SAMPIE - A SHUTTLE-BASED SOLAR ARRAY ARCING EXPERIMENT

Dr. Dale C. Ferguson
Principal Investigator
NASA Lewis Research Center

Abstract:

SAMPIE (the Solar Array Module Plasma Interaction Experiment) is a joint NASA/ESA Shuttle flight experiment to investigate arcing thresholds and plasma collection currents for modern solar array designs in low Earth orbit (LEO). Previous ground and space flight tests have shown that anomalous current collection ("snapover") at high positive voltages and arcing at high negative voltages may be expected for solar arrays in LEO. New, high power solar arrays being considered for use in LEO use new materials and construction techniques, which may change arcing thresholds and collection currents. SAMPIE has been manifested for launch aboard the Shuttle in late calendar year 1994. The experiment will be justified on the basis of previous ground test results and the results of flight experiments PIX and PIX-II, and on the new materials and construction techniques for modern, high power solar array designs. Phase B design and definition are now in progress. Considerations which influence the experiment design will be discussed, and objectives and constraints will be identified.

I. Background and Justification for SAMPIE

Numerous ground experiments and two flight experiments (PIX I and PIX II, Grier and Stevens, 1978, and Grier, 1983) have shown two ways that solar arrays interact with the plasma. First, they collect current from the plasma. Because the mass of an electron is much smaller than the mass of a positive ion, the electron current collected at positive bias relative to the plasma is much greater than the ion current collected at comparable negative biases. At positive biases greater than about two hundred volts relative to the plasma potential, insulating surfaces surrounding exposed conductors behave as if they were themselves conductors, due to the phenomenon called "snapover", greatly enhancing electron collection. On an operating solar array, the currents collected from the plasma appear as losses in the array operating current and in the efficiency of the array. Furthermore, the currents collected from the plasma determine the potential at which different parts of the array will "float". It is important to determine the manner in which solar arrays collect current from the space plasma, in order to evaluate array operating efficiency and to predict and control spacecraft potentials.

Secondly, at high negative biases relative to the surrounding plasma, solar arrays arc into the plasma, causing disruptions in the current produced, electromagnetic interference, and large discontinuous changes in the array potentials. Both ground tests and flight tests have indicated that for arrays having silver-coated interconnects a threshold potential relative to the plasma exists, below which no arcing occurs, at about -230 volts (Ferguson, 1986). There are theoretical reasons and some indications from ground tests (Jongeward et al, 1985, Snyder, 1986) that different conducting materials exposed to the plasma have different arcing threshold potentials. It is important to determine the arcing threshold, arc strengths, and arc rates for solar arrays operating at high negative potentials in the space plasma.

High power level solar arrays now being considered for space applications will operate at high end-to-end voltages to minimize the array currents. A major driver toward higher operating voltages is the mass of cabling which must be lofted into orbit to transmit the electrical power from the arrays at high efficiencies. Because the resistance of the cable is a strongly decreasing function of the cable mass per unit length, and because the cable losses are proportional to the current squared, it is advantageous to operate at high voltages, where the currents will be low, and a larger resistance per unit length (less cable mass per unit length) may be employed. A further factor in operating at high voltage and low current is that magnetic interaction effects (such as magnetic torques and magnetic drag) are minimized with minimum current operation.

To save weight and manufacturing cost, new solar arrays being considered for NASA and ESA missions are of a new design and utilize new materials, which may change the currents collected and the arcing threshold. In particular, new arrays being considered for NASA missions have solar cells with interconnects in the back, bonded to lightweight flexible substrates, employing copper traces which may become exposed to the space plasma. All of the solar arrays which have been flown in space to-date have had silver-coated interconnects exposed to the plasma between cells on the front of a rigid substrate.

A full panel of new array technology solar cells planned for Space Station Freedom application have been shown to arc at biases as small as -210 V, relative to the plasma, in ground tests at the Lewis Research Center (Nahra, Felder, and Staskus, this session). No in-space tests of these arrays have been done, or are planned. The Space Station Freedom array nominal operating voltage of 160 V is uncomfortably close to the 210 V arcing threshold found in these ground tests and may be exceeded when the arrays come out of eclipse.

Comparison of ground tests and flight tests of the old-technology solar arrays have shown many differences between their behavior in vacuum tanks and in the real space plasma. On PIX II, for example, the shape of the collection current versus voltage curves were quite different in space than on the ground, and two different types of curves were obtained, depending on whether the arrays were in the ram (forward facing) or wake (backward facing) orientation. Although the same arcing threshold seems to obtain for the PIX II cells in orbit and in the ground plasma, the arc rate versus potential above the threshold potential was quite different (and much higher at voltages less than about 1000 V) in the space plasma than on the ground. The origin of the discrepancies is not known, due to inadequacies in the theory of the arcing phenomenon (Jongeward et al, 1985, and Hastings et al, 1989). Thus, while ground tests may give us information about the arcing threshold potential, they will not give us the detailed information necessary to allow confident design of large future NASA and ESA solar arrays.

For these reasons, it is important to determine the dependence of plasma collection currents, arc rates and strengths on potential relative to the plasma, and arcing potential thresholds for new technology solar arrays in a real space plasma through one or more space flight experiments. The relevant plasma parameters, such as electron density and temperature, and spacecraft factors, such as orientation relative to the velocity vector, and potential relative to the plasma, must be concurrently measured along with the array performance, in order to understand the interactions which take place, and to enable confident and reliable design and operation of future NASA and ESA space power systems. SAMPIE will help enable the design of such systems.

II. SAMPIE Objectives

The objectives of SAMPIE are to:

1) Determine the voltage thresholds at which arcing occurs on the NASA and ESA solar array test modules and the arc rates and strengths.

2) Determine the plasma current collection characteristics of the solar array test modules.

3) Measure a basic set of plasma parameters to aid in data analysis.

III. Description of SAMPIE

SAMPIE will consist of two small solar arrays, individually biased to high potentials relative to the plasma, mounted on the end of a collapsible tube mast (CTM) which may be extended up to 15 meters from the payload bay of the Space Shuttle (see Figures 1 and 2). The CTM is of ESA design and construction, and will impose operational and design constraints on SAMPIE. One of the solar arrays will be of NASA chosen design and construction, and the other will be of ESA design and construction. The arrays will be biased by a power supply to DC voltages as high as -700 V and +700 V with respect to the array structure ground, so that the arrays will be at high potentials with respect to the space plasma. While the arrays are biased, instruments will detect the occurrence of and measure the strength of any arcs from the arrays to the plasma, and will measure the amount of current being collected from the plasma. To characterize the plasma and other test conditions, other instruments will measure the degree of solar insolation and the plasma electron density and temperature, as well as the potential of the solar array structure ground with respect to the plasma, this being a minimum set of conditions to be measured. The orientation of the solar arrays with respect to the Shuttle velocity vector will be known at all times, as well as the times and conditions of Shuttle reaction control thruster events. This information will be obtained from Shuttle operations logs or tapes.

SAMPIE will be performed with the CTM at full extension and at two or more intermediate extensions, including zero extension, to derive information about the influence of the large Shuttle Orbiter body on the ram and wake conditions seen by the arrays, and on the plasma surrounding the Orbiter. While at full extension, the maneuvering capability of the Shuttle will be limited to the use of the vernier thrusters only, for structural dynamics reasons. A further limitation on Shuttle operations is imposed by the fact that the experiment ground will be tied to Shuttle Orbiter ground, which is tied to the plasma potential mainly through about 30 m^2 of exposed metal on the Shuttle Main Engines (Sasaki *et al*, 1986). When the arrays are biased to positive voltages higher than about 100 volts, the orientation of the Orbiter will be restricted such that the Main Engine nozzles are not in the vehicle wake, for large vehicle potential excursions would occur at those times, due to the low collectible ion density in the Orbiter wake. An operational constraint may also be imposed on the conduct of the experiment by the prospect of the Orbiter charging to high potentials. The maximum desirable positive array bias will be considered under IV. Scientific and Technological Constraints.

SAMPIE will be mounted on a Hitchhiker attachment plate within the Orbiter payload bay, and will use the standard Hitchhiker data recovery systems. Because of limitations on the size and number of wires for power and data transmission which may be extended with the CTM, as much as possible of the electronics necessary to perform the experiment and diagnose experiment conditions will be placed on the end of the mast along with the solar arrays. Mass limitations on the package at the end of the CTM are imposed by structural dynamics, and a maximum mass of 15 kg on the end of the mast has been agreed to by NASA and ESA.

SAMPIE's operational mode will be to bias one array segment to a certain voltage for a certain length of time, measuring the current collected and the times and strengths of arcs as they occur, and simultaneously to measure the diagnostics of solar insolation, plasma conditions, and vehicle potential, and then to move on to another bias voltage, measuring all of the same things, repeating until all of the design bias voltages have been covered. Then the other array segment will be tested in a similar fashion. The arrays will be tested at each CTM extension in a wide variety of vehicle orientations with respect to the sun and the vehicle velocity vector in order to determine effects on collection currents due to solar insolation, ram and wake conditions at different distances from the Orbiter body, and aspect with respect to the Earth's magnetic field. SAMPIE will have control of the Orbiter orientation.

Because the solar arrays at high negative potentials relative to the plasma will produce arcs, which are known to emit broadband electromagnetic interference (Leung, 1985), the capacitance of the arrays to space will be tailored to produce arcs of acceptable size and EMI production. Also, a waiver of the EMI specs for Orbiter payload bay experiments will be necessary.

SAMPIE will benefit from the prior experience gained at the Lewis Research Center in design and construction of the SPHINX, PIX, PIX-II, and VOLT-A plasma interaction space flight experiments.

IV. Scientific and Technological Constraints

SAMPIE will be placed in an orbit which keeps it from entering the auroral oval, for occasional strong high energy electron fluxes and low thermal electron fluxes there make conditions hard to measure, unpredictable, and therefore not ideal for this experiment. The Orbiter orbital inclination during SAMPIE will be restricted to less than about 58° to the equator.

SAMPIE is now manifested for flight in 1994, shortly after the maximum of the solar activity cycle, in 1992, but there is a possibility that it will fly in 1993. The plasma density in low Earth orbit depends on the level of solar activity, peaking at times of solar maximum. Recent estimates of the level of solar activity expected at the peak in 1991 or 1992 place the level unusually high, with some estimates of the averaged sunspot number as high as 200. Runs of the IRI-86 computer model for the ionosphere (Rawer and Bradley, 1987) place the maximum daytime electron density for such high solar activity levels as high as 3.8×10^{6} electrons per cubic centimeter, at electron temperatures between 1100 K and 2300 K. Nighttime electron densities are predicted to be as low as 1.6×10^5. Under these conditions, the plasma will be capable of maintaining electric fields at low potentials over a distance of approximately one Debye length, which is given by equation (1),

$$\text{lambda}_d = (kT_e/4\text{pi } ne^2)^{1/2} = 7.43 \times 10^2 \ (T_e/n)^{1/2},$$

where T_e is the electron temperature in eV, k is the Boltzmann constant, pi = 3.14159..., e is the charge of the electron, and n is the electron density in cm^{-3}. Placing representative values from runs of the IRI model in the above equation, one finds a minimum Debye length from 0.12 cm at 1100 K to 0.17 cm at 2300 K. Openings in the experiment electronics enclosure will be smaller than the minimum Debye length to prohibit plasma interactions with the experiment electronics.

It is be desirable for SAMPIE to place its plasma diagnostic instruments outside the plasma sheath (the sheath being the region where the plasma is significantly disturbed by the applied electric fields) of the array being biased. For large potentials, using orbit-limited collection (see Galofaro, this session) the plasma sheath radius may be taken as the radius of a sphere with the same area as the area of the collecting array segment, multiplied by the square root of the quantity, the applied bias in volts divided by the electron energy in eV. Under ram conditions, the ion sheath may be somewhat smaller than this (perhaps 1/4 the radius), because the flux of ram ions is greater than the thermal flux. For a voltage of 700 V, this implies a sheath radius of more than a meter under all reasonable plasma densities. At even moderate voltages, such as two hundred volts, the sheath will extend for a distance of more than 45 cm, using orbit-limited theory.

Alternatively, one may assume that the flow of charged particles to the solar arrays is limited by a build-up of space charge around the collecting array. In this case, calculations indicate that at 200 V, the sheath radius will be at least 30 cm for electron collection and/or ion collection without ram ion impingement, and at least 9 cm collecting ions in the ram direction. In the case of electron and non-ram ions, this indicates that the sheath radius is much greater than the array dimensions discussed below, so that orbit-limited theory will apply. Recent experiments of Thiemann and Bogus (1986 and 1988), indicating much smaller plasma sheaths, may have been influenced by electron ionization of the dense background gas, or by ram ion impingement in their high energy streaming plasma. The discrepancies will be investigated as part of SAMPIE by means of NASCAP/LEO.

A preliminary mechanical design of the array package to be placed on the end of the CTM is shown in Figures 3, 4, and 5. It may not be possible to have the Langmuir probe or other instruments measure the undisturbed plasma density and temperature and "ground" potential on the array structure when an array segment is being biased to significant voltages because the plasma sheath will have dimensions exceeding the dimensions of the array structure. Between array bias voltages the array bias will be switched off for a short time, to allow sensors mounted on the structure to measure the undisturbed plasma, before going on to the next bias voltage.

Calculations of the rate of change of plasma parameters in the IRI model of the ionosphere show that within 5 degrees of orbit, the plasma densities and temperatures may change by 25%. Since it is desired to measure the plasma conditions to within about 50%, each bias voltage interval will be restricted to less than about 10 degrees in the orbit, or about 3 minutes of time.

Of great interest to SAMPIE is a calculation of the floating potential of the Shuttle Orbiter when the array segments are biased to high voltages. Not only do the true potentials of the array segments with respect to the plasma depend on the potential of the spacecraft "ground" relative to the plasma, but it may be possible to charge the Orbiter up to potentials where non-array material junctions could arc into the plasma. As this is clearly undesirable, I will perform a calculation of the expected Orbiter floating potential. In this first calculation, I will assume that the plasma sheath dimensions greatly exceed the collecting surface dimensions, so that current collecting surfaces collect current according to the spherical orbit-limited collection law,

$$I = J_o A (1 + eV/kT), \qquad (2)$$

where A is the area of exposed conductor, e is the electron charge, V is the applied potential relative to the plasma, k is the Boltzmann constant as before, and T is the temperature of the collected species (Chen, 1965). Here, J_o is the so-called "thermal current density", given by the expression

$$J_o = (ne/4)(8\ kT/pi\ m)^{1/2}, \qquad (3)$$

where n is the density of the charged species, k and T are as defined before, and m is the mass of the charged species. Evaluating J_o for electrons at the maximum density of $3.8 \times 10^6\ cm^{-3}$, it may be seen that

$$J_o = 3.1 \times 10^{-6}\ amps/cm^2 \text{ at } 1100\ K, \text{ or}$$
$$4.5 \times 10^{-6}\ amps/cm^2 \text{ at } 2300\ K.$$

Because of the difference in atomic oxygen ion mass and electron mass, for ions,

$$J_o = 1.8 \times 10^{-8}\ amps/cm^2 \text{ at } 1100\ K, \text{ or}$$
$$2.1 \times 10^{-8}\ amps/cm^2 \text{ at } 1400\ K.$$

There is evidence from ground tests that the plasma current collection characteristics of solar arrays depends on the potential of the surrounding material, and also on the speed with which the bias is applied (Carruth, 1987). The surrounding material may alter the orbits of the electrons to be collected, and thus change the currents reaching the exposed biased conductors. For this reason, to simulate a large solar array, where large adjacent areas are at about the same potential, it is best to bias up both array segments when measuring the electron collection current of either of them, to give a surrounding potential nearly the same as that of the array segment being measured.

Setting the electron and ion currents equal, and approximating the distribution of voltages on the Orbiter as a high negative voltage area at one negative potential and one high positive voltage area at one positive potential, equation (3) yields

$$V_+/V_- = -(A_-/A_+)(J_i/J_e)(T_e/T_i), \qquad (4)$$

where the subscript e refers to electrons, i to ions, and + and - to negative and positive potential collecting areas. At low voltages, the array collecting areas will be the areas of exposed conductor, which for solar arrays even of the old technology comes out about 5% of the array area. However, under snapover conditions, at positive array potentials of more than about 150 volts, the entire biased array area starts to behave as if it were exposed conducting material, and the effective collecting area of the array is greatly increased over the interconnect area. Taking the electron and ion temperatures equal, and the ratio of $J_-/J_+ = 171$, as it is for an atomic oxygen plasma in LEO, and assuming a biased array electron collecting area of 1000 cm^2 and an area of 30 m^2 for the Shuttle Orbiter, under snapover conditions,

$$V_+/V_- = -1.75.$$

Thus, under snapover conditions on the array segment, the Orbiter is likely to charge up to a potential comparable to the potential on the array segment. Quantitatively, if the array segment is biased to +300 V with respect to the plasma, V_-, the Orbiter potential, becomes -171 V, a potential where it is unknown whether arcing could occur from the Orbiter to the plasma. Laboratory measurements made by the late J. Staskus, of LeRC, on new technology solar arrays (Staskus, 1988), show that at a potential of +200 V relative to the plasma, only about 30% of the cell area acts as collecting area, but at +300 V, nearly all of the cell area acts as a collector. In practical terms, this implies that to keep the Orbiter potential, V_-, lower than about -75 V, the Skylab proven "safe" operating potential to avoid arcing, the array potential relative to the plasma must be limited to about +260 V, and the array bias relative to the Orbiter must be limited to below about +335 V.

A somewhat more realistic calculation takes account of the fact that the main engine nozzles of the Shuttle, where the ion collection takes place, are much larger in dimension than the ion sheath will be at realistic Shuttle potentials. The currents collected at this end will then be space charge limited, rather than orbit limited, as they will be at the electron collecting array end. Also, the flux of ions onto the Main Engine nozzles due to the Orbiter velocity will exceed the thermal flux, modifying the size of the ion sheath and the currents collected. A preliminary calculation indicates that the Shuttle may float at -75 V when the array is at +240 V relative to the plasma, putting a possible limit on the maximum positive array bias voltage of 315 V. This calculation depends sensitively on the ion density hitting the nozzles, however. Further calculations using NASCAP/LEO are required to place realistic constraints on the experiment.

A possibly more serious limitation on the positive bias of the arrays will be current limitations on practical power supplies. Again, using Staskus's measurements, the thermal current is collected at a potential of about +150 V. This corresponds to about 3 mA, for a SAMPIE 1000 cm^2 array at 3.7×10^6 cm^{-3} and a temperature of 1100 K. At about +200 V, the current in Staskus's experiments increased to about 3/10 the full snapover current, or about 1.8 A in terms of SAMPIE. At +300 V, full snapover was reached, implying currents of several amps and power levels of over 1000 W, clearly impractical for the mass and power constraints on the SAMPIE power supply. One might expect that at about +175 V potential, the array may sometimes be drawing as much current as a 100 mA power supply (for example) could provide.

Using equation (4), and assuming that at this potential, the effective array current collecting area is about 300 cm^2, gives $V_- = -30$ V. Then $V_+ - V_-$, the bias voltage, is 205 V.

From these considerations, it appears that a positive bias of from +205 V to +335 V is the maximum practical for the bias voltages which may be used in SAMPIE. This will restrict the ability of SAMPIE to explore the snapover regime fully, but under ordinary conditions, voltage limitations on arrays imposed by the possibility of arcing on the negative end may make snapover unreachable on the positive end, so that space measurements of full snapover may not be as immediately important as measurements of arcing thresholds. Ground tests may help further illuminate the snapover voltage for the new technology solar cells, and computer modeling may help to specify the maximum usable bias voltage in SAMPIE. On SAMPIE, since instruments will be measuring the "ground" potential V_- relative to the plasma, it may be possible to design so as to stop increasing the array positive bias when the Shuttle Orbiter goes a specified number of volts (such as -75 V), away from plasma potential.

On the negative bias side, constraints on the experiment are imposed by the expected arc rate of the solar panels. In the only quantitive, large scale ground tests of new technology, welded-through interconnect solar panel arc rates to date, Norman Grier's (1984) measurements may be interpreted to yield an arc rate versus voltage law of

$$R = 6.6 \times 10^{-27} V^{8.1} n T^{0.5} m^{-0.5},$$

where T is the plasma temperature in eV, V is negative potential in volts, n is the plasma density in cm^{-3}, and m is the ion mass in amu (Ferguson, 1986). Taking $n = 3.8 \times 10^6$, the maximum expected in orbit, T = 5 eV (the ram ion energy), and m = 16 (atomic oxygen), one finds that the expected arc rate at -700 V is 1552 arcs per second! Because of the strong dependence of arc rate on voltage, the expected arc rate drops to 0.06 arcs per second at -200 V, and 0.00022 arcs per second at -100 V.

Ground experiments done by David Snyder, of LeRC, have shown (Snyder, 1986) that for simulated silver solar cell interconnects, the potential after arcing drops to about -230 V, the same as the arcing voltage threshold found from PIX II and ground tests. Similar tests done for copper, the material likely to be exposed to the plasma in the new technology solar cells, show that the potential after arcing drops to a much lower voltage, on the order of -100 V, suggesting that the arcing threshold for copper may be as low as -100 V. Thus, it is desirable for SAMPIE to be able to measure arc rates as low as they may be at -100 V in orbit.

For a single arc at -100 V at the arc rates calculated above, SAMPIE would need to dwell at -100 V for 76 minutes, the greater part of a complete orbit, even at the maximum predicted plasma density. This seems to be impractical, given the time constraints on any experiment in orbit. Because of the strong dependence on voltage, however, a dwell time of only about 20 minutes would be necessary to expect one arc at -120 V. Thus, an experiment timeline has been set up which allows at least a twenty minute dwell time at -120 V, and correspondingly shorter times at higher voltages. SAMPIE will not to test for arcs at a voltage greater than -600 V. At this voltage, the arc counter may be filled up at the end of two seconds, and it may be impractical to reset the high voltage power supply on a time scale shorter than a few milliseconds, as will be seen below. To follow the plasma density during the long dwell times it may be necessary to break them up into increments of 3 minutes or less, with Langmuir probe sweeps in between.

To keep the solar arrays from being damaged by large arcs powered by the high voltage power supply, a large impedance will be placed in the bias voltage circuit, between the high voltage power supply and the biased array segment. This will isolate the array segment from the power supply during the short duration arcs. To tailor the size of the arcs to something that the transient detector can comfortably detect, the capacitance of the array segment to the Orbiter will be specified. These considerations limit the ability of circuit to recover rapidly after an arc takes place, and may limit the highest negative voltage to be used in arcing studies because of the expected high arc rates at high negative voltages. Because the arcs are likely to last for about 20 microseconds at the most, SAMPIE will have an RC time constant in the bias circuit of at least 100 microseconds.

There is evidence that the arc rate of a solar array in a plasma decreases to a steady state value on a time scale of a few hours (Miller, 1983, Ferguson, 1986). Also, outgassing from the Orbiter payload bay may make neutral densities abnormally high for a matter of many hours after the Orbiter is in orbit. Under such conditions, electron ionization of the neutral gas may make collection currents and arc rates and strengths uncharacteristic of the values obtained in a long-lived solar array in orbit. For these reasons, the start of SAMPIE will be delayed for at least 24 hours after the Orbiter is in orbit with the payload bay doors open.

In order to compile good statistics and to cover an adequate range of plasma conditions, Orbiter attitudes and CTM extensions, the one orbit voltage bias sequence will be done for at least six times with each array segment, for a total of at least twelve orbits (18 hours).

Finally, arcing may be exacerbated by the presence of strong electric fields in the vicinity of the arc site. For this reason, when one of the array segments is being biased negative, the other segment will be grounded, to strengthen the local fields. This also will help simulate the possible adjacency of different parts of the large area array string in future large space power systems. In ground experiments, arcs sometimes have also occurred between adjacent conductors at high relative potentials. The arc detector on SAMPIE will be capable of discriminating these two types of arcs, based on characteristics found in ground experiments.

V. SAMPIE Arrays to be Tested

Part of the SAMPIE flight project is a ground-based testing effort, to evaluate array arcing and collection models, and to determine the most informative samples to flight test. Dr. G. Barry Hillard will be conducting this ground-test effort in laboratories at Lewis Research Center. Dr. Hillard presents his plans as another paper in this session, so I won't go into them further here. However it is interesting to note that SAMPIE is being designed so that which the flight samples are tested may be determined as late as possible, to allow ground-based testing to help optimize the information to be gained in flight.

VI. Conclusions

SAMPIE is a Shuttle-based flight experiment which will investigate the currents collected by, and the arcing behavior of, new technology solar arrays in LEO. It is in the Phase B design and definition stage of development, but is manifested for launch in 1994. Design and construction of modern high power, high voltage, solar arrays for use in LEO require the information that a flight experiment such as SAMPIE may obtain.

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POWER TECHNOLOGY DIVISION

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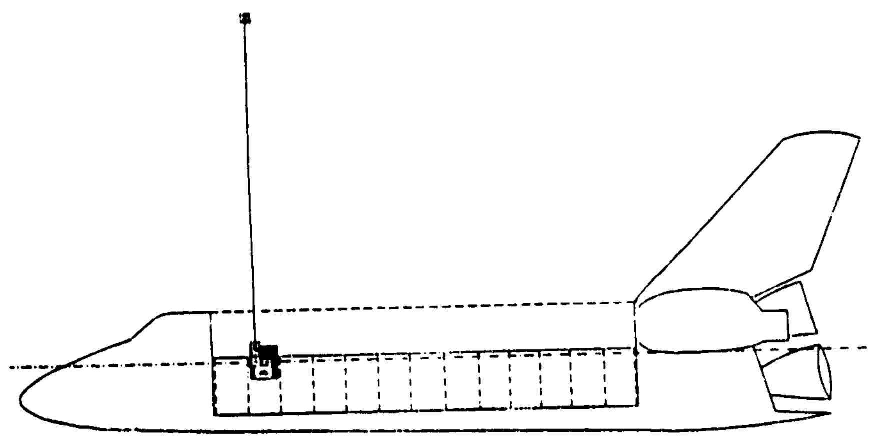
SOLAR ARRAY MODULE PLASMA INTERACTION EXPERIMENT



Accomodation of CTM/SAMPIE (side view)

Figure 1

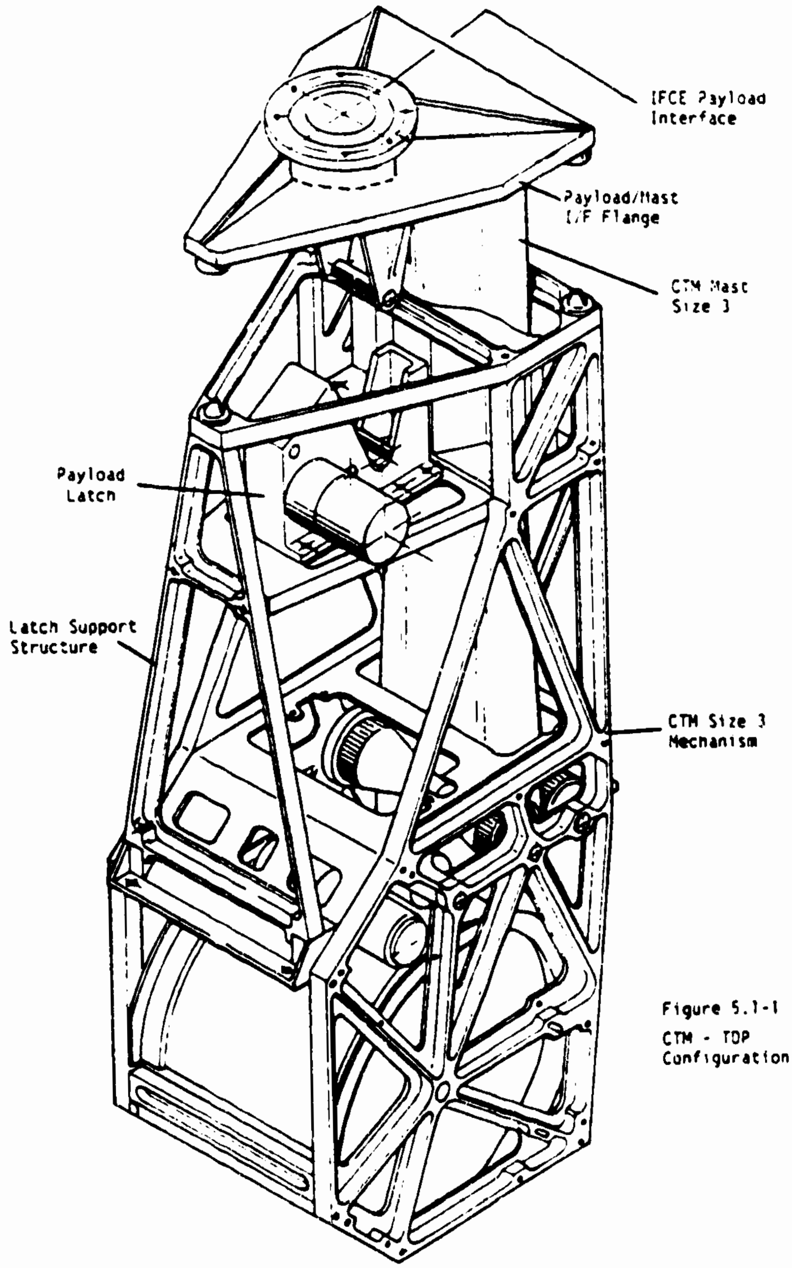
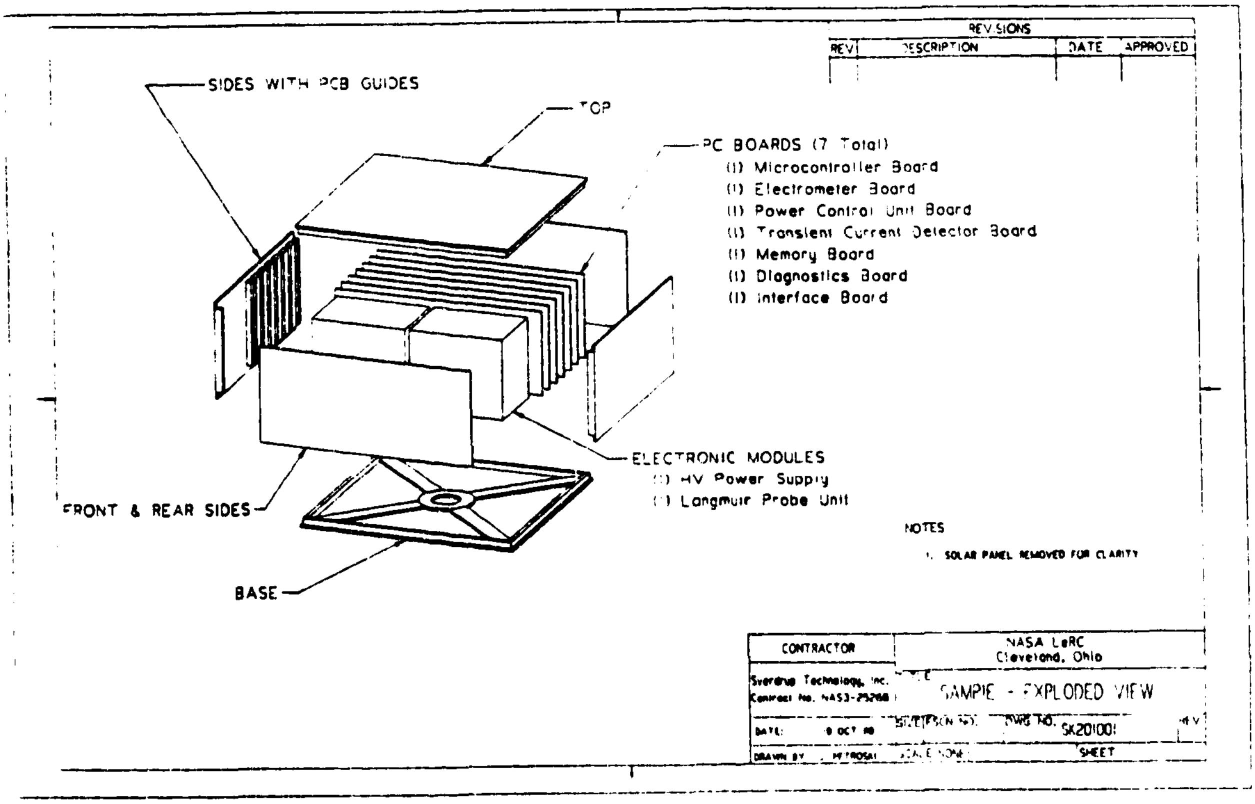


Figure 2: CTM Mast Deployment Unit (MDU)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SIDES WITH PCB GUIDES
TOP
PC BOARDS (7 Total)
(1) Microcontroller Board
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(1) Power Control Unit Board
(1) Transient Current Detector Board
(1) Memory Board
(1) Diagnostics Board
(1) Interface Board
ELECTRONIC MODULES
(1) HV Power Supply
(1) Langmuir Probe Unit
FRONT & REAR SIDES
BASE
NOTES
1. SOLAR PANEL REMOVED FOR CLARITY
CONTRACTOR
NASA LeRC
Cleveland, Ohio
Sverdrup Technology, Inc.
Contract No. NAS3-25266
SAMPIE - EXPLODED VIEW
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SHEET

Figure 3

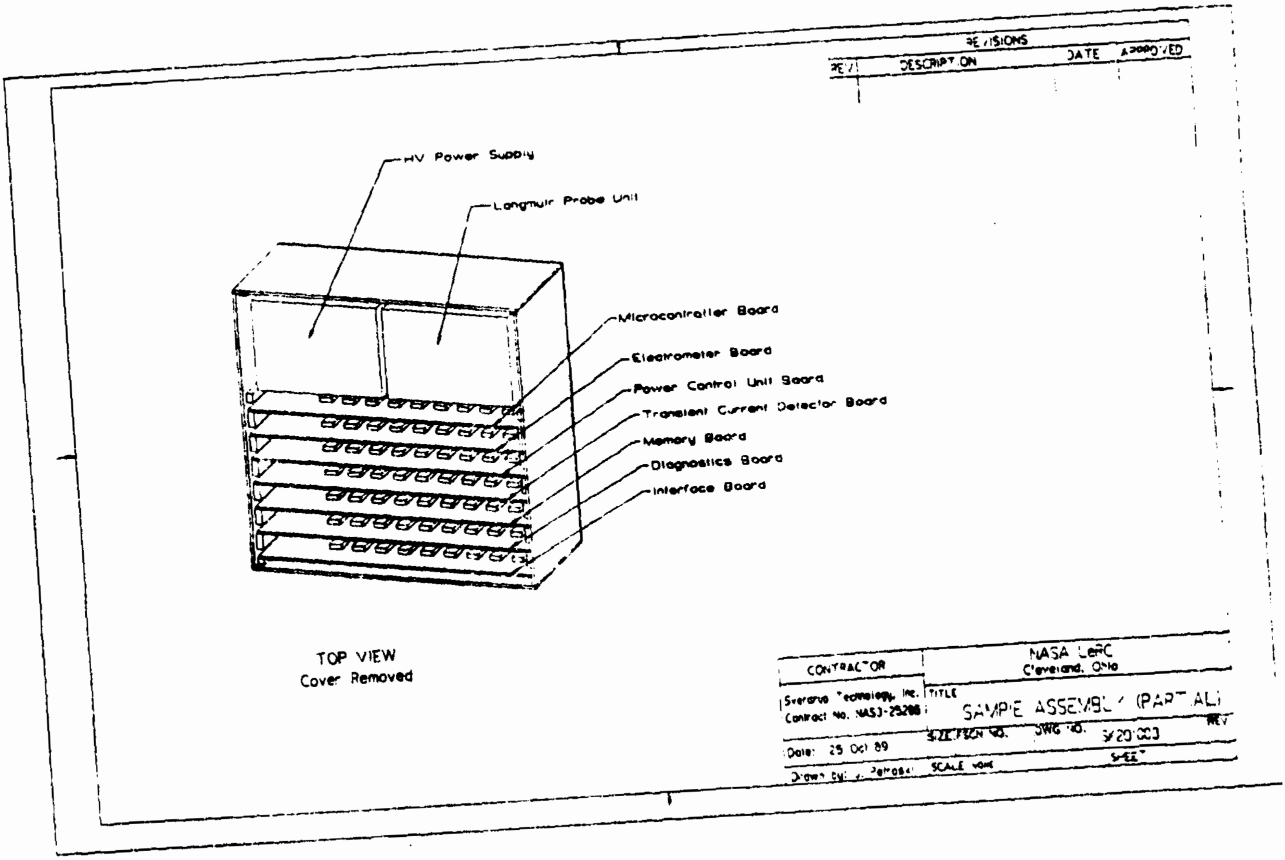
REVISIONS
DESCRIPTION
DATE
APPROVED
HV Power Supply
Langmuir Probe Unit
Microcontroller Board
Electrometer Board
Power Control Unit Board
Transient Current Detector Board
Memory Board
Diagnostics Board
Interface Board
TOP VIEW
Cover Removed
CONTRACTOR
NASA LeRC
Cleveland, Ohio
TITLE
Date: 25 Oct 89
SCALE
REV

Figure 4

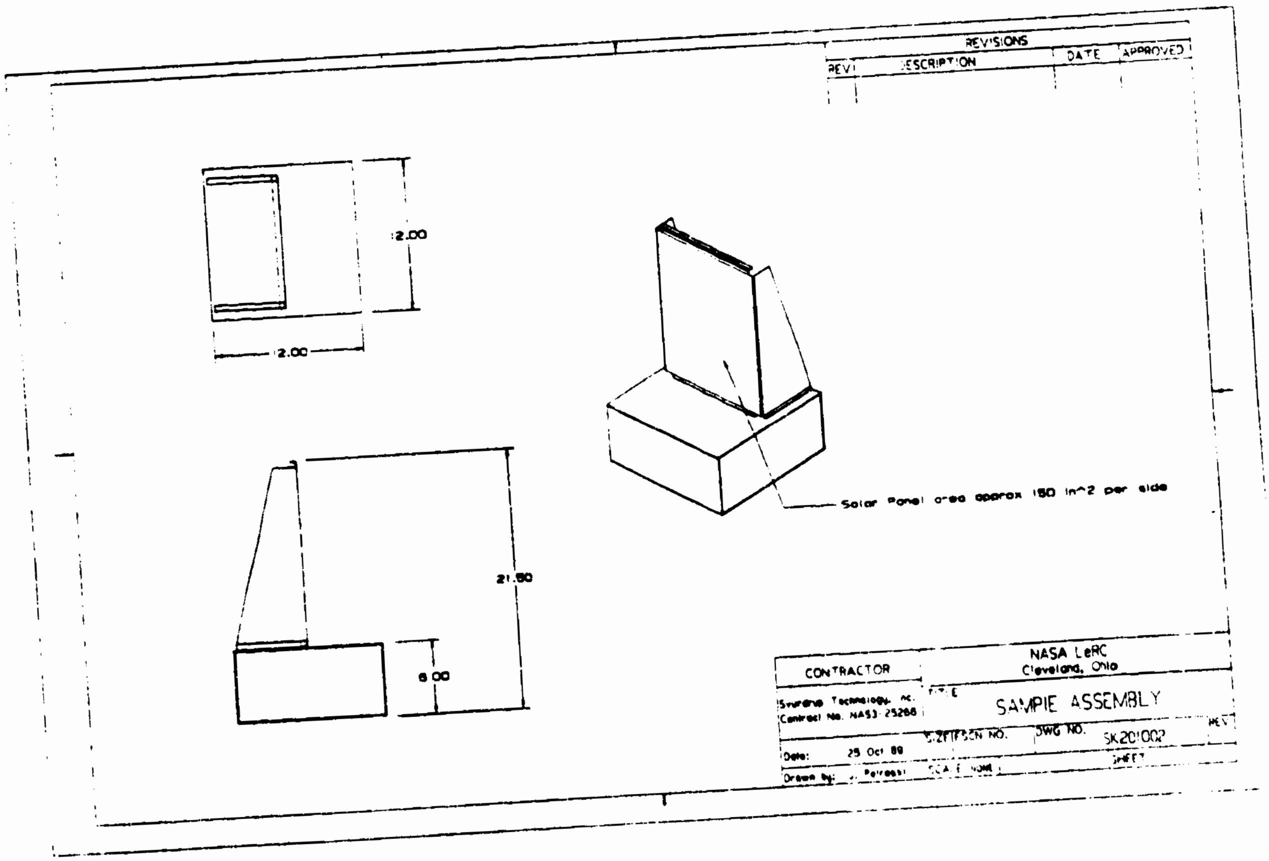
REVISIONS
REV
DESCRIPTION
DATE
APPROVED
12.00
12.00
Solar Panel area approx 150 in^2 per side
21.50
6.00
CONTRACTOR
NASA LeRC
Cleveland, Ohio
Contract No. NAS3-25266
SAMPIE ASSEMBLY
DWG NO.
SK201002
Date:
25 Oct 89
SHEET

Figure 5