SRP-4 Preliminary Design Review

Note: The design this document represents is a work in progress and will most likely change.

The Student Rocket Project 4 (SRP-4) payload is a collaborative project between the University of Alaska Fairbanks, Toyama Prefectural University, and Tokai University. All payload components will be designed and built by students at these three institutions.

1. Science Objectives

The science objectives for SRP-4 are possible due to the Orion motor that will be provided by NASA. There are two science objectives for the SRP-4 mission, they are summarized below.

1.1 D-region ionosphere experiment

The primary science objective is to study the ionization structure of the D-region of the ionosphere at high latitudes. Measurements of the ambient ionization will be made at altitudes of 50–80 km using a radio receiver to determine plasma cutoff frequencies for ground-based beacons in combination with in-situ probes to measure the relative plasma density. These instruments are being developed by students at Toyama Prefectural University under the guidance of Professor Toshimi Okada.

1.2 Magnetometer

A second science objective is to validate the performance of a new 3-axis fluxgate magnetometer with increased sensitivity being built by students at Tokai University under the guidance of Professor Fumio Tohyama. This magnetometer will be used for attitude determination on the SRP-4 flight, and to search for magnetic perturbations associated with current systems that might exist in the D-region of the ionosphere. In the future, it will be used to measure magnetic field perturbations from auroral currents on future SRP flights that can reach the E-region of the high latitude ionosphere.

2. Mission Overview

2.1 Flight Profile

Figure 1 shows the generic flight profile of the SRP-4 Orion single-stage sounding rocket mission. It shows the flight trajectory for launch phase to apogee, and recovery phase for ballistic reentry to payload touch down. Total mission time is approximately 25 to 30 minutes.

See section 3.4.4 for a more detailed parachute flight profile.

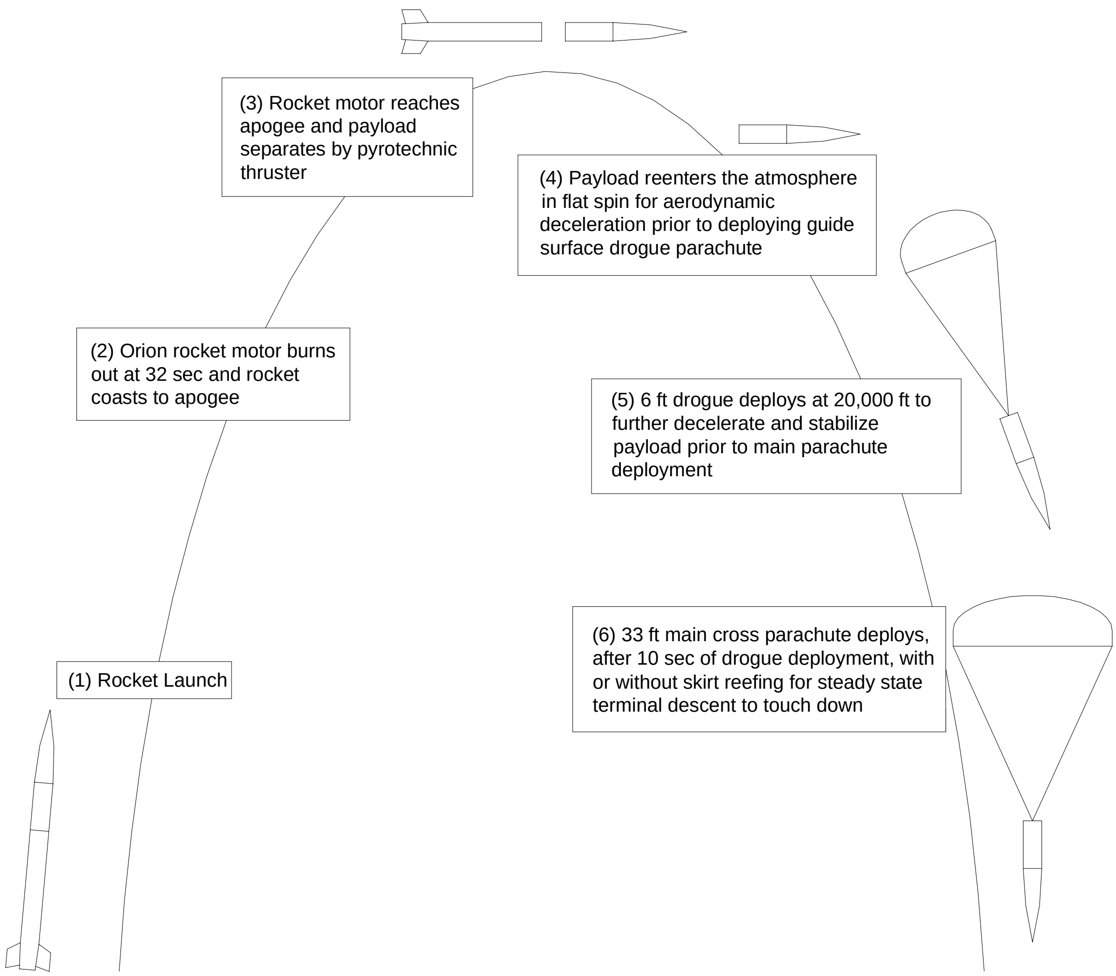

Figure 1: Flight Profile

2.2 Orion Motor

The Orion rocket motor is a single-stage dual thrust, solid propellant vehicle on which sounding (SubOrbital, UNmanneD) rockets are launched. Its basic specifications are as follows: 35.56 cm (14 in) in diameter, 2.68 m in length, with a weight around 420 kg, and a total burn time of 32 seconds.

The Orion motor will reach an altitude of 60 km with a 113.4 kg (250 lb) payload or 90 km with a 34 kg (75 lb) payload.

2.3 SRP-4 Development Schedule

The following is preliminary development schedule for the SRP-4 payload.

December 2000. Finish specification, design, and conduct critical design review for all components.
August 2001. Complete construction and testing of all components.
December 2001. Complete integration and acceptance testing of complete payload.
March 2002. Preferred launch date.

3. Mechanical System

3.1 Nose Cone

The nose cone is to be a 4:1 ogive. This will be 1.442 m (56 in) tall and afford us space for three of the payload deck plates and two antennae.

The material of construction must be transparent to radio transmission, strong, light weight, and heat resistant. For this, two materials are under consideration: PEEK and epoxy resin--either of which would be used in conjunction with glass filament or cloth.

3.1.1 Materials Considered

PEEK (polyetheretherketon) is a high-temperature thermoplastic with a maximum continuous working temperature of 249 °C. The addition of glass or carbon fibers to this plastic further enhances the mechanical and thermal properties. The heat distortion temperature of PEEK without fiber reinforcement is 160 °C. Addition of 30% glass or carbon fiber will increase this value to 315 °C.

Epoxy resin / fiberglass is a material already proven on TR-1.

3.1.2 Nose Tip

This will be the first 5.08 cm (2 in) of the nose cone assembly. Its function will be to absorb the most extreme heat generated at the lead point during supersonic flight. A thermocouple will be installed here to register this temperature throughout the flight. This tip will have a radius to 7.14 mm at the end to project the shock wave 15.2 cm in front of the vehicle thus reducing the temperature potential.

3.1.3 Nose Cone Adapter Ring

An aluminum ring will join the nose cone to the payload tube fitting approximately 7.62 cm (3 in) into each with a 35.5 cm (14 in) diameter shoulder 7 mm (0.276 in) long between the nose cone and payload tube. Twelve flat head screws will be applied from the exterior of the cone and tube each to threaded holes in this ring.

3.1.4 Nose Cone Specifications

Figures 2 and 3 show drawings of the nose cone. Figure 2 shows the general layout of the nose cone and the structure within it. Figure 3 gives the dimensions of the nose cone. Table 1 gives the volume, dimension, and mass budgets for the nose cone.

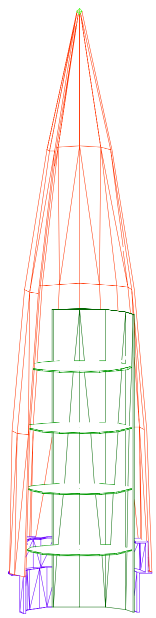

Figure 2: Nose cone general layout

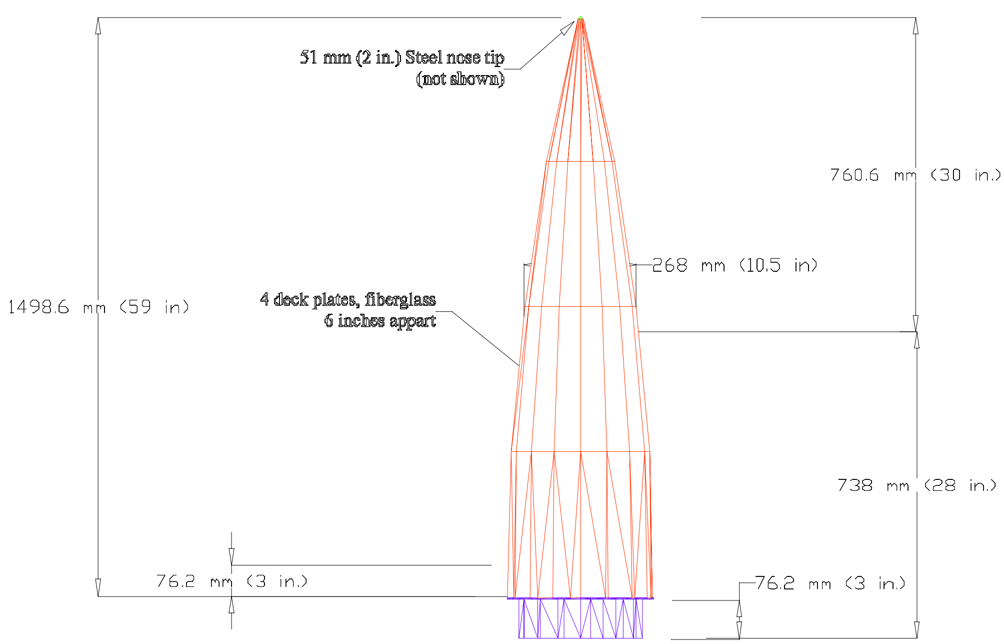

Figure 3: Nose cone dimensions

Table 1: Volume, Height, and Weight

Component	*Volume (Shell Material)*	*Volume (Inside)*	*Height*	*Weight (mass)*
Fiberglass shell	1667 cm^3 (102 in^3)	~47,854 cm^3 (2920 in^3)	1499 mm (59 in)	2.04 kg (4.5 lb)
Nose tip (mild steel)			51 mm (2 in)	0.04 kg (0.088 lb)
Ring			152 mm (6 in)	1.4 kg (3.2 lb)
Internal tube				4.36 kg (9.6 lb)
3 deck plates (epoxy)				1.52 kg (3.36 lb)
Payload (per Ed Burkett)				5 kg (11 lb)
Total				14.36 kg (31.66 lb)

3.2 Payload Structure

3.2.1 Payload Tube

The tube will be 91.44 cm (3 ft) long 3.175 mm (1/8 inch) wall thickness. The material will be either aluminum or filament-wound epoxy resin. If aluminum, it will be rolled with a welded seam. The primary purpose of this tube will be to shield the payload and provide rigidity to the internal payload structure (longerons) which will be carrying the load of the deck plates and nose cone assembly.

3.2.2 Payload Assembly

Chief components here are the 6 longerons and 6 deck plates. *Over-all length is 91.44 cm (36 inches)*. The longerons will be the backbone of the payload section carrying all the load and extending from the separation mechanism to the nose cone adapter ring. These longerons will be machined with two datum planes with maximum tolerances of +0.127 mm (.005in.), -0.0 mm. This will ensure all are identical and the assembly will run true and concentric end to end. The tube will be slid down over this assembly and fastened to the longerons with a screw between each deck plate on each longeron. The tube will support this assembly to prevent bending.

At the base is an aluminum ring which will serve as a foundation. This base ring will be 7.02 cm (2.5 in) long with a 5.1 cm (2 in) wall. The longerons will be fitted into vertical slots cut in six places in this ring which will be the junction between the payload assembly and separation mechanism. The separation mechanism will be bolted to the underside of this base ring.

Figure 4 shows a drawing of the payload structure. The payload assembly pictured is *1.22 m (4 ft) long (0.91 m (3 ft) tube is planned for SRP-4)*, consists of 6 deck plates, 4 of six longerons (are shown), base ring, recovery system canister, and payload tube. Table 2 gives a mass budget for the payload structure.

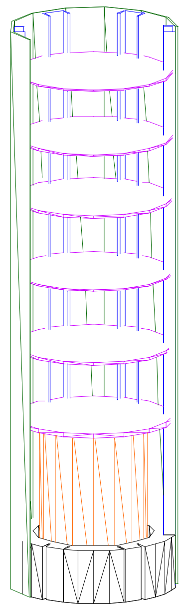

Figure 4: Payload Structure

Table 2: Payload Structure Specifications

Components	*Number of items*	*Mass per item*	*Subtotal*
Longerons	6	0.759 kg (1.67 lb)	4.55 kg (10 lb)
Deck plates (aluminum)	3	1.28 kg (2.84 lb)	3.86 kg (8.5 lb)
Base ring	1	8.3 kg (18.3 lb)	8.3 kg (18.3 lb)
Recovery system	1	6.35 kg (14 lb)	6.35 kg (14 lb)
Tube (aluminum)	1*	8.63 kg (19 lb)	8.63 kg (19 lb)
Tube (epoxy)	1*	3.8 kg (8.4 lb)	3.8 kg (8.4 lb)
Total (w/**aluminum** tube)			**31.69 kg (70 lb)**
Total (w/ **epoxy** tube)			**26.86 kg (59.2 lb)**

3.2.3 Recovery System Canister

Inside the base ring and fastened to the underside of the first deck plate is the recovery system canister. This will be 25.4 cm (10 in) in diameter and 43.18 cm (17 in) long. There will be a space between this canister and the inside of the payload tube to accommodate wiring. This space will be 36.8 cm (14.5 in) long and 5.08 cm (2 in) wide (radial distance).

3.2.4 Total Mass

Total mass (Nose cone + Payload): Aluminum tube: 46.32 kg, (101.66 lb) Epoxy tube: 41.2 kg (90.86 lb).

This, of course will change as we add more hardware and refine the design. The choice between epoxy and aluminum for the tube will be influenced by how my trial nose cone turns out.

The nose cone and payload tube can both be made in-house which would be the preferred course. However, alternate venders are being registered as a back-up in the event their services should be needed.

3.3 Separation Mechanism

The separation mechanism is being designed by students at Tokai University.

3.4 Recovery System

3.4.1 Introduction

The SRP-4, 2-stage parachute recovery system, consisting of a 1.83 m (6 ft) guide surface drogue and a 10.06 m (33 ft) main cross parachute, are designed to recover a 45.4 to 68.0 kg (100 to 150 lb) payload. The parachute recovery system will be deployed from the aft end of the payload structure. The recovery system has previously been designed, fabricated and tested, all that remains is to fabricate new deployment bags for integration of the recovery system into the payload tube. The 10.06 m (33 ft) cross parachute can handle payloads up to 99.8 kg (220 lb) for an impact velocity of 5.8 m/s (19 ft/s, 13 mph), which is the upper limit of payload weight flown on the Orion vehicle. For the proposed 45.4 to 68.0 kg (100 to 150 lb) payloads, this recovery system provides a low impact velocity of 4.0 m/s (13 ft/s, 8.7 mph) to 4.8 m/s (15.7 ft/s, 10.7 mph). The recovery system can also handle the drogue and main parachute opening loads.

3.4.2 Background

Randy Thomas has designed and fabricated 3 complete sounding rocket parachute recovery systems for the student rocket program at the University of Alaska Fairbanks. The first recovery system launched on a sounding rocket from Poker Flat Research Range in May 1995.[1] Preliminary design of a second parachute recovery system was completed by Randy Thomas in the space systems engineering class (ME656) during spring semester of 1995.[2] The recovery system was fabricated, packed, and successfully drop tested and flight qualified from an Air Force C-130 aircraft in February 1997.[3] ***This is the parachute recovery system described that is being reconfigured for the SRP-4 mission***. A third parachute recovery system designed and fabricated by Randy Thomas will be later flight tested on hybrid sounding rockets for low altitude check out flights of payload components before being flown on NASA Orion sounding rocket missions.[4]

3.4.3 Implementation

This parachute recovery system will be reconfigured with larger 24.13 cm (9.5 in) in diameter deployment bags to fit into a 24.13 cm (9.5 in) diameter parachute canister for integration into the aft end of 35.56 cm (14 in) diameter payloads. Appendix A shows packed recovery system length and volume for different deployment bag diameters. A general design rule is to have the main parachute deployment bag length to diameter ratio be at least one. From the information provided in Appendix A, it can be seen that the optimum parachute deployment bag configuration is a length of 24.13 cm (9.5 in). Rigging, packing and deployment of the parachute recovery system *(has already been packed once for the C-130 drop test)* is done according to industry standards currently employed by NASA, NSROC and Sandia for sounding rocket payloads.[3] Details are outlined in chapter 5 of the final report generated by the Space Systems Engineering course (1995), as an official NASA report from reference number 2.

3.4.4 Parachute Flight Profile

Note: payload reentry parameters not yet known, i.e. ballistic coeff & Cd

The single stage Orion flight profile is known from NASA's statistical flight data and UAF's Test Rocket 1 (TR-1) launch of Jan. 2000. TR-1 reached an apogee of 78.83 km (48.98 mi) in about 2.5 minutes. At apogee the payload will be separated from the motor with a separation mechanism. The payload will then flat spin or tumble from apogee for passive aerodynamic deceleration to the drogue deployment altitude of 3048 to 6096 m (10,000 to 20,000 ft).

The drogue parachute pulls a pin to start a pyrotechnic delay charge of 10 seconds to further decelerate and stabilize the payload. At the end of 10 seconds the pyrotechnic charge fires to sever the staging bridle of the drogue for main parachute deployment. The cross parachute is then deployed at 15% of its inflated diameter with skirt reefing for 6 seconds to lower the peak opening load (snatch force) on the main parachute. At the end of 6 seconds the cutters fire to sever the skirt reefing line and the cross parachute comes to full inflation for terminal descent.

Main parachute descent time will be 12 to 19 minutes as shown in Appendix B for the payload weight range of 45.36 to 68.05 kg (100 to 150 lb) for deployment at 6,096 m (20,000 ft). Time to apogee is approximately 2.5 minutes, and reentry time to parachute deployment altitude is approximately 4.0 minutes. Projected total flight time will be between 21 to 30 minutes depending on final payload weight and parachute deployment altitude. Final parachute recovery system configuration and payload separation mechanism will be further defined by collaborations with Dave Moltedo at NASA/Wallops, who has served with the recovery systems group at Wallops for over 95 Orion missions.

3.4.5 Recovery System Mass Budget

The completely packed parachute recovery system weighs 6.12 kg (13.5 lb) as determined from the previous design, fabrication, packing and successful aerial drop testing of this system. The system mass budget is itemized and listed in reference number 3.

3.4.6 Recovery System Reconfiguration

Material and hardware to fabricate newly dimensioned deployment bags for the Orion payload have been purchased. The new deployment bags will be fabricated before the end of August 2000. The parachute recovery system will be packed by the end of September 2000. The completed parachute recovery system will then be ready to integrate into the SRP-4 payload.

3.4.7 Recovery System Support Requirements

3.4.7.1 EED Board

An EED board is required to activate 1 A, 1 W no fire pyrotechnic squibbs.

To activate the recovery system deployment, a Precision Sensors 6,096 m (20,000 ft) barometric altitude pressure switch is to be used. Activation of this pressure switch generates the electrical signal to fire a *Holex actuator* at 6,096 m (20,000 ft), for jettisoning parachute canister drag plates for initiating drogue parachute extraction to initiate recovery system sequence.

Four static ports at 90-degree rotation from each other with a pressure plenum to correctly sense barometric pressure for initiating the recovery system deployment sequence needs to be implemented.

A backup timer should be implemented to the Holex actuator in case the barometric pressure switch should fail to sense parachute deployment altitude. It would then send the electrical signal to activate the actuator to initiate the recovery system deployment sequence.

3.4.7.2 Pyrotechnic Devices

The following pyrotechnic devices are required:

An electronically actuated Holex actuator to initiate drogue extraction at parachute deployment altitude for payload recovery.

Two mechanically actuated Technical Ordnance 1,361 kg (3,000 lb) pencil cutters with 10 sec delays for staging drogue to main parachute deployment.

Two mechanically actuated Technical Ordnance 340 kg (750 lb) pencil cutters with 6 sec delays for disreefing main cross parachute if skirt reefing is used. Note: if pencil cutters aren't used for main parachute skirt reefing, then these two cutters aren't required, or if a slider is used for skirt reefing.

3.4.7.3 Radio Beacon

A Telonics radio beacon self contained in the packed parachute recovery system, or a Walston Retrieval System small whip antenna mounted in the payload will be implemented.

3.4.8 Recovery System Deployment

The Holex actuator is required to extract the drogue parachute from the payload for deployment between 3048 to 6096 m (10,000 to 20,000 ft). Pencil cutters are integrated into the packed parachute recovery system and are mechanically activated once the drogue parachute is deployed.

It is proposed to use a *"slider"* on the main cross parachute to alleviate the need for pyrotechnic pencil cutters for parachute reefing. This concept will be tested on 3.66 to 5.49 m (12 to 18 ft) cross parachutes in hybrid rocket flight testing with an undergraduate research grant currently being conducted. This slider will then be incorporated into the SRP-4 parachute recovery system to eliminate the need for pyrotechnic pencil cutters to reef the main parachute. This will reduce the number of pencil cutters required to only two for staging drogue to main parachute deployment.

4. Electrical System

4.1 Telemetry Transmitter and Antenna

4.1.1 Telemetry Transmitter

An S-band transmitter designed by Stephen Bruss will be flown on SRP-4. The transmitter was designed for ASGP as part of a graduate research program. The transmitter was specifically designed for ASGP rocket flights, and its operation has been tested over a wide temperature range (-66 °C to +70 °C). Vibration tests revealed FM modulations greater than the desired 750 Hz/G at some vibration frequencies, but this is not expected to be a significant problem.

The transmitter requires a +28.8 VDC power supply. RF power is nominally 3 Watts from 2.2 GHz to 2.3 GHz, with the minimum RF output being 2.5 Watts. The DC power used is approximately 16 Watts. The transmitter was designed for use on one of the four 16 MHz FM bands or on one of the eight 3 MHz FM bands that are designated for telemetry at Poker Flat.

The transmitter weighs 400 grams and measures 50.8 mm x 47.775 mm x 127 mm (2.00" x 1.95" x 5.00").

4.1.2 Telemetry Transmitting Antenna

The telemetry antenna is a circularly polarized microstrip patch antenna which consists of 16 individual elements wrapped around the outside of the rocket. The gain of the antenna will be approximately 0 dB with less than 3 dB of gain variation around the rocket's spin axis. The patch antenna will be 1.524 mm (60 mil) thick and will require an inset in the rocket's skin (outer payload tube). The width of the patch antenna array is approximately 80 mm and wraps completely around the rocket.

4.2 Flight Data System

4.2.1 Flight Instrumentation Board

The flight instrumentation board provides pressure and temperature data to the flight computer. The board contains an ambient pressure sensor, one ambient temperature sensor, one temperature sensing chip which samples an external sensor, and two thermocouple sensing chips which are used to sample external K-type thermocouples. K-type thermocouples are chosen because of their ability to measure higher temperatures than J-type thermocouples. K-type thermocouples can measure temperatures from -73 to 871 °C (–100 to 1600 °F).

The temperature sensing chip will be used in conjunction with a thermistor or AD590 temperature sensor to monitor battery pack temperature. One of the thermocouple sensing chips will be used to sample a thermocouple in the rocket's nose tip. The second thermocouple sensing chip will be used to sample a thermocouple on the rocket's surface ("skin temperature").

The ambient pressure sensor (MPX5100AP) will be connected to a plenum which is connected to four static ports on the payload tube. The plenum will also be connected to two pressure sensors on the EED boards.

Data from each of the five sensors will be sampled at 100 Hz. Anti-aliasing filters with a cut-off frequency of 40 Hz will be used on each of the data channels.

4.2.1.1 Instrumentation Board Estimates

Mass	50 grams
Volume	< 300 cm^3
Power	< 0.5 W
Data Bandwidth	500 Hz
Voltage Requirements	+5 V, GND

4.2.2 Accelerometer Board

The accelerometer board provides x-axis, y-axis, longitudinal, radial, and tangential acceleration data to the flight computer. Five engineering data channels will be required to sample each of the data channels at 100 Hz. The accelerometer board design includes anti-aliasing filters with a cut-off frequency of 40 Hz.

The basic accelerometer board design has been successfully flown on a sub-SEM sounding rocket. For SRP-4, the accelerometer will be modified to fit on a smaller printed circuit board and will use a single clock to set the cut-off frequency of the five anti-aliasing filters.

Complete details of the sub-SEM accelerometer design are given in the Sub-SEM Accelerometer Design documentation.

4.2.2.1 Accelerometer Board Estimates

Mass	75 grams
Volume	<400 cm^3
Power	<1 W
Data Bandwidth	500 Hz
Voltage Requirements	+5 V, +/- 15 V, GND

4.2.3 Status Switches

The status switches are electronic indicators used by the flight computer to determine when a major launch event happens. Status switches used for SRP-4 will show when umbilical cable separation, motor-payload separation, and parachute deployment occur.

Status switches will be implemented by grounding the switch input using a Winchester connector. The other end of the connector will be connected to the +5 V supply via a pull-up resistor. The switch input will be at +5 V when the Winchester connector is unplugged by a launch event.

Due to the manner in which the status switches are implemented, signal buffering is unnecessary.

4.3 Power System

4.3.1 Battery Packs

4.3.1.1 Main Battery Pack

The main battery voltage will be 28.8 V. This decision was made based on these assumptions: 1.) it is difficult to regulate 28.8 V from a 30 V to 33 V battery pack and 2.) specifying a main battery voltage of 10.8 V increases the complexity of the power board. Lithium-ion cells will be used (8 cells at 3.6 V per cell) if they can be obtained from manufacturers in small quantities. If lithium-ion cells cannot be obtained, nickel metal hydride cells will be used providing that the NASA safety team has no objections. Nickel metal hydride cells produce small amounts of hydrogen gas when they are being charged or discharged. If nickel metal hydride cells are used, 24 cells at 1.2 V each will be needed to produce the desired battery voltage.

The main battery pack will use a poly-switch fuse for short circuit protection. Poly-switch fuses consist of tiny conducting fibers that mechanically separate when heated due to high currents. When the fibers cool, electrical continuity is re-established, but with a slightly higher resistance. Since the poly-switch fuse functions as an automatically resetting fuse, it is an optimal means of providing overcurrent protection for the main battery pack.

4.3.1.2 EED Board Auxiliary Battery Pack

Each of the EED boards will have a 9 V alkaline battery to power the firing circuit. Two 9 V batteries in series will also provide backup power for the EED boards in case of main battery failure.

4.3.1.3 Locator Beacon Battery Pack

The locator beacon needs 6 V and uses two 3 V, AA, ½ size lithium batteries.

4.3.2 Power Board

The power board converts the main battery voltage into the voltage levels needed by the payload electrical systems. To provide clean power efficiently, switching regulators will be followed by linear regulators. The power board will supply +/- 15 VDC and +5 VDC.

4.3.3 Power Budget

The power budget listed in Table 3 does not include the power requirements of any electronic device which contains its own battery pack. At this point the locator beacon is the only independent device.

Table 3: Power budget

Device	*Power*
D-region ionosphere experiment	15 W
Magnetometer	2 W
Accelerometers	<1 W
EED Board	0.5 W
Instrumentation Board	0.5 W
Flight Computer	~8 W
GPS	<2 W
Transmitter	16 W
ESTIMATED TOTAL	45 W

At this stage of the design process (7/11/2000) the SRP-4 power budget is defined as 45 Watts.

4.4 Recovery System Electronics

An EED board has already been designed and built by Jay Helmericks. The board has not been flight qualified so the board needs to be thoroughly tested under various pressure and temperature conditions. Since SRP-4 will use two EED boards (main and backup), another EED board needs to be fabricated.

The EED board uses a pressure switch in conjunction with a Motorola's 68HC11 microcontroller to calculate the proper altitude for firing the pyrotechnics. The 68HC11 will need to be reprogrammed for the chosen deployment altitude for SRP-4 (6.07 km or 20,000 ft). Each board will house a 9 V alkaline battery which will be used to power the firing circuit.

4.5 GPS

The GPS module consists of an OEM GPS receiver board, an interface board, and a microstrip patch antenna. The patch antenna will wrap around the outside of the rocket to provide continuous signal reception as the rocket spins. There will be a connector through the skin to pass the signals to the receiver board. The receiver board uses Rockwell's Jupiter chipset. The receiver tracks all visible satellites and passes the information via a serial link to the interface board. The interface board stores the data in onboard RAM and passes it on to the flight computer for downlink to the ground station. If the telemetry system fails but the rocket is still recovered the flight path of the rocket can be recovered from the information stored in memory.

4.6 Data Budget

Table 4 shows the SRP-4 data budget to be handled by the flight computer. The figures shown are minimums and may change in the interest of minimizing the number of different sampling frequencies and resolutions used. The total bit rate is well within the transmitter's 300 kbps limit.

Table 4: SRP-4 Data Budget

Science Data

Rx	Resolution (bits)	Min. Sampling Freq. (Hz)	Bit Rate (bps)
ch 1	8	50	400
ch 2	8	50	400
ch 3	8	50	400
ch 4	8	50	400
ch 5	8	50	400
ch 6	8	50	400
ch 7	8	50	400
ch 8	8	50	400
Probes			
ch 9	8	50	400
ch 10	8	50	400
ch 11	8	50	400
ch 12	8	50	400
Magnetometer			
ch 13	16	100	1600
ch 14	16	100	1600
ch 15	16	100	1600

Flight Data

Pressure Sensor	Resolution (bits)	Min. Sampling Freq. (Hz)	Bit Rate (bps)
ch 16	12	10	120
Temperature Sensors			
ch 17	12	10	120
ch 18	12	10	120
ch 19	12	10	120
ch 20	12	10	120
Accelerometers			
ch 21	12	100	1200
ch 22	12	100	1200
ch 23	12	100	1200
ch 24	12	100	1200
ch 25	12	100	1200
Voltage & Current Sensors			
ch 26	12	10	120
ch 27	12	10	120
ch 28	12	10	120
ch 29	12	10	120
ch 30	12	10	120
ch 31	12	10	120
ch 32	12	10	120
ch 33	12	10	120
Status Swithches			
ch 34	1	10	10
ch 35	1	10	10
ch 36	1	10	10
ch 37	1	10	10
GPS			
ch 38	Asynch serial data		5,771 avg. 30 s
	Total bit rate		**22,971 bps**

4.7 Flight Computer and Data Logger

4.7.1 Flight Computer

Flight computers on previous ASRP missions have been implemented using Motorola’s 68HC11 family of microcontrollers. As a preliminary design for SRP-4 and future standardized payloads it has been determined that a flight computer will be needed that can handle more data, faster. With that in mind, Motorola’s 68HC16 family of microcontrollers has been chosen. Internally, the microcontroller handles data, addresses, and instructions with 16 bit words per clock cycle at 16 MHz.

In choosing a 68HC16 family member, several features are being considered. One feature that is of primary importance to ASRP’s development efforts for a flight computer is easily reprogrammable ROM. Another important feature is being able to acquire development hardware and software for the family member that is not only reasonable in price, but can also be acquired in a timely manner. At this point in time a specific family member is still being researched.

4.7.2 Data Logger

ASRP members have determined that an onboard data logger is important for SRP-4 and all future missions. They have also determined that flash memory would work most effectively due to its small size. This kind of memory would be implemented directly with the flight computer.

5. Ground Receive Station

The ground station contains sensitive and expensive radio receivers, spectrum analyzers, computers, and other equipment. Numerous cords and cables connect the ground station equipment to the antenna dish and to power outlets. Traffic near the ground station by those viewing the launch should be kept to a minimum.

5.1 Receive Antenna

The ground receive station will use a 1.22 m (4 ft) parabolic antenna dish, which will give a gain of approximately 35 dB at S-band frequencies. The antenna dish is fairly heavy, so a sturdy tripod and counterweight will be necessary if the rocket is to be tracked by hand. A low noise amplifier (LNA) should be placed near the receive antenna, and low loss coaxial cable will connect the LNA to the receiver.

5.2 Receiver

The ground station receiver is a Microdyne 1400 S-band receiver.

5.3 Data Logger and Software

A Serial Converter card will convert the demodulated output of the receiver into a clean serial bit stream. The RS422 standard should be used. The TR-1 ground station used the RS232 standard. RS232 is only defined for data rates less than 20 kbps. RS422 is the proper standard for high data rates (up to 10 Mbps). A single RS422 driver can drive up to ten RS422 receivers, so it would be possible to have separate archive and data display computers receive data simultaneously. RS422 serial cards cost approximately $200.

Ground receive station computers are needed to archive and display the received data. The program used to display the data should be capable of running under an up-to-date operating system.

5.4 Link Budget

Transmitter Power (S_{Tx}): 34 dBm
Losses from Tx to antenna (L_T): 0.5 dB
Gain of Tx antenna (GA_T): -4 dB
Transmitted power from rocket (S_T): 33.5 dBm

Polarization loss (L_{pol}): 3 dB
Gain of receiving antenna (GA_R): 26 dB
Atmospheric absorption loss (L_{atm}):
Free space loss for 90 km (L_{fsl}): 138.4 dB
Power at receiving antenna flange (S_{FR}): -86.9 dBm

$S_{FR} = (S_T - L_{fsl} + GA_T + GA_R) - L_{atm} - L_{pol}$

Appendix A: Parachute Packed Dimensions and Volume

SRP4 PARACHUTE RECOVERY SYSTEM PACKED DIMENSIONS AND VOLUME					
System Mass = 13.5 lb (6.1 kg)					
ORIGINAL 7.2" (18.29 CM) DIA CONFIGURATION					
	Dia (in/cm)	Len (in/cm)	Vol (in^3)	Vol (ft^3)	Vol (cm^3)
Main	7.20/18.28	17.00/43.18	692.16	**0.401**	11342.42
Drogue	7.20/18.28	2.50\6.35	101.79	**0.059**	1668.00
Total Length and Vol		19.5	793.94	**0.459**	13010.43
Tota Length (cm)		49.53			

9.0" (22.86 cm) DIA CONFIGURATION					
	Dia (in/cm)	Len (in/cm)	Vol (in^3)	Vol (ft^3)	Vol (cm^3)
Main	9.00/22.86	11.00\27.94	699.79	**0.405**	11467.52
Drogue	9.00/22.86	1.75/4.44	111.33	**0.064**	1824.38
Total Length and Vol		12.75	811.12	**0.469**	13291.90
Tota Length (cm)		32.39			

9.5" (22.86 cm) DIA CONFIGURATION					
	Dia (in/cm)	Len (in/cm)	Vol (in^3)	Vol (ft^3)	Vol (cm^3)
Main	9.50/24.13	10.00\25.40	708.82	**0.41**	11615.53
Drogue	9.50/24.13	1.50/3.81	106.32	**0.062**	1742.33
Total Length and Vol		11.5	815.15	**0.472**	13357.86
Tota Length (cm)		29.21			

Parachute recovery system reconfiguration length and volume based on deployment bag diameter. First table shows original packed dimensions of parachute recovery system from C-130 drop test for original ARIM mission for Apache sounding rocket payload. Second and third tables show dimensions and volume for Orion sounding rocket payload reconfiguration. The third table shows the ideal reconfigured parachute recovery system packed dimensions for length to diameter ratio of greater than one for ease in lacing up the deployment bag for packing purposes. 35.56 cm (14 in) has been allocated for the total length of the packed parachute recovery system. The packed length of 29.21 cm (11.5 in) for the recovery system leaves another 6.35 cm (2.5 in) for integrating the payload separation and drogue parachute extraction apparatus.

Appendix B: Parachute Descent Time

Parachute Descent Time As A Function of Weight and Deployment Altitude				
	100 lb	**150 lb**	**100 lb**	**150 lb**
Altitude (ft)	**Vel (ft/Sec)**	**Vel (ft/Sec)**	**Time (sec)**	**Time (sec)**
20,000	17.53	21.46	0.00	0.00
18000	16.95	20.76	118.02	96.36
16000	16.40	20.08	121.99	99.60
14000	15.87	19.44	126.03	102.90
12000	15.37	18.82	130.14	106.26
10000	14.89	18.24	134.32	109.67
8000	14.43	17.68	138.57	113.14
6000	14.00	17.14	142.89	116.67
4000	13.58	16.63	147.29	120.26
2000	13.18	16.14	151.75	123.90
0	12.80	15.67	156.29	127.61

Time (sec) From 20,000 ft	1367.26	1116.37
Time (min)	22.79	18.61
Time (sec) From 16,000 ft	1249.25	1020.01
Time (min)	20.82	17.000
Time (sec) From 10,000 ft	871.10	711.25
Time (min)	14.52	11.85

Payload descent time of 10.06 m (33 ft) cross parachute for payload weight at deployment altitude. Starting from 6,096 m (20,000 ft) parachute deployment altitude, the descent rate is determined for each 609.6 m (2,000 ft) interval and averaged to provide the total descent time from parachute deployment to touch down.

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