BACKGROUND INFORMATION FOR THE ORBITAL TEST BED (OTB) SATELLITE

This document supports the General Atomics Electromagnetic Systems (GA-EMS) Orbital Test Bed Satellite FCC license.

Date: March 2019

Document No.: OTB-DOC-000636-05

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DOCUMENT REVISION STATUS

Revision Number	Nature of Changes	Edited by	Date
01	Initial issue for comment	M Brown	Aug ‘13
02	Incorporates updated spacecraft design information.	M Brown	Aug ‘13
03	Incorporates change in frequency and update of critical dates	T Murphy	June ‘15
04	Incorporates change in ground station selection	S Taylor	Jan ‘18
05	Incorporates change in Hawaii ground station	R Moreland	Mar ‘19

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List of Figures

1 Applicable Documents

AD#	Title	Doc. No.	Issue
AD-1	GUIDANCE ON OBTAINING LICENSES FOR SMALL SATELLITES	13-445	March 15th, 2013
AD-2	Orbital Debris Assessment Report (ODAR) for the Orbital Test Bed (OTB) Satellite	OTB-DOC-000638-05	December 2017

2 Acronyms and Abbreviations

AFRL	Air Force Research Laboratory
CAD	Computer Aided Design
DAS	Debris Assessment Software
DSAC	Deep Space Atomic Clock
EELV	Evolved Expendable Launch Vehicle
EOM	End of Mission
ESPA	EELV Secondary Payload Adapter
FCC	Federal Communications Commission
GA-EMS	General Atomics Electromagnetic Systems
HDRM	Hold Down Release Mechanism
HDRS	Hold Down and Release System
JPL	Jet Propulsion Laboratory
LANL	Los Alamos National Laboratory
LEO	Low Earth Orbit
MSA	Modular Solar Array
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
ODAR	Orbital Debris Assessment Report
OTB	Orbital Test Bed
PDM	Power Distribution Module
RF	Radio Frequency
SERB	Space Experiments Review Board
USAF	United States Air Force

3 Preamble

This document supports GA-EMS' application for an experimental license [1]. General information on the Orbital Test Bed (OTB) spacecraft is provided in reference [2].

4 Overview

4.1 Mission Concept of Operations

The GA-EMS 'Orbital Test Bed' (OTB) satellite is a 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 equipment. These 'hosted' payloads are detailed in section 2 of this document.

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

The RF transmitter communications links required to operate the OTB satellite are reviewed in Section 6 of this document.

4.1.1 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	November 2017
Launch	June 2018

The spacecraft will operate in orbit for 2 years to allow data to be gathered on the effects of long term exposure to radiation on the experiments. Therefore GA-EMS will apply for a 2 year experimental license.

4.1.2 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. GA-EMS is not sponsoring the launch.

4.1.3 Orbital Parameters

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

4.2 Earth Stations

GA-EMS has completed selection of an appropriate ground station, which will be used for TT&C (transmit and receive) and payload data download. The selected primary groundstation location is in Pendergrass, Georgia, USA. Multiple backup stations are also listed below.

4.2.1 Primary: 5.4m Antenna – Pendergrass, Georgia, USA

Location: 34.1747° N, 83.6719° W
Site Elevation: 283 m
Antenna Height above Terrain: 6.4 m
Antenna Type: Parabolic Tracking Antenna
Azimuth Range: 000 – 360 degrees
Minimum Elevation Angle: 5 degrees downlink, 10 degrees uplink

Antenna Polarization: Right or Left Hand Circular
Peak Gain: 38.1 dBi @ 2025 MHz
Antenna Beamwidth: 1.9 degrees @ 2025 MHz

4.2.2 Secondary: 12m Antenna – Naalehu, Hawaii, USA

Location: 19.0138°N, 155.6629°W
Site Elevation: 378 m
Antenna Height above Terrain: 20 m
Antenna Type: Parabolic Tracking Antenna
Azimuth Range: 000 – 360 degrees
Minimum Elevation Angle: 5 degrees uplink and downlink
Antenna Polarization: Right or Left Hand Circular
Peak Gain: 45.9 dBi @ 2025 MHz
Antenna Beamwidth: 0.8 degrees @ 2025 MHz

4.2.3 Secondary: 5.4m Antenna – Cordoba, Argentina

Location: 31.52° S, 64.46° W
Site Elevation: 691 m
Antenna Height above Terrain: 6.4 m
Antenna Type: Parabolic Tracking Antenna
Azimuth Range: 000 – 360 degrees
Minimum Elevation Angle: 5 degrees uplink and downlink
Antenna Polarization: Right or Left Hand Circular
Peak Gain: 38.1 dBi @ 2025 MHz
Antenna Beamwidth: 1.9 degrees @ 2025 MHz

4.2.4 Secondary: 3.7m Antenna – Hartebeesthoek, South Africa

Location: 25.8865° S, 27.7056° E
Site Elevation: 1563.5 m
Antenna Height above Terrain: m
Antenna Type: Parabolic Tracking Antenna
Azimuth Range: 000 – 360 degrees
Minimum Elevation Angle: 5 degrees uplink, 3 degree downlink
Antenna Polarization: Right or Left Hand Circular
Peak Gain: 27 dBi @ 2025 MHz
Antenna Beamwidth: 2.8 degrees @ 2025 MHz

4.3 Contact(s) for Interference Issues

4.3.1 Primary

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5 Satellite Description

The OTB 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). OTB is an ESPA class spacecraft with four deployable solar panels. The spacecraft will be operated in a nadir fixed orientation for the mission duration and requires only seasonal attitude maneuvers to adjust for the position of the Sun relative to the orbit.

For further general information on the OTB platform, see reference [2].

5.1 Data Download

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. None of the payloads separately radiate RF signals.

5.2 Spacecraft Link Sessions

GA-EMS will require four 7-8 minute link sessions during launch and commissioning. The launch and commissioning phase will last for 75 days. Following launch and commissioning GA-EMS will enter the nominal operations phase. During the nominal operations phase GA-EMS will require one 7-8 minute link session per day for satellite TT&C and to download platform status information and payload data. A separate FCC application will be made for ground station operations.

5.3 Operations of Payloads

No testing of the payloads listed in section reference [2] will alter the orbital, physical or RF characteristics of the OTB satellite from nominal during their testing, as such they should be regarded as ‘passive’ in operation.

6 RF Communications

6.1 Summary

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

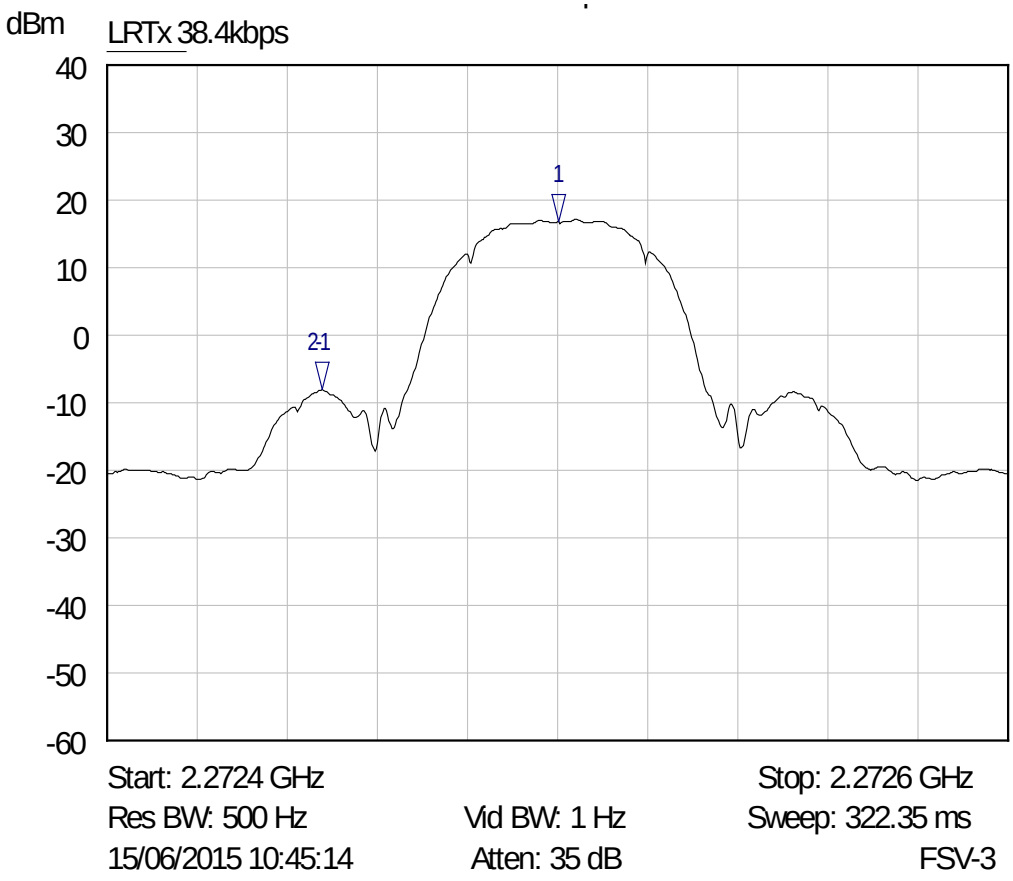
1. A low rate; 38.4kbits/s; S-band transmitter to downlink platform status information to the ground station.
2. A high rate; 2.0352 Mbits/s; S-band transmitter to downlink payload data to the ground station *(NOTE: there are two S-band transmitters onboard although only one is operational, the other is a cold redundant spare).*

For information the satellite uplink is a low rate, 19.2 kbits/s S-Band uplink from the ground station.

6.2 S-band; Low-rate 38.4 kbits/s transmitter

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 6-1	
Emission Designator	G-1-D	



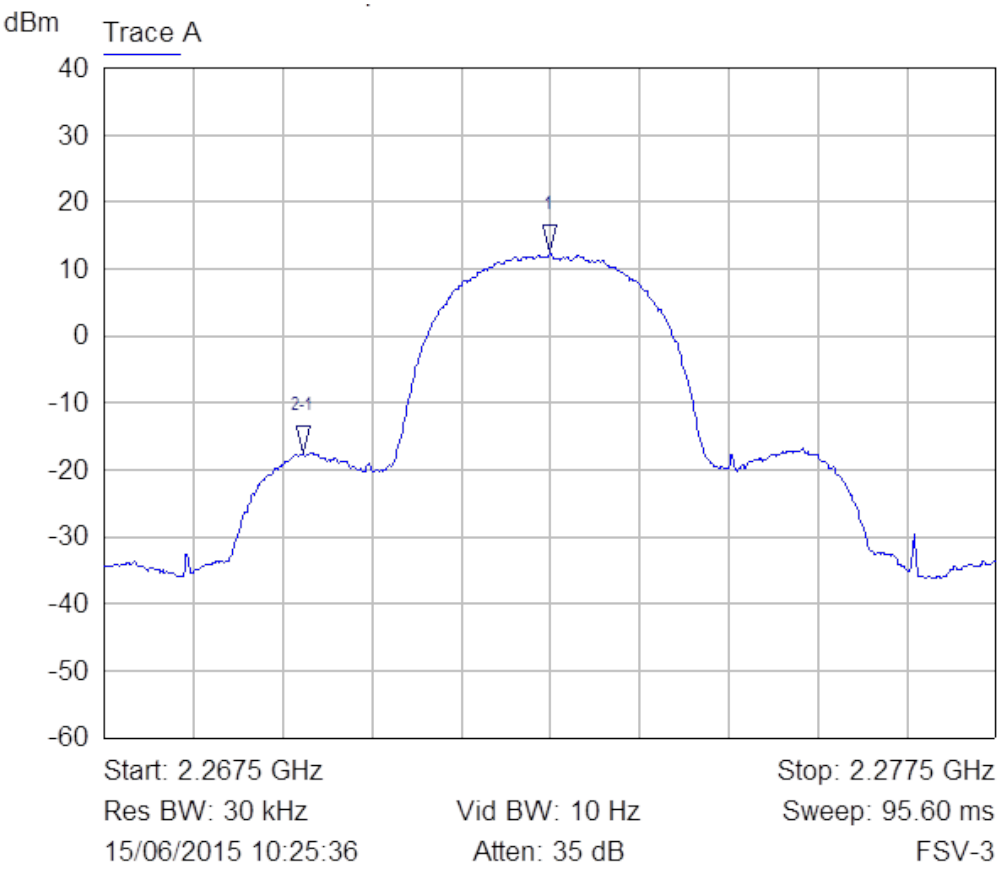
Mkr	Trace	X-Axis	Value	Notes
1 ▽	LRTx 38.4kbps	2.2725 GHz	16.81 dBm	
2 1 ▽	LRTx 38.4kbps	-52.4638 kHz	-24.87 dB	

Figure 6-1: Emission spectrum of S-band Low Rate Tx

6.3 S-band; High-rate 2.0352 Mbits/s transmitter

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 6-2	
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 6-2: Emission spectrum of S-Band High Rate Tx

7 Further Information

7.1 Related Frequency Filing Activity

A previous frequency filing submission was performed for OTB under Surrey Satellite Technology US (SST-US), prior to the acquisition of SST-US by GA-EMS. The previous FCC submission file number was 0426-EX-PL-2015.

7.2 Exhibits Relating to FCC Form 422 – Question 4

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.

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.

7.2.1 Contact Information for DSAC

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7.3 Exhibits Relating to FCC form 442 – Question 6

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:

1. **A description of the nature of the research project being conducted.**
2. **A showing that the communications facilities requested are necessary for the research project.**
3. **A showing that existing communications facilities are inadequate.**

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 Orbital Test Bed (OTB) satellite is a GA-EMS owned and operated small LEO satellite that will provide an on-orbit test bed for the demonstration of scientific, research and prototype payloads, subsystems and equipment. A number of hosted payloads are sponsored by external parties:

1) Deep Space Atomic Clock (DSAC) – sponsored by the Jet Propulsion Laboratory (JPL) under 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 Space Experiments Review Board (SERB) (http://www.usafa.edu/df/dfe/dfer/centers/sparc).
3) Modular Solar Array (MSA) – built by Vanguard and sponsored through AFRL Space Experiments Review Board (SERB).
4) Cremains – sponsored by Celestis, Inc.

In addition, the GA-EMS primary payloads are:

1) FlexRx – a new spacecraft RF receiver design.
2) Radiation Monitor – a new spacecraft radiation monitor device.
3) Custom Experimental Solar Panel – a new solar panel technology.

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. GA-EMS will require one 7 - 8 minute RF link session every day for satellite Telemetry & Telecommand (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 2 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 satellite from nominal during their testing, as such they should be regarded as 'passive' in operation.