Before the

FEDERAL COMMUNICATIONS COMMISSION

Washington, DC 20554

In the Matter of	)	
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THE BOEING COMPANY	)	
	)	
Application for Authority to	)	
Launch and Operate an	)	File No.
Experimental Non-Geostationary	)	
Low Earth Orbit Satellite	)	

NARRATIVE EXHIBIT

Table of Contents

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NARRATIVE EXHIBIT

The Boeing Company ("Boeing") is a leading contributor to the global aerospace and satellite telecommunications industries, providing technical expertise, manufacturing, launch services, and on-orbit network control for a wide variety of commercial and government satellite systems. With this Application, Boeing requests authority to launch and operate an experimental non-geostationary ("NGSO") low earth orbit ("LEO") satellite.

I. NARRATIVE INFORMATION REQUIRED BY FCC FORM 442

Question 6A. Description of the nature of the research project being conducted

Boeing is developing an experimental satellite system in order to perform on-orbit testing of miniature satellite components and software algorithms. The proposed satellite will adhere to a design specification co-developed by Stanford University ("Stanford") and California State University, San Luis Obispo ("Cal Poly") referred to as the CubeSat Standard. Additional information regarding the CubeSat Standard can be found at the CubeSat Community website, http://littonlab.atl.calpoly.edu.

Boeing has developed a satellite based on this standard, hereinafter referred to as the CubeSat Test Bed ("CSTB1"), which will serve as a space platform for hosting and testing small satellite components and subsystems. CSTB1 is a short-lived satellite with an expected lifespan of 9 to 12 months on-orbit, which will provide useful performance data on imaging technology, spacecraft attitude sensors, low-power processors, and software algorithms for space applications.

Question 6B. Showing that the communications facilities requested are necessary for the research project

On-orbit testing of components and systems provides a cost-effective way of collecting component functional and performance data and permits collection of experimental data in a relevant operational environment that cannot be adequately captured by ground testing or computer simulation.

With the proliferation of the CubeSat Standard and the availability of low-cost space access for those adhering to that standard, the cost to test miniature components on-orbit has become relatively inexpensive compared to equivalent ground testing and simulation. This is largely due to the availability of low-cost secondary payload launch options and cost sharing among multiple CubeSat developers.

In addition, on-orbit data provides confidence to potential customers that future products will operate successfully on-orbit at the specified performance. The evaluation of hardware and software in an environment similar to that found in space is not easily replicated on Earth. On-orbit component failures are often attributed to unforeseen conditions or coupling of effects that cannot be adequately tested until on-orbit. Consequently, the use of an on-orbit test bed provides significant direct and indirect financial benefits and risk reduction for future satellite programs.

Question 6C. Showing that existing communications facilities are inadequate.

Currently, there are no comparable communications facilities to support the operation of the CSTB1 system. The communications facilities requested for the CSTB1 system serve two purposes. The first use (*i.e.*, earth-to-space link) will be to send command information from the earth station to the CSTB1 satellite to schedule the start of experiments, request the transmission of payload experiment and spacecraft state-of-health data, and initiate CSTB1 decommissioning procedures for termination of mission operations. The second use (*i.e.*, space-to-earth link) will be to transmit experiment data and vehicle health and status information from CSTB1 to the earth station for further analysis.

Question 10. Transmitting equipment to be installed, including manufacturer, model number and whether the equipment is experimental in nature

The CSTB1 system is comprised of two transmitting elements: a) a space component aboard the CSTB1 satellite; and b) a ground component located at the CSTB1 earth station site. The following graphic provides an overview of the transmitting components of each element. The specific model numbers are subject to change based on product availability and system upgrades.

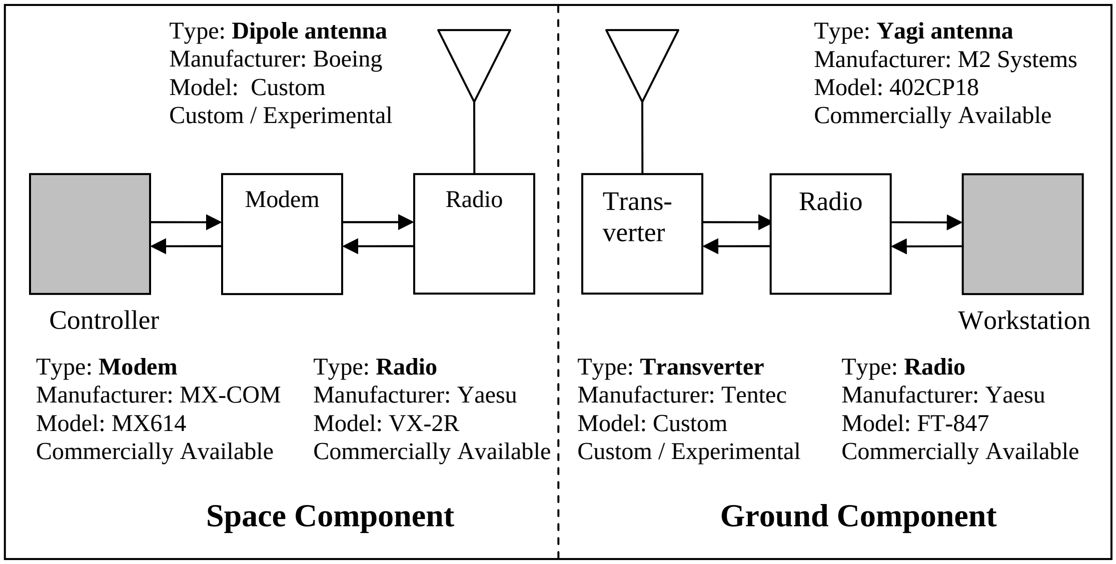

Figure 1: CSTB1 Communications Components

The transmitting component aboard the CSTB1 vehicle is controlled by a dedicated on-board processor, which processes data for transmission, sends and receives data from the modem, and activates the radio system. The CSTB1 vehicle possesses redundant modem and radio systems, a single custom one quarter wavelength dipole antenna, and RF switching electronics. The modem (manufacturer/model: MX-COM/MX614) and radio (manufacturer/model: Yaesu/VX-2R) are commercially available, off-the-shelf units modified to work at the requested frequencies.

The transmitting component located at the CSTB1 earth station is controlled by dedicated Microsoft Windows and Apple OS X-based workstations. The workstations are used for antenna pointing control, Doppler frequency shift corrections, and data processing for transmission. The antenna (manufacturer/model: M2 Antenna Systems, Inc./402CP18) and radio (manufacturer/model: Yaesu/FT-847) are commercially available, off-the-shelf units, which require additional hardware to work at the requested frequencies.

Question 11A. Is the equipment listed in Item 10 capable of station identification pursuant to Section 5.115

Each transmitting component of the CSTB1 system is capable of station identification at the end of each complete transmission and this process is incorporated into the CSTB1 operations procedure. The space component will transmit in Morse code the assigned call sign at the end of each complete data transmission. The ground component will broadcast in clear voice the assigned call sign at the end of each data transmission by ground station operators.

Question 4 - Antenna Registration Form. Operation of Directional Antenna

The CSTB1 satellite is a low earth orbiting satellite, which has an orbit period of approximately 1.6 hours. The satellite will pass over the earth station roughly twice per day with an average access time of 5 to 7 minutes. The earth station will use a computer-controlled tracking antenna to point the earth station's antenna in the direction of the moving satellite. The antenna has a maximum gain of +16dBi along the bore-sight of the antenna and a 1/2 power beam-width (*i.e.*, -3dB) of approximately 30 degrees. The antenna is an off-the-shelf, yagi-type antenna developed by M2 Antenna Systems, Inc.

Since CSTB1 is an NGSO satellite, the range of antenna azimuth and elevation will vary based on the relative motion of the satellite with respect to the ground station and will differ for each satellite pass. The earth station will only transmit above a 10 degree elevation angle. Consequently, the range of antenna elevation angles for all satellite passes will be between 10 and 170 degrees. The azimuth can vary between 0 and 360 degrees. Earth station software will be used to control the antenna azimuth and elevation rotors for antenna pointing and limit the range of permissible elevation angles. In addition, the software will be used to predict satellite contact times and antenna pointing angles to support earth station planning and operations.

II. INFORMATION REQUIRED BY PART 5 OF THE COMMISSION'S RULES

Section 5.63 Orbital Debris Mitigation

The design and operational strategies for CSTB1 attempt to mitigate orbital debris by the following means:

Section 5.63(e)(1)(i) Limiting the amount of debris released during normal operations

In order to limit the amount of debris generated during normal operations, CSTB1 has been designed so that all parts will remain attached to the satellite during launch, ejection, and normal operations. This requirement is intrinsic to all satellites conforming to the CubeSat Standard and compliance is required for launch using the Poly-Picosatellite Orbital Deployer ("P-POD") system.

Section 5.63(e)(1)(ii) Limiting the probability of the satellite becoming a source of debris by collisions with small debris or meteoroids that could cause loss of control and prevent post-mission disposal

The basic geometry of the CSTB1 satellite is a monolithic cubic structure with a maximum dimension of 10 centimeters per side. Based on a simple orbital debris model (ref. Tribble, 1995), the probability of a single particle impact with a size of 1 millimeter or larger over the mission lifetime is very low (*i.e.*, roughly 7 x 10^{-5}). This low probability of impact for the CSTB1 mission is a result of the small effective area of the space vehicle (*i.e.*, effective area ~ 0.01 m^2) and the relatively short mission duration (*i.e.*, mission life < 1 year).

Catastrophic system failure due to orbital debris or micrometeoroid impact will not affect the vehicle's ability to de-orbit within the guidelines for vehicles operating in low earth orbit (*i.e.*, less than 25 years). Based on the mission orbit of 510 kilometers and lack of any active means to maintain its orbit, the space vehicle is anticipated to re-enter the atmosphere in less than five years based on lifetime prediction simulations for the current mission epoch (*i.e.*, launch in CY2006).

Section 5.63(e)(2) Limiting the probability of accidental explosions during and after completion of the mission operations

The CSTB1 satellite does not have any pressurized systems or kinetic energy sources that could result in debris generation from the conversion of energy sources on board the satellite into energy that can fragment the spacecraft. In addition, the CSTB1 spacecraft does not include any propellants, pressurants, ordinance devices, or momentum storage devices. The vehicle does possess energy storage devices (*i.e.*, Li-ion batteries), which will be left in a nearly discharged state as part of the decommissioning procedure.

Section 5.63(e)(3) Limiting the probability of the satellite becoming a source of debris by collisions with large debris or other operational space stations

Based on a simple orbital debris model (ref. Tribble, 1995), the probability of CSTB1 colliding with large debris or other space systems of sizes one centimeter or greater at the CSTB1 mission orbit altitude and inclination is negligible (*i.e.*, roughly

$3x10^{-7}$). The CSTB1 vehicle does not possess any propulsive means to avoid in-orbit collisions or maintain its orbit parameters.

The launch provider has instituted deployment procedures in order to place the co-manifested satellites into slightly different orbits in order to reduce the risk of collision. Some of these procedures include staggering deployment times and accelerating the launch platform during the deployment sequence.

Section 5.63(e)(4) Post-mission disposal plans for the space station at end of life

The post-mission disposal plan for CSTB1 includes the transition of all vehicle systems to a dormant state, which includes the cessation of all radio operations (*i.e.*, transmission and receipt). CSTB1 energy storage devices will be held at a minimal charge state at the end of the life of the vehicle. The atmospheric re-entry of the CSTB1 satellite is predicted to occur within five years based on its mission orbit, vehicle mass, geometry, and mission epoch (*i.e.*, launch in CY2006 – solar min). No active de-orbit maneuvers are required to meet the 25 year re-entry guidelines.

Re-entry debris and probability of human casualty will be negligible. The materials used on the vehicle include aluminum and PCB material, which have a relatively low melting temperature as compared to other materials such as Ti or stainless steel.

III. RELEVANT INFORMATION ADDRESSED IN SECTION 25.114 OF THE COMMISSION'S RULES

Section 25.114(c)(4) General Description of Overall System Facilities, Operations and Services

The Boeing CSTB1 satellite system provides a platform for on-orbit testing of miniature spacecraft components and subsystems. The CSTB1 space vehicle provides nominal attitude, electrical power, data storage, and command function for a set of mission payloads. These payloads consist of commercial-based imaging technology, spacecraft attitude sensors, low-power processors, and software algorithms. The CSTB1 space vehicle communicates with the earth station through a half-duplex communications link operating in the UHF band.

The single CSTB1 earth station is located on the Boeing facility in Huntington Beach, California and serves as both the Mission and Spacecraft Operations Centers ("MSOC"). The MSOC will be developed and operated by Boeing personnel. The primary responsibilities of the MSOC will be to command the space vehicle to initiate the experiments, recover spacecraft engineering telemetry and mission data, and perform analysis and processing of data to support the mission.

The earth station equipment is comprised of a yagi antenna, communications transceiver, MSOC workstations, and a mission data archive server. The workstations will serve as the primary interface with the ground controllers and will be used for data processing, antenna/radio control, and engineering analysis. The mission data archive server will archive command and telemetry data to support mission operations, status, troubleshooting, and post-mission assessment.

Section 25.114(c)(5) Radio Frequency Plan

The CSTB1 communications system will operate using half-duplex communications within the 399.9-400.05 MHz frequency band for both telecommand (*i.e.*, earth-to-space) and telemetry (*i.e.*, space-to-earth) functions. Boeing specifically requests authority to use 25 kilohertz of spectrum from 400.025 MHz to 400.05 MHz for the CSTB1 spacecraft and ground station, although the CSTB1 network is technically capable of operating anywhere in the 399.9-400.05 MHz frequency band.

The CSTB1 spacecraft will communicate with the CSTB1 ground station only when it is within line-of-sight of the ground station and has received a communication from the ground station directing the spacecraft to initiate transmissions. As a consequence, the CSTB1 system will utilize the 399.9-400.05 MHz spectrum band only in the Southwestern United States and potentially conflicting uses of the band in other regions of the world are not relevant to this application.

The following diagram shows the proposed spectrum use of the CSTB1 network and also shows authorized spectrum uses in adjacent bands, such as the use by the Orbcomm Little LEO MSS network of the 400.075-400.125 MHz band as a beacon frequency. As explained below, the 399.9-400.05 MHz frequency band does not appear to be used by any authorized government or non-government operator in the United States, nor is the spectrum designated for use in the near future. Therefore, Boeing's proposed operation of its experimental CSTB1 satellite network will not cause harmful interference to any authorized spectrum user.

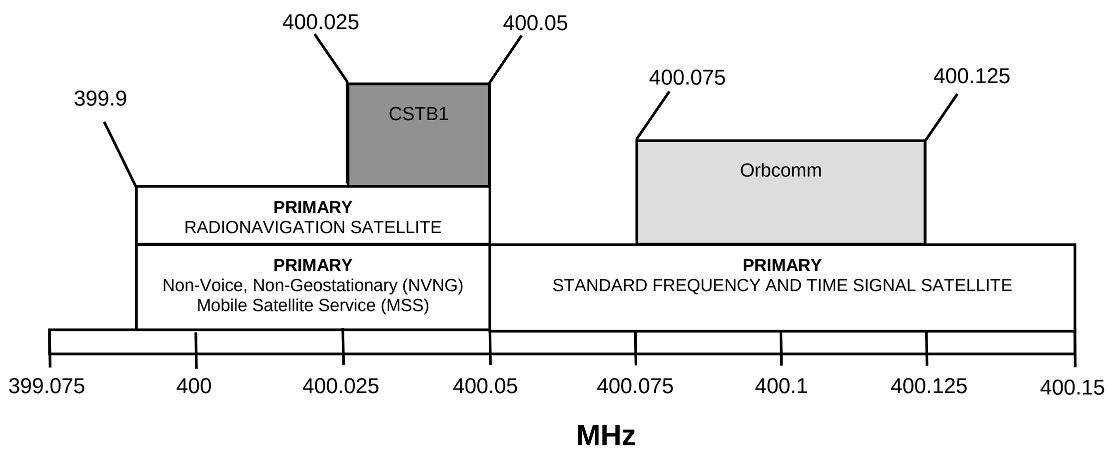

Figure 2: CSTB1 Spectrum Diagram

The 399.9-400.05 MHz frequency band is allocated internationally on a primary basis to the Mobile Satellite Service ("MSS") (earth-to-space). The 399.9-400.05 MHz frequency band is also allocated internationally on a primary basis to the Radionavigation Satellite Service ("RNSS") until January 1, 2015.[1] In the United States, the 399.9-400.05 MHz frequency band is allocated to the MSS and RNSS services for both government and non-government use.

During the 1995 World Radiocommunication Conference ("WRC-95"), the International Telecommunication Union ("ITU") allocated the 399.9-400.05 MHz band for the Little LEO MSS service. The Commission subsequently designated the 399.9-

[1] *See* 47 C.F.R. § 2.106 n.5.224B.

400.05 MHz band as available for use by Little LEO MSS networks.[2] None of the applicants for Little LEO MSS licenses in the United States, however, requested authority to operate in the 399.9-400.05 MHz band.[3] Therefore, the Commission refrained from adopting service rules for Little LEO MSS networks operating in the 399.9-400.05 MHz band and did not issue any licenses to Little LEO MSS networks authorizing them to operate in the band.[4] Boeing is unaware of any Little LEO MSS network operating anywhere in the world (and particularly not in the United States) that uses the 399.9-400.05 MHz band.

The 399.9-400.05 MHz frequency band is also allocated internationally on a primary basis to RNSS until January 1, 2015. The 399.9-400.05 MHz frequency band was previously used by the U.S. Department of Defense for its TRANSIT-SAT RNSS system, which was a polar orbiting satellite network that was primarily used for commercial and government maritime navigation. The TRANSIT-SAT network, however, was decommissioned in December 1996.[5]

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[2] *See Amendment of Section 2.106 of the Commission's Rules to Allocate Spectrum to the Fixed-Satellite Service and the Mobile-Satellite Service for Low-Earth Orbit Satellites*, Report and Order, 8 FCC Rcd 1812 (1993); 47 C.F.R. §§ 2.106 n.US320 & 25.202(a)(3). Although the Commission originally included the 399.9-400.05 MHz band in footnote US320, reference to the 399.9-400.05 MHz band was inadvertently deleted from US320 during a Commission effort to consolidate footnotes. The Commission recently corrected the error, reincorporating the reference to the 399.9-400.05 MHz band in footnote US320. *See Amendment of Parts 2, 25, and 73 of the Commission's Rules to Implement Decisions from the World Radiocommunication Conference (Geneva, 2003) (WRC-03) Concerning Frequency Bands Between 5900 kHz and 27.5 GHz and to Otherwise Update the Rules in this Frequency Range*, Report and Order, 20 FCC Rcd 6570, 6625 (2005).

[3] *See Amendment of Part 25 of the Commission's Rules to Establish Rules and Policies Pertaining to the Second Processing Round of the Non-Voice, Non-Geostationary Mobile Satellite Service*, Report and Order, 13 FCC Rcd 9111, 9120-21 (1997).

[4] *See id.* at 9121.

[5] *See Federal Long-Range Spectrum Plan*, Working Group 7 of the NTIA Spectrum Planning Subcommittee (Sept. 2000), available at http://www.ntia.doc.gov/osmhome/LRSP/LRSP5a.htm.

It does not appear that the United States government or commercial operators are using the 399.9-400.05 MHz frequency band for any other RNSS service. Furthermore, no future RNSS use appears to be under development. Boeing understands that government and non-government operators avoid the use of the 399.9-400.05 MHz frequency band for RNSS because of anticipated spectrum sharing difficulties with any Little LEO MSS network that might be authorized by the Commission to use the band in the future. As a consequence, the 399.9-400.05 MHz frequency band appears to be fallow of any authorized use in the United States. Therefore, the short term operation of Boeing's experimental CSTB1 satellite network will not result in harmful interference to any authorized spectrum user.

Despite the absence of any authorized spectrum users in the 399.9-400.05 MHz band, the CSTB1 system has been designed to include several precautions to prevent harmful interference to other services. First, as noted above, satellite transmissions will be controlled from the earth station and the spacecraft will not transmit until it receives a request from the earth station.

Second, the satellite uplink and downlink will use the same 25 kHz bandwidth in half-duplex mode to send digital data using standard FSK modulation with maximum data rates up to 9,600 baud. The spacecraft transceiver will alternate between transmit and receive modes with a maximum transmission interval of 60 seconds to provide the ability to command the satellite to cease transmission operations in a timely manner, if required. Third, the radio has a built-in, power-saving feature that automatically places the radio in receive-only mode three minutes after its last radio transmission.

The satellite transmitter can be adjusted to provide up to 1 watt of power output. Transmission power on the earth station transmitter can be adjusted to provide up to 50 watts of power output. The communications parameters for both the satellite and earth station transmitters can be found in the following tables.

CSTB1 Satellites Communications Parameters	**Value**
Emission Designator	25K0F1D
Service	Digital Data
Frequency	400.0375 MHz
Bandwidth	25 kHz
Modulation	FSK
Data Rate	1,200 to 9,600 bps
Polarization	Linear
Antenna Type	Dipole
Antenna Gain	+2 dBi (Max)
RF Power Output	1W
Line Losses	-1dB
EIRP	1 dBW

Table 1: CSTB1 Satellite Communications Parameters

CSTB1 Earth Station Communications Parameters	**Value**
Emission Designator	25K0F1D
Service	Digital Data
Frequency	400.0375 MHz
Bandwidth	25 kHz
Modulation	FSK
Data Rate	1,200 to 9,600 bps
Polarization	Linear (H, V) or Circular
Antenna Type	Yagi
Antenna Gain	+16 dBi (Max)
RF Power Output	50 W
Line Losses	-3dB
EIRP	30 dBW

Table 2: CSTB1 Earth Station Communications Parameters

Section 25.114(c)(6) Orbital Locations

The CSTB1 system is comprised of a single space vehicle operating in a non-geostationary satellite orbit ("NGSO"). The CSTB1 spacecraft is intended to operate using a 510 kilometer circular sun-synchronous orbit with a longitude of the ascending node of approximately 11:30 GMT. The satellite has an orbit period of roughly 1.6 hours with typical ground access times of 5 to 7 minutes per pass. The orbit parameters are presented in the following table:

Parameter	**Units**	**Value**
Orbit Period	Hrs	1.58 hrs
Orbit Altitude	Km	510 km
Inclination	Deg	98 deg
Longitude of the Ascending Node (LTAN)	GMT	11:25-11:35 GMT

Table 3: CSTB1 Orbit Parameters

Section 25.114(c)(7) Predicted Spacecraft Antenna Gain Contours

The CSTB1 spacecraft antenna is a one quarter wavelength dipole antenna, which is essentially omni-directional, possessing a toroidal radiation pattern with maximum gain perpendicular to the linear elements. An antenna gain contour plot is provided below.

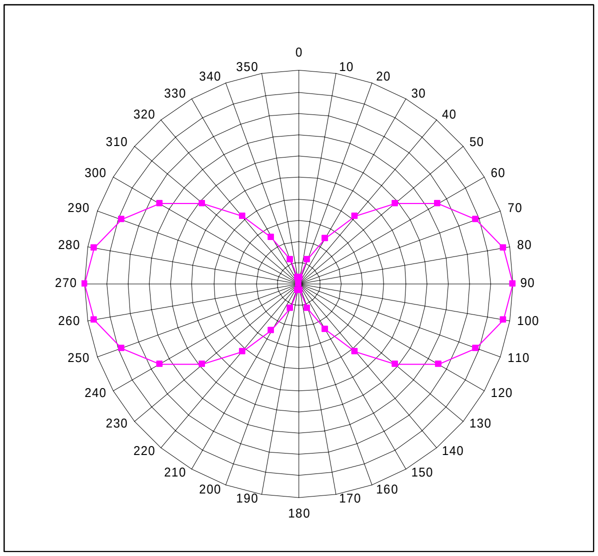

Figure 3: CSTB1 Dipole Antenna Gain Plot

Section 25.114(c)(12) Physical Characteristics of Satellites

CSTB1 is a pico-class satellite (< 1 kg), which conforms to the CubeSat Standard. The CubeSat specification limits the total vehicle mass to less than 1 kilogram with maximum dimensions of approximately 10cm x 10cm x 10cm. The CSTB1 vehicle has been designed primarily as a single-string system using commercial off-the-shelf parts with a mission lifetime of less than one year on-orbit. The mass budget is provided in the following table:

Component / Subsystem	**Mass [g]**
Payload	150
Spacecraft (Subtotal)	850
Structure	300
Electrical Power System	250
ADCS	50
C&DH	50
Communication	200
TOTAL	1,000

Table 4: CSTB1 Mass Budget

The CSTB1 spacecraft generates approximately one watt of power during a typical orbit using body-mounted GaAs solar cells. Because of the short lifetime of the satellite (*i.e.*, less than a year), the difference between the beginning of life ("BOL") and end of life ("EOL") power generation is negligible. To permit operations during eclipse, the energy is stored on-board using Li-ion batteries, with power being distributed to subsystems and components through the CSTB1 electrical power subsystem circuitry. The EOL power budget is provided in the following table:

Component / Subsystem	**EOL Power [mW] Orbit Averaged**
Payload	150
Spacecraft (Subtotal)	730
Electrical Power System	150
ADCS	50
C&DH	150
Communication	380
TOTAL	880

Table 5: CSTB1 Power Budget

Section 25.114(c)(15) Schedule

The project timeline and major milestones for the launch and operation of the CSTB1 system are provided in the following table. The dates are approximate and contingent upon the exact launch date ("Time of Launch" or "ToL"), orbit parameters, and unforeseen events during on-orbit operations.

Milestone	**Date**	**Notes**
Delivery for Launch Integration	Dec 2005	ToL – 3 months
Launch	Mar 2006	ToL = Time of Launch
Release from Launch adapter	Mar 2006	ToL + 0hr 30min
On-orbit check	Mar 2006	ToL + 2hr 00 min
Start of Experiments	Apr 2006	ToL + 5 day
Decommissioning	Dec 2006	ToL + 9 months
Re-entry	Dec 2011	ToL + 5 years

Table 6: CSTB1 System Major Milestones