Dettwiler and Associates (MDA) based on an SSTL-150 bus produced by Surrey Satellite Technology Ltd. http://en.wikipedia.org/wiki/Sapphire_(satellite). SSTL provided information for the Sapphire project to show that the S-Band Low Rate transmitter (section 3.2) and S-Band High rate transmitter (section 3.3) meet ITU recommendations for in band and out of band emissions. Sapphire is controlled and data downloaded from the Vancouver Ground Station in British Columbia.

4.1.3 CFESat was built by SSTL in conjunction with the Los Alamos National Laboratory (LANL) and was launched in 2007 http://en.wikipedia.org/wiki/CFESat , section 1.2. The frequency filing was placed the NTIA. CFESat operated with a similar 4Mbps S-Band high rate transmitter for the payload downlink (section 3.3).

4.2 *Exhibits relating to FCC form 442 – Question 4*

4.2.1 **Question 4:** ***Is this authorization to be used for fulfilling the requirement of a government contract with an agency of the United States Government? If "YES", include as an exhibit a narrative statement describing the government project, agency and contract number.***

4.2.2 The OTB satellite will accommodate the Jet Propulsion Laboratory (JPL) Deep Space Atomic Clock (DSAC) under JPL subcontract No 1468935. The website address describing the program can be found at http://www.nasa.gov/mission_pages/tdm/clock/ and the fact sheet describing the DSAC technology can be found at http://www.nasa.gov/sites/default/files/files/DSAC_Fact_Sheet.pdf

4.2.3 Contact Information for DSAC

Primary -
Allen H. Farrington
Manager, Deep Space Atomic Clock Project
(703)
Jet Propulsion Laboratory
4800 Oak Grove Drive, M/S 251-100
Pasadena, CA 91109
Desk: 818-393-5260
Cell: 818-653-2284
Allen.h.farrington@jpl.nasa.gov

Secondary -
Karen Lee
Payload Manager
Deep Space Atomic Clock Project
Jet Propulsion Laboratory
4800 Oak Grove Drive, M/S 251-100
Pasadena, CA 91109
Desk (818)354-3863
Cell (818)645-2984
Karen.a.lee@jpl.nasa.gov

4.3 *Exhibits relating to FCC form 442 – Question 6*

4.3.1 **Question 6:** ***Is this authorization to be used for providing communications essential to a research project? (The radio communication is not the objective of the research project)? If "YES", include as an exhibit the following information:***

- ***a. A description of the nature of the research project being conducted.***
- ***b. A showing that the communications facilities requested are necessary for the research project.***
- ***c. A showing that existing communications facilities are inadequate.***

4.3.2 The OTB satellite uses two RF transmitters as referenced from the ground station, which are:

1) A low rate; 38.4kbits/s; S-band transmitter to downlink platform status information to the ground station.

2) A high rate; 2.0352 Mbits/s; S-band transmitter to downlink payload data to the ground station. *(NOTE: there are two S-band transmitters onboard although only one is operational; the other is a cold redundant spare).*

These transmitters are essential to the operation of the satellite and the retrieval of data from the various experiments onboard. They are not the objective of the research themselves.

The OTB satellite accommodates a number of experiments, provided either by SST-US or sponsored by external parties, including US Government Agencies.

1. Deep Space Atomic Clock (DSAC) – sponsored by the Jet Propulsion Laboratory under JPL subcontract No 1468935. http://www.nasa.gov/mission_pages/tdm/clock/

2. iMESA-R – A space weather monitor built by the USAF Academy and sponsored through AFRL. http://www.usafa.edu/df/dfe/dfer/centers/sparc

3. Modular Solar Array (MSA) – built by Vanguard and sponsored through AFRL. http://www.vst-inc.com

4. SSC Electronics Test Bed – An experiment designed to monitor the effects of spaceflight on new electronics components, sponsored by the Surrey Space Centre at the University of Surrey www.surrey.ac.uk/ssc This experiment is designed to understand the effects of radiation on a variety of commercial-off-the-shelf components to assess whether they are suitable for spaceflight.

5. CUSP - A microprocessor and memory storage experiment from the University of Colorado Boulder www.colorado.edu

6. FlexRx – A new spacecraft RF receiver design sponsored by SST-US. The receiver will be tested to assess its RF reception characteristics in space. It does not radiate RF signals.

7. Radiation Monitor – A new spacecraft radiation monitor sponsored by SST-US. This experiment is designed to provide data on the long-term radiation environment experienced in LEO. It helps calibrate the effects of radiation on other payloads.

8. Custom Experimental Solar Panel – A new solar panel sponsored by SST-US.

.

All data generated from the various payloads are multiplexed within the OTB spacecraft and down linked via the single, high rate, S-band; 2.0352 Mbits/s data link to the ground station. None of the payloads separately radiate RF signals. SST-US will require one 7 - 8 minute RF link session every day for satellite Telemetry & Tele-Command (TT&C) and to download satellite status information and payload data. This is the minimum practical to ensure spacecraft health and retrieve experimental data. The satellite will not radiate any RF signals at any other time.

The spacecraft will operate for 5 years, although a number of payloads will operate for a shorter time and will be switched off as required. No testing of the payloads will alter the orbital, physical or RF characteristics of the OTB mini-satellite from nominal during their testing, as such they should be regarded as ‘passive’ in operation.

.