SRP-4 External Review Design Document

SRP-4 Design Team

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Abstract

The Alaska Space Grant's Student Rocket Program will be launching a payload designed to measure the plasma density of the high-latitude D-region of the ionosphere in March 2002. All payload components are being produced by students at the University of Alaska-Fairbanks, and by students at Tokai University and Toyama Prefectural University in Japan. This document provides an overview of the mission requirements as well as the requirements of the individual components and systems that are required for mission success. Detailed designs for many of the components and systems have already been completed, but some of the more complex designs are still in the process of iteration. This document is based heavily upon the detailed designs that have been completed. While intended for external review, it can also serve as a requirements guide for those still involved in the design process.

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1 Introduction

Overview of the SRP-4 Project

The SRP-4 project is the latest of a series of student designed and built rocket payloads sponsored by the Alaska Space Grant Student Rocket Program. The SRP-4 payload was designed by a team of students participating in the graduate-level Space Systems Engineering class taught by Dr. Joseph Hawkins at the University of Alaska Fairbanks, by science and engineering students under the guidance of Dr. Fumio Tohyama at Tokai University, Japan, and by science and engineering students under the guidance of Dr. Toshimi Okada at Toyama Prefectual University, Japan.

Purpose of This Document

This document serves as the top level document in a hierarchy of design documents created for the SRP-4 sounding rocket mission by individual student design engineers. This document specifies the mission objectives and the requirements of each system and subsystem that is required for mission success.

2 Mission Overview

Mission Statement

The purpose of the SRP-4 mission is to acquire scientific data on the plasma density in the D-region of the ionosphere while validating the performance of student-designed components and systems. Payload system standardization and the development of design manuals to guide future participants in the student rocket project are additional mission goals. The SRP-4 mission will provide the opportunity for students to design, implement, and test innovative systems. The SRP-4 mission will also provide the opportunity for students to acquire experience collaborating with students from different disciplines and universities, and with practicing aerospace engineers and scientists.

Mission Science Objectives

The primary mission objective is to acquire science data that will be used to study the ionization structure of the D-region of the ionosphere at high latitudes. Ambient ionization will be measured at altitudes between 50 km and 80 km. *In situ* probes will measure relative plasma density. These relative density measurements will be calibrated using radio receivers to determine the plasma cutoff frequency by monitoring ground-based radio beacons. Measurement frequencies will be centered at 257 kHz, 660 kHz, and 820 kHz. All instruments used to meet this mission objective are being developed by students at Toyama Prefectual University.

Another scientific objective is to validate the performance of a sensitive 3-axis fluxgate magnetometer which will be used for attitude determination as well as detecting magnetic perturbations associated with any current systems that may exist in the ionosphere's D-region. This magnetometer will be used in future flights to measure magnetic field perturbations from auroral currents that occur at high latitudes in the E-region of the ionosphere.

Mission Requirements

General Requirements for Mission Success

1. Since the mission's science objective is to study the D-region of the ionosphere, a daytime launch is required.
2. The payload must reach a minimum altitude of 85 km in order for the radio receivers to obtain a calibration point for the relative plasma density measurements from the ion and electron probes.
3. The science data must be successfully recovered. If a failure in the telemetry system occurs, the data archived in the on-board flash memory must be recovered. A telemetry system failure makes payload recovery a necessity.

General System Requirements

Payload weight and balance must be considered when designing all payload components and systems. The maximum payload weight is 100 lbs. and the payload must be spin balanced. The payload's center of gravity must be carefully chosen in order to insure the aerodynamic stability of the rocket/payload combination as well as insuring that the payload will tumble after separation when it re-enters the atmosphere.

All payload components and systems must be designed to operate in temperatures as high as 41° C. The nose cone should be designed for external temperatures as high as 400° C at the nose tip and 177° C at the base.

The payload systems and components must be designed to withstand the vibration envelope and the "shock/jerk" loads defined in the *NASA Sounding Rocket Handbook.*

3 Flight Profile

The approximate times of major launch events are shown in Table 1. Total rocket flight time is approximately 30 minutes from launch to touch down under the main parachute. Time to apogee is approximately 2.5 minutes. Payload free-fall re-entry time from apogee to parachute recovery system deployment at 20,000 feet is approximately 4 minutes. Time of payload descent under the main parachute from the deployment altitude of 20,000 ft. to touch down is approximately 19 to 23 minutes for a payload weight range of 100 lbs. to 150 lbs. The actual payload weight may be less than 100 lbs, but this value was chosen as a conservative estimate.

4 Payload Standardization and Modularity

The SRP-4 payload bus has been designed with reusablity and adaptability in mind. This approach is atypical in sounding rocket payload design, as most payloads are designed for a single launch and a specific science instrumentation package. By emphasizing modularity in the design of the SRP-4 payload, the Alaska Student Rocket Program will have a payload bus which can be quickly adapted to different

Table 1: Launch Events

Event	Time (min.)	Alt. (km)	Vel. (m/sec)
Launch	0	0.2	0
Motor Burnout	0.53	27.4	1189
Coast to Apogee	1.95 -2.3	-	-
Apogee	2.48 -2.78	85 - 95	188
Payload Separation	3.5- 4.1	65	TBD
Aero. Deceleration	4.45- 5.28	39 - 35	TBD
Drogue Deploys	5.71- 6.65	6.1	61
Main Chute Deploys	5.88- 6.82	5.64	39
Touch Down	33.18- 34.65	TBD	3.9

instrumentation packages with minimal design effort. By eliminating the need for a new payload bus design to accommodate each new instrumentation package, more design time can be devoted to the development of increasingly complex science instrumentation.

Standardization and modularity is apparent in both the electrical and mechanical systems. The deck plates have standard sizes, printed circuit board (PCB) mounting hole layouts, and wiring through-holes. The electrical system has eliminated the need for custom wiring harnesses by using standardized data cables and power connectors. A power bus distributes power to the instruments on each deckplate, and the power bus can be quickly modified to accommodate additional instruments due to its modular nature. Using standardized PCB sizes allows a wide variety of circuit board shapes and sizes to be quickly mounted on the deck plates in various configurations.

5 Mechanical System

The primary components or subsystems of the mechanical system are :

- A nose cone
- A payload tube
- A payload frame
- A parachute recovery system
- A separation system

5.1 Nose Cone

Requirements

The nose cone must be transparent to radio frequencies, lightweight, and able to withstand aerodynamic loading. It must be able to withstand temperatures of approximately 400° C at the tip and 177° C at the base.

Description

- A 4:1 tangent ogive nose cone will be used. This shape provides good aerodynamic performance at speeds greater than MACH 1 and provides sufficient usable volume.

- The nose tip will be made of mild steel in order to withstand the extreme aerodynamic heating. The tip will have a 3/16" radius in order to project the shockwave approximately 15" beyond the nosetip.

- The nose cone will house the RF antennas for the science mission. Four screws will attach the antenna support frame to the nosecone.

Materials

The nose cone will be constructed of glass-reinforced epoxy approximately 1/8" thick and will be covered with Kapton film for a heat shield.

Interfaces

The nose cone will be attached to the payload tube by a 4" aluminum ring. The ring will extend 2" into the nose cone and 2" into the payload tube. It will be connected by two rows of 10 screws in both the payload and nose cone. These will be flat head screws set flush to the surface.

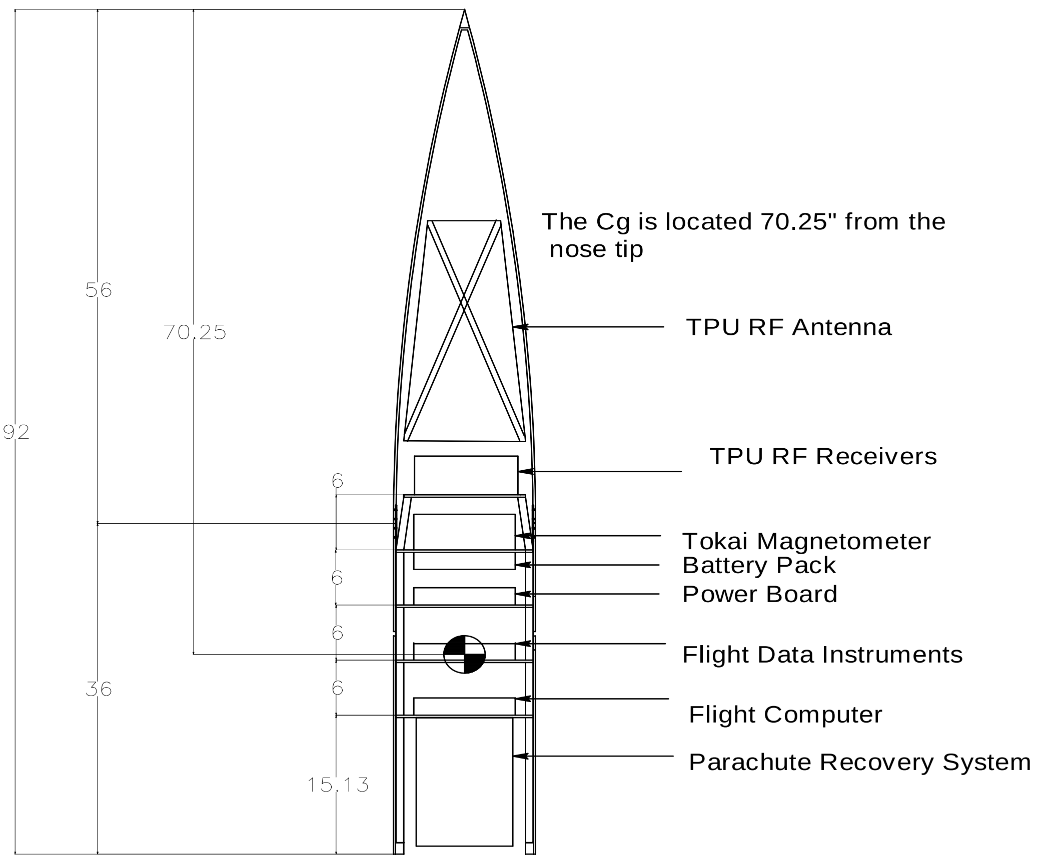


Figure 1: SRP-4 Mechanical System Overview

5.2 Payload Tube

Requirements

The payload tube must have a 14" outside diameter and a minimum bending moment of 100,000 in-lbs.

Description

The payload tube will be a 14" diameter tube with a wall thickness of 1/8". Holes must be machined in it to allow for the following penetrations:

- Sun sensor
- Pressure equalizing ports (4)
- Umbilical block
- GPS antenna cables
- Transmitter antenna cables

Materials

A cold-rolled 6061 aluminum tube will be used.

Interfaces

The payload tube will attach to the nose cone with a double row of screws and it will attach to the radex joint with a lap joint. A high strength epoxy is recommended to hold this joint together due to the structural weakness of the lap joint. A 100,000 in-lbs. bending moment at this interface is required by NASA. It is proposed that this joint be re-inforced with a double row of 20 button-head screws. Button-head screws provide superior shear resistance and protrusions from the payload skin are not a significant issue in this region due to the behavior of the boundary flow layer.

Umbilical Block

The aluminum umbilical block supports the umbilical plug. The umbilical block will be located below the patch antennas to prevent the block from interfering with the installation of the payload frame. This will also provide access to the block so the umbilical cable can be attached after the payload is installed.

Radax Joint

A radax joint will be used to attach the payload tube to the separation system. This will allow the use of the epoxy-reinforced lap joint at the payload tube interface while providing the ability to change separation systems as necessary. The radax joint will provide support for the lower end of the recovery system housing tube. It will also house the drag plate which is utilized for the recovery system deployment.

5.3 Payload Frame

Requirements

The payload frame must be able to withstand 20 g of acceleration during launch and maintain integrity in a high vibration environment. It must provide a mounting surface for the electrical components and it must provide a mounting structure for the parachute recovery system. The frame must also be able to withstand the "shock/jerk" load that occurs when the parachute opens.

Description

- The payload frame consists of two main components: the longerons and the deck plates.
- The longerons consist of 1/2" x 1/2" (1.27 cm x 1.27 cm) square rods that bend in at the top to clear the sides of the nose cone. Fastened to the inner side of each longeron are 1/2" x 1/4" (1.27 cm x 0.64 cm) strips. These strips support the weight of the deck plates. They are fastened with two button-head screws per strip. This method eliminates stress risers that would occur if the longerons were notched solid strips and increases flexibility in deck plate location.
- The deck plates are 1/4" (0.64 cm) plates that are machined to fit the interior diameter of the payload tube. The plates should slide freely within the tube while fitting as closely as possible. (The tube is not expected to have an exact diameter, so the machining of the deckplates should not be done until the payload tube can be measured accurately.) The deckplates have two

1/2" x 1/2" (1.27 cm x 1.27 cm) notches located 180° apart. These notches allow the deck plates to extend to the payload tube while accommodating the longerons. Both sides of the deck plates that are 90°away from the notches will be "trimmed" back 1/2" (1.27 cm). This allows the plates to clear the other two longerons. The plates can be installed or removed while three out of the four longerons are assembled. The deck plates have four 2" (5.1 cm) holes drilled in them for wiring throughways and weight reduction.

Materials

The deck plates and longerons can be machined out of either 6061 or 7075 aluminum alloy. Simple compression calculations have been made. For a static load on a column made of 6061 aluminum

$$Buckling\,Load = 20.2 - 0.126(\frac{L}{r})$$

with units of Ksi where L = length of column and r = radius of column. The 6" section of longeron between screws will have a compressive strength of 4294 lbs. (1952 kg) which is far in excess of the 120 lbs. (54.5 kg) maximum load expected on an individual longeron. Greater compression strength would be obtained by using 7075 aluminum.

Interfaces

The longerons will rest directly on top of the radax joint's upper ring. This will allow the weight of the payload to transfer directly to the motor instead of to the payload tube. The longerons will be attached to the payload tube every 6" (minimum) with flat-head screws to prevent deflection under load. Although the top deckplate is inside the nose cone, there is no contact between the payload frame and the nose cone.

5.4 Parachute Recovery System

Requirements

The parachute recovery system must lower the payload at a rate that will prevent damage at impact. The recovery system must deploy reliably under any payload orientation.

Description

The SRP-4 2-stage parachute recovery system consists of a 6 ft. guide surface drogue and a 33 ft. main cross parachute designed to recover a 75-lbs. to 150-lbs. sounding rocket payload. The recovery system is deployed from the aft end of a 3-ft. payload tube with a 14" diameter.

After descending to 65 km, the payload section is separated from the separation system. The payload will tumble during re-entry for maximum passive aerodynamic deceleration prior to deploying the parachute recovery system. At 20,000 ft., a barometric pressure switch will send an electrical signal to jettison the drag plate which will extract and deploy the drogue parachute. The drogue parachute will fly for 10 seconds to stabilize and decelerate the payload prior to deploying the main cross parachute. Drogue deployment will pull pins to mechanically activate the 10 second pyrotechnic charge of the Technical Ordinance pyrotechnic pencil cutters on the drogue staging bridle. After 10 seconds, the pencil cutters will fire to sever the staging bridle drogue parachute drag line to extract and deploy the main cross parachute. The main cross parachute will then be deployed for inflation with or without skirt reefing using two additional 750-lbs. Technical Ordinance pencil cutters. The cross parachute will stabilize the payload during descent.

The parachutes being used for this recovery system were successfully drop tested from an Air Force C-130 in 1997, thereby flight qualifying them for use in sounding rocket missions such as SRP-4.

Drag Plate

The drag plate is an aluminum disk which covers the aft end of the rocket during re-entry. Its function is to pull the drogue chute out of its bag. The drag plate will be released by mechanical actuators and pushed away by springs. This will separate the plate from the payload and air drag will do the rest.

Interfaces

The parachute recovery system will ride in a thin walled rigid tube that has a 9-1/2" (24.13 cm) diameter. This tube will be secured to the bottom of the first deck plate with screws. The parachute will be attached to the payload frame using a 4-way bridle which is constructed from Kevlar straps. The straps will be fed through 1/4" x 1-1/2" (0.64 cm x 3.81 cm) slots in the deck plates and mount to 1/4" (0.64 cm) dia. aluminum bars attached to the top of the deck plate.

5.5 Separation System

Requirements

The separation system must hold the payload and motor together within the acceptable deviation limits with 100,000 in-lbs. of torque. The separation system must have a hole 9.5" (24.13 cm) or greater in diameter in its center for recovery system deployment. The separation system must also provide positive separation in zero g and zero drag environments.

Description

Two separation systems are being considered for the SRP-4 mission. Either a student designed separation system (which is still in the early design phase and will be evaluated for acceptance when a prototype is presented), or a NASA constructed system will be used. The separation system will attach to the payload tube via the radex joint, and to the Orion motor according to NASA specifications. The separation system must electrically interface with the EED board.

5.6 Center of Gravity Calculations and Mass Budget

A mass budget and center of gravity calculations are shown in the following table. The weight of many of the lighter components, such as electrical circuit boards, are a approximate. The weight of the heavier components are known more accurately. All locations are precise.

Table 2: Center of Gravity and Mass Budget

Component	Weight in lbs (kg)	Distance of Cg NEP in inches (cm)	Moment About Nose Tip (in-lbs)
Nose cone	14 (6.35)	34.9 (88.7)	489
TPU Antenna	1 (0.454)	36 (91.4)	36
TPU Receiver Deck (D5)	2.5 (1.13)	53.1 (135)	133
TPU Receiver	1 (0.454)	50.8 (129)	50.8
Tokai Magnetometer Deck (D4)	3.2 (1.45)	59 (150)	188.3
Tokai Magnetometer	2 (0.907)	57 (145)	114
Battery Pack	4 (1.81)	60 (152)	240
Power Board Deck (D3)	3.2 (1.45)	64.8 (164)	206.7
Power Board	0.25 (0.113)	63.8 (162)	16
Flight Data Board Deck (D2)	3.2 (1.45)	70.5 (179)	225.1
Flight Data Board	0.25 (0.113)	69.5 (177)	17.4
Flight Computer Deck (D1)	3.2 (1.45)	76.5 (194)	244.25
Flight Computer	0.25 (0.113)	75.5 (192)	18.9
Payload Recovery System	14.5 (6.58)	84 (213)	1220
Longerons	3.64 (1.65)	73 (185)	265
Separation Mechanism	20 (9.07)	91.5 (232)	1830
Payload Tube	20 (9.07)	74 (188)	1480
Total Mass	96.1 (43.6)		6772.4
Cg of Payload	70.4 inches NEP		
	178.9 cm NEP		
Mass of main deck plates	3.2 lbs (1.45 kg)		
Mass of small deck plates	2.5 lbs (1.13 kg)		

6 Electrical Systems

6.1 Power System

Requirements

The power system must provide clean, stable, regulated power to all payload electrical components for the duration of the flight. It must not electrically interfere with other modules in the payload and it must be absolutely reliable through all modes and conditions of operation, including vibration and harsh environments.

Description

The power system stores enough electrical energy to power all SRP-4 electrical components for the expected duration of the flight. It converts this stored energy into voltage levels that can be used by the electrical components and distributes these voltages throughout the payload using a power bus. The ripple and noise in these voltages must be below the maximum tolerable noise and ripple levels of the science instrumentation. The power system must not create electromagnetic interference at sufficient levels to affect the science instruments.

The power system is comprised of :

- Battery pack
- Power board
- Power bus

Battery Pack

The battery pack supplies an output voltage compatible with the S-band transmitter and the power board. It must contain enough energy capacity for the entire mission and it must have over/under voltage protection, short circuit protection, and thermal protection.

Important battery pack specifications include :

- Mass: ~500g per pack using Lithium-ion cells, ~850g per pack using NiMH
- Size: 90x115x56 mm (3.5x4.5x2")
- Mounting: individual cells will be sealed in a plastic case and internally secured with adhesive foam. Four screws will attach the plastic case to the bottom of a deck plate and a metal strap over the pack will provide additional support.
- Nominal Voltage: 28.8 V
- Energy Capacity: Two battery packs will be used for a total capacity of 90 W-H.

Lithium-ion cells are the preferred choice for battery pack cells, but they are hard to obtain and they are dangerous if used improperly. NiMH cells are widely available and are more tolerant of misuse, but these cells release small amounts of hydrogen gas while charging which may be a safety problem.

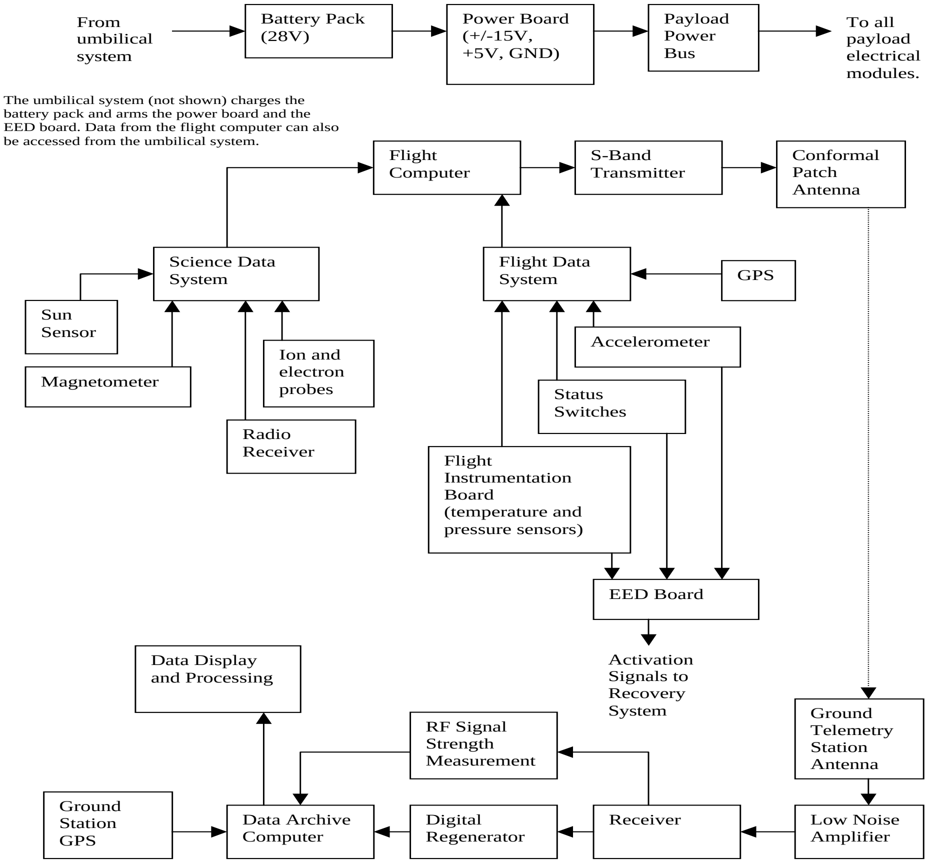
Power Board

The power board converts the 28.8 VDC from the battery pack into the voltages needed by the payload components: +15 VDC, -15 VDC, +5 VDC and GND. The power board is also responsible for controlling payload power activation and deactivation and for providing voltage and current monitoring. The power board can be divided into :

- Power input board
- Power system controller
- Filter system

The power input board is expected to receive contains the payload activation/deactivation circuit. Failure of this circuit could cause an unsafe condition on the launch rail if it activates prematurely or fails to deactivate. On the other hand, if this circuit fails to activate at launch, the mission would fail. Recognizing the safety and performance demands that are placed on this circuit, careful design attention has been given to this circuit. This circuit features AC noise rejection, a high ON voltage threshold, and quick, reliable deactivation.

The power system controller converts the 28.8 VDC from the battery pack into the voltages needed by the payload components using rectified outputs of



The umbilical system (not shown) charges the battery pack and arms the power board and the EED board. Data from the flight computer can also be accessed from the umbilical system.

Figure 2: SRP-4 Electrical System Block Diagram

switched transformers. These rectified outputs are then low-pass filtered to reduce switching transients. An optional linear regulation system may be added after the filtering stage to eliminate ripple if the filter system does not perform as expected.

All power system components which may cause electromagnetic interference with the science instruments with be shielded with μ-metal.

Table 3: Power Budget

Component	28V Current (mA)	+15V Current (mA)	-15V Current (mA)	5V Current (mA)
S-band TX	650	-	-	-
Flight Computer	-	46	40	145
Flight Instruments	-	65	45	100
GPS System	-	-	-	250
Magnetometer	-	67	67	-
TPU Experiment	-	295	271	2
TPU Filters	-	10	10	10
Data Filters	-	100	10	25
Component	28V Power (W)	15V Power (W)	-15V Power (W)	5V Power (W)
S-band TX	18.2	-	-	-
Flight Computer	-	0.92	0.8	0.97
Flight Instruments	-	1.3	0.9	0.67
GPS System	-	-	-	1.67
Magnetometer	-	1.34	1.34	-
TPU Experiment	-	5.9	5.42	0.01
TPU Filters	-	0.2	0.2	0.07
Data Filters	-	2	0.2	0.17

6.2 Science Instruments

Overview

Toyama Prefectual University in Japan is providing a science instrumentation package that will measure D-region ionization. The package consists of a ion and electron probe, and a radio receiver. The probes are thin platinum strips mounted on the outer surface of the nose cone. These probes will measure the *relative* ionization density. The radio receiver and its loop antenna is mounted inside the nose cone. It will monitor the received field strength from three ground based radio beacons. The radio receiver will detect a sudden attenuation in signal strength at the plasma cutoff frequency. The exact electron density can be determined at the altitude where the sudden attenuation occurs (approximately 85-90 km for the lowest beacon frequency). This allows the relative ionization density obtained by the probes to be calibrated. *For this science mission to be successful, the rocket must reach an altitude of 85 - 90 km.*

Tokai University in Japan is providing a science instrumentation package that consists of a sensitive magnetometer and a sun sensor. The magnetometer was designed to detect magnetic perturbations arising from current systems in the E-region of the ionosphere. Since the SRP-4 payload will not attain the altitude necessary to measure current systems in the E-region, the magnetometer will provide attitude determination. If any current systems exist in the D-region, the magnetometer will be sensitive enough to detect the associated magnetic perturbations. The sun sensor will also provide attitude determination.

Radio Receiver Specifications

- Receiver frequencies: 257 kHz, 660 kHz, and 820 kHz
- IF frequency: 455 kHz
- Approximate magnetic loop antenna size: 30 cm at base, 8.5 cm at top, 82.5 cm high (trapezoidal)

Probe Specifications

- Size: 5 cm x 10 cm x 0.05 mm
- Mass: 0.5 g
- Material: platinum

Magnetometer Specifications

- Channels: x, y, and z
- Sensitivity: +/- 1.5 nT
- Sensor drive frequency: 9.6 kHz

Sun Sensor

- Size: 114.3 mm x 35 mm x 30 mm
- Mass: 100 g
- Slot size: 10 mm x 10 mm

6.3 Flight Instruments

Overview

The flight data system collects data on the rocket payload environment. The SRP-4 flight data system will measure :

- Skin temperature
- Ambient temperature
- Battery pack temperature
- Acceleration
- Ambient pressure
- Payload position (GPS)

Accelerometer Board

The accelerometer board amplifies and adjusts the offset of several Analog Devices acceleration sensors to provide longitudinal, radial, tangential and x/y acceleration data. The accelerometer board also filters these outputs to eliminate aliasing when the outputs are sampled by the flight computer.

Instrumentation Board

The instrumentation board scales the output of an ambient temperature sensor and a battery pack temperature sensor. The instrumentation board also provides a 0° C reference junction and amplifier for the skin temperature thermocouple. The ambient pressure sensor is also located on this board.

Status Switches

The status switches will indicate when major launch events have taken place, including:

- Umbilical separation
- EED board fired for motor/payload separation
- Motor separated from payload
- EED board fired for parachute deployment
- Parachute deployed
- Dead battery indicator (necessary for graceful flight computer shutdown)

The mechanical event status switches will be implemented with a Winchester connector. One end of the connector will be tied to +5V through a pull-up resistor. The other end will be grounded until the connector is unplugged.

Flight GPS

The flight GPS tracks the position of the rocket and sends the data to the flight computer for transmission to the ground.

6.4 Flight Computer

Overview

The flight computer manages all data that is generated by the science and flight data instruments. The computer processes this information for transmission and storage in non-volatile memory and also timestamps the data.

Specifications

- Motorola MH68HC916Y1 microcontroller
- 16-bit A/D conversion for science data, 12-bit A/D conversion for flight data
- CompactFlash Non-volatile Memory Card will be used to archive all data onboard the rocket. This will allow for data recovery in the event of a communication system failure.
- Asynchronous data handling: GPS and status switch data
- Umbilical Communications: an RS422 serial link will provide communication between the flight computer and a PC through the umbilical block. This will allow pre-launch testing, data retrieval, and reprogramming.
- Output to transmitter: High-speed 0-1 V serial data stream through an SMA connected coaxial cable.

6.5 EED Board

Overview

The electro-explosive discharge (EED) board is responsible for arming and firing the electro-explosive devices that cause payload separation and parachute deployment to occur. A software algorithm is being developed that would detect anomalies in the flight profile and adapt the motor separation and parachute deployment trigger times so that the payload could be recovered even in the event of a rocket motor failure.

Algorithm

A timer on the EED board is started when launch is detected. After launch, altimeters and acceleration sensors are monitored to determine if the trajectory is normal. The EED board will then arm the firing circuits when ascending through 22.5 km based on altimeter readings, or when 35 seconds have elaspsed on the timer. When the payload has passed apogee and descended to 65 km, an EED board firing circuit will trigger the separation of the motor and payload. When the payload has descended below 6.1 km, an EED board firing circuit will deploy the parachute recovery system.

Multiple firing signals will be used to trigger the firing circuits.

Safety Issues

The EED board and its associated pyrotechnics must be handled and operated safely. Power to the EED board will be completely disconnected until just prior to launch. EED board power will be activated from the umbilical box, and a return signal will provide a positive indicator that the EED board is on. The EED board will be activated approximately 30 seconds before launch. The EED board will be immediately deactivated if the launch is delayed.

6.6 Communications

Overview

The communication system will transfer data from the rocket to the ground support equipment via a telemetry link. After the science and flight data has be digitized and packetized by the flight computer, it sends a serial bit stream to an S-band telemetry transmitter. The transmitted data is received, stored, and displayed by the ground support station.

Transmitter Specifications

- Carrier frequency range: 2.2 -2.3 GHz
- Frequency Stability: 0.001%, 10 ppm
- Supply voltage: 24-32 VDC
- Power Output: 3 W
- Power Consumption: 18 W at 28 V
- Modulation: FM
- Deviation: +/- 8 MHz max

Patch Antenna Specifications

- Mounting: Conformal patch antenna wrapped around payload tube
- Center frequency: 2.2155 GHz
- Bandwidth: 20 MHz
- Max. Theoretical Gain (Broadside): 0 dB
- Minimum Gain: - 3 dB
- Polarization: circular

The remainder of the communication system is ground-based instead of rocket-borne. The ground-based communication system equipment consists of a parabolic dish antenna, a low noise amplifier (LNA), a Microdyne telemetry receiver, and a digital regenerator. The parabolic dish is 1.22 meters in diameter and will be pointed manually. The LNA is a Mini-Circuits (tm) ZEL-1724HLN, which has a gain of 20 dB. A digital regenerator will be used to regenerate the received signal before sending it to the archive computer as an RS422 serial bit stream.

6.7 Ground Support

A ground support system is required by the SRP-4 mission to accomplish these tasks:

- Activation and deactivation of payload prior to launch
- Communication with payload prior to launch
- Provide differential GPS data
- Provide RF received signal strength data
- Archive all flight, science, GPS, and RF signal strength data in real-time
- Display acquired data in real-time during flight
- Display archived data after the flight
- Process archived data into data packets

Umbilical Box and Cable

The umbilical box allows the payload's power board to be activated and deactivated. It also allows the payload batteries to be charged and monitored. Communication with the flight computer can also be done through a connection on the umbilical box.

The umbilical box has an internal battery pack which can be bypassed when external power is used. A "Main Power ON" switch will activate the payload power board and a return signal from the payload will provide a positive indication that the payload power system is active. A voltmeter is connected in parallel with the payload battery pack connection. A serial connector on the umbilical box allows a computer to communicate with the payload's flight computer while the rocket is on the rail.

A custom adapter cable will connect the umbilical box to a Poker Flat umbilical cable (Cannon connector). Another adapter cable will be needed to connect the umbilical cable to the high-density DB15 connector on the payload.

Ground Support Blockhouse Computing Resources

A computer in the blockhouse will receive a serial data stream from the flight computer through the umbilical box and cable. The data will consist of flight computer health check data and flight data packets that are collected by the flight computer prior to launch. The blockhouse computer will run software similar to the telemetry station ground support computer, but the data rate will be lower. This is because differential GPS or RF power data will not be processed. Any Pentium II or later computer with a RS422 interface running either Windows NT or Windows 2000 will be suitable.

Ground Support Telemetry Computing Resources

A computer capable of receiving, archiving, and displaying the serial data streams of data packets from the telemetry system, the differential GPS data, and the RF signal strength data is required. This computer must have sufficient hard disk storage for all the data received over the duration of the flight (approximately 90 MB/hour). The minimum requirements for this computer are :

- 20+ Gigabyte hard drive for data archival
- 128 MB system RAM
- Windows NT or Windows 2000 operating system
- Large capacity removable media drive (i.e. CD/RW device)
- An RS232 interface, and either an RS422 interface card capable of receiving two separate data streams, or two RS422 interface cards
- Intel processor running at the highest available clock speed
- Uninterruptible power supply (UPS)

Ground-based GPS Hardware

A GPS receiver with an antenna at a surveyed location will provided data which can be used for differential correction of the GPS data acquired by the rocket-borne GPS receiver.

7 Module Placement and Payload Deck Assignment

The placement and deck assignments of individual payload modules have been carefully chosen in a effort to meet a number of requirements, including:

- The overall center of gravity of the payload must be within one calibre of its center of pressure in order to ensure that the payload will tumble when it re-enters the atmosphere after separation. Since the parachute recovery system, which is more massive than the other payload modules, is located at the aft end of the payload, other massive modules (i.e. battery pack) should be placed towards the nose tip.

- The radio receiver's magnetic loop antenna and the magnetometer must be placed in an area of the payload that is RF transparent. Since the payload tube is metal, the loop antenna and magnetometer must be located in the nosecone.
- The magnetometer and magnetic loop antenna must be shielded from payload electromagnetic interference (EMI) and placed as far away from high current sources as possible.
- Any component requiring a penetration through the payload tube (patch antennas, ion and electron probes, sun sensor) should be mounted in a location that is easy to reach during payload assembly.

8 Credits

All the information is this document was taken from design documents produced by students participating in the Space Systems Engineering course offered at the University of Alaska Fairbanks during the Fall Semester, 2000. These documents were edited by Edward Burket to create a more streamlined format suitable for external design review. Those desiring detailed design information regarding a component or system mentioned in this document are encouraged to refer to the original design documents which at this time are compiled in the *SRP-4 Design Document.* The designers and original authors are :

- RJ Ponchione: *Mechanical Systems*
- Randy Thomas: *Parachute Recovery Systems and Flight Profile*
- Gaelen Hatfield: *Power Board*
- Brian Hay: *Ground Support System, EED Software Algorithms*
- Jay Helmericks: *Battery Pack and Charger, GPS*
- Tianpeng Yuan, Jeff Sikkink: *Communication System*
- JoAnn Neumaier: *Science Interfaces*
- Greg Kvokov, Bipin Satavalekar: *Flight Computer*
- Steve LeClerk, Kyle Whitmer: *Flight Instrumentation*
- Edward Burket: *Electrical Systems*
- Erin Boyd, Mark Charlton: *Mission Objectives and Requirements*
- Josh Kline, *Umbilical System*

9 Appendices - Mechanical and Electrical Schematics

Appendix A - Mechancial Schematics

Appendix B - Electrical Schematics