Sub-SEM

CONFIGURATION MANUAL

September 2003

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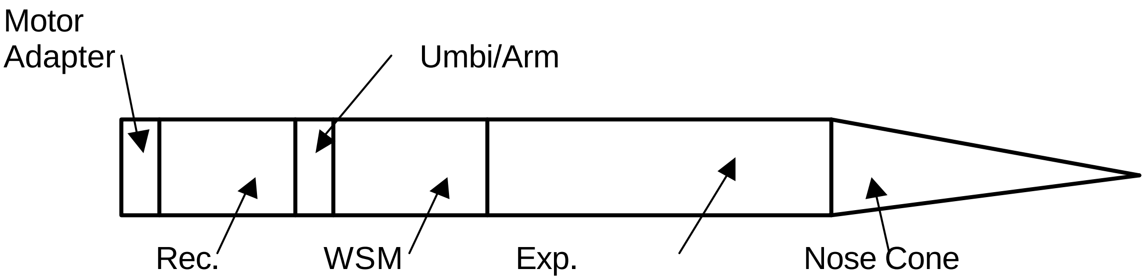
1.0 GENERAL DISCRIPTION OF THE Sub-SEM PAYLOAD

The Sub-SEM payload includes the following sub-systems.



Rec.: Recovery
Umbi/Arm: Umbilical/Antenna/Wet Section
WSM: Wallops Support Module (Instrumentation)/Telemetry
Exp.: Experiment

The length and weight for each section is as follows:

PAYLOAD SECTION	**LENGTH** (in)	**WEIGHT** (lbs)
Nose Cone	41.0	10.0
Fwd Experiment Bulkhead	1.4	10.0
Experiment Section w/ Aft Bulkhead, w/out exps.	41.5	93.0
Wallops Support Module - W/ Typical exps. - Aft Bulkhead - Umbi/Arm Section	29.5	100
Recovery Section w/ 24' Flat Circular Parachute	20.35	57.0
Motor Adapter	6	15.5

The nose cone, experiment bay, and WFF (Wallops Flight Facility) support Module (WSM), are sealed with O-rings to prevent water leakage and provides flotation after water impact. Approximately 380 lbs. of buoyancy is provided. Fill ports, located on the aft bulkhead of the WSM (Wallops Support Module) and on the forward experiment bulkhead, are used for pressurizing the payload before environmental testing to check for leaks in the sealed sections. After final build-up, the WSM and experiment sections are once again pressurized with 5 PSI of Nitrogen (20 psia) to verify that all of the O-rings are sealing properly before flight. Nosecone flies (20 psia) positive pressure with no TM pressure monitor.

The Sub-SEM payload frame is designed to interface to the modified WSM deck. This deck, the standard WSM, has been modified to accommodate the connectors for the

SUB-SEM power and data transfer. The interface connectors are included in each WSM, which provides the necessary power, data collection for Telemetry and timer functions for each experiment deck. The WSM timers control all timing functions.

A 24' Flat Circular (FC) parachute is used as part of the IRMA Recovery System, which is standard for all Sub-SEM missions.

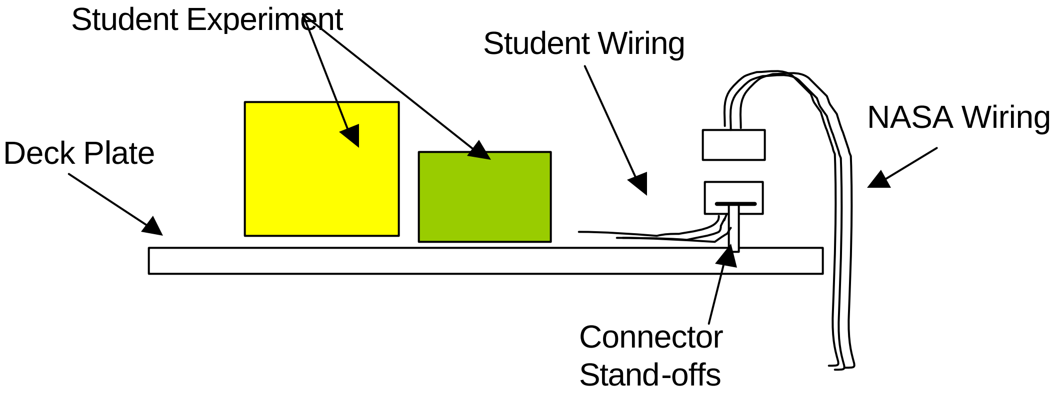
2.0 EXPERIMENT DECK MECHANICAL CONSIDERATIONS

2.1 Dimensions of Allotted Experiment Space

Each experiment deck has a usable diameter of 11 inches and a total usable height of 8.5 inches. Experiment parts should be at least .5 inches from the edge of the deck plate so as to not overlap the mounting screw holes. The experiment package cannot exceed this envelope. No bolts, nuts, screws, or other devices for attachment may protrude below the deck plate. It is recommended that tapped holes be installed in the deck face for mounting experiment components. The total acceptable weight for each experiment is 10 lbs.

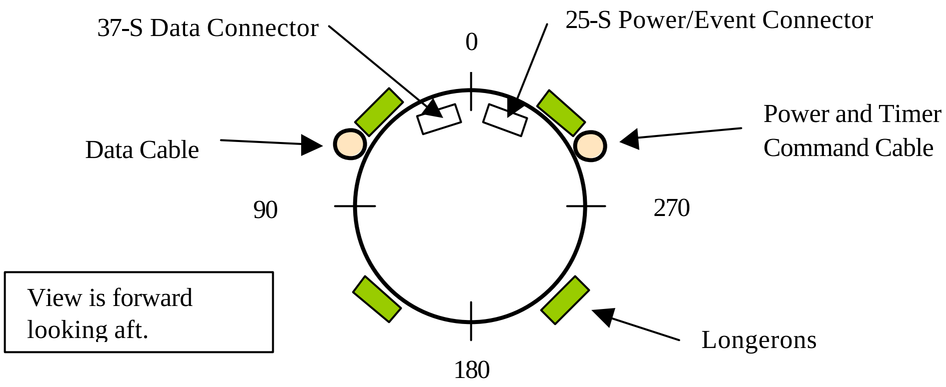
2.2 Deck Layout

The student-side of the interface connectors is hard mounted to the deck plate and the NASA wiring harness loops up and over the interface connector as depicted below:



Each deck has two interface connectors mounted on stand-offs. The locations of these connectors are fixed since they must interface to the NASA wiring harness on the experiment deck support structure. Each deck is stamped with " 0° " and "Fwd" stamped on it for proper orientation. All experiment components must mount on the forward side of the deck.

Each deck includes one 25-Pin Power/Timer Command Connector, one 37-Pin Data Line Connector, standoffs, connectors, and one tube of RTV. The orientation for the decks, longerons, and harnesses is depicted in the following figure:



The Power/Timer Command Connector is located at approximately 340 degrees (looking aft) and the Data Line Connector is located at approximately 20 degrees (looking aft).

One video deck package with additional connectors for output, power and TM are available per flight. These lines are included in the data line and power/time command bundles outlined above. NASA will finalize the wiring for the video lighting systems after the decks are delivered for integration.

2.3 Access Doors

Each experiment bay has a 5” x 5” sealed access door. These doors are used for the following:

1. Limited access to the experiment bay for the loading of flight specimens during the flight week
2. Viewing window for external observation (max: 2” in diameter)
3. Pressure port for atmospheric sensing

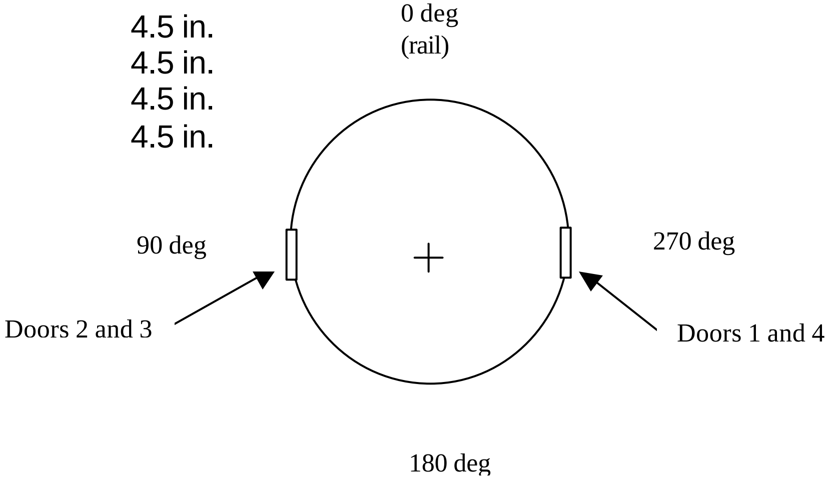
Science teams are cautioned that the watertight seal must be maintained for flight. NASA will provide custom design and fabrication of the doors to meet the experimenters’ requirements.

2.3.1 Door Locations

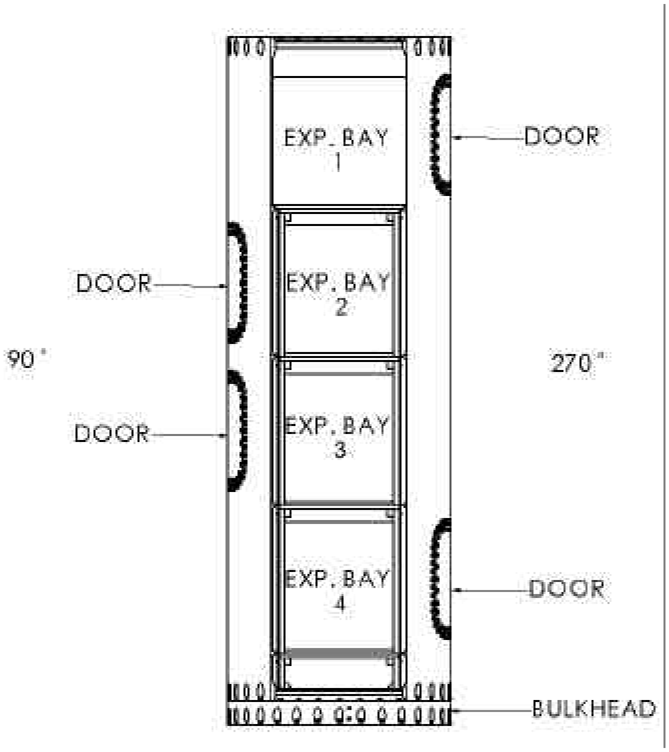
The location of each door is as follows:

Aft	Radial	Door center Ht. above Deck
Deck 1	270 deg	4.5 in.
Deck 2	90 deg	4.5 in.
Deck 3	90 deg	4.5 in.
Deck 4	270 deg	4.5 in.

Forward Looking View

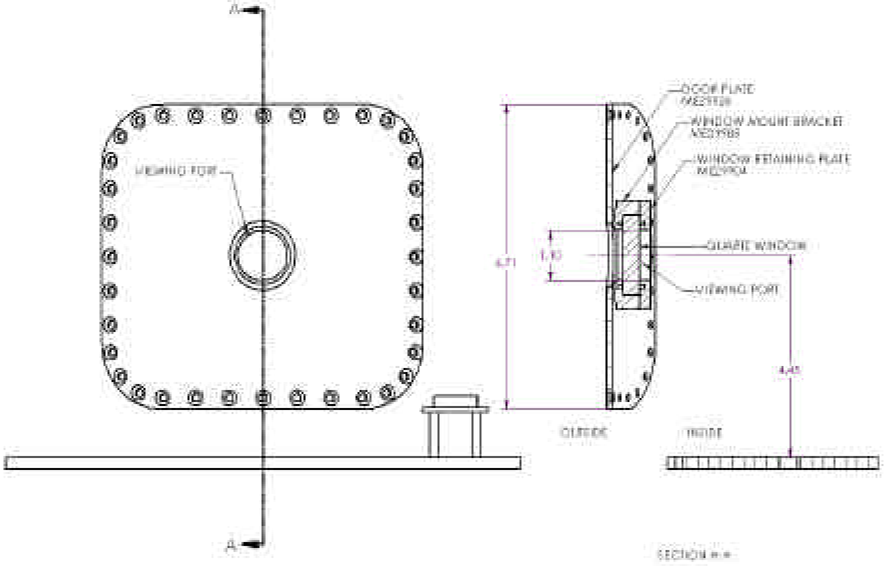


These orientations run COUNTER CLOCKWISE looking AFT. The launch rail is located at 0 degrees.



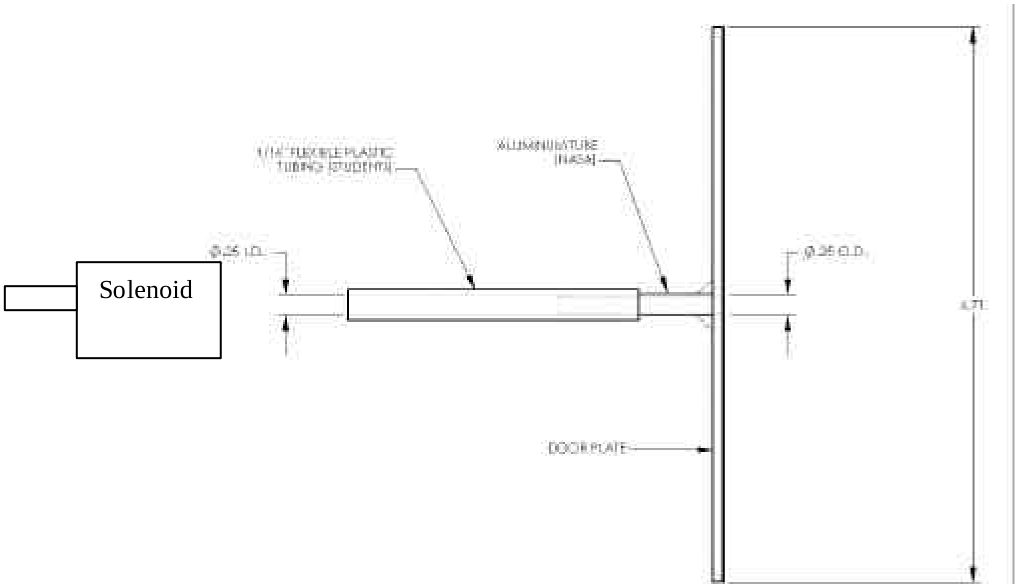
2.3.2 Windows

The standard door can be outfitted with a 1-inch diameter quartz window to allow for external observations to be made. The quartz windows will be installed by NASA in order to ensure that an adequate water seal is maintained.

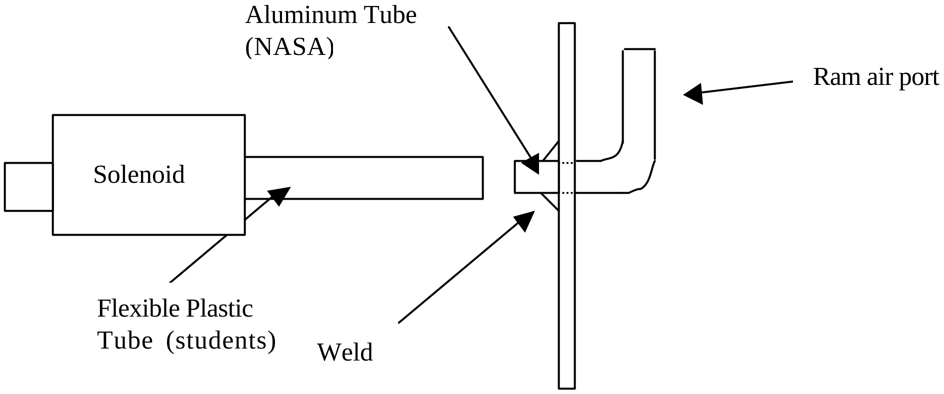


2.3.3 Sensing Ports

The standard door can be outfitted with an aluminum pipe to allow for atmospheric measurements to be made during the flight. The port can be configured as a static pressure port as depicted below.



It may also be possible to extend the pipe outside the door to create a ram pressure port or some other type of pressure port.



The experiment pressure sensor is connected to the pressure port using standard flexible plastic tubing that can be found at the local hardware store. Solenoids are required for all pressure ports to maintain positive pressure inside the experiment deck.

All instruments involving the measurement of pressure or the collection of air samples must be sealed in an internal vessel to prevent water from entering the experiment bay.

Project Engineers should be consulted early in the experiment design for recommendations and advice in creating an airtight internal vessel in order to prevent pressure loss inside the experiment section.

3.0 EXPERIMENT DECK ELECTRICAL CONSIDERATIONS

3.1 Interface Connector Pin Assignments

The Sub-SEM payload provides standard interface connectors. The student teams must develop their designs so they can interface properly to the NASA hardware. The following paragraphs outline these standard electrical interfaces. NASA requires that all wiring be done at electrical interfaces using 22-gauge multi-strand wire.

3.1.1 Data Line Connector

The pins on the STUDENT SIDE of the connector pair are connected to the various experiment devices. The STUDENT SIDE of this connector pair is rigidly mounted to the student experiment deck on stand-offs. The mating connectors and wiring harness are an integral part of the NASA provided experiment structure.

NASA SIDE 37 Sockets	STUDENT SIDE 37 Pins	Deck1	Deck2	Deck3	Deck4
Channel 1	1	A1	A17	A33	A49
Channel 2	2	A2	A18	A34	A50
Channel 3	3	A3	A19	A35	A51
Channel 4	4	A4	A20	A36	A52
Channel 5	5	A5	A21	A37	A53
Channel 6	6	A6	A22	A38	A54
Channel 7	7	A7	A23	A39	A55
Channel 8	8	A8	A24	A40	A56
Channel 9	9	A9	A25	A41	A57
Channel 10	10	A10	A26	A42	A58
Channel 11	11	A11	A27	A43	A59
Channel 12	12	A12	A28	A44	A60
Channel 13	13	A13	A29	A45	A61
Channel 14	14	A14	A30	A46	A62
Channel 15	15	A15	A31	A47	A63
Channel 16	16	A16	A32	A48	A64
	17				
	18				
	19				
	20				
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	23				
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	25				
	26				
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	28				
	29				
	30				
	31				
	32				
	33				
	34				
	35				
Analog Gnd	36				
Analog Gnd	37				

37S 37P

Where A# is the analog input to the PCM stack.

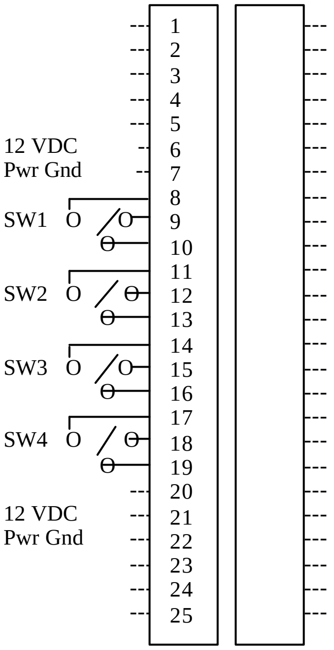
NOTE: Any pins that do not have a designation are OPEN

This connector configuration (separate data and power/switching connectors) allows the data lines to be externally monitored while the power and switching lines are still connected to the experiment deck. This feature may be helpful when troubleshooting is necessary.

3.1.2 Power and Switching Connector

NASA SIDE
25 Sockets

STUDENT SIDE
25 pins



Two independent power inputs are provided to each experiment deck to allow for separate power switching to experiment if desired. This is highly recommended for those experiments requiring two distinct "T Minus" power up times.

The switching lines can be used to turn things on and off during flight. There are four switches, each having both a normally open and normally closed contact. The normally closed contacts are always ON (closed) until the timer command occurs. The normally open contacts are always OFF (open) until the timer command occurs.

Timer commands can be continuous or pulsed. Timer commands can be set to occur between 0.1 and 1000 seconds in increments of 0.1 seconds.

NASA provides the power and in-flight timing circuitry to the student experiment decks. Each deck is supplied a voltage of +12 VDC and MUST NOT EXCEED A CURRENT DRAW OF 2.0 AMPS.

Desired event times must be communicated to NASA approximately 2 weeks prior to delivery of the student experiment decks to Wallops Flight Facility. This will allow for setting of the timer well in advance of experiment integration.

3.1.3 Video Connector

NASA personnel will wire video camera connectors for TM, power, and lighting. Only one of the four decks can be supported with video in the downlink; however, all decks can have their own video recorders.

4.0 SCIENCE DATA CONSIDERATIONS

4.1 Telemetry / Data Acquisition

The data is multiplexed and digitized by a WFF93 PCM (Pulse Code Modulation) stack. A PCM stack can accommodate a number of analog (0V to 5V) signals at a wide range of sample rates per channel. The PCM stack is fully programmable. Generally, the bit rate for the stack is 800,000 bits per second. The word length is 10 bits per word. This results in a word rate of 80,000 words per second. For a previous flight, there were 40 words in the minor frame. This resulted in a minor frame rate of 2000 minor frames a second. The number of minor frames within the major frame was 32. Therefore the major frame repeated (2000/32) or 62.5 times a second. The output of the PCM stack modulates a S-Band Transmitter. The data is then broadcast to the ground station.

The first two words of the minor frame are Synchronization Words. The next word is a SFID (Sub-Frame IDentification) word – which is merely a counter that keeps track of the minor frames.

With respect to the previous matrix, sample rates of 2000, or even multiples of 2000, or reduced rates that are a power of 2 less than 2000 (i.e. 1000, 500, 250, 125, etc.) are readily available. Obviously, there can be some arbitration of resources. Generally speaking, PCM stack running at 80,000 words per second should allow something just under 20,000 words a second per student deck. There is a little loss due to the overhead from the Synchronization words. That 20,000-word capacity can be divided between the 16 channels per deck. So, basically, 1000 sps (samples per second) per channel is a good starting point. If an experiment only used one channel, it could take all of the 16K to 20K capacity for that experiment.

It is worth mentioning that not all schools use their analog monitors. Therefore, their surplus sample rate can be made available to other schools with a higher sample rate requirement. It is difficult to predict what the total demand is going to be. So, start your design with lower rates. If you can use higher rates, once we know what schools are on a given mission, we can accommodate additional requirements.

Also, be careful what you ask for in the way of sample rate. The more you ask for means the more you are required to process after the flight. Assuming that you are using a spreadsheet like Excel to graph your data, you can quickly exceed Excel's row limitation. If you have access to a number cruncher like MatLab, you can process just about anything. In general, the more channels you have at higher sample rates means the more work you have to do in evaluating all those points. Depending on the science, sometimes a lot of data points are required. So, plan ahead and consider what tools you are going to have available to work your data.

4.2 Number of Data Channels

Each experiment deck is provided 16 analog (0V to 5V) channels. Each channel can be sampled 10s, 100s, or 1000s of samples per second. The sample rate may not work out to an even order of magnitude. It is dependent on the total number of data words per frame, the number of bits per word and the stack bit rate. If you ask for a sample rate of 100, you may actually get 125. We tend to go to the next higher available rate. If you are trying to use your sample rate as a clock, this can be a problem. We can tell you what the even sample rates are going to be as the design develops. Also, the PCM post flight data product is automatically time tagged. But, here again, it is time tagged to an external clock and the time deltas may not be even.

The 0 to 5 volt analog input is digitized. This analog to digital conversion results in a 10-bit data word. (1111111111) = 1023 and represents 1024 states including the all zero state. Therefore, each count of the binary word represents 5V/1023 = 0.00488 volts/count.

4.3 Sensor Impedance

The data collection systems used in the Sub-SEM payload is fairly tolerant of the resistance (impedance) of the sensor circuits. Voltage dividers, which are composed of commonly available electrical parts (photocells, thermistors, etc), pose no problems for the collection systems. Direct monitoring of IC outputs and voltage regulator outputs are also possible without the need for buffer circuitry. For a WFF93 PCM stack the analog input impedance is => 1Meg Ohm.

Sensors are, by definition, “usually” low current and low voltage devices. They convert some phenomenon (temperature, pressure, acceleration, G’s, etc.) into some electrical analog. This means changing resistance, capacitance, inductance, etc. That changing electric parameter is then amplified, and/or signal conditioned into some usable scaled output voltage. The output impedance of the signal conditioning circuit is usually fairly low, approximately 10’s to 100’s of ohms.

A Transducer is a bit easier to deal with. A transducer is a sensor with built in signal conditioning. An engineer at the factory has already figured out the signal conditioning. The buyer merely reviews the available features/parameters and picks what fits his or her requirements. Transducers are more expensive than sensors.

So, now your sensor/transducer is giving you information in the form of temperature vs. voltage, pressure vs. voltage or acceleration, etc vs. voltage.

Keep in mind that the A/D (Analog to Digital) converter in the PCM stack can’t convert a voltage greater than 5V or negative voltages. If you signal condition outside of the 0 to 5V range, data will be lost.

To be able to use the PCM data, you will have to convert your sensor/transducer calibration into some thing that can deal with PCM counts. To do this, you have to multiply your calibration by the quantization factor (.00488 volts/count)

For example:

A pressure monitor may have a total scale of 0 to 100 psia.
0 psia = 0 volts

100 psia = 5 volts
The slope of the calibration curve is (100-0)/(5-0) = 20 psia/volt
In the PCM domain it converts to:
(20 psia/volt)*(.00488 volts/count) = 0.0976 psia/count
0.0976 psia/count (this will be your conversion constant)

So, if your PCM pressure data channel is reading 205 counts…
205 * 0.0976 = 20.008 psia

Frequently, the sensor calibration can be expressed as a linear equation:

$Y = mX + B$
Where: X is the PCM counts.
B is the Y intercept (= data offset) not every thing intersects at Zero.
m is the conversion constant.

The data display supports EU's (Engineering conversion Units). If you know your calibrations (and they conform to a linear equation), we can provide a screen display of that value during integration and flight.

4.4 Suggested Wiring and Testing Practices

4.4.1 Power and Switching Connector

Test connectors (37 socket & 25 socket) can be obtained from a local electronics supply store. The power and switching test connector can be connected to a 12-volt power supply or a 12 VDC battery. Timer switching functions can be simulated using single pole / double throw micro-switches (also available at local electronics supply stores). Experimenters must make sure the normally-open (NO) and normally-closed (NC) contacts are connected to the circuits properly so that the timers are simulated correctly.

4.4.2 Data Line Connector

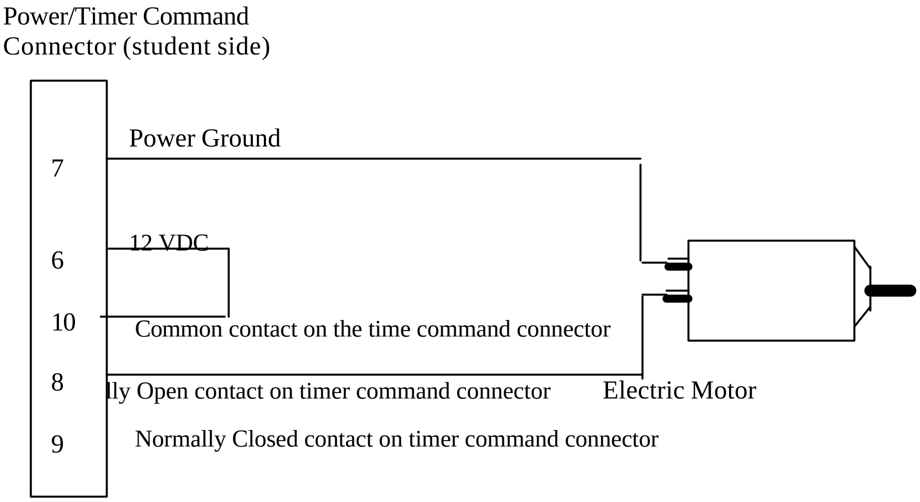
Output voltages from the experiment sensors can be tested at the 37 Pin Data Connector. The data signals (which must provide a 0-5 VDC voltage levels) can be checked using a voltmeter (available from a local electronics supply store) if the signal levels change slowly. An oscilloscope must be used to monitor signals that change faster than 1 Hz. When testing, connect the positive (red) probe to the appropriate channel pin and connect the negative (black) probe to either pins 36 or 37 for grounds).

4.5 Sample Circuits

The following circuits may provide some insight into how the experiment is connected to the interface connectors.

4.5.1 Device Control Circuit

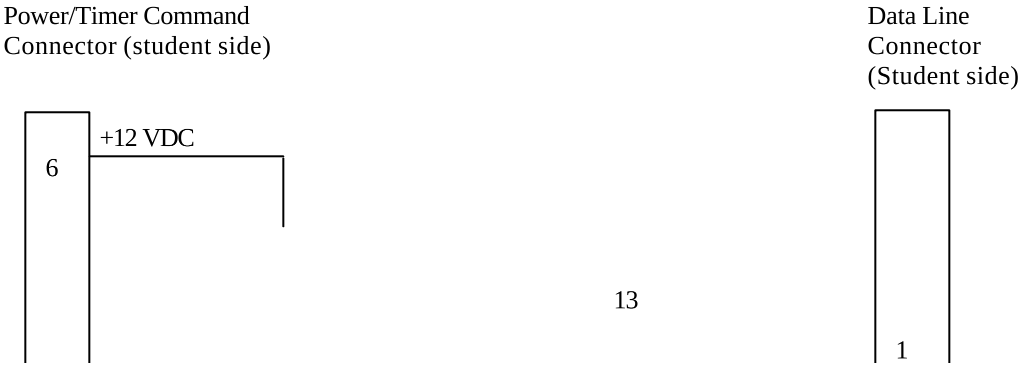
The following circuit diagram shows a simple circuit for controlling an electric motor.

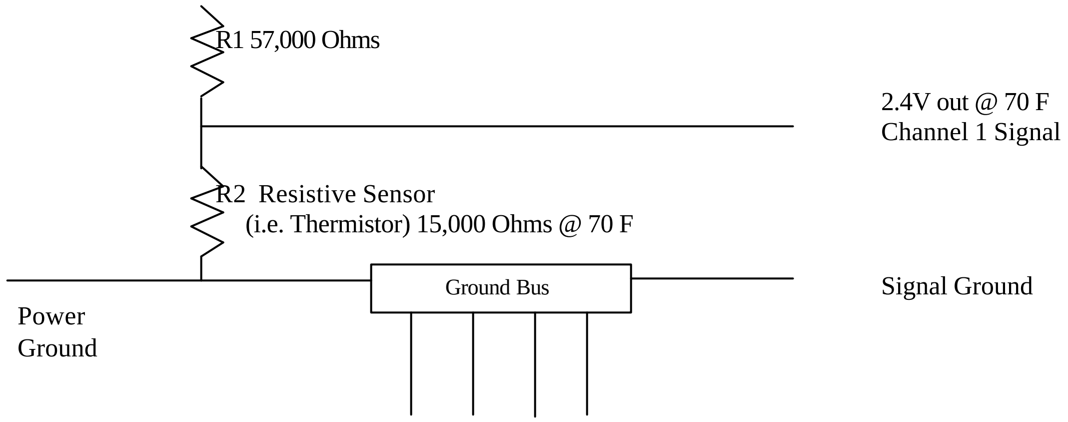


This circuit will turn on the electric motor when the timer reaches the preset “on” time.

4.5.2 Sensor Circuit

The following circuit diagram shows a simple voltage divider that can be used to measure temperature (either air temperature or rocket skin temperature). The diagram demonstrates how the sensor circuit is wired into the Data Line Connector and the Power/Timer Command Connector.





Multiple sensor grounds can be attached to the same signal ground pin. This is usually done using a ground bus in the experiment wiring.

4.5.3 Advanced Circuits

Circuits such as solid-state pressure transducers, strain gauges, and accelerometers may require signal amplification.

4.5.4 Monitor Circuit Applications

The 16 analog channels can be used in a variety of ways. Obviously, raw science data would be expected. However, housekeeping and diagnostic channels are helpful when things don't go as planned.

Depending on how the experiment is designed, your housekeeping monitors can inform you of your operational status and flight readiness. If you will be building an experiment with actuators (levers, doors, valves, gears, etc.) that have to start from a given position, then a monitor to validate that state/condition would be a good idea. If your experiment accidentally got powered up without your knowledge, then motors could have run, valves could have opened, and pictures could have been taken.

If it is supposed to be "ON" at lift off, some sort of run monitor would be helpful. Even if it is supposed to be "OFF" at lift off, a run monitor is nice just to confirm that your experiment came "ON" at the right time.

The WSM has some nominal monitors in support of the MFT (Multi-Function Timer). But, it's often better if the experiment can confirm this also. The MFT monitor is an initiator monitor. The experiment monitor is a responsive monitor which creates a did it really happen kind of monitor.

The MFT is run during integration testing (sequence tests) and it is confirmed to be operational as designed. But, if the experiments support monitors on the decks, which confirm that the voltages (operational states) delivered by the MFT actually got to the experiment deck, it is far more meaningful. This is relatively easy to do with a 4 to 1 voltage divider. A 10K ohm resistor to ground connected thru a 40K ohm resistor to whatever 12V event is being sent to you thru an MFT will result in a 2.4 volt monitor at the junction of the resistors. A wire brought to the data connector from the resistor junction will provide corroboration that the MFT event occurred.

4.5.5 TM Monitor Considerations:

- What is the condition (pre-launch status) of your experiment?

i.e. Is off actually "OFF"? Is on actually "ON"? Has anything accidentally been run that wasn't supposed to have been turned on? Did you need something to start in a vacuum and is the vacuum still there? Did you need part of the experiment to be at a certain temperature? Did you need a valve in a certain position? Did you need an actuator in a certain position?

- What do you want to see in flight?

Do you need it on chart recorder paper? Do you need it on numeric display? Do you need to print out the numeric display? Do you need the numeric display converted into engineering units?

- What do you have to do with the data after flight?

Will the chart records be enough? Will the numeric displays and/or screen prints be enough? Are you going to have to post process your telemetry data from the CDrom?

The WSM provides a thrust axis accelerometer, a 3axis magnetometer, voltage monitors for the batteries (+28V and +12V), and pressure monitors for the Experiment and TM sealed sections. It also provides current monitors, temperature monitor for the transmitter and PCM stack. We have some additional monitors to confirm, when we are internal and external power, as well as, monitors that determine ignition/lift-off (i.e. when the MFTs start running). These monitors are all on the same CD that is delivered to the students. The calibration information can be provided upon request.

However, since the experiment deck is implemented remotely (at the schools), it would be better to design in all of your own anticipated monitors. By doing that, you can guarantee that they are all there and operating as intended and you learn what they are supposed to look like in terms of sensor value/volt at the data interface. If you plan on using one of the WFF housekeeping channels, it may not turn out to be in the proper range or proper sensor orientation to be of use to you. If that happens during integration, it will be too late to change it in the WSM or add it to your experiment.

4.5.6 Integration Support

Once you have resolved your telemetry requirements, you will be faced with "how do you use it?" By upgrading the data acquisition, we are now capable of providing real time display of data during integration and environmental testing.

The data channels that you specified could be displayed on a numeric screen that supports hard copy screen prints. The data can be sent to chart recorders where the analog data is scaled in real time.

During integration, each school will have their data available either on chart or display. As testing proceeds, they will be able to monitor the operational status of their equipment. If there is a systemic problem during vibration, they may be able to determine that they have a problem immediately.

This process helps train the students in how to look at their data for flight.
The Ground Station in F-10 where they integrated can also be used during flight. So, they should be familiar with the equipment and set up.

4.5.7 Post Flight Data Products

During flight the data will be recorded on digital tape. It will, also, be streamed to the hard drive of a dedicated data acquisition computer, a PTP (Programmable Telemetry Processor). The PTP will time tag each minor frame and stamp each minor frame with a header.

After the flight, a master CD will be burned and copies made. The utility application called Extract will be made available which will allow individual schools to download their data into an ACSII file, which can be imported into Excel or some other spreadsheet.

Note: We provide the data CD and the data extracting software. The schools have to provide the analysis software.

The real time data recording feature allows us to (typically) have CD’s ready for analysis by the time that the payload has been recovered.

4.5.8 Telemetry Summary:

The Minimum telemetry request requirements are:

- The number of analog channels you intend to use (16 channels maximum per school at 0 to 5 volt range).
- The sample rates (how frequently do you want to look at the data) for each analog channel.
- The pins of your interface connector that you intend to use for each channel (1 thru 16). Also, remember to include a signal ground on your data interface.

5.0 ENVIRONMENTAL TESTING

5.1 Spin Balance

The payload is balanced in the lift-off configuration only (single stage configuration). The forward balance plane is located on the fwd side of the forward experiment bulkhead. The aft balance plane is located in the motor adapter. Balance weights, usually 5 lbs. or less, used in previous payload were as follows:

Forward:	2.2 lbs	
Aft:	0.0 lbs	(only 19 grams were required and thus omitted)

5.2 Operational Spin Test

It is suggested that a 5 Hz operational spin test be conducted whenever the video recorder configuration is altered. Tests conducted during the development of Sub-SEM I revealed that the Sony VRC is subject to tape jamming if the acceleration loads are applied in the wrong axes. The placement of the VCR in the WSM was optimized to prevent any loading problems.

If an Op-Spin test is required, it can be conducted on the spin balance table after the payload is balanced. All recorders should be active during this test.

5.3 Vibration

The payload is typically subjected to only a 3 axis random vibration only, however various vibration test methods may be used. The WSM and experiment section should be pressurized to -5 PSI during vibration to verify proper o-ring seal.

5.4 Bend Test

A bend test is not required unless new skins have been fabricated. Payload are bent to 125% of predicted bend movement or 50,050 inch-pounds, which ever is greater, to qualify the new WSM.

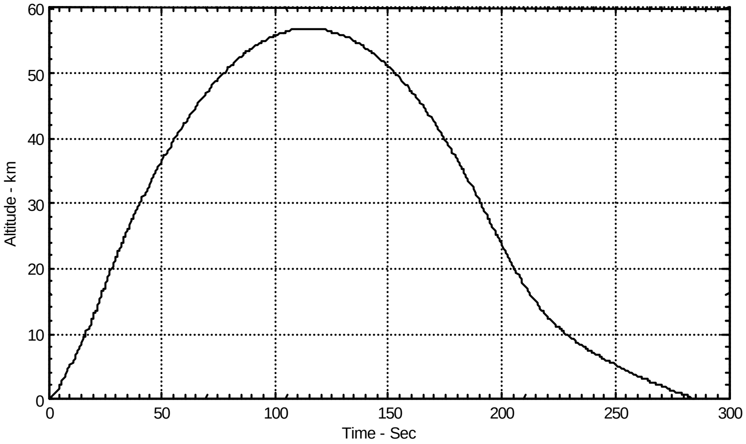
5.5 Physical Properties

The weight, CG, pitch inertia, and roll inertia are measured in the lift-off and re-entry configurations.

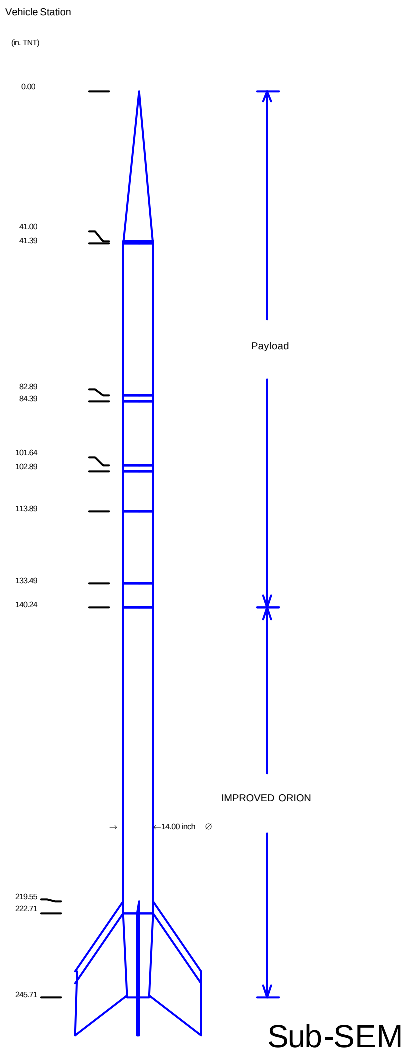
6.0 VEHICLE PERFORMANCE

Based on a payload weight of ~282 lbs., a single stage Improved-Orion launch vehicle will loft the payload to an apogee of 56.8 kilometers. The maximum thrust axis acceleration realized during motor burn is 17 Gs. A launcher elevation of 82 degrees is the typical setting for the Sub-SEM mission. Below are a trajectory plot, a carpet plot and a launch configuration of the rocket.

Improved Orion 30.xxx Sub-SEM
282# P/L, 82.0 o QE, 140.0 o AZ, WFF



Altitude vs Time

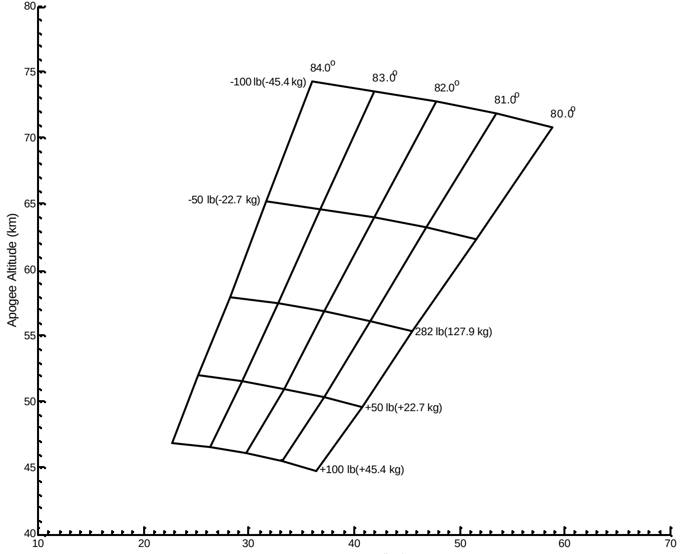


Improved Orion Sub-SEM Vehicle Configuration

7.0. Sub-SEM SCHEDULE OF EVENTS

Below is a schedule of the major milestones for the 2004 Sub-SEM mission. It includes general dates and duration of events. All dates are approximate and will depend on the given calendar year. Precise dates will be distributed once a Mission Initiation Conference, MIC has taken place.

Improved Orion 30.xxx Sub-SEM
282# P/L, 82.0° QE, 140.0° AZ, WFF



Carpet Plot

Milestone		**Date**		**Duration**
Mission Initiation Conference (MIC)		February 1		1 day
Decks sent to students		March 1		3 days
Requirements Definition Meeting (RDM)		March 1		1 day
Fabrication of Decks		March 1		2 months
Deliver Decks to Wallops		May 1		3 days
Integration (Testing & Environmental)		May 15		5 days
Flight Week		June 6 – 11		5 – 7 days
Mission Readiness Review (MRR)		June 7		1 day
Build Up of Rocket		June 8		1 day
Launch & Recovery		Jun 9 – 11		1 – 3 days

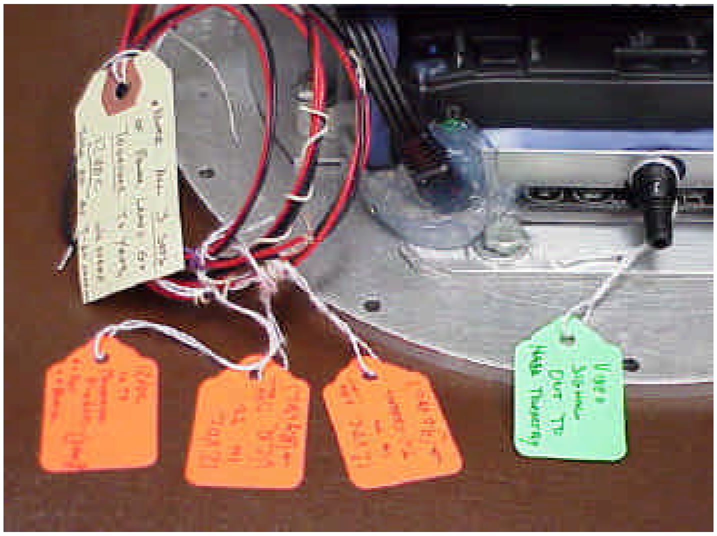
Decks and associated hardware will be sent to the students after the MIC. Associated hardware includes standoffs, connectors (solder type) and 1 tube of RTV. A “Fwd” stamp indicates the forward side of the deck. Upon completion of deck fabrication, the decks will need to be sent, completely populated and flight ready, to arrive on the given day (will vary depending on calendar). All student decks will be integrated into the payload and tested prior to flight week. During flight week, decks will be available to students. The mission will be reviewed, built up and launched during flight week also.

Experimenter’s Guide to Construction

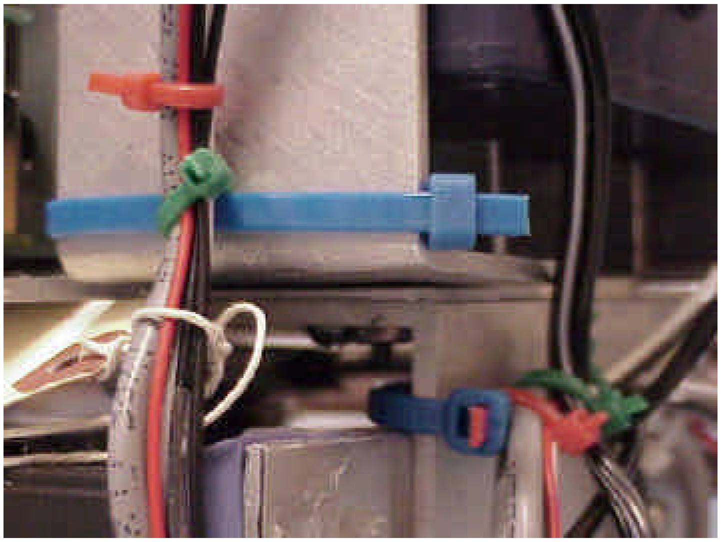
Below you will find some helpful hints on constructing your experiment. Please read carefully and follow the directions stated in the manual. These suggestions may eliminate the need for NASA personnel to modify or change your experiment configuration upon its arrival.

Electrical

- Prepare and arrange pins with proper solder joints to all connectors.
- Supply electrical schematics for all components when shipped to WFF.
- Flag/Label all wires with complete descriptions.

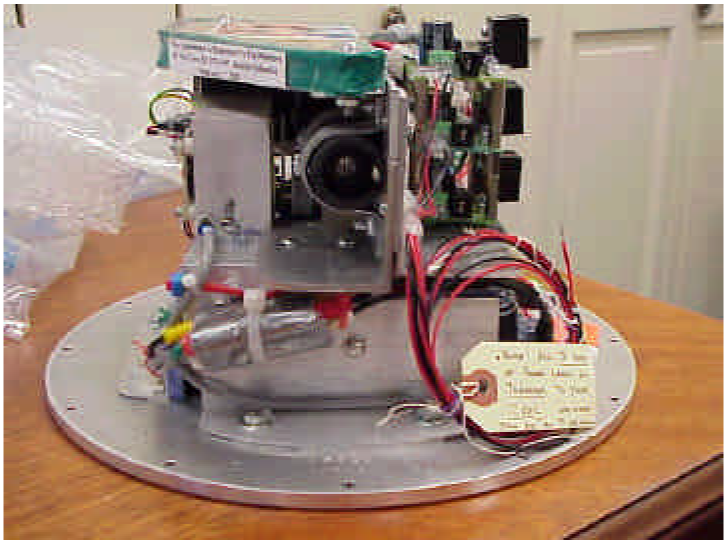


- Use multi-stranded wire (22 gauge) for all electrical needs.
- Tether wires securely using tie-wraps or lacing cord <u>only</u>.



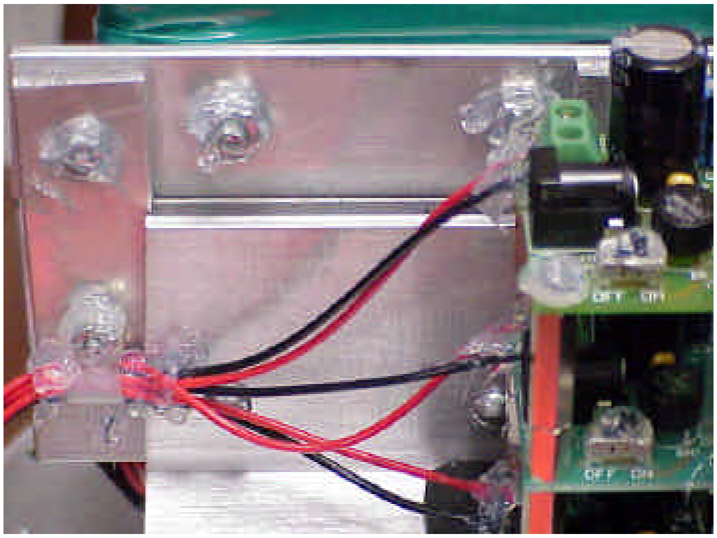
Mechanical

- Secure all experiment components to the deck using **tapped holes** for all metal brackets or supports with appropriate bolts, screws …etc.



- Counter-sink all screws to be flush with the bottom of the deck if securing components through the deck.

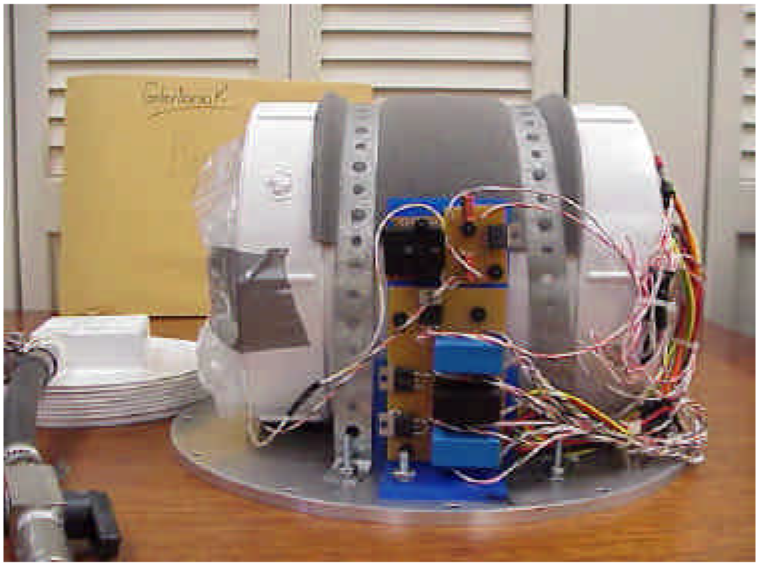
- RTV all fasteners onto the deck and between components.



- Be sure the experiment stays within the 11-inch diameter surface of the deck with a half-inch back off from the deck's edge.
- No components or hardware should exceed the 8-½ inch height requirement.
- All experiments should weigh no more than 10 pounds. This includes the weight of the deck. Weight affects rocket performance.
- If flying video cameras, center the camera lens 4-¾ inches above the deck according to the angular orientation of that deck's window.
- If components with reeled tape are included in the experiment, be sure the rotational force of the rocket matches the tape direction when recording to avoid

distortion. The rocket will rotate approximately 4-½ revolutions per second counterclockwise, looking aft.

- When using liquids in an experiment, a secondary containment component is required in case of leakage.
- When using gas ports in an experiment, a sealed secondary containment component with screw on caps, Teflon tape, and solenoids are required so that positive pressure can be maintained in the payload for recovery.



- All other possible experiment components not discussed here will be approved on a case-by-case basis.
- Performing static load tests on all brackets as described in the Mechanical section ensures better flight performance. Include data from all load tests to WFF when shipping your experiment.