Short-Range Ionospheric Modeling Picosat (ShRIMP-Sat)

Systems Requirements Document
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Introduction

The University of Washington Department of Aeronautics and Astronautics (UWAA) AA420/421 Space Design class, with the support of the General Dynamics Corporation (GD), has begun research and design of a pair of picosatellites to accomplish science objectives related to ionospheric modeling. Two science missions are being considered. One mission will use a combined Plasma Impedance Probe/DC Probe system on two picosatellites separated by a short (10m) tether (the PIP mission). The other mission will use a technique known as GPS scintillation using two picosatellites separated by at least 100 meters (the GPS mission). Both missions will use the same generic satellite platform, with the only differences being those necessary to accomplish the different missions. To date, the team has completed preliminary mission analysis and requirements definition. This document is the official systems requirements document and will refer to individual subsystem specifications for more detailed component requirements definition.

Background

Variations in ionospheric plasma density can create large amplitude and phase fluctuations in radio waves passing through this region. For this reason, the creation of models of ionosphere density is of critical interest to scientists working in the field of satellite communications. Multiple measurements of plasma density over a region are of particular value when creating these models. This type of measurement can be accomplished through the use of multiple low-cost picosatellites.

Picosatellites show great promise as low-cost platforms for short-duration Low-Earth Orbit (LEO) science missions. The CubeSat program created at Stanford University's Space Systems Development Laboratory provides logistics and launch support for picosatellites.

Mission Objectives

The ShRIMP-Sat shall accomplish each of the following objectives:

- Gather data that will contribute to the modeling of ionospheric structures that affect the performance of space-based communications systems
- Develop CubeSats as a low-cost LEO science platform

Mission Requirements

From the above objectives the following mission requirements were derived:

- The ShRIMP-Sat shall take ionosphere density measurements simultaneously at two locations
    - The PIP mission shall have a separation of at least 3 meters when taking data
    - The GPS mission shall have a separation of at least 100 meters when taking data
- These measurements shall be taken between 100 and 600 km altitude
- These measurements shall be taken for a minimum of 14 days
- The ShRIMP-Sat shall be designed to meet the requirements to participate in the CubeSat program

Systems Specification

Scope

This specification establishes the design, construction, performance, development, and test requirements for the ShRIMP-Sat.

Applicable Documents

The following documents of the exact issue shown shall form part of this specification to the extent specified herein. In the event of conflict between the requirements of this specification and any referenced document the order of precedence shall be 1. This specification and 2. Referenced documents.

Government Documents

Industry Documents

Stanford University and California Polytechnic Institute at San Louis Obispo (CalPoly), CubeSat Design Specifications Document, Revision 1, January 2001.

One Stop Satellite Solutions, Launch Services Specifications, applicable excerpts available at http://ssdl.stanford.edu/cubesat/specs-1_files/CubeSat%20Launch%20Environment.htm

Additional Specifications

ShRIMP-Sat subsystem specifications: Attitude Determination & Control (AD&C-PIP), Command & Data Handling (C&DH), Communications & Navigation (Comm/Nav), Power, Science-PIP, Structures, Thermal

Item Definition

The ShRIMP-Sat shall consist of a pair of identical satellites. Generic fittings shall be provided to accommodate the AD&C and science components for either the PIP or the GPS mission.

Mission Plan

The following is the mission plan for the ShRIMP-Sat system:

Day 0:	Deployment from P-POD launcher, separation of master and slave
Day 1-10:	Passive attitude stabilization into data-taking formation
Day 11-30:	Data taking and downlink
Day 31-44:	Mission margin, additional data collecting
Day 45:	De-orbit and end-of-life

Mission Modes

Table 1 defines the modes of operation of the ShRIMP-Sat system.

Table 1. Mission Modes

Mission Mode	Task
0	Power off
1	On ground power on
2	Deployment/power on
3	Stabilization
4	Data taking
5	Ground communication
6	Conserve power/recharge

Modes 1 and 2 apply only to the initial deployment and stabilization portions of the mission. Mode 3, data taking, shall be the primary mode of operation, with the ShRIMP-Sat switching to mode 4, ground communication, as communication opportunities occur. Mode 5, conserve power and recharge, shall only be used in the event that normal operations cannot be supported by the power subsystem.

Coordinate Systems

Figure 1 depicts the coordinate system and side numbering scheme that will be used to describe locations within and on the satellites. The faces shall be numbered as follows: side 1 shall be the side that faces into the freestream and side three shall be the face opposite it; sides 2 and 4 shall be the "sides," i.e. they shall be parallel to the direction of flight and not zenith or nadir pointing; and sides 5 and 6 shall be zenith or nadir pointing – the satellite could be oriented with either side "up" in flight. The coordinate system shall be defined with its origin at the corner shared by sides 1, 2, and 5, with the x-axis defined by the edge between sides 2 and 5, the y-axis defined by the edge between sides 1 and 5, and the z-axis defined by the edge between sides 1 and 2.

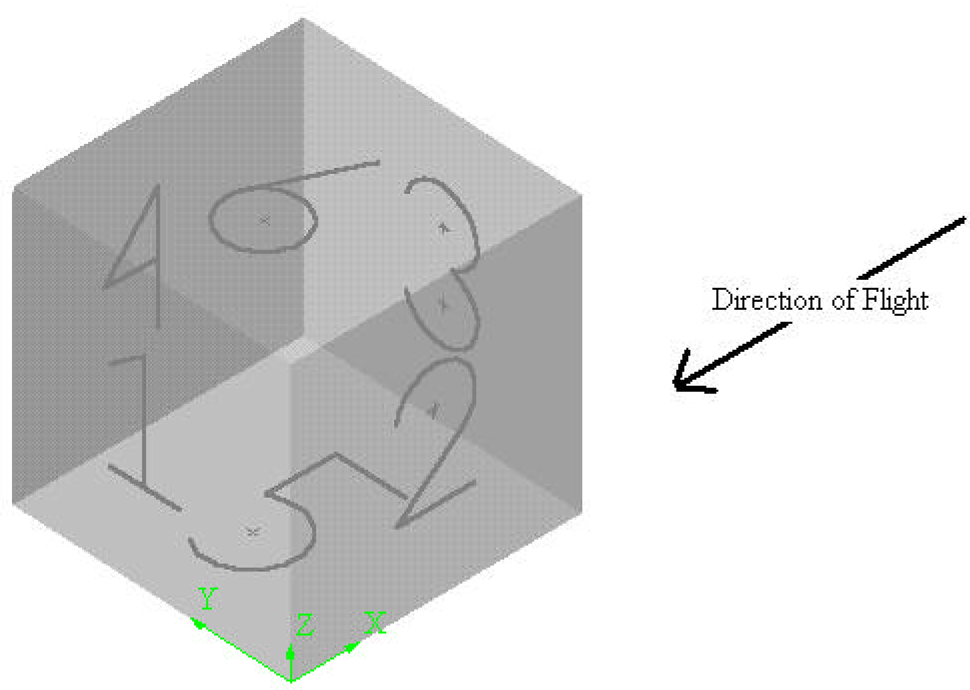

Figure 1. Coordinate System

Configuration

Figure 2 is a diagram outlining the spacecraft configuration. For more detailed bock diagrams of individual subsystems, refer to the subsystem specifications.

Figure 2. System Configuration

Interface Definition

Physical Interfaces

The ShRIMP-Sat shall be interfaced to the launch vehicle through the Poly Pico Orbital Deployer (P-POD), developed at Stanford and CalPoly and described in the CubeSat Design Specifications Document.

Mounting of all components to ShRIMP-Sat structures shall be by means of NASA-qualified fasteners or epoxy. For further information refer to the structures subsystem specification.

Electrical Interfaces

All components shall accept a power supply of either 9-12 V DC unregulated or +/- 5 V DC regulated to +/- 0.3 V. Table 2 is a summary of all electrical interfaces on the ShRIMP-Sat.

Table 2. Electrical Interfaces

	Power Connection				Data Connection	
Part	**Connected to**	**Voltage (V)**	**Max Current (mA)**	**Type**	**Connected to**	**Type**
Power						
Batteries	PDU	9-12	330	TBD		
Distribution (PDU)	all systems	9-12 in, multiple out	330	multiple		
Solar Cells	PDU	9-12	330	TBD		
C&DH						
C&DH Board	PDU	9-12	25	TBD	all systems	multiple
Data Port	external power supply	9-12	TBD	9-pin RJ45	external computer	9-pin RJ45 ethernet
Comm/Nav						
Tranceiver	PDU	9-12	110	TBD	C&DH board	TBD
Radio Antenna					tranceiver	TBD
Science - GPS						
GPS Antenna					GPS board	TBD
GPS Board	PDU	5	360	TBD	C&DH board	TBD
Science - DC/PIP						
DC Probe	science board	5	TBD	SMA connector		
PIP	science board	TBD	TBD	ACTEL FPGA		
DC/PIP Board	PDU	+/- 5	300	TBD	C&DH	Motorola SPI
Attitude - GPS						
Deployment	PDU	TBD	TBD	TBD	C&DH	TBD
Attitude - DC/PIP						
Deployment	PDU	TBD	TBD	TBD	C&DH	TBD
Thermal						
Heaters	PDU	9-12	170	TBD		
Temp Sensors	C&DH	0.03	10	TBD	C&DH	TBD

Two independent methods for ensuring that the ShRIMP-Sat remains unpowered before deployment shall be used. A microswitch on the end of one of the deployment rails (pictured in figure 3 below) shall cut off all satellite power when depressed by another satellite within the P-POD. The release of this microswitch upon deployment shall power on the satellite and initiate the mission. Furthermore, a "remove-before-flight pin" shall provide a physical power cutoff when in place in the location pictured in figure 3 below and shall be removed by launch services before launch.

Functional or Informational Interfaces

A 9-pin RJ45 ethernet connector shall be provided by the C&DH subsystem in the location specified in figure 3 below to allow for post-integration diagnostics and configuration.

Refer to the C&DH subsystem specification for information on internal functional and data interfaces.

Characteristics

Performance Characteristics

The ShRIMP-Sat shall take ionospheric plasma density measurements at TBD resolution between TBD and TBD latitudes. These measurements shall be made in pairs, with the two data points of the pair separated by the distance required for each science mission. The ShRIMP-Sat shall downlink at least 1000 bytes of these data to a ground station each day. The downlinked data shall include the measurement pairs as well as the time of selected measurements, from which the measurement locations shall be determined by satellite tracking and Keplerian analysis at the ground station.

Physical Characteristics

Figure 3, from the Stanford/CalPoly CubeSat Design Specifications Document, depicts the external configuration and interface requirements from the CubeSat program. The primary CubeSat size requirement is that each satellite shall be a 10 cm cube. Additionally, 4 of the cube edges shall be defined by 8.5x8.5mm rails on which the satellite shall slide as it exits the P-POD.

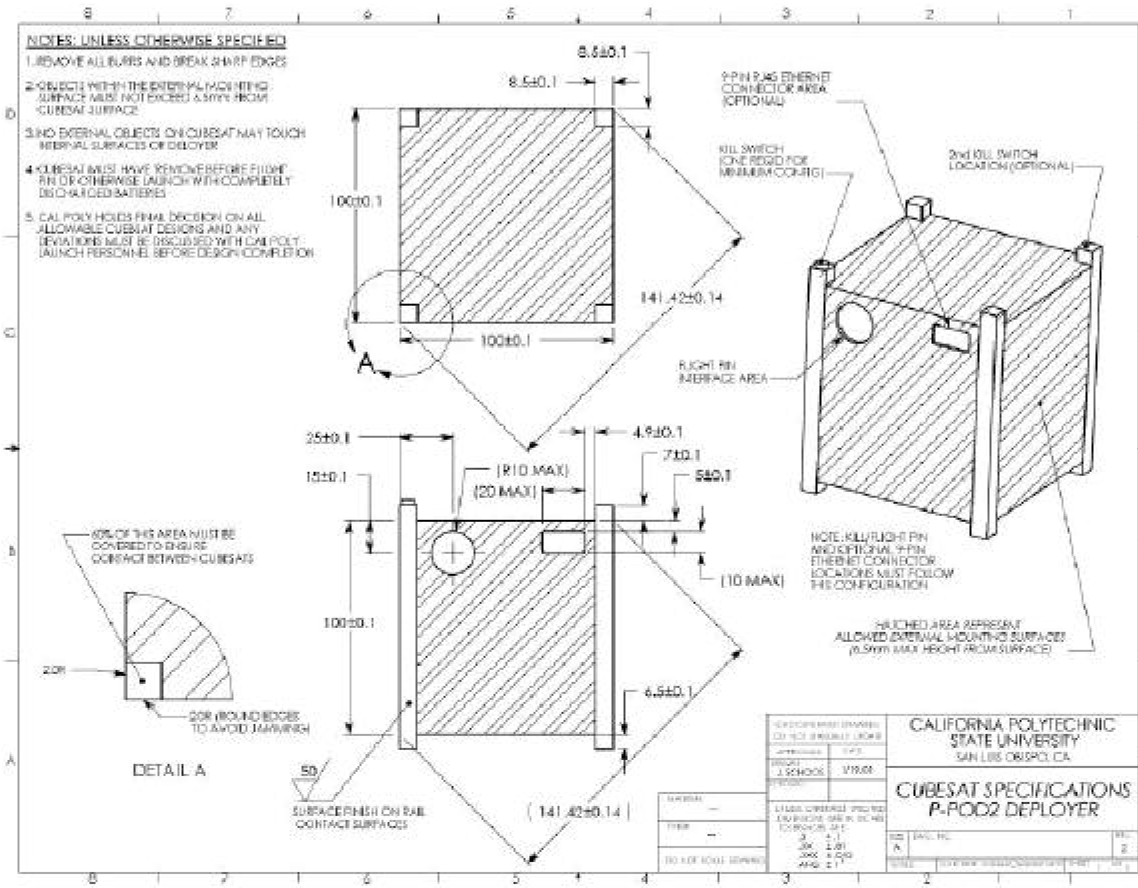

Figure 3. External Dimensions

Mass Budget

Table 3 is the mass budget for both ShRIMP-Sat missions. All figures are given per satellite. The maximum allowable mass is 1 kg for one complete system.

Table 3. Mass Budget

	Budgeted		Actual			
			Preliminary Mass Estimates (g)		Variance (g)	
Subsytem	**Percentage of Total**	**Allocated Mass (g)**	**DC/PIP**	**GPS**	**DC/PIP**	**GPS**
Structure	20%	200	200	200	0	0
Thermal	4%	40	10	10	30	30
Attitude Dynamics	13%	130	70	130	60	0
C&DH	6%	60	60	60	0	0
Comm/Nav	13%	130	125	125	5	5
Power	14%	140	140	140	0	0
Science	20%	200	200	100	0	100
Total Allocated	90%	900	805	765	95	135
Contingency	10%	100	100	100		
Total Mass	100%	1000	905	865	95	135

Power Budget

Table 4 is the power budget for the ShRIMP-Sat system. The estimated maximum available power is 1.7W orbital average power (OAP).

Table 4. Power Budget

a. PIP mission

	Budgeted		Actual				
Subsytem	**Percentage of Total**	**Allocated Power (W)**	**Standby Power Estimate (W)**	**Peak Power Estimate (W)**	**Peak On Time (%)**	**Average Power Estimate (W)**	**Variance (W)**
Thermal	12%	0.20	0.002	2.00	10%	0.20	0.002
Attitude Dynamics	1%	0.02	0.00	0.00	0%	0.00	0.02
C&DH	12%	0.20	0.05	0.50	30%	0.19	0.02
Comm/Nav	15%	0.26	0.20	1.00	5%	0.24	0.02
Power	12%	0.20	0.03	0.30	60%	0.19	0.01
Science	28%	0.48	0.00	1.50	25%	0.38	0.10
Total Allocated	80%	1.36	0.28	5.30		1.19	0.17
Contingency	20%	0.34				0.40	
Total Power	100%	1.70				1.59	0.11

b. GPS mission

	Budgeted		Actual				
Subsytem	**Percentage of Total**	**Allocated Power (W)**	**Standby Power Estimate (W)**	**Peak Power Estimate (W)**	**Peak On Time (%)**	**Average Power Estimate (W)**	**Variance (W)**
Thermal	12%	0.20	0.002	2.00	10%	0.20	0.002
Attitude Dynamics	1%	0.02	0.00	0.00	0%	0.00	0.02
C&DH	12%	0.20	0.05	0.50	30%	0.19	0.02
Comm/Nav	15%	0.26	0.20	1.00	5%	0.24	0.02
Power	12%	0.20	0.03	0.30	60%	0.19	0.01
Science	28%	0.48	0.00	1.80	25%	0.45	0.03
Total Allocated	80%	1.36	0.28	5.60		1.27	0.09
Contingency	20%	0.34				0.40	
Total Power	100%	1.70				1.67	0.03

Volume Allocations

Table 5 outlines the volume allocated to each component.

Table 5. Volume Allocations

Maintainability

No physical maintenance shall be required. An external RJ45 Ethernet connector shall be provided in the location shown in figure 3 to provide for C&DH monitoring and configuration prior to launch. Refer to the C&DH subsystem specification for more detail on this connection.

Environments

Natural Environments

The ShRIMP-Sat shall meet the requirements of this specification after exposure to the following worst-case environmental conditions prior to launch:

1) Ambient temperatures up to 30 degrees C
2) Relative humidity of up to 80%

The ShRIMP-Sat shall meet the requirements of this specification during and after exposure to the expected P-POD temperature range prior to deployment of –40 to 80 degrees C.

For more details on these environmental conditions and on-orbit environmental conditions, refer to the thermal subsystem specification.

Induced Environments

The ShRIMP-Sat shall meet the requirements of this specification during and after exposure to launch loading. Maximum launch loads are as follows:

1) Static load: 7.7 g any direction
2) Dynamic load: 0.64 g at 2-20 Hz any direction
3) Acoustic load: 140 dB sound pressure

For more details on these loads (power spectral density, duration, etc.) refer to the structures subsystem specification.

Design and Construction

Parts, Materials, and Processes

Materials

Only NASA-qualified flight materials shall be used. The primary structural shell shall be 6061 or 7075 Aluminum to avoid thermal mismatch and jamming within the P-POD.

Fasteners

Only NASA-qualified flight fasteners shall be used.

Adhesives

Only adhesives with space heritage shall be used.

Lubricants

Lubricants must have limited outgasing, must not migrate away from desired location, and must be effective over the expected operational and storage temperature range.

Cleanliness

Satellite assembly shall take place within a class 10,000 clean room.

Electromagnetic Interference (EMI)

The ShRIMP-Sat shall not interfere with operations of the P-POD electrical or communications systems in any way.

Outgasing and Venting

Satellite components must be vented to provide for gradual outgasing of internal volume during launch.

Workmanship

The ShRIMP-Sat shall be fabricated and finished in a thoroughly workmanlike manner. Particular attention shall be given to freedom from blemishes, defects, burrs, and sharp edges; accuracy of dimensions; radii of fillets; marking of parts; thoroughness of cleaning; quality of brazing, welding, riveting, painting, and wiring; alignment of parts; and tightness and torquing of fasteners.

Safety

The design of the ShRIMP-Sat shall be such that when the equipment is stored, transported, operated, or maintained in accordance with applicable procedures and precautions it will not cause damage to itself or to other equipment, or cause injury to or be detrimental to the health or safety of personnel. Hazardous conditions and or precautions to be observed shall be marked in a manner easily observed by personnel.

Hazardous Materials

The materials utilized in the unit when subjected to specified environments and non-operating conditions, shall not liberate fumes, vapors, gases, or dust in excess of the permissible exposure limits listed in OSHA 2206. In the event of conflicting standards the more stringent shall apply.

Structural Integrity

All structural designs shall incorporate a factor of safety of 1.6 if the design is based on analysis alone and 1.2 if the design is based on analysis and test.

Quality Assurance

This section describes the requirements for the verification process during design, fabrication, development, acceptance, and qualification test programs.

Component Tests

All component-level testing shall be the responsibility of the component's subsystem lead engineer.

System Tests

The systems engineer shall have final responsibility for all complete system tests, and shall participate and over see all such tests. Responsibility for individual tests shall be as follows.

Vibration Tests

Complete system vibration testing shall be the responsibility of the structures subsystem lead engineer.

Thermal Vacuum Tests

Complete system thermal vacuum testing shall be the responsibility of the thermal subsystem lead engineer.

Electromagnetic Interference Tests

Complete system electromagnetic interference testing shall be conducted jointly by the power and comm/nav subsystem lead engineers.

Integration Tests

Integrated vibration, thermal vacuum, and electromagnetic interference testing shall be the responsibility of the CubeSat program integration team at CalPoly.