

# **SPACE EXPERIMENT MODULE -- A NEW LOW-COST CAPABILITY FOR EDUCATION PAYLOADS**

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## **INTRODUCTION**

The Space Experiment Module (SEM) concept is one of a number of education initiatives being pursued by the NASA Shuttle Small Payloads Project (SSPP) in an effort to increase educational access to space by means of Space Shuttle Small Payloads and associated activities. In the SEM concept, NASA will provide small containers ("modules") which can accommodate small zero-gravity experiments designed and constructed by students. A number, (nominally ten), of the modules will then be flown in an existing Get Away Special (GAS) carrier on the Shuttle for a flight of 5 to 10 days. In addition to the module container, the NASA carrier system will provide small amounts of electrical power and a computer system for controlling the operation of the experiments and recording experiment data.

This paper describes the proposed SEM carrier system and program approach.

### **SEM Objectives**

The objectives of the SEM program are to provide increased U.S. educational access to space especially for K-12 participants and increase educational use of the Shuttle and GAS Program.

As a goal, the cost to the experimenter organization for development and space flight of a SEM experiment should be reduced by at least 90 percent relative to GAS.

SEM should be reasonably equally available nationwide and not depend on the experimenter's proximity to a NASA installation or other locality dependent aspect.

The SEM program should provide a reasonable number of flight opportunities such that students from a wide number of localities may participate in the flight program. The system should allow for a larger number of students to participate in experiment design exercises.

The SEM system should provide easy access to design information and information on previously developed student experiments via internet or other public means.

The SEM system design should minimize the recurring cost to the government involved in processing, supporting, and flying SEM experiments.

### **Get Away Special (GAS)**

The GAS Program has been operating since 1982 and has currently flown over 110 payloads. Each payload is housed in a NASA provided canister which can hold customer equipment of up to 5 cubic feet (142 L) in a volume measuring 19.75 inches (50 cm) in diameter and 28.25 inches (72 cm) in height. Up to 200 lb. (91 Kg) of customer equipment can be accommodated. GAS payloads and contents typically wait as much as 3 months between the last access opportunity and flight. GAS payloads are controlled by the Shuttle astronauts using a laptop class computer keyboard and display.

The GAS carrier will be used to carry the Space Experiment Module System.

## **Space Experiment Module (SEM) Overview**

In the GAS Student Space Experiment Module concept NASA will provide a small enclosed module which can contain approximately 300 cubic inches (4.9 L) of experimenter apparatus weighing up to approximately 6 lb. (2.7 Kg.). After installation of the experimenter's equipment up to 10 modules will be housed in a pressurized GAS canister which will have NASA supplied equipment for providing electrical power and means for recording simple data such as temperatures, pressures, etc. A control system for activating user apparatus according to a preset time sequence devised by the user will also be provided.

Following the mission the experiment hardware and SEM mounting plate will be returned to and retained by the customer. A computer diskette containing experiment measurement data taken during the flight will also be sent to the experimenter. NASA supplied software can be used by the experimenter to generate printed plots and other displays of the experiment data.

Because power, data system, software, and most of the required mechanical structure is provided, and because of the smaller size, the cost and effort to the end user is dramatically reduced relative to a full GAS payload. The remaining effort is more concentrated in areas germane to the actual experiment being performed.

Experiments selected for flight will be delivered to NASA approximately 4 months prior to the assigned Shuttle mission and returned approximately three weeks after the mission.

SEM modules and flight service will be provided to domestic educational institutions at a cost to be determined. Recipients will be selected by means of a procedure to be determined.

## **Space Experiment Module Technical Implementation**

The following is a preliminary plan for implementing the SEM hardware and software.

The module system will be designed to fly in a standard GAS carrier and consists of :

A battery compartment containing 12 volt batteries. Fuses and cables will be provided to connect power to each module. Power will be turned on near the beginning of the mission by the flight crew and turned off near the end of the mission using the existing GAS relay system.

Experiment modules containing a sealed compartment and a separate electronics compartment. The sealed experimenter compartment is designed to accept an experiment mounting plate with attached experiment hardware. The modules are integrated to the GAS carrier with a simple attachment scheme to minimize integration effort.

A Module Electronics Unit (MEU) for each module provides for programmed sequencing of the experiment operation and acquisition and storage of experiment data.

A ground version of the MEU for use at the experimenter's location. The GMEU will be a small unit which simulates the operation of the module electronics at the experimenter's location. The GMEU requires the use of an experimenter supplied IBM type computer and 12 volt power supply, and will probably be implemented as an electronics card to be installed in the experimenter's computer. Initially, a stand-alone version which connects to the experimenter's computer with a cable will also be developed.

## **Experiment Development and Test Scenario**

In order to develop and test a space experiment the following experimenter (user) and NASA supplied items will be involved:

#### NASA Supplied Items:

Experiment Mounting Plate  
Module Electronics Unit (ground version)  
Ground Software  
Documentation  
Internet Data Base

#### Experimenter Supplied Items:

Experiment hardware to be mounted to mounting plate  
Power Supply (12 Volt, Radio Shack No. 22-120 for 2.5 A or less)  
IBM PC compatible computer with:

Microsoft DOS and Windows 3.1  
Modem and serial port if required by modem, or other internet access  
Printer  
Two card slots for GMEU  
Access to internet (at least E-mail)

#### SEM Participation

Three levels of participation are anticipated; the design phase, hardware phase, and flight phase.

In the **design phase**, experimenters will perform a paper design of an experiment. NASA supplied documentation and electronic data base will provide support to this activity including examples, tips, etc. The NASA supplied software running in an experimenter supplied computer will prompt the experimenter to "fill-in-the-blanks" in the Experiment Data File (EDF). The EDF will contain information describing the experimenters and experiment including addresses, phone numbers, purpose, method, components, parts, materials, etc. The EDF will also contain the experimenter's scenario or timeline for sending control commands from the module electronics to the experiment apparatus and for sampling and recording experiment data such as temperatures, pressures, etc.

The supplied software will provide for printing the experimenter information on an experimenter supplied printer for making reports or papers. The EDF or printed report will form the basis for an application to the hardware phase.

The software and documentation can be widely distributed allowing any number of participants in the design phase.

Participants selected for the **hardware phase** will receive a NASA experiment mounting plate and Ground Module Electronics Unit. Experimenter supplied components will be mounted on the mounting plate, drilling screw holes as necessary. The experiment hardware is then connected to the GMEU which will simulate the functions of the flight MEU. Trial runs of the experiment can then be conducted according to the chosen timeline. Experiment data from the trial runs is recorded in a Measurement Data File (MDF) on the experimenter's computer and can be printed or plotted using the supplied software. The electronic or paper version of the experimenter's report from the hardware phase is used as part of an application for the flight phase.

The number of participants in the hardware phase will be limited by the number of available Ground Module Electronics Units but could be extensive. The GMEU is being designed to be as inexpensive as possible and could be shared by several experimenter groups.

Experimenters selected for participation in the **flight phase** will submit their experiments (on mounting plates) and data files to NASA/SSPP to be installed in modules. The timeline data in the experimenter's EDF will be loaded into the module processor. Following flight of the module, the mounting plate and experiment hardware will be returned to the experimenter with a copy of the measurement data from the module processor.

### **Shuttle Flight Manifesting**

Modules selected for flight will be accommodated as part of the existing Get Away Special Program.

### **MODULE TECHNICAL CHARACTERISTICS**

The following are preliminary technical characteristics for the Space Experiment Module system. Specifications are for each module unless otherwise stated:

#### **Mechanical Specifications:**

Mounting plate surface: Approximately 85 in<sup>2</sup> (550 cm<sup>2</sup>) (see drawing)  
Depth of Experiment compartment below mounting plate: 3.5 inches (8.8 cm)  
Maximum weight of experimenter hardware: 6 lb. (2.7 Kg.)

Experiment hardware to be attached to the mounting plate using supplied 6/32 screws, nuts, and sealing washers.

#### **Electrical Specifications:**

The module will have a D type 37 pin connector socket (D37S) on the side of the experiment compartment. The experimenter will provide a 37 pin plug connector (D37P) and the necessary wires to connect any desired components to the provided electrical services. Outputs to Experiment:

One, timeline controlled 12 Volt (10V to 12.6 V depending on battery charge and temperature) output, 5 amps peak maximum, (P1)

Eight, individually timeline controlled 12 Volt outputs, 1 Amp peak maximum (P2 - P9)

Total simultaneous current from all the outputs P1 through P9 together must not exceed 5 Amps.

Experimenter components to be connected to the programmed power outputs typically include heaters, electric valves for fluid control, fans, pumps for fluid circulation, motors, or camera actuators. All connections to the P1 - P9 or PWRRET pins to be made by means of size #20 stranded copper wire, teflon insulated.

Sensor power, regulated 5.0 volts, 10 milliampere maximum. The sensor power is turned on only when the processor is making a measurement and can be used to power an experiment sensor which works on a voltage divider (potentiometer) principle such as a pressure gauge or linear position sensor.

The energy drawn from the all of the five experimenter power lines together cannot exceed 60 Watt Hours during the flight. This corresponds to a current-time product of 5 ampere hours at the nominal 12 V battery voltage.

As instructed by the timeline, the module processor will sample the voltage on any or all of the six input data lines, convert the voltage into a digital number, and store the number in a memory. The memory can hold at least 16,000 measurements. The digital number will be ten bits in length which means that there are only 1024 possible numbers and that the corresponding voltage between 0 and 5.12 volts can only be

determined to a precision of approximately one part in 1024 or about .1 percent. Actual accuracy will be somewhat lower. Experiment information to be stored must be converted into a voltage between zero and +5.12 volts by components in the experiment and connected to one of the six data input lines designated I7 - I12. These inputs each have an input resistance of not less than 1 megohm.

Three additional inputs, designated I1 - I3 are special and are designed to be connected to a NASA supplied temperature sensor. The sensor is a small bead (.1 inches (2.5 mm) in diameter) which can be glued to the component whose temperature is to be measured and wired to one of the temperature inputs. This sensor is designed to measure temperatures in the range of -40 degrees C to + 80 degrees C. The sensor will continue to work between -50 degrees C and +110 degrees C but with reduced accuracy. The sensor has two wires. One must be connected to a temperature input and the other connected to SIGGND. The temperature sensor, known as a thermistor, has an electrical resistance which varies with temperature. The special inputs I1 - I3 are the same as the I7 - I12 inputs except for a resistor (10K ohms) connected to 5.00 volts.

Three of the processor inputs, I4, I5, and I6 are prewired in the MEU to measure module processor temperature, battery voltage, 5.00 V supply voltage.

### **Electrical grounds and returns**

Current flowing from the +12 V power lines must be returned to the battery on the wires designated power return (PWRRET).

The wire designated signal ground (SIGGND) is the reference point for measurement of voltage for the input signals. One side of all temperature sensors and other sensors should be connected to SIGGND. SIGGND should have no connection to any power line or power return line.

The experimenter should provide a wire connecting the plate ground pin on the connector (PLTGND) to the mounting plate.

### **Experiment Operations Timeline**

Power to the module system will be turned on several hours after launch by a crew command. Following activation, the computer in each module will follow its unique experiment program to activate control functions and acquire data samples as a function of time. Analog circuitry and the 5.00 volt supply will only be turned on during sampling of data to conserve power.

The timeline data is ultimately converted to binary and downloaded to the experiment control microprocessor. Only three simple commands are currently possible: turn on (set) a power line, turn off (reset) a power output, and begin sampling a data channel at one of the allowed sampling rates. Sampling of a data channel can be stopped by setting its sample rate to zero.

The experiment clock is started at the time the experiment system is turned on by the astronaut crew and increments at 0.1 second intervals. Experiment time is specified as days, hours, minutes seconds and tenths of second since turn-on. Time range is 00D 00H 00M 00.0S to 19D 23H 59M 59.9S. Successive times in the timeline file must be the same or greater than previous statements.

Power outputs are designated P1 to P9. A set (SET) command turns on the specified output to allow power to flow to the experimenter components connected to that output. The power remains on until reset (RES) command is sent.

Data sampling for the various data channels is initially set to zero or no sampling. A rate (RATE) command sets the sample rate for the specified channel which is then sampled at the specified rate until the rate is set again. Each data sample requires two bytes in the data storage memory. Software will check the specified timeline to insure that data memory capacity will not be exceeded.

Data channels are as follows:

Channel #	ID	Description
I0	PROC	Processor internal status
I1	TEMP1	Experimenter temperature sensor #1
I2	TEMP2	Experimenter temperature sensor #2
I3	TEMP3	Experimenter temperature sensor #3
I4	TEMP4	Module internal temperature sensor
I5	BATTV	Battery voltage (12v) monitor
I6	500V	Sensor power (5.00v) voltage
I7	EXPD1	Experimenter data input #1
I8	EXPD2	Experimenter data input #2
I9	EXPD3	Experimenter data input #3
I10	EXPD4	Experimenter data input #4
I11	EXPD5	Experimenter data input #5
I12	EXPD6	Experimenter data input #6

Data sample rates are as follows:

Rate #	Rate ID	Description	Measurements (per hour)
0	ZERO	No sampling	-
1	ONCE	Sample once only	-
2	10MIN	Sample every 10 minutes	6
3	5MIN	Sample every 5 minutes	12
4	1MIN	Sample every minute	60
5	10SEC	Sample every 10 seconds	360
6	5SEC	Sample every 5 seconds	720
7	1SEC	Sample every second	3600
8	.2SEC	Sample 5 times per second	18000
9	.1SEC	Sample 10 times per second	36000

Timeline command statements in the experiment data file will have the format shown below. A comment can be provided on each line. Software will prompt the experimenter to enter the timeline data, insert the data into the format shown, and perform checks on entries. Software will also compute energy usage, and memory usage, and will flag any attempt to exceed the allowable parameters.

```

00D 00H 00M 00.0S RATE TEMP3 10MIN Start sampling temperature
00D 00H 00M 00.0S RATE BATTV 10MIN and battery voltage
00D 00H 50M 00.0S RATE EXPD1 1SEC Start sampling pressure sensor
00D 01H 00M 00.0S SET P1 Turn on solenoid valve
00D 01H 00M 14.5S RES P1 Valve off after 14.5 sec
00D 01H 15M 00.0S RATE EXPD1 10SEC Reduce rate for pressure sensor

```

## **SEM Experimenter Software**

The SEM experimenter software will be available at no cost to anyone wishing to design a SEM experiment. The software is designed to run on a PC type computer running Microsoft DOS 5.0 or later and Microsoft Windows 3.1 or later. A preliminary partial version of the software is available by anonymous FTP to: [sspp.gsfc.nasa.gov/pub/software/](ftp://sspp.gsfc.nasa.gov/pub/software/) file: semxx.zip where xx is the version number.

The SEM software will perform the following functions:

The Experiment Data File Editor will allow entry and editing of the various parts of the Experiment Data File (EDF) which includes narrative data, timeline, electrical information, parts list, and materials list. Printed reports can be made of each section.

The Experiment Data File Analyzer reads a completed or partly completed EDF and generates a printed report. The analyzer flags missing data, determines the electrical power and energy required by the timeline, and determines the amount of data memory consumed. Plots can also be made of power and energy vs time and the times that various outputs are "on".

The Module Operations Program will download the timeline data to a flight or ground version of the SEM module processor. Following a ground test run or flight the program will upload the measurement data and create a Measurement Data File.

The Measurement Data Processor program will read data from a Measurement Data File and produce a variety of printed plots and tabular lists of flight or test data.

## **Environmental Conditions**

During launch, payloads are subjected to vibration from the Shuttle rocket engines. Additional information to be supplied.

At launch, when the solid rocket boosters are fired, payloads are subjected to a substantial shock force. A second shock force is encountered at landing. These shock events can involve momentary accelerations of the payload of as much as 11 times the force of gravity or 11 "Gs". Additional information to be supplied.

SEMs will be flown in GAS canisters with insulation on all exterior surfaces. At launch, payloads are normally at a temperature of 65 - 70 degrees F (18 -21 degrees C). During flight the payload temperature gradually changes depending on the orientation of the Shuttle with respect to the ground and sun. Usually temperatures fall during the flight, sometimes to below zero degrees C. Additional information to be supplied.

## **Safety Considerations**

All experiments flown in SEMs must meet Shuttle safety requirements. In order to satisfy this requirement the experimenter must supply a list of all components and materials used in construction of the experiment as part of the Experiment Data File. Highly toxic, flammable, corrosive, or explosive materials may not be used.

All experiments will be inspected by NASA prior to installation into modules.

The Project will develop and maintain a list of acceptable materials and components in the data base.

## **Typical Experiments**

Experiments to be flown could include investigations in the following areas:

### **Behavior of liquids**

- Bubbles
- Surface tension
- Immiscible fluids
- Fluid management in microgravity

### **Bacteria growth**

### **Crystal growth from liquids**

### **Crystal formation from melting/freezing**

### **Plant behavior**

## **Certificate of Space Flight**

Experiments returned to experimenters following flight will be accompanied by a certificate certifying the flight on a specific mission.

## **Art and Decoration**

The experimenters may decorate the surfaces of the mounting plate with art or decorations except that inks or paints should be from an approved list to avoid contamination of the carrier.

## **Restrictions on Resale**

NASA regulations prohibit commercial use of SEM experiments including resale for profit of flown items such as the experiment or mounting plate.

## **Internet Data Base**

The Project will develop and maintain a data base of information for those interested in the SEM program and other SSPP activities. An E-mail mailing list and/or newsgroup will also be provided for those interested in SEM. The data base is accessible by E-mail by sending a message to [Majordomo@sspp.gsfc.nasa.gov](mailto:Majordomo@sspp.gsfc.nasa.gov) with the word help in the body of the message. A return message will automatically be sent giving instructions. The E-mail service may be accessed by anyone having access to CompuServe, Prodigy, America On-line, or other similar information service. Internet users can also access the Project data using FTP, Gopher, or WWW at: [sspp.gsfc.nasa.gov](http://sspp.gsfc.nasa.gov).

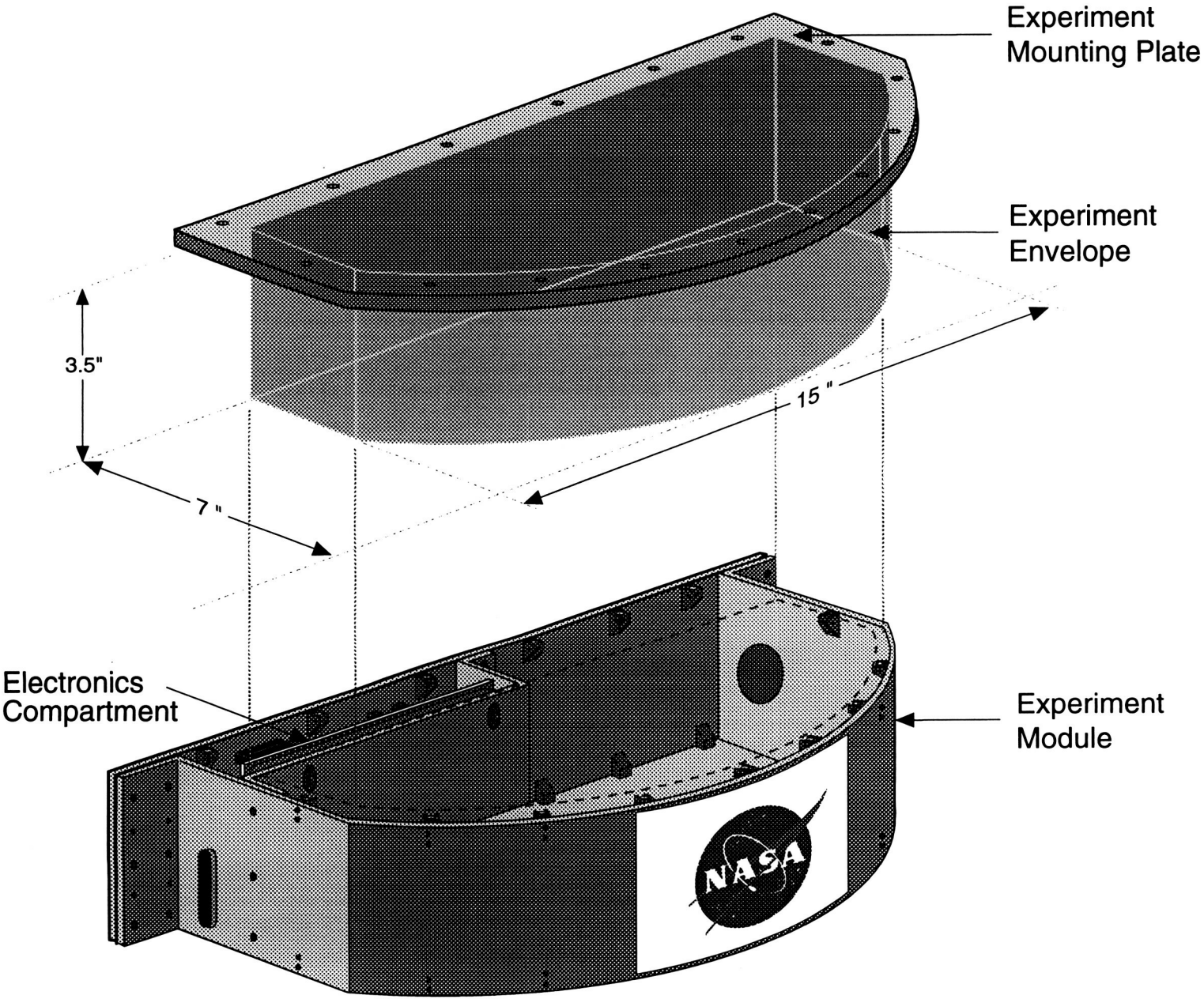
It is very important that participants contribute to the data base to help future participants. Experiment data files submitted to NASA will be put in the data base unless the experimenter requests that this not be done.

## **Project Contacts**

Contact T. Goldsmith or R. Lewis for more information.  
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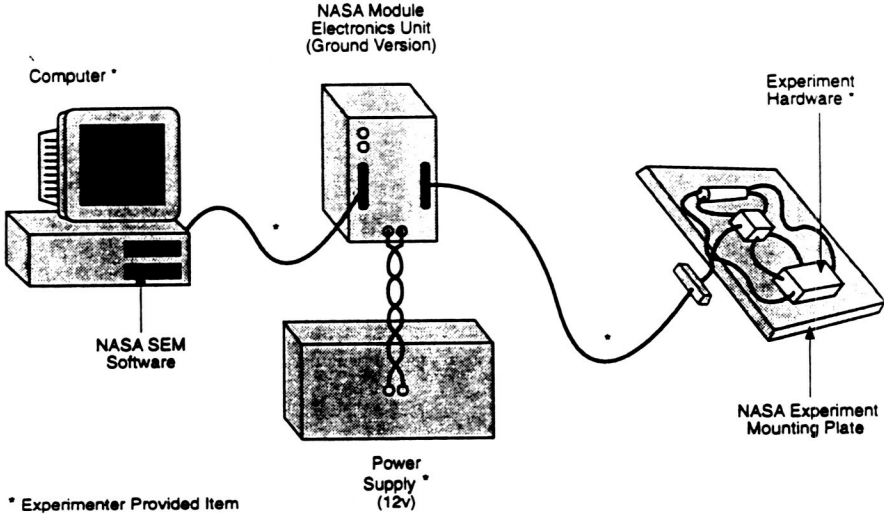


# SPACE EXPERIMENT MODULE (Experiment Envelope)



I1160.072595

# EXPERIMENT DEVELOPMENT CONFIGURATION



# SEM EXPERIMENT MOUNTING PLATE

