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

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APPROVALS

SST-US

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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.

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 - Preliminary Design Review (PDR) ODAR Document Number OTB-DOC-000638-02 Dated: August 2013. 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. A number of primary payloads from SST-US are included and other 'hosted' payloads from 3rd parties. The 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
Payload Integration	December 2014
Flight Readiness Review	**1st May 2015 Requested Grant Date**
Launch	Q3 2015

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 - 31st October 2013. SST-US needs to make a final design decision on the RF center frequencies of the S band transmitters in section 3. These center frequencies can be set in the band 2200GHz – 2290GHz to accommodate any concerns the FCC have, however they cannot be changed once in manufacture i.e. they are not software programmable radios. Therefore SST-US would appreciate any feedback from the FCC on these center frequencies by 31st October 2013 to prevent delay to the launch schedule.

Critical date -1st May 2015. 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 700+/-20km 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 Currently, SST-US have not chosen a ground station solution for communicating with the OTB mini-satellite and are in negotiation with ground station service suppliers and antenna providers to find the optimum way forward. Orbital modelling of the OTB mission suggests that given the orbital inclination of the satellite, then a ground station would need to be at latitudes of +/-35º or less and while a station based in US territory is preferred, it is not considered mandatory and the location/service will be chosen based on a cost-effectiveness basis.

1.2.2 SST-US will only require one 5 minute link session per day for satellite TT&C and to download payload data. The OTB satellite will not radiate RF signals when out of visibility of the ground station. A separate FCC application will be made for ground station operations.

1.3 Contact(s) for interference issues

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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 maximum mass is 180kg and has the deployed configuration as shown in figure 2-1.

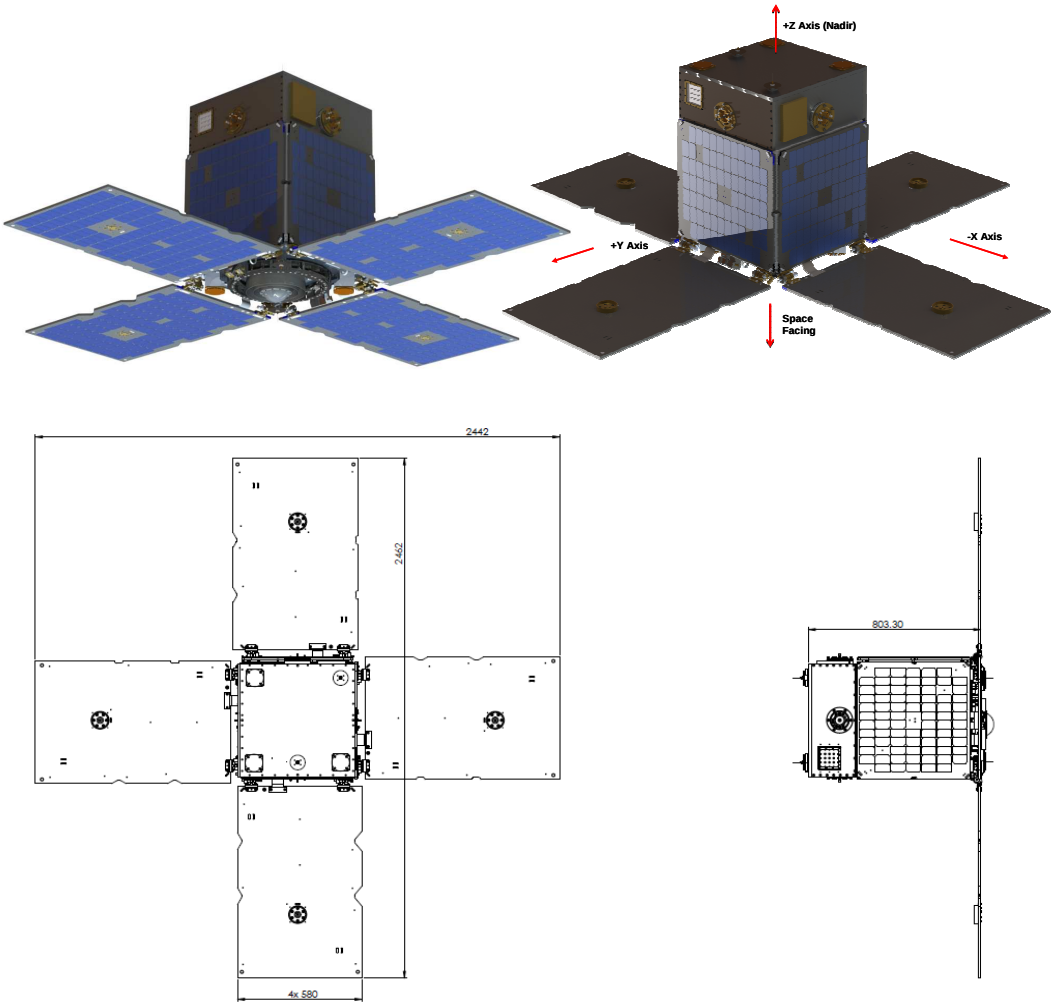


Figure 2-1 Outline of OTB mini satellite configuration (all dimensions in mm).

2.2 Experimental Payloads and Testing

2.2.1 The 'Orbital Test Bed' (OTB) mini-satellite is a small LEO experimental satellite that will provide an in-orbit test bed for the experimentation and demonstration of scientific; research and prototype payloads, subsystems and equipments. The OTB mini-satellite will accommodate eight experimental payloads, including a number of 'hosted' payloads are 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. CUSP - A microprocessor and memory storage experiment from the University of Colorado Boulder www.colorado.edu

5. SSC Electronics Test Bed – An experiment designed to monitor the effects of spaceflight on new electronics components, co-sponsored by the Surrey Space Centre at the University of Surrey and SST-US. 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.

In addition, SST-US primary payloads are also included:

1. 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.

2. 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.

3. 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; 4.07Mbits/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 5 minute RF link session every day for satellite Telemetry & Tele-Command (TT&C) and to download 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 may 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; 4.07Mbits/s; S-band transmitter to downlink payload data to the ground station. When the high rate transmitter is used, the platform status information is multi-plexed with the payload data and therefore the low rate transmitter will not be used at this time.

(NOTE: there are two S-band high rate transmitters onboard although only one is operational, the other is a cold redundant spare)

3.1.2 **Critical date - 31st October 2013.** SST-US needs to make a final design decision on the RF center frequencies of the S band transmitters in section 3. These center frequencies can set in the band 2200GHz – 2290GHz to accommodate any concerns the FCC have, however they cannot be changed once in manufacture i.e. they are not software programmable radios. Therefore SST-US would appreciate any feedback from the FCC on these center frequencies by 31st October 2013 to prevent delay to the launch schedule.

3.1.3 For information, the satellite Tele-Command 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.

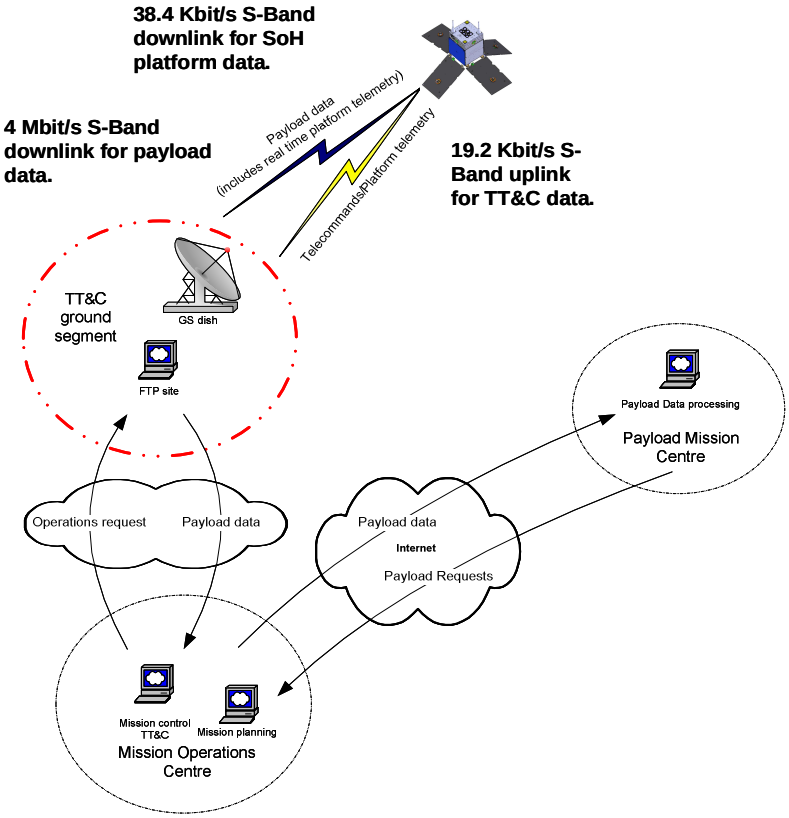
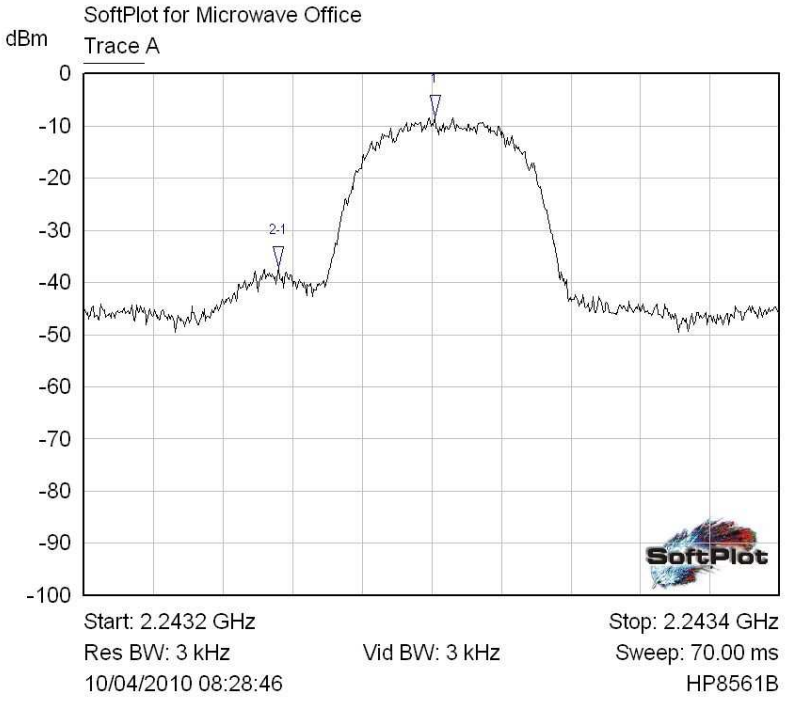


Figure 3-1 Ground Station - OTB satellite relationship

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:	2230 MHz	
C/F tolerance	<±20ppm	
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	



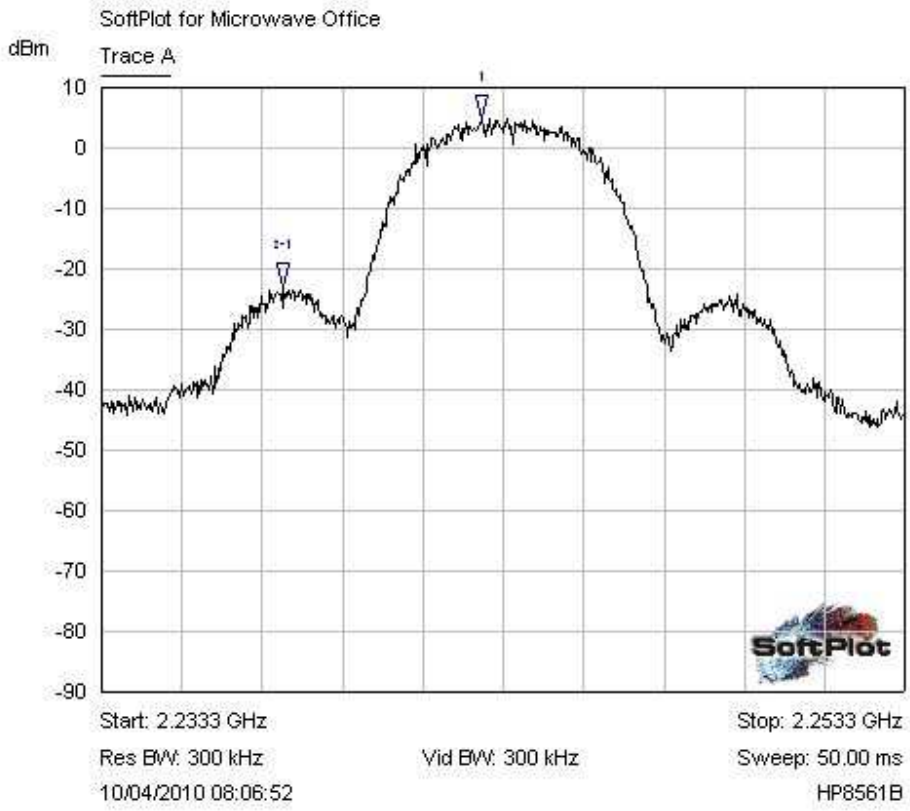
Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	2.2433 GHz	-8.16 dBm	
2-1 ▽	Trace A	-45.0000 kHz	-29.00 dB	

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

3.3 *S-band; High-rate; 4.07 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:	6.5 MHz	
Operating Frequency:	2243.333 MHz	
C/F tolerance	<±20ppm	
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-LHC	
Data Rate:	4.07Mbits/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	2.2428 GHz	4.90 dBm	
1-1	Trace A	-4.9333 MHz	-27.83 dB	

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

4. FURTHER INFORMATION

4.1 *Related frequency filing activity*

4.1.2 Sapphire is a Canadian DND space surveillance satellite which was launched in 2013. MacDonald, Dettwiler and Associates (MDA) were the mission prime for Sapphire, while Surrey Satellite Technology Ltd (SSTL) manufactured the platform. http://www.sst-us.com/missions/sapphire/news/sapphire-the-mission SSTL provided information for the Sapphire project to show that the S-Band Low Rate transmitter (section 3.2) and S-Band 4Mbps 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://www.sst-us.com/missions/cfesat/news/cfesat--the-mission. The frequency filing was placed the NTIA. CFESat operated with a similar High Rate 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

4.3 *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 Surrey Satellite Technology US LLC (SST-US) 'Orbital Test Bed' (OTB) mini-satellite is a small LEO experimental satellite that will provide an in-orbit test bed for the experimentation and demonstration of scientific; research and prototype payloads, subsystems and equipments. The OTB mini-satellite will accommodate eight experimental payloads, including a number of 'hosted' payloads are sponsored by external parties which support their research programs:

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In addition, SST-US primary payloads are also included which support the technical development of space technologies:

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The spacecraft will operate for 5 years, although a number of payloads may 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. None of the payloads separately radiate RF signals.

All data generated from the various payloads are multiplexed within the OTB spacecraft and down linked via the single, high rate, S-band; 4.07Mbits/s data link to the ground station.

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