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MRC CORPORATION

2201 Russell Street
Baltimore, Maryland 21230

NASA

CONTRACTOR REPORT

Preliminary Design Polymeric Materials Experiment

By: G. Samuel Mattingly
Edward T. Rude
Robert L. Marshner

PREPARED FOR

NASA
Langley Research Center
Hampton, Virginia 23665

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MRC CORPORATION
2201 Russell Street
Baltimore, Maryland 21230

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SUMMARY

This report covers the preliminary design of an inexpensive and reliable means of exposing material samples to the space environment utilizing the shuttle and Spacelab elements of the Space Transportation System. Previous experiments of this nature have been less than fully successful due to problems associated with isolation of the experiment before and after space exposure, and contamination of the experiment during space exposure.

A typical Advanced Technology Laboratory mission flight plan was developed and used as a guideline for the identification of a number of experiment considerations. The experiment logistics beginning with sample preparation and ending with sample analysis are then overlaid on the mission in order to have a complete picture of the design requirements.

The preliminary design study breaks naturally into three sections. The first section is containment which includes the handling of the prepared samples in a vacuum chamber and then sealing the samples in the container which goes to the space environment. The second section concerns the location of the sample container relative to the Spacelab pallet during the period of sample exposure. The third section concerns deployment of the sample container from its launch position to its exposure position.

The results of this preliminary design study fall into two categories. First specific preliminary designs of experiment hardware which is adaptable to a variety of mission requirements. Second, identification of those mission considerations which affect hardware design and will require further definition prior to final design.

Finally, a program plan is presented which will provide the necessary experiment hardware in a realistic time period to match the planned shuttle flights. A bibliography of all material reviewed and consulted but not specifically referenced is provided at the end of this report.

Section 1

INTRODUCTION

The NASA Spacer Transportation System is a comprehensive program to provide an overall space flight capability for the next generation. The System includes the Shuttle vehicles, boosters and arbiters, as well as an experiment support module, Spacelab, and an orbital tug for orbital operation beyond the Orbiter range. Virtually all of the United States and cooperative nations space experiment programs will make use of this Transportation System. Most experiments which cannot justify a dedicated flight will be grouped together on the Spacelab experiment support module.

Spacelab will consist of two sections: a pressurized laboratory where the experimenters will work, and an adjacent platform, or pallet, supporting instruments such as large telescopes and antennae needing direct exposure to space or a broad field of view. The laboratory and pallet can be used in various configurations according to user requirements.

Both sections will be developed and manufactured by the European Space Research Organization (ESRO) made up of many countries.

A statement issued by ESRO sets out the benefits to Europe and the United States:

(a) Greatly increased weight and volume available for experimentation at relatively low cost;

(b) Presence of trained scientists and technicians to maximise positive results from all on-board experiments;

(c) Maximum use (and subsequent recovery and re-use) of existing, "off-the-shelf" instrumentation and support equipment eliminating expensive test and qualification programmes;

(d) Short experiment realisation time;

(e) Possibility of Earth laboratory-type experimentation in space as a result of favourable launch environment and the presence of man; and

(f) Increased mission opportunities resulting from reusability and shared mission costs.

Current NASA planning envisages that approximately 40 percent of all Space Shuttle flights from 1980 to 1991 will be Spacelab missions. Because of the Shuttle's large payload capacity and relatively low cost per launch, the cost per experiment will be significantly lower than at present. A unique characteristic of Spacelab is that it is being designed to accommodate the needs of as many kinds of user in Europe and the United States as possible. Their requirements are currently being established jointly by ESA and NASA.

The Polymeric Materials experiment is intended to be one of a group of experiments which will be flown one or more times and designated as an Advanced Technology Laboratory mission. This experiment is the subject of this preliminary design study.

The polymeric Materials experiment is simply the exposure of a group of material samples to the space environment, particularly ultraviolet. However, in order to isolate the effect of the space exposure, the samples must be prepared and then sealed in an evacuated container. The container is to be opened and the samples exposed during a portion of the flight. The container must then be resealed and stowed prior to reentry and maintained in that condition until return to the experimenter at the Langley Research Center.

This preliminary design study has investigated the total experiment system including: preparation and handling of the material samples; vacuum chamber design; container design; Shuttle Orbiter considerations; mission and flight considerations; and the logistic of the Polymeric Materials experiment.

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Section 2

ADVANCED TECHNOLOGY LABORATORY (ATL) MISSION

2.0 MISSION SELECTION

The preliminary design of the polymeric materials experiment requires a knowledge of a particular shuttle flight on which the experiment is covered and a general knowledge of the other experiments on that mission. In order to provide such a perspective we used a typical ATL-1 Flight Plan. Table 2-1 is a listing of the experiment group that would be flown at ATL-1.

2.1 ORBITAL CHARACTERISTICS

The ATL-1 mission is scheduled to lift off at 1600 hours Greenwich Mean Time 1 June 1982. Launch puts the spacecraft into a 230 nautical mile circular orbit approximately 45° with a resultant beta angle of approximately 16°. During the seven day mission the beta angle gradually decreases to a final angle of approximately 11°. Of the total of 154 hours in orbit it is planned that approximately 100 hours will be spent with the spacecraft in a Z along local vertical (ZLV) attitude. Since this is a major attitude of the spacecraft it is used as the basis of a location selection for the polymeric materials experiment package.

Table 2-2 indicates some of the major considerations and their relative values during the flight. After several hours in orbit the shuttle doors are opened, exposing the pallet, and the spacecraft is maneuvered into a Z along local vertical attitude. The longest period of time in continuous ZLV attitude is approximately 24 hours between flight days 2 and 3. A total of 18 maneuver periods are identified and are spaced throughout the flight. Attitude control is maintained continuously by use of the vernier reaction control system whereas the maneuvers as identified in Table 2-2 are accomplished by the main reaction control system engines. The shuttle orbiter is vented on the order of every 12 hours.

TABLE 2-1. ADVANCED TECHNOLOGY LABORATORY (ATL-1) PAYLOAD

NV-1	MICROWAVE INTERFEROMETER NAVIGATION AND TRACKING AID
NV-2	AUTONOMOUS NAVIGATION
EO-1	LIDAR MEASUREMENTS OF CIRRUS CLOUDS AND LOWER STRATOSPHERIC AEROSOLS
EO-7/8	SEARCH AND RESCUE AND IMAGING RADAR
PH-6	ULTRAVIOLET METEOR SPECTROSCOPY FROM NEAR EARTH ORBIT
MB-1	COLONY GROWTH IN ZERO GRAVITY
MB-2	INTERPERSONAL TRANSFER OF MICRO-ORGANISMS IN ZERO GRAVITY
MB-4	ELECTRICAL CHARACTERISTICS OF CELLS
MB-5	SPECIAL PROPERTIES OF BIOLOGICAL CELLS
CS-2	ZERO GRAVITY STEAM GENERATOR
EN-1	SAMPLING OF AIRBORNE PARTICLES AND MICRO-ORGANISMS IN THE SPACE CABIN ENVIRONMENT
EN-3	ENVIRONMENTAL EFFECTS OF POLYMERIC MATERIALS

TABLE 2-2. POLYMERIC MATERIALS EXPERIMENT

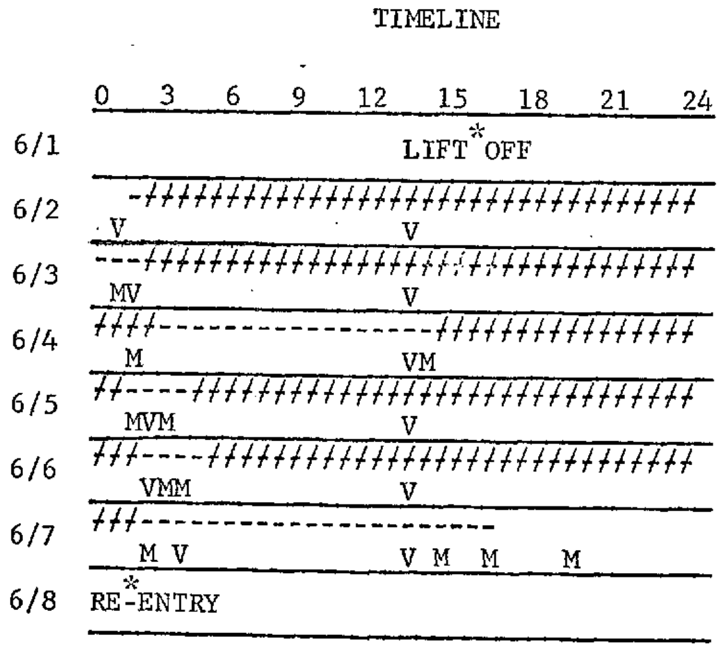

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TABLE 2-2. POLYMERIC MATERIALS EXPERIMENT - (Continued)

CONSIDERATIONS

DOY	152	153	154	155	156	157	158	SUM
ORBITAL	8	24	24	24	24	24	24	154
OPEN		03----	----	----	----	----	----16	
EXPOSURE	0	21	24	24	24	24	16	133
ZLV	0	21	23	10	22	22	2	100
INERTIAL	8	3	1	13	1	2	23	51
MANEUVER	4	2	2	2	2	2	4	18
VENT	0	2	2	2	2	2	2	14

EN 3 = ----
ZLV = ////
V = VENT
M = MANEUVER

2.2 ABORT

The shuttle payload accommodations handbook, reference 1, specifies that any payload equipment which is deployed beyond the payload bay doors must be capable of being separated in the event of an abort situation. It should be further recognized, however, that some types of experimental equipment will utilize launch restraints that will be uncoupled during experiment activation. It seems probable that such hardware would have to be restrained again prior to re-entry. The requirement to jettison hardware during an abort situation may encompass a greater number of experiments than had been previously considered.

If a large number of experiment hardware items should fall into this category it may be worth considering the provision of a pallet separation sequence which would unlock and separate an entire pallet in the same fashion as is being considered for the Long Duration Exposure Facility, reference 2. The pallet-shuttle interface is essentially the same approach as is being used on the Long Duration Exposure Facility.

A study of pallet separation for abort could identify the tradeoffs and values of this approach. Two obvious values would be a lowered reentry weight and a potential for retrieval of pallet and experiments on a later shuttle flight.

2.3 EXPERIMENT OPERATIONS

This experiment is scheduled for deployment 11 hours after lift-off or 3.00 hours of day 2. After 134 hours, 17.00 hours of day 7, the polymeric materials experiment is scheduled to be retracted and stowed. Retraction and stowage is estimated to be accomplished in approximately 20 minutes.

2.4 EXPERIMENT INTEGRATION

Although experiment integration is not required of this preliminary design contract, it is necessary to make a cursory review of all other experiments to determine that the deployment and operation of the polymeric materials experiment does not obviously compromise any other experiment or visa-versa. This polymeric materials experiment package is expected to be a low mass and its deployment even to distances of 30 meters or more will have only a negligible effect on the center of gravity (CG) of the orbiter. Any power required for deployment or retraction operations is anticipated to be well within the power capabilities of the Spacelab. For the selection of an exposure location and for the deployment operation itself there may be some interaction with the Microwave Interferometer Experiment. Consideration must be given to the deployment activities of these two experiments. It can not be determined from the brief writeups on the various experiments, whether the deployment of this experiment into an area between the other experiments and the earth will result in shadowing or antenna effect. Both the maneuvering operation and the venting of the orbiter have an impact on this experiment and are discussed in greater detail in Section 5.2, Orbiter Contamination.

2.5 ASTRONAUT PARTICIPATION

Current information indicates that the shuttle orbiter is baselined to provide a capability for 3 - 6 hour periods of extra vehicular activity (EVA). Two of the 6 hour EVA's are available to payloads for planned or unscheduled activities. The third is a contingency EVA reserved for the shuttle orbiter. Additional EVA's to support payloads are available with the expendables being provided as a payload weight chargeable item. The use of this capability for experiment deployment operation and data gathering must be compared with use of automatic equipment within the parameters of cost of development, reliability and time of operation. This report includes a discussion of EVA used for experiment deployment in Section 6, Deployment Techniques.

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Section 3

LOGISTICS

3.0 GENERAL

The logistics of the polymeric materials experiment must consider the overall philosophy of the shuttle and Spacelab designs. The space shuttle is to be the next generation of space vehicle which will be reuseable with a maximum turnaround period. The Spacelab payload is a similar concept that will be very versatile and capable of many missions.

It must be recognized, however, that the vehicle and the payloads that under discussion are among the very early flights of the shuttle program. As such, the considerations of scheduling for delivery of experimental hardware are most similar to the schedules required of the Skylab program. That is to say, while reflights of the ATL payloads may be accomplished in very short time periods the initial ATL flight will require planning and testing in a similar fashion to most previous space programs.

3.1 PRE-EXPOSURE

3.1.1 MATERIAL SAMPLE PREPARATION

Samples for the polymeric materials experiment will be prepared at LaRC far in advance of the launch date of ATL-1. Delivery of all major hardware to the launch site will be required 12 to 24 months prior to the launch date. It may be feasible to replace the sample container on the pallet at some point in time relatively close to launch. However, the sample container delivered originally for the integration test periods would have to be identical with its replacement. These are current requirements for KSC Integration Testing.

3.1.2 ANALYSIS AND CONTROLS

Experiment protocol requires the preparation of a large number of samples which have been analyzed and separated into experiment samples and control samples. The experiment samples would be placed in the flight hardware containers and sealed while still in the vacuum chambers. Control samples would be housed in identical containers but without the mechanisms for deployment and stored for the duration of this flight.

3.1.3 SHIPPING AND STORAGE

Shipping and storage containers would have to be procured to house both the experiment samples and the control samples. These containers are available from a number of sources and should present no scheduling difficulties.

The experiment program may include shipment of the control samples along with the experiment samples to the launch site where they would be placed in storage until the time for loading on the Spacelab pallet. Present plans call for the Spacelab and pallet to be fully checked out prior to loading in the shuttle orbiter.

3.1.4 LAUNCH

The requirement for launch constraints has not been identified in this preliminary design. It is, however, a consideration which must be identified at this time. Maximum launch loads for the 65,000 lb. payload are 3.3 g in -X and substantially less in the other planes. The re-entry load is a maximum of 1.25 g both positive and negative in the Y plane.

3.2 ORBITAL OPERATIONS

After the orbiter has achieved orbit and exposed the Spacelab pallet, the polymeric materials experiment will be deployed some distance from the pallet structure. The experiment will be unsealed and opened after deployment to minimize contamination. It will be aimed at an angle relative to the shuttle orbiter selected for maximum solar exposure over the mission period. The experiment is passive and will not be articulated to follow the sun.

At some time prior to closing the orbiter payload doors the experiment container will be closed, sealed, retracted, and secured for reentry.

3.3 POST EXPOSURE

3.3.1 UNLOADING

After the shuttle orbiter has landed, there will be a cooling down period of hours. After that period, the shuttle payload doors will be opened and the Spacelab pallet payload will be withdrawn. Technicians will then begin extracting the experiment packages from the pallet and prepare them for shipment to the experimenter. It is reasonable to assume that this may require a time period of days and weeks.

3.3.2 RETURN

The polymeric materials experiment will be returned to its storage container and shipped to the Langley Research Center where it will be returned to the principal investigator for analysis. Each of the containers, both the flight container and the control container, will be placed in the vacuum chamber and each sample will be analyzed.

3.4 LOGISTIC CONCLUSIONS

At this time it appears that the polymeric materials experiment will be subjected to long periods of time between the first and last analysis. Even if the flight experiment package is not prepared until after the orbiter integration test, the minimum time period appears to be on the order of 3 to 5 months. If the flight hardware package must be on the orbiter for integration test, this time period becomes 12 to 24 months. Consideration should be given to one of two techniques to minimize seal leakage and resultant contamination. The simplest of the two techniques is to flood the container with an inert gas. This would require an inert gas charge to be built into the container so that it could be flooded after the period of exposure in orbit. The second technique presents somewhat more difficulty. This technique would require a vacuum hold by means of an ion pump during the period of storage and shipping. Early design and fabrication of the experiment container will provide time for life testing of the seal and a decision as to the best method of maintaining an uncontaminated environment.

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Section 4

CONTAINMENT

4.0 GENERAL

Containment of the experiment samples begins when the samples are prepared and analyzed. These samples must then be protected until they are exposed in orbit and then protected again until they are re-analyzed at LaRC. The sample container, the handling system and the vacuum system are the functional elements of containment.

4.1 CONTAINER DESIGN

4.1.1 GENERAL

Container design as with all other design elements must consider above all else the program objective; that is, to successfully obtain and retrieve the experiment data. The container requirements to meet that objective are:

1. Protect samples from contamination from container loading through sample analysis.
2. Provide for exposure of the samples to the sun's rays.
3. Provide for means of sample analysis.

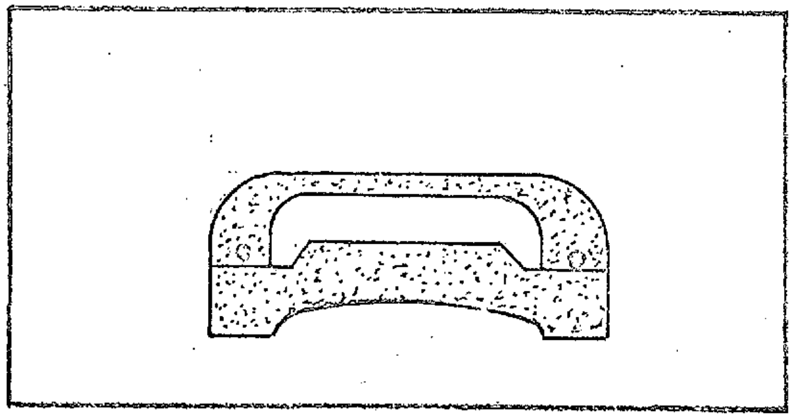
All other considerations such as size, weight, cost, convenience in handling, etc., must be evaluated primarily as they relate to the above. If this relationship is adverse then that particular design approach would have to be rated poorly.

Making these value judgements is not always so easy. Obviously weight and cost are factors and at some point their magnitude can force compromises in reliability. In addition, the three stated requirements can often indicate conflicting design directions. An obvious example of this occurs between protecting the samples from contamination and obtaining reliable exposure (container opening and closing). One could conclude that container opening and closing is best accomplished prior to boom deployment. This however has an adverse effect on sample contamination. The point is that the recommended design concept will invariably involve compromises resulting from an intelligent evaluation of these tradeoffs with the eye firmly fixed on mission success.

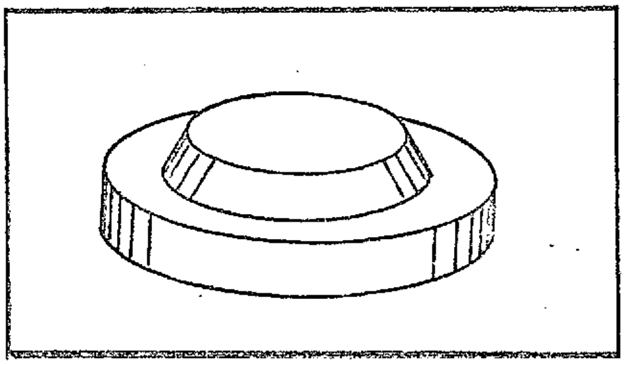
The following discussion will identify various factors which were considered in arriving at the recommended design approaches.

4.1.2 CONTAINER GEOMETRY

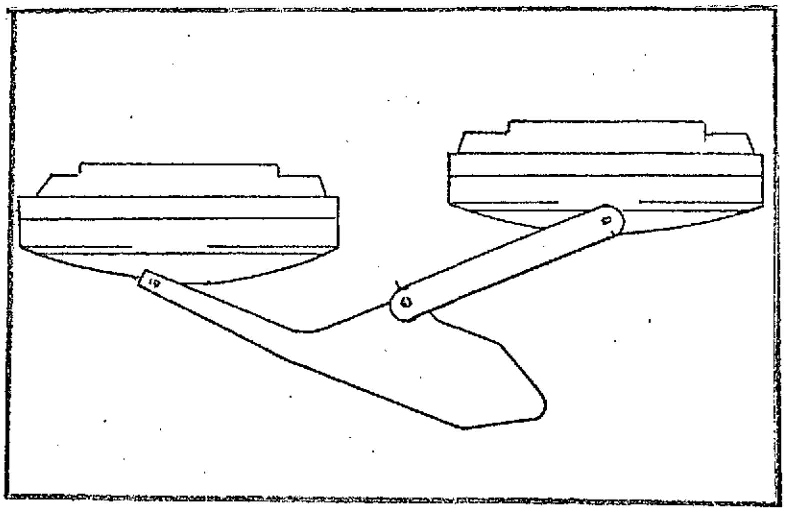
Container geometry is primarily influenced by sample size and capacity, weight, seal design, deployment technique, sample removal technique and structural integrity. The sample size is 7/8 to 1 inch (22 - 25 mm) in diameter while the capacity is tentatively set at approximately 50 samples. The samples must be sealed prior to deployment. When deployed the samples must be arranged in a single plane so that all samples receive the same sun exposure and no shadowing results from sample to sample or from the container mechanism. Essentially then we start with a "clamshell" type container with the samples housed in one or both halves of the clamshell. A seal exists between the two halves as shown below.



To maintain design simplicity, and seal and structural integrity we will assume a round container. So that one half of the container is approximately:

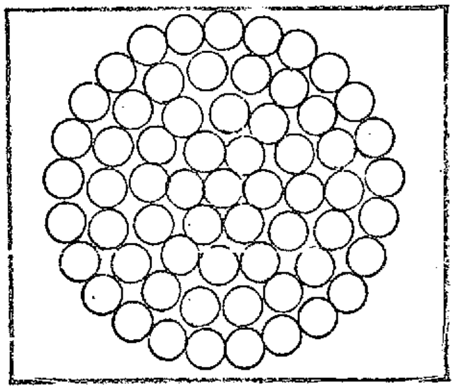


There would have to be some compelling operational deficiency to the above to force consideration of a more complex shape. The overall size of the container can be reduced by incorporating samples in both halves of the clamshell. There are however disadvantages to this approach, particularly the constraint on deployment technique in that both halves must be deployed into a single plane. (See below.)

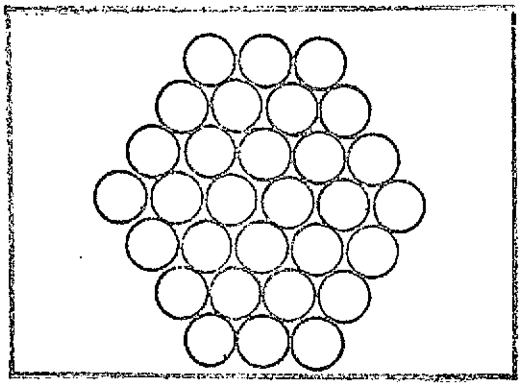


This is of course not exceedingly difficult to achieve but other disadvantages will arise as the discussion proceeds. For the present however, it can assume two viable arrangements, one with all samples in one clamshell half and the other with samples divided between the two clamshell halves.

The samples can be arranged in several ways within the clamshell assuming a relatively circular array of samples they can be arranged in concentric rings as shown below:



or in honeycomb fashion such as;



The latter method has a better packing efficiency over a large area but, for the number of samples considered here, the edge effects are such that there is no significant size advantage in either case.

A key element in the selection of sample arrangement is the ease of loading and unloading the container within the vacuum chamber. Consider the following possible methods of accomplishing this task.

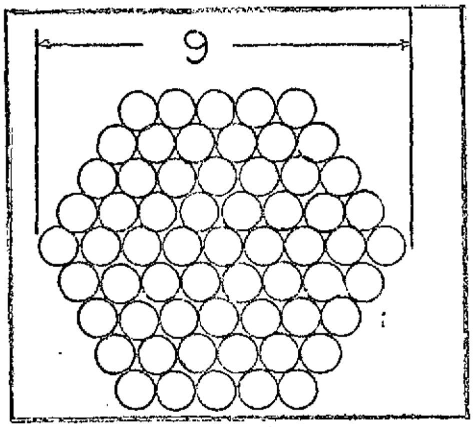
1. The individual samples can be removed by pushing or lifting them upward from the sample array.
2. The samples can be arranged in a tray or "holder" which is removed from the container and from which the individual samples are removed.
3. The samples can be removed in the sample plane, i.e., radially from the array.

In method #1 the samples are held or locked into the array. Prior to removal they must be unlocked, gripped from above and removed. It is mechanically simpler to push the samples out of the array from below. This may involve sealing the interface between the sample and the pusher which would cause greater complexity.

Method #2 involves loading a tray and then locking the tray into the container. The operations here are not difficult mechanically but there will invariably be a large number of operations requiring a large chamber with many control feed throughs. The added complexity is due to the requirement for separate mechanisms for tray handling and sample handling.

The third method is probably the simplest from the standpoint of sample removal. The samples can be gripped from the periphery of the array and pulled radially outward. Or, even simpler, pushed in rows from the array. None of the sample arrangements permits the removal of samples by rows. In the circular pattern the samples are not arranged in rows and in the honeycomb pattern the rows are interlocking so as to prevent the movement of any one row. It is expected that removal by rows may prove so simple and reliable as to justify a small increase in size to permit handling in this way. Even so it may be possible to achieve this arrangement with virtually no size penalty. The discussion has shown only round samples. If the samples are square or square with rounded corners, the row arrangement is highly efficient neglecting the area lost at the edges due to the round container shape. The greater packing efficiency may compensate for that loss.

Consider the 61 sample honeycomb array shown below.

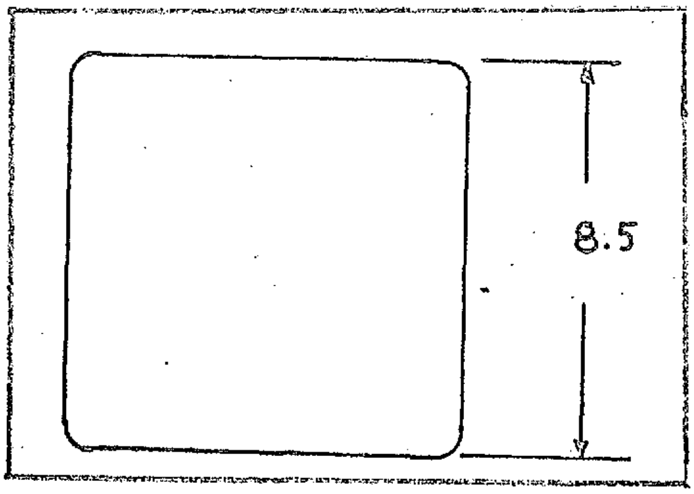


Assuming a sample size of one inch diameter the array can fit into a 9 inch (22.86 cm) circle. Since 61 is more samples than required, remove the corner sample indicated with an X and reduce the circle. To determine the magnitude of this reduction calculate the distance from the array center to the center of the sample tangent to the circle.

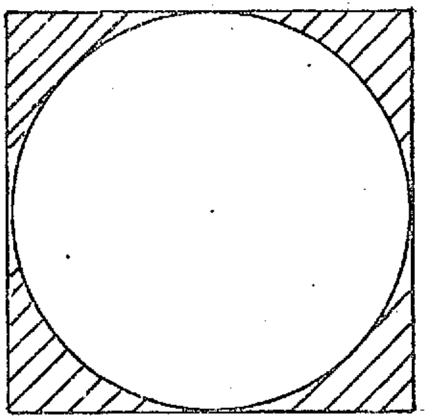
$$R = \quad 3.5^2 + 1^2 = 3.64$$

$$D = 2R + 1 = \underline{8.28} \text{ IN.} = 210 \text{ mm}$$

If the sample is redesigned making it basically square shaped with rounded corners the array size can be further reduced. Consider a square sample with 1/8 inch (3.175 mm) corner radii.



The area lost due to the corner radius is the sectioned area shown below.



$$\text{Area Lost} = (1/4)^2 - \frac{\pi}{4}(1/4)^2 = .0135 \text{ IN}^2 = 0.087 \text{ cm}^2$$

For the square sample area to be equivalent to the 1.0 IN. (25.4 mm) Dia. sample:

$$d = \sqrt{\frac{\pi}{4}(1)^2 + .0135} = .894 \text{ IN} = 22.7 \text{ mm}$$

Making the corner radius smaller, the distance can be reduced to 7/8 inches (22.225 mm).

Using this sample configuration the overall array size is

$$D = (\sqrt{2})\ (7)\ (7/8) - 2\ (\sqrt{2}\ 1/8 - 1/8)$$

$$= \underline{8.54} \text{ IN.} = 216.9 \text{ mm}$$

The most favorable arrangement of nested circular samples occupied 8.28 inch (21 cm) diameter circle. Thus utilizing square samples in rows has had a minimal effect on array size.

It is tentatively concluded that the container will be round or at least incorporate a round real. The samples will be square and the array of samples will be arranged in rows as shown in Figure 4-1.

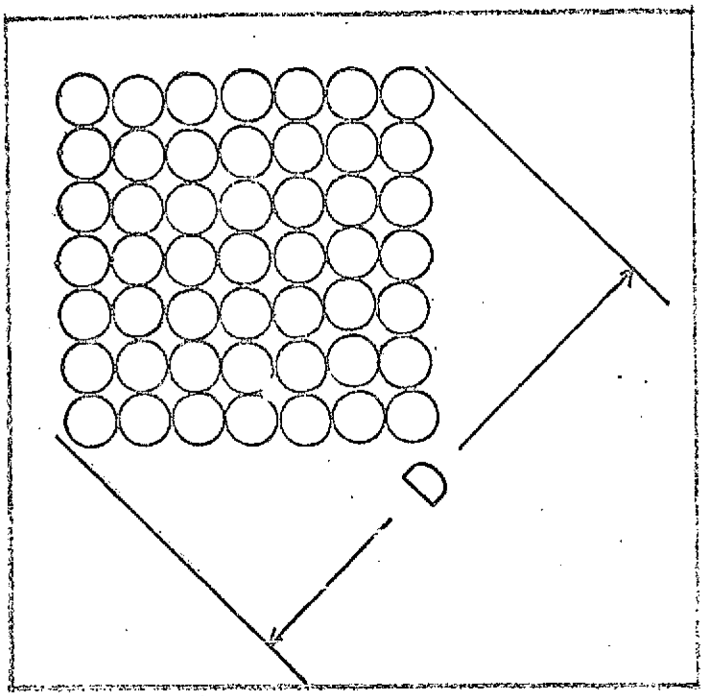


Figure 4-1. Square Array System

4.1.3 CONTAINER SEALING

Since it is the integrity of the seal that will determine the success or failure of the mission, seal design is a critical element of the overall design approach. Of primary importance is the selection of the appropriate seal material. After this selection is made the optimum configuration and closure forces can be determined.

Material selection is dependent on the following design considerations:

- Required leak rate
- Vacuum to be maintained by seal
- Duty cycle (number of opening and closing cycles)
- Permeability of seal material

- Weight loss of seal material due to outgassing in vacuum
- Load required to effect seal
- Ambient environment at orbit altitude

Metal as well as elastomeric seal materials were considered. Metal seals are highly effective in sealing extremely hard vacuums of 10^{-7} Pa and greater and have extremely low permeability with virtually no outgassing. These seals however are not suited to repeated cycles of opening and closing and further, require extremely high clamping forces. Since the clamshell might be cycled as many as 30 times during the mission to avoid contamination by the main thrusters, metal seals have tentatively been rejected as a viable candidate.

The vacuum to be maintained by the seal is 10^{-3} Pa. This is not considered hard vacuum and can be achieved with well known commercial elastomeric seal materials.

The ambient pressure at orbiter altitude, however, can be as low as 10^{-6} Pa. At this pressure the more commonly used materials sublimate sufficiently to pose both a potential contamination threat plus a degradation to physical properties such that subsequent sealability may be affected. Table 4-1, obtained from reference 3, shows a list of elastomeric candidates along with their percentage weight loss due to outgassing in a vacuum environment. Viton and Silicone rubber exhibit the best characteristics. Since outgassing is basically a surface phenomena, continued material degradation does not occur beyond a certain percentage of weight loss of the surface material.

The permeability of Viton along with other materials is shown in Table 4-2. Silicone rubber has excellent outgassing properties but exhibits a permeability rate of 100 times that of Butyl rubber and is therefore not recommended for this application. Since the permeability of Viton is comparable to the other elastomerics, it is recommended as the seal material.

TABLE 4-1. WEIGHT LOSS OF COMPOUNDS IN VACUUM

Test Samples: Approximately .075 thick
Vacuum Level: Approximately 1 x 10^{-4} Pa
Time: 336 hours (two weeks)
Room Temperature

Compound Number	Polymer	Percent Weight Loss
B612-70	Butyl	.18
E515-80	Ethylene Proplyene	.39
E529-65	Ethylene Proplyene	.92
E692-75	Ethylene Proplyene	.78
S604-70	Silicone	.31
L449-65	Fluorosilicone	.28
L677-70	Fluorosilicone	.25
77-545*	Fluorocarbon	.10
N406-60	Nitrile	3.45
N219-70	Nitrile	.53
P648-90	Polyurethane	1.29

* This material is VITON, a copolymer of vinylidene floride and herafloropropylene (E.I. DuPont de Nemours & Co.)

TABLE 4-2. HELIUM PERMEABILITY RATES OF COMPOUNDS

Pressure: Helium at one atmosphere vs. vacuum of 2 x 10^{-4} Pa
Test Samples: .085 thick slabs

Compound Number	Polymer	Permeability – $cm^3/sec/cm^2/cm$ of ATM Helium at standard temperature and pressure x 10^7		
		25°C (77°F)	80°C (176°F)	150°C (302°F)
B612-70	Butyl	.65	5.16	24.0
B591-80	Butyl	.69	5.70	24.0
N406-60	Nitrile	1.22	4.29	20.9
N219-70	Nitrile	.72	6.68	22.5
E515-80	Ethylene-Propylene	1.97	6.10	32.0
E529-60	Ethylene-Propylene	2.08	15.8	53.0
77-545	Fluorocarbon	1.30	5.60	30.0
L449-60	Fluorosilicone	14.3	46.1	97.3
S604-70	Silicone	23.8	56.0	125.0
P642-70	Polyurethane	.36	3.35	—
C557-70	Chloroprene	.65	5.96	18.7
A607-70	Polyacrylate	1.63	11.0	31.0

The Viton material can be configured several ways to form the vacuum seal. It can be molded into various shapes such as "O" rings or quad rings, or it can be molded and at the same time bonded into the gland as in the Parker product known as Gask-O-Seal. This product can affect seals for pressures as low as 2×10^{-7} Pa. While these seals are highly effective in vacuum application, they require 110 to 130 newtons per lineal inch to affect a seal. With an "O" ring seal these forces are considerably less. The actual force depends on % compression, material hardness and "O" ring diameter. While the Gask-O-Seal if used properly will seal a "harder" vacuum our task is not to design the "tightest" seal but to design an adequate seal considering reliability and complexity of clamshell deployment. Should a seal requiring high closing force be employed it will have profound effects on every aspect of the clamshell design, clamshell deployment and even boom design. For example if closure requires a high torque mechanism on the end of the boom this will undoubtedly result in a significant increase in weight of the clamshell and its deployment mechanism. This increase will result in an increase in moments produced in the boom when firing the orbiter thrusters and thus affect the size and weight of the boom. For these reasons the simplest approach which meets the design goals and places the least constraint on other aspects of the design is recommended - an "O" ring configured Viton seal.

4.1.4 CLAMSHELL DEPLOYMENT MECHANISM

In developing recommendations for clamshell deployment MRC has endeavored to make the approach flexible; allowing for variations in duty cycle and power source. For example, the approach presented here in allows for deployment to be affected manually or by motor, with the motive force applied either on the pallet and transferred to the end of the boom, or by a motor located on the end of the boom, or by an energy storing device located on the end of the boom. In this way the design will be compatible with constraints placed on the overall experiment which may not be entirely determined at this time. Thus our recommendations comprise a rotating shaft which can be powered remotely or directly to affect deployment.

One deployment scheme is illustrated in Figure 4-2. This shows the clamshell in its closed and locked position. The overcenter arrangement of the 4-bar linkage guarantees a high clamping force. When the drive shaft is driven CCW approximately 200 degrees the clamshell is opened as shown. Note that the sample array is attached directly to the boom while the cover is integral with the drive and linkage. Thus the operating mechanism and cover rotate away from the sample array. This particular arrangement was based on attempts to shadow the seal by positioning the cover so as to see the sun either on its "back" or edge and thus avoid exposure. However the mission profile makes it clear that the inflight maneuvers preclude this possibility so that a cover in this position will not only receive intermittent exposure on the seal but will cause shadowing of the sample array. Even if this were not the case such a design would severly limit the versatility of the system.

In an effort to guarantee shadowing regardless of the vehicle orientation the scheme shown in Figure 4-3 was developed. In this design the sample array is pivoted away from the cover. When sufficient separation between the cover and sample array is achieved the array is rotated as in step 2 and then returned to the position shown in step 3. As can be seen, the back side of the array housing completely shields the seal from exposure. It now remains to develop a simple means of achieving what appears to be a relatively complex motion.

The opening and closing of the clamshell can be achieved with a bell-crank type actuation. The "flip-flop" action of the array can be achieved in three ways:

1. Incorporate a second power source to pivot the array housing
2. Utilize the motion of the housing in such a way as to interact with a cam device to achieve pivoting
3. Use a drive train from the drift shaft of the bell crank to drive the housing

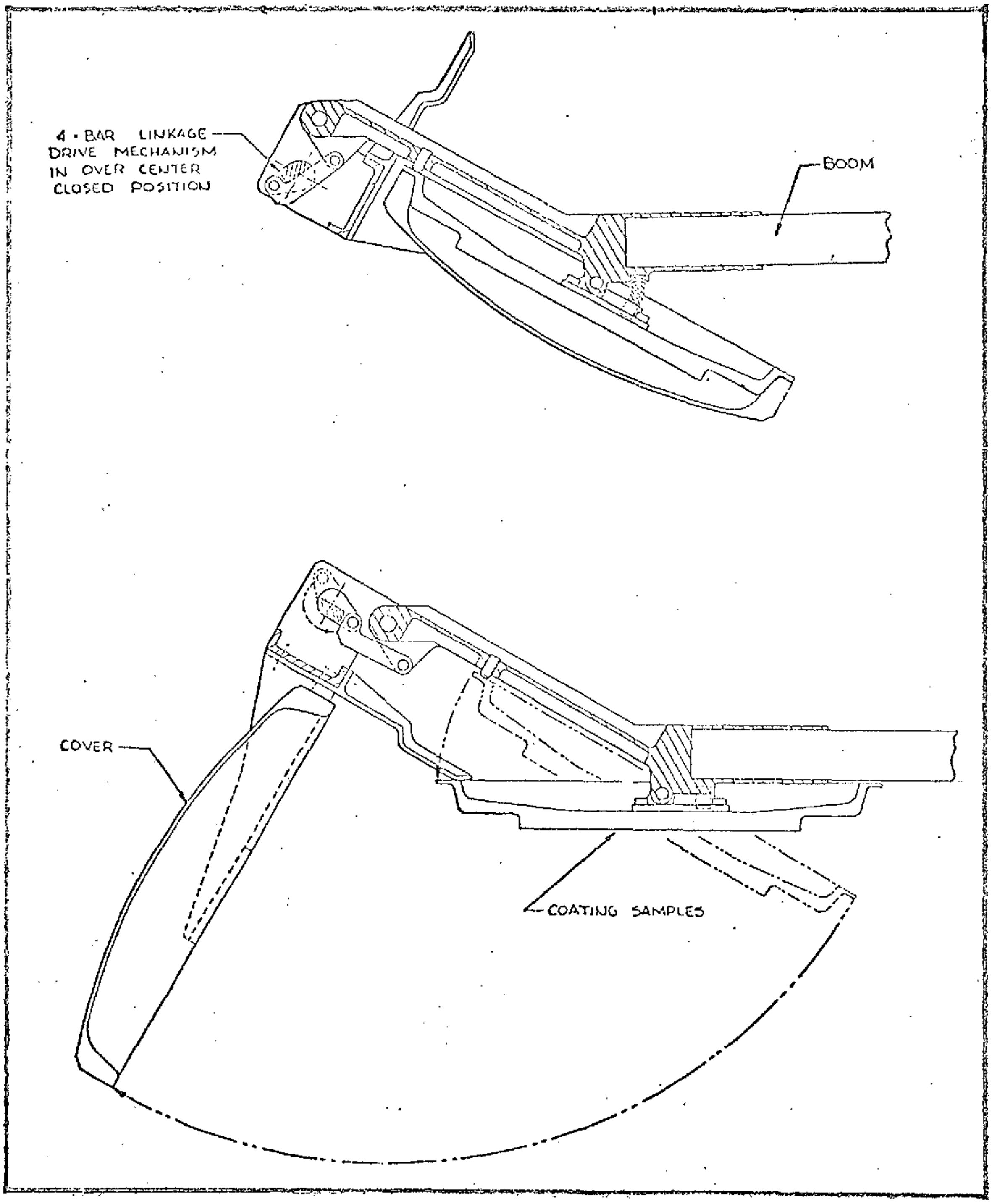


Figure 4-2. Sample Exposure

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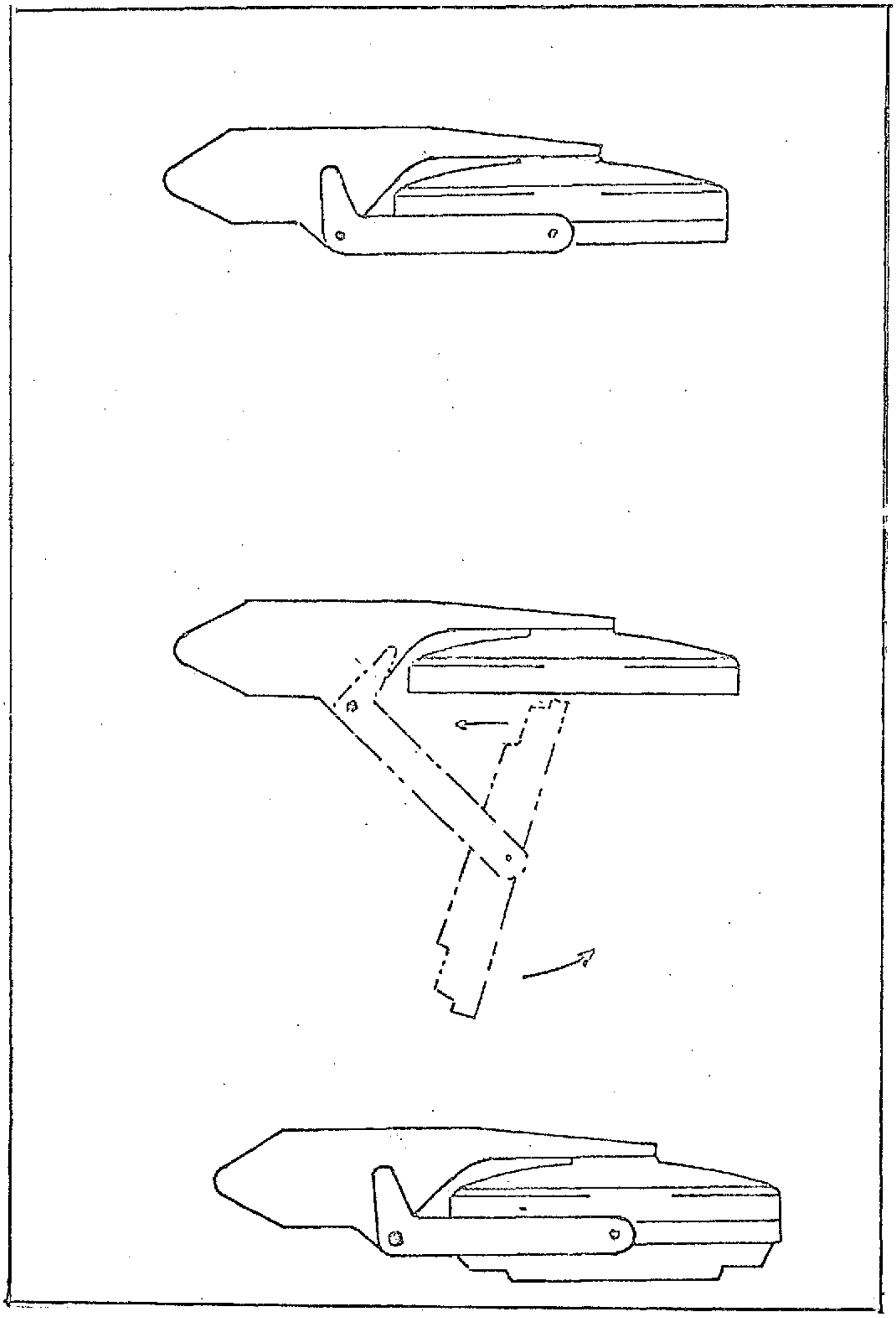

Figure 4-3. Deployment Sequence

For the sake of reliability and cost the first method will be avoided.

Figure 4-4 (Plan View) shows the yoke-type arrangement which permits pivoting the array housing. A cam track is added which is articulated from the cover as shown and engages cam followers on the array housing. Pivoting is obtained as shown in the sequence described in this figure. The one disadvantage of this design is its reliance on the clockwise (CW) spring loading of the cam track and therefore its susceptibility to malfunction due to unforeseen frictional forces. Preference is given to a mechanism which is positively driven rather than one in which the motion is permitted to occur and takes place under spring bias.

This positive drive is achieved utilizing the drive train from the drive shaft of the bell crank to drive the housing.

This employs a geneva mechanism such that during clamshell opening the driven geneva wheel is in a dwell condition. At the appropriate time the wheel is indexed 90^{o} by the driving member this motion is transferred by the roller chain to the housing pivot where a 2:1 sprocket wheel ratio provided 180^{o} rotation of the housing. In this configuration the drive shaft rotates 360 degrees. During 3/4 of this rotation the geneva mechanism is in a dwell condition. Rotation of the drive shaft an additional 360^{o} in the same direction repeats the process. However, the housing has rotated 360 degrees and is thus returned to the closed and sealed position, i.e., continued revolutions of the drive shaft produce alternate opening and closing of the clamshell.

This mechanism can be powered by a D.C. gearmotor by an energy storing mechanical device, or by transfer of power from a remote source. The decision as to which of these is employed will be governed by the following considerations:

- contamination
- reliability
- duty cycle
- versatility of design

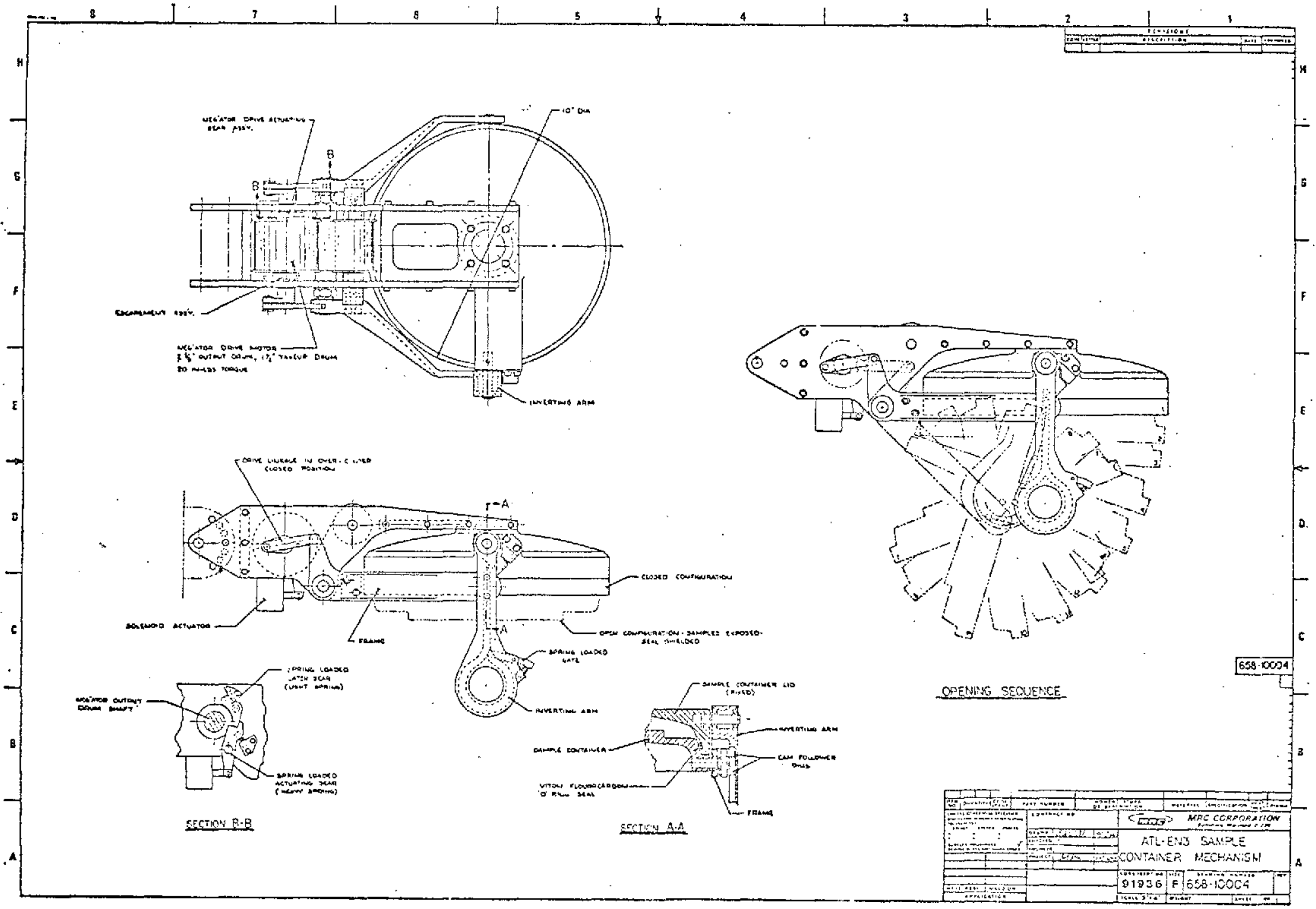

Figure 4-4. Container Mechanism Plan View

A spring device is well suited to applications where the number of actuations is limited to some number which does not affect the size of the output and take-up drums adversely. For example, the spring motor described above employs a band thickness of 0.012 inches (3 mm). Thus for 50 cycles, 50 openings and 50 closings, the output drum diameter increases by (50 + 50) (2) (.012) (3 mm) or 2.4 inches (61 mm); clearly an unacceptable increase over the initial 2 5/8 inch (69 mm) diameter. Whereas 10 cycles requires 20 wraps necessitating an increase in diameter of (20) (2) (.012), or .48 inches (12 mm). Both of these numbers can be reduced if a more detailed analysis shows that less torque can be tolerated permitting a reduction in band thickness. Howver, if it is impossible to place a limit on the number of cycles, the clamshell would be closed for the last time with no capability for reopening. If this device were employed on a "dedicated" satellite, these closings would not be required so often and this method could prove an advantageous way of limiting power requirements

Third design approach, a direct motor drive, is the simplest and most flexible. Care must be exercised however to minimize its production of contamination. Obviously if a lubricated gearhead and motor bearings are used the lubricant must be selected for its outgassing properties. The motor considered in a secondary housing with the output shaft passing through a labyrinth type seal. The labyrinth shaft seal is superior to a contact seal such as an "O" Ring type for this application as an "O" Ring seal would itself require lubrication or produce contaminants through excessive wear. The labyrinth seal in that it avoids friction poses no such threat. It is possible that the motor and a gearbox can be run completely free of any lubrication. As this may produce contaminants from wear this must be evaluated with more detailed analysis and experimentation in future studies. The results of the container actuation analysis are given in Table 4-3.

The use of a remote power source for actuation of the sample container is the least desirable from the standpoint of reliability, cost,

TABLE 4-3. RESULTS OF CONTAINER ACTUATION ANALYSIS

Design Approach	Contamination	Reliability	Versatility	Duty Cycle	Complexity
1. Remote Power Source	Least likely to pose contamination problem	Reliability reduced due to necessity of some type of deployment power train	Versatility limited by boom design	Not affected by duty cycle	Complex power train required
2. Energy Storing device at end of boom	Greater contamination source than (1) but perhaps less than (3)	Reliability enhanced by location but limited by limintation in available torque	Versatility limited by number of cyclic operations practical	Too many cycles make this approach unwieldy	More complex than (3) but less than (1)
3. Motor @ end of boom	Extreme care must be exercised with this approach to avoid contamination	Highly reliable (seal motor)	This approach is highly adaptable to any clamshell deployment technique	Not affected by duty cycle	This is by far the simplest approach mechanically

versatility and complexity. This however does not totally eliminate it as a candidate design. For example should the energy storing device not possess sufficient capacity while remaining within reasonable size and weight, and should it prove too risky from the contamination standpoint to place a motor at the end of the boom, then the remote power source is a remaining alternative.

The practicality of approach (2) (energy storing device at end of boom) is mostly dependent on the number of operating cycles required. The design illustrated in Figure 4-3 is an example of this deployment method. A constant force spring motor of the NEGATOR type is employed as the power source. The motor torque is dependent on the spring band width, the band thickness and drum diameters. The band is prestressed to the curvature of the smaller take-up drum and prior to operation is would onto the larger output drum. When the drum is released the spring winds onto the take-up drum. The capacity of the device is limited by the number of wraps which can be placed on the output drum without critically affecting the band radius. This device is controlled to produce one revolution of the output drum for each actuation. A primary sear interacts with a secondary such that when one sear is engaged the other is disengaged. The primary sear is springloaded with sufficient torque so that its release will force the disengagement of the secondary. The output drum is seared by the primary sear. This sear is retracted either by solenoid or by some action on the far end of a push pull cable. This action allows the secondary sear output to bear against the rim of the drum. As the drum rotates it engages a relief in the rim. When the primary sear is released it rotates against the rim forcing the disengagement of the secondary sear. This action can then be repeated for as many cycles as there are windings on the output drum. The device shown incorporates a spring motor 2 inches (50.8 mm) wide with an output drum diameter of 2 5/8 inches (67 mm) and has an output torque of approximately 20 inch pounds (2.26 nm). Considering that this device is driving a bell crank which is nearly "over center" when sealing the clamshell, this torque should be adequate to affect reliable sealing.

4.2 VACUUM CHAMBER SYSTEM

This system must provide a means for sample analysis without exposure of the samples to any contamination. The entire process of sample loading, sample removal and sample analysis is accomplished in an evacuated chamber.

In order that this system be reliable and reasonable in cost the handling equipment must be as simple as possible. The approach to achieving this goal is to analyze the basic sample motions required and develop a scheme of sample movement such that each element of movement is as elementary as possible. This approach will then lend itself to the most cost effective and reliable hardware.

When speaking of elementary motions only two motions are categorized: (1) simple rotation, and (2) motion along a single line.

In any X, Y, Z system the hardware will be simplified if each control element provides for motion in only one of these directions. Further simplification results if that particular control element is itself not free to move perpendicular to its control direction. For example a device providing for X sample movement should not be movable in the Y, Z plane. Or a rotational device should be stationary except for its rotation.

In analysis of the task, a scheme of sample movements incorporating these principals, has been developed, Figure 4-4. Note that the row arrangement of samples is an important part of this approach. The objective is to transfer each or any sample from the array to point "P" in the integrating sphere. Assume that the sample array is in the same X, Y plane as the integrating sphere; thus no Z axis motion is required. If the array move along line A-A any row can be selected for movement along line B-B. As the row moves along B-B it can be positioned for movement of any particular sample along line C-C and on to point P. The mechanism to provide these motions does not require movement in any other direction. Each control element is stationary and separate from the others.

4.2.1 SAMPLE HANDLING SYSTEM

This motion scheme is developed into a handling system based on its implementation. This system is shown in Figure 4-5, Vacuum Chamber Handling. A description of its operational sequence follows.

The container is locked into the container carriage as shown in the elevation view and section A-A of Figure 4-5. A linear motion feed-thru lowers a bracket into engagement with the container lid. The lid is then attached to the bracket. The chamber door is closed and the chamber evacuated. This same feed-thru is raised, removing the lid as shown. The container carriage, supported by a ball screw and guide rod is translated perpendicular to the chamber axis by rotation of the ball screw. This rotation which is provided by an angular motion feed-thru, corresponds to movement along Line A-A. A stationary "T" track is provided in the chamber which will receive the row of samples from the sample housing. The movement of samples in this track corresponds to movement along line B-B. This track cannot be permanently butted against the mating track in the sample housing as this would interfere with the container lid prior to lid removal. In order, therefore, to provide for an uninterrupted transition of samples into the track a section of track has been designed to be articulated in order to bring it into contact with the track in the sample housing. This track sections is shown in the elevation view. It is controlled by the track section lever as shown. When the lever is rotated clockwise the track section moves up and to the right. The left side of this track moves horizontally due to the constraint of the guide slot. Note that the short track section immediately to the right of the pivoting section is removable so that there is adequate clearance for this motion.

After aligning the selected row of samples with the chamber track, the samples in this row are moved to the track. This movement of samples is accomplished by the operation of the sample actuators shown in section A-A and the elevation view. The actuator on the left in the elevation view provides for rightward movement of samples while the actuator to the right provides for movement of the sample to the left.

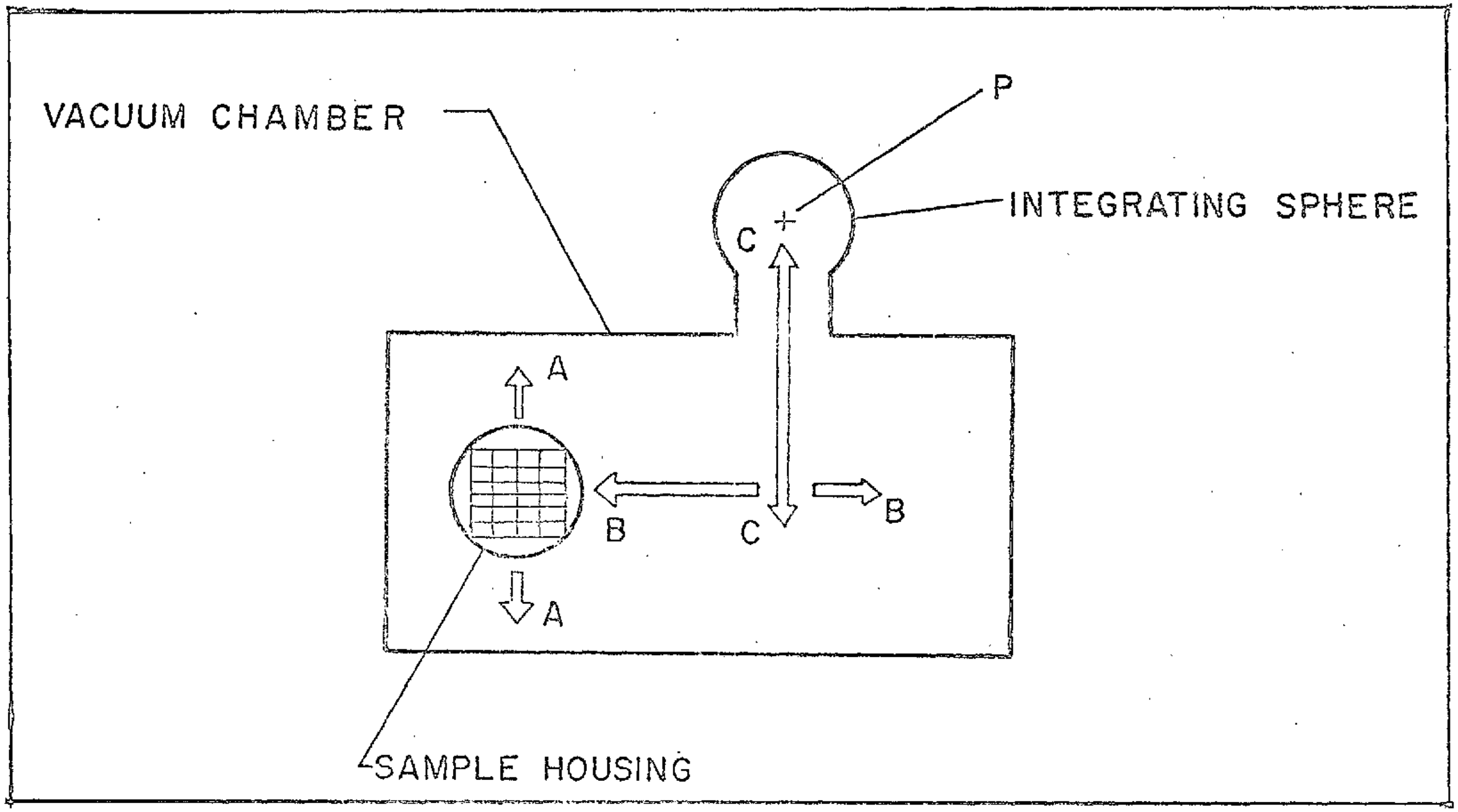

Figure 4-5. Sample Movement

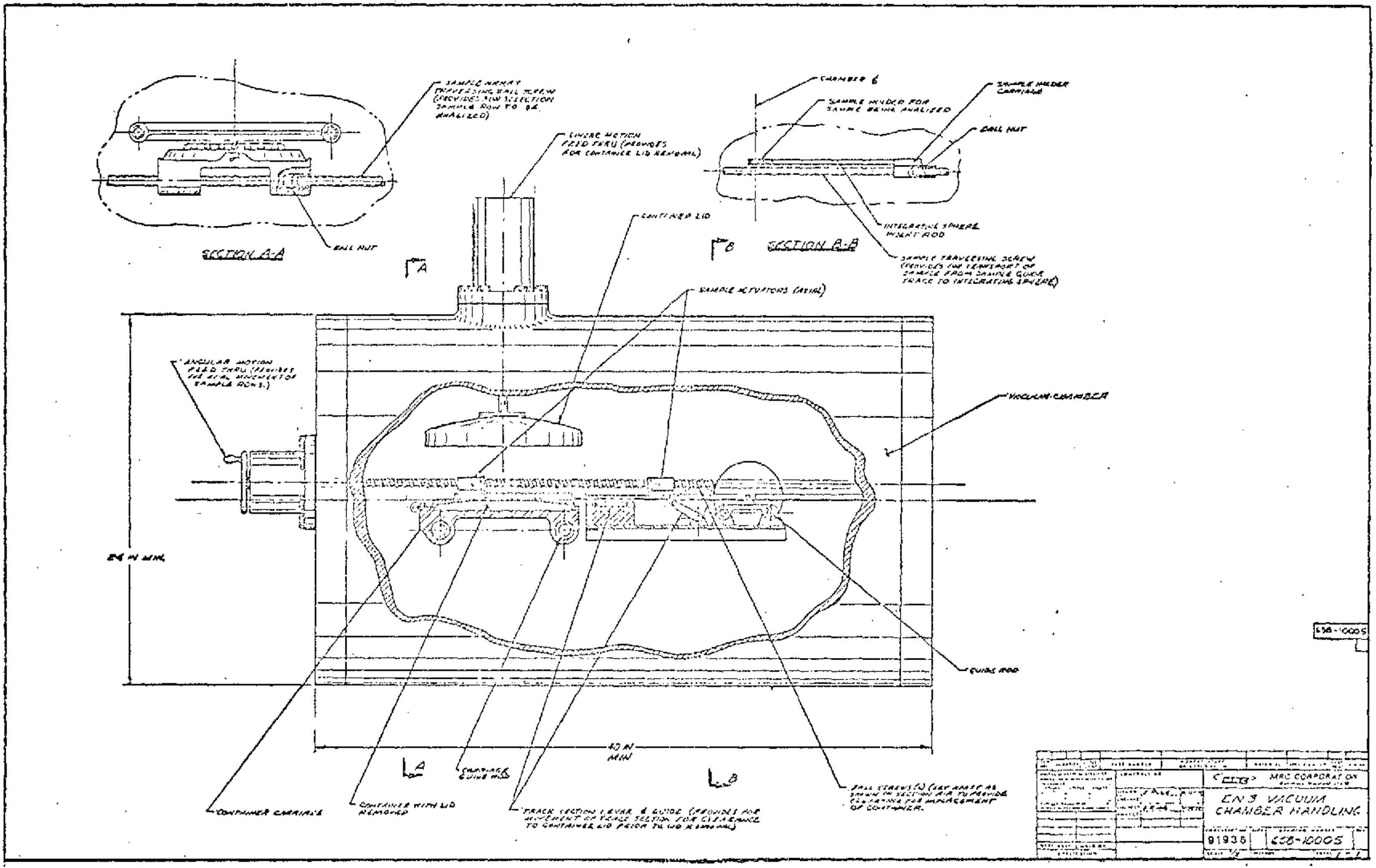

Figure 4-6. Vacuum Chamber Handling

Since both these actuators engage the same ball screw they move simultaneously with the distance between them remaining constant. These actuators "stradle" the container as it is loaded into the carriage so that the sample rows are between the actuators. As the ball screw is rotated by means of an angular motion feed-thru the selected row is pushed into the chamber track until the first sample in the row is located in the sample holder shown in section B-B. When this holder is on the chamber centerline it forms a part of the stationary track. The holder can then be transferred into the integrating sphere by means of the sample hold carriages engagement with a ball screw and guide rod. This movement corresponds to movement along line C-C. Thus when the first sample is in the holder it can be transferred to the integrating sphere for analysis. It can then be returned to the main track and the row indexed one sample length such that the second sample is in position for transfer to the integrating sphere. It is not mandatory that the sample be handled serially. Any one sample can be selected out of the array by aligning the appropriate row with the chamber track and then moving it through the track until the selected sample is in the sample holder. After all the sample in a given row are analyzed the entire row is driven to the left and back into the sample housing.

None of these handling procedures requires great skill on the part of an operator. In fact this process could easily, if not inexpensively, be automated for the serial analysis of the entire array. Or a sample row and location can be entered into a control computer and the particular sample automatically transferred to the integrating sphere.

4.2.2 CONTAINER LOADING AND UNLOADING

In the investigation of possible loading techniques and sequences, it became apparent that the loading of samples by rows in the sample housing permits the greatest simplification to the vacuum chamber handling equipment and does not compromise the container design. One of the design requirements provides that a barrier exists between samples so as to prevent inter-sample contamination. This barrier must be ten thousandths of an inch above the sample surface and fifteen thousandths wide. It is preferred that this barrier not be a permanent feature of the sample so that polishing can be more easily accomplished. With the sample arranged in rows, a barrier between rows can be a permanent feature of the sample housing thus the only remaining barrier required is the one between adjacent samples in the same row. In this configuration a square sample and its substrate can be attached to a sample holder which incorporates this barrier. When the entire array is loaded each sample is bounded on all 4 sides except the last or first sample in the row. If the samples are oriented properly with the single barrier toward the direction of sample removal then the barrier on the fourth side of the sample, on the opposite end of the rows, can be a feature of the housing.

4.3 CONTAINMENT SELECTION

The container preliminary design shown in Figure 4-4 is the recommended design and the vacuum handling system shown in Figure 4-5 and 4-6 is the recommended handling concept.

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Section 5

EXPOSURE LOCATION

5.0 GENERAL

There are two major considerations in selecting an exposure location relative to the ATL pallet. The first consideration is the total exposure time during the flight. A ground rule for the preliminary design of the polymeric materials experiment is that it would be a passive experiment in the sense that it would not be designed to continuously articulate in order to seek maximum exposure time. It was therefore necessary to examine the mission description and determine which fixed orientation would provide the maximum exposure values.

Secondly the experiment must be positioned at a location of minimum contamination from the shuttle induced atmosphere. In evaluating each of these considerations various referenced documents were thoroughly studied. It should be emphasized that the location selected for this preliminary design is based on current references. Changes in the orbiter vehicle, the ATL payload or the mission considerations may have a severe effect on this location.

5.1 SAMPLE ORIENTATION

Since the objective is to maximize exposure to the sun's rays, the selection of aiming angle is dependent on the following:

- Orientation of orbit plane in relation to sun's position ($\beta \measuredangle$).
- Vehicle attitude.

The Flight Plan shows that the *β will vary from 16 to 11 degrees with the angle starting at 16 degrees and changing approximately one

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*β angle is the angle between the orbit plane and the line of centers between the earth and sun.

degree per day. It is assumed therefore that the β angle is a constant 13 degrees.

It is preferable from the standpoint of complexity to avoid any articulation of either the boom supporting the sample container on the container with respect to the boom. In order for this to be practical, the experiment should be carried on a flight in which the ATL is predominantly in one attitude. In this way a reasonable percentage of exposure can be obtained with maximum aiming of the sample array without the necessity of altering the aiming angle during the mission. The flight plan for ATL-1 shows that the vehicle will be in a ZLV (Z axis local vertical, which means that the yaw axis is an Earth radial) attitude with the nose forward and the vertical stabilizer toward the Earth for one hundred (100) hours of the one hundred and thirty four (134) available exposure hours. Thus the optimum aiming angle based on this orientation and a β angle of 13 degrees must be determined. The following analysis is a determination of the optimum aiming angle for these conditions.

With the ATL in the described attitude it pitches one revolution per orbit. Considering that the orbit altitude is negligible as an influence on the angle then consider that the vehicle exists at a point where it is simply pitching constantly. It is assumed that the boom is along the ATL pitch axis and that θ is the angle between the pitch axis and a line normal to the sample plane. This line then forms a cone as the orbiter pitches where the cone angle is 2 θ as shown in Figure 5-1.

Construct plane Y, Z, containing the sun and perpendicular to the vehicle pitch axis X as shown in Figure 5-2.

The intersection of the cone in, Figure 5-1, and this plane is circle "I". Place the sun at any point along Z. When the line normal to the sample array passes through the axis the vehicle is in a noon or midnight condition considering its exposure to the sun. In Figure 5-2 the constructed line F represents noon aiming of the sample at angle θ from the pitch axis and line R from the vehicle to the sun. Line R subtends angle α from the pitch axis which is equal to 90 degrees minus the β angle.

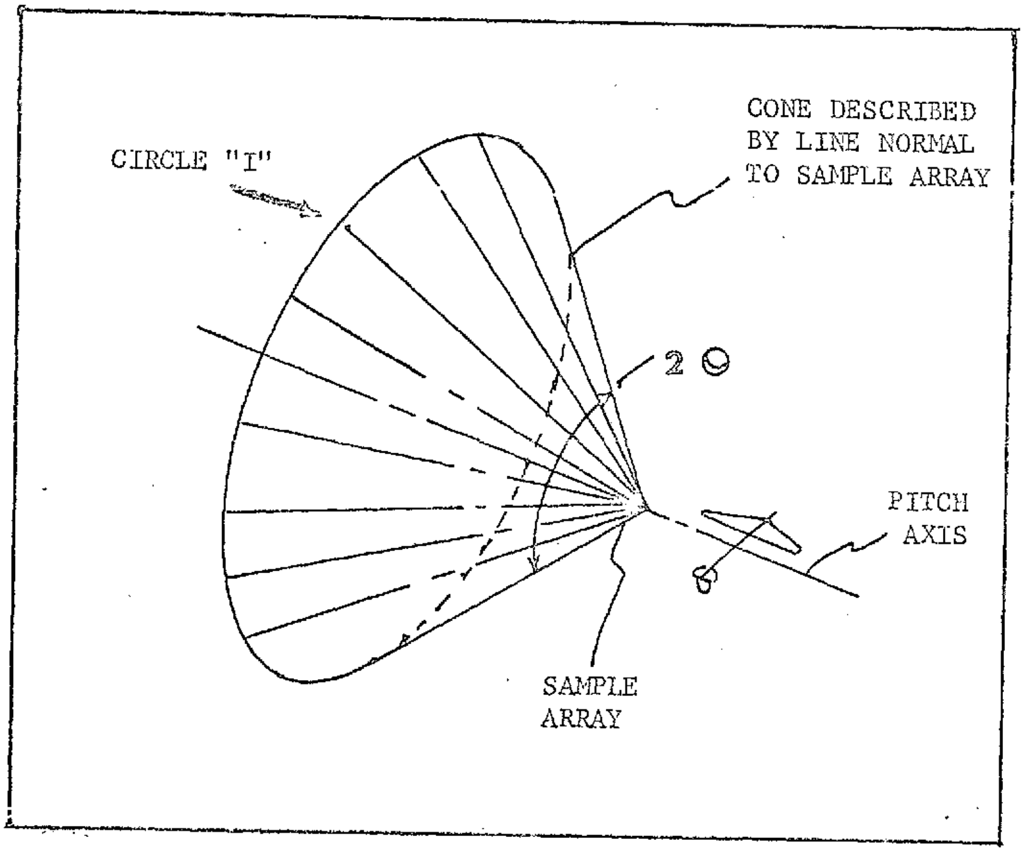


Figure 5-1. Orientation Cone

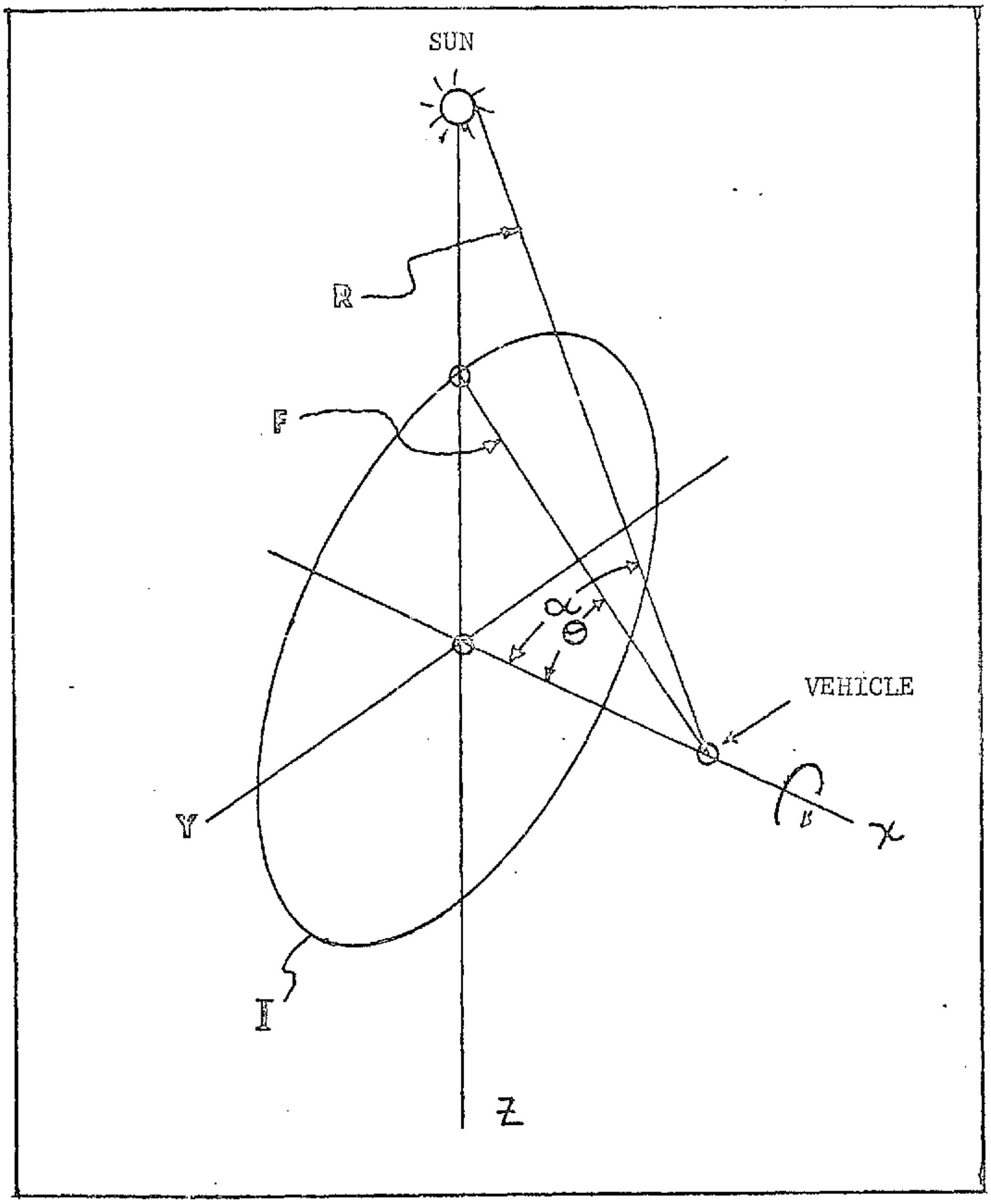


Figure 5-2. Noon Aiming

As the vehicle pitches about χ the line normal to the sample array intersects plane Y, Z tracing the locus of points circle I. Consider the vehicle at a "noon" position such that the sample array faces along line F. It now pitches through angle ϕ as shown in Figure 5-3. Construct line "C" from the vehicle to the intersection of a line now perpendicular to the sample array and the Y Z plane and lines a, b, and d as shown.

Let δ be the true view angle between lines c and r. Then the light level on the array in a function of the cosine of δ. Using the law of cosines then solve triangle c, r, d for cos δ :

$$\cos \delta = \frac{C^2 + R^2 - d^2}{2CR}$$

SUBSTITUTING: $C = \frac{b}{\cos \theta}$, $R = \frac{b}{\cos \alpha}$

$$\text{and } - d^2 = (\cos \phi)\ (2\, b^2 \tan \alpha)\ (\tan \theta) - (b^2 \tan^2 \alpha) - (b^2 \tan^2 \theta)$$

$$\cos = \frac{\frac{b^2}{\cos^2} + \frac{b^2}{\cos^2} + (\cos \phi)\ (2\, b^2 \tan \alpha)\ (\tan \theta) - (b^2 \tan^2 \alpha) - (b^2 \tan^2 \theta)}{\frac{2b^2}{\cos \theta \cos \alpha}}$$

Simplifying

$$\cos \delta = \cos \alpha \cos \theta + \cos \phi \sin \alpha \sin \theta \qquad (2)$$

To obtain total exposure to sun for hours of daylight with respect to the samples, simply integrate over $-\phi$ to $+\phi$ setting limits as to include only hours of sample exposure. This exposure (E.V.) is:

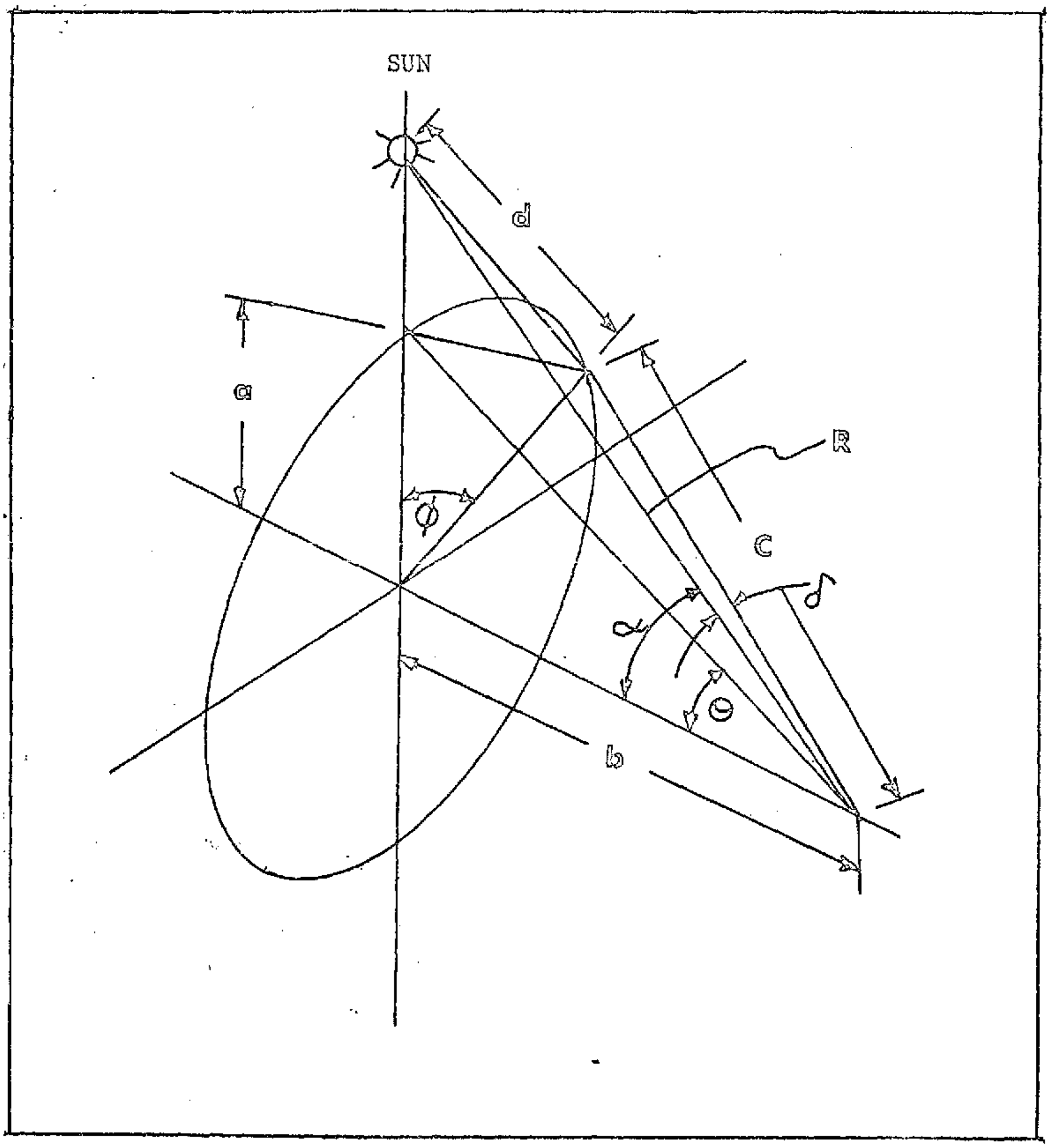


Figure 5-3. Noon Aiming With Pitch

$$\text{E.V.} = \int_{-\phi}^{+\phi} \cos\alpha \, d\theta = 2\,\phi \cos\alpha \cos\theta + 2 \sin\phi \sin\alpha \sin\theta \qquad (2)$$

To determine optimum for peak value of E.V. take first derivative of E.V. with respect to θ and set equal to zero.

$$\frac{\sin}{\cos} = \frac{2 \sin\phi \sin\alpha}{2\phi \cos\alpha}$$

$$\tan\theta = \frac{\sin\phi \tan\alpha}{\phi} \qquad (3)$$

Substituting (3) in (2) and simplifying

$$\text{E.V.} = 2\sqrt{\phi^2 \cos^2\alpha + \sin^2\phi \sin\alpha} \qquad (4)$$

Now substitute the values for ϕ defining ϕ in two ways. First as angle at which the orbiter beams daylight. That is:

$$\phi = \frac{\pi}{2} + \tan^{-1}\left[\frac{K}{\sqrt{\sin^2\alpha - K^2}}\right] \qquad (5)$$

where:

$K = \sqrt{1 - \left(\frac{r}{a+r}\right)^2}$

$\alpha = 90 - \beta$

r = EARTH RADIUS

a = ORBIT ALTITUDE

The second limit occurs when $\cos\delta = 0$. This is obtained from equation (1).

$$\cos\alpha \cos\theta + \cos\phi \sin\alpha \sin\theta = 0$$

$$\phi = \cos^{-1} - \frac{1}{\tan\alpha \tan\theta} \qquad (6)$$

The ϕ used as the limit is the smaller number between (5) and (6).

A program can be written using equations (3), (4), (5) and (6) printing out the optimum θ for given orbit β angles ($90-\alpha$) and altitudes.

The above program and data print out is shown in Tables 5-1 and 5-2. Since $\alpha = 90-\beta$ it can be seen θ varies with β angles. Since the mission plan calls for a β angle of approximately 13°; $\alpha = +77^{\circ}$ thus $\theta = 65^{\circ}$.

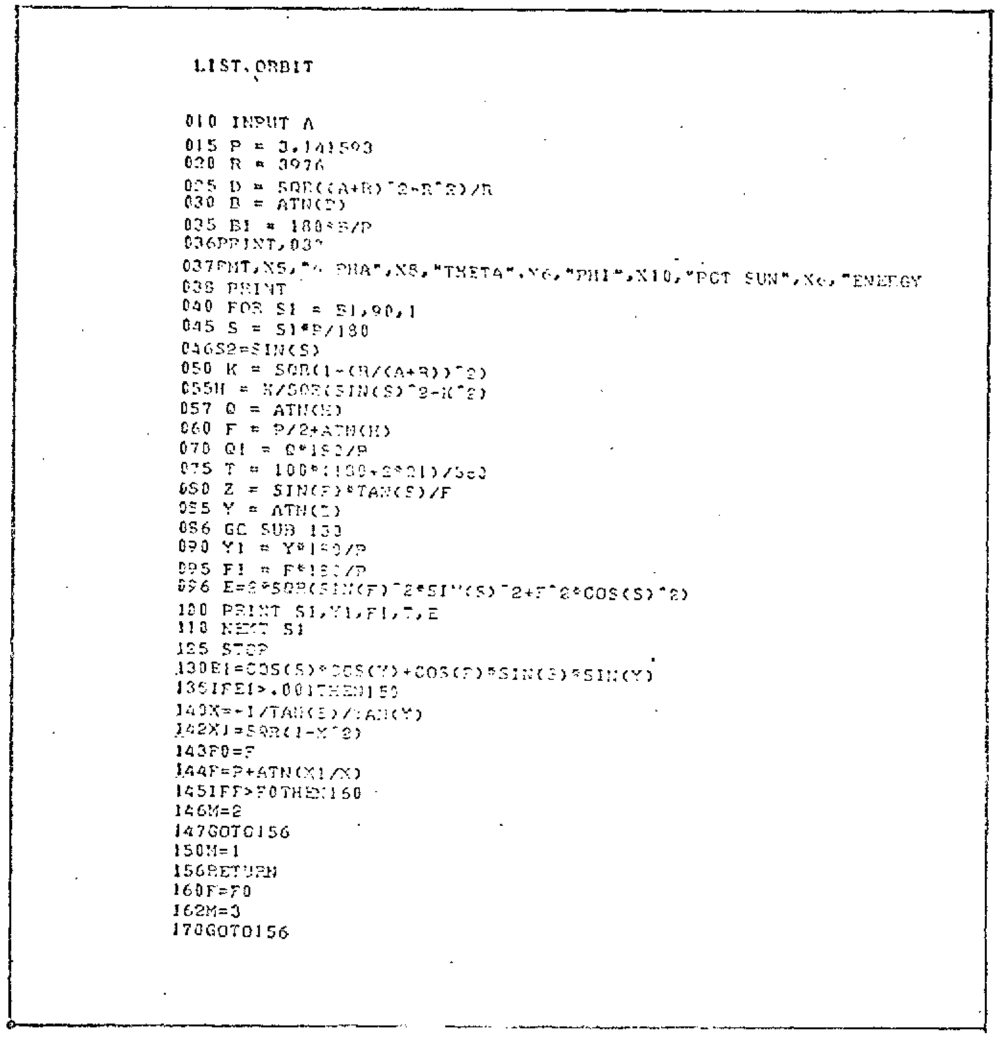
5.2 ORBITER CONTAMINATION

During the course of this contract, MRC studied the nature of the contaminant environment associated with an orbiting vehicle. Available reports and material dealing with a number of satellite experiments in addition to the Skylab mission and studies related to the Shuttle Orbiter have been reviewed. The objective of this work was to establish a suitable basis for the selection of the extended location of the polymeric materials experiment. Since the experiment is sensitive to contamination and shadowing by the orbiter, it is imperative that samples be projected to a location affording minimal contamination and maximum solar incidence consistent with the practical and cost effective considerations attendant with deployment activities.

5.2.1 BACKGROUND

It has long been known that orbiting spacecraft exhibit a self-contamination characteristic that may readily interfere with onboard experiment activity. The useful life of many satellites has been terminated due to sensor degradation resulting from contaminant influence. A number of experiment degradations and anomalies on the Skylab missions are traceable to contaminant environment; for instance, the D024 thermal control coating experiment involving polymeric strips and the S230 experiment involving

TABLE 5-1. COMPUTER PROGRAM PRINTOUT



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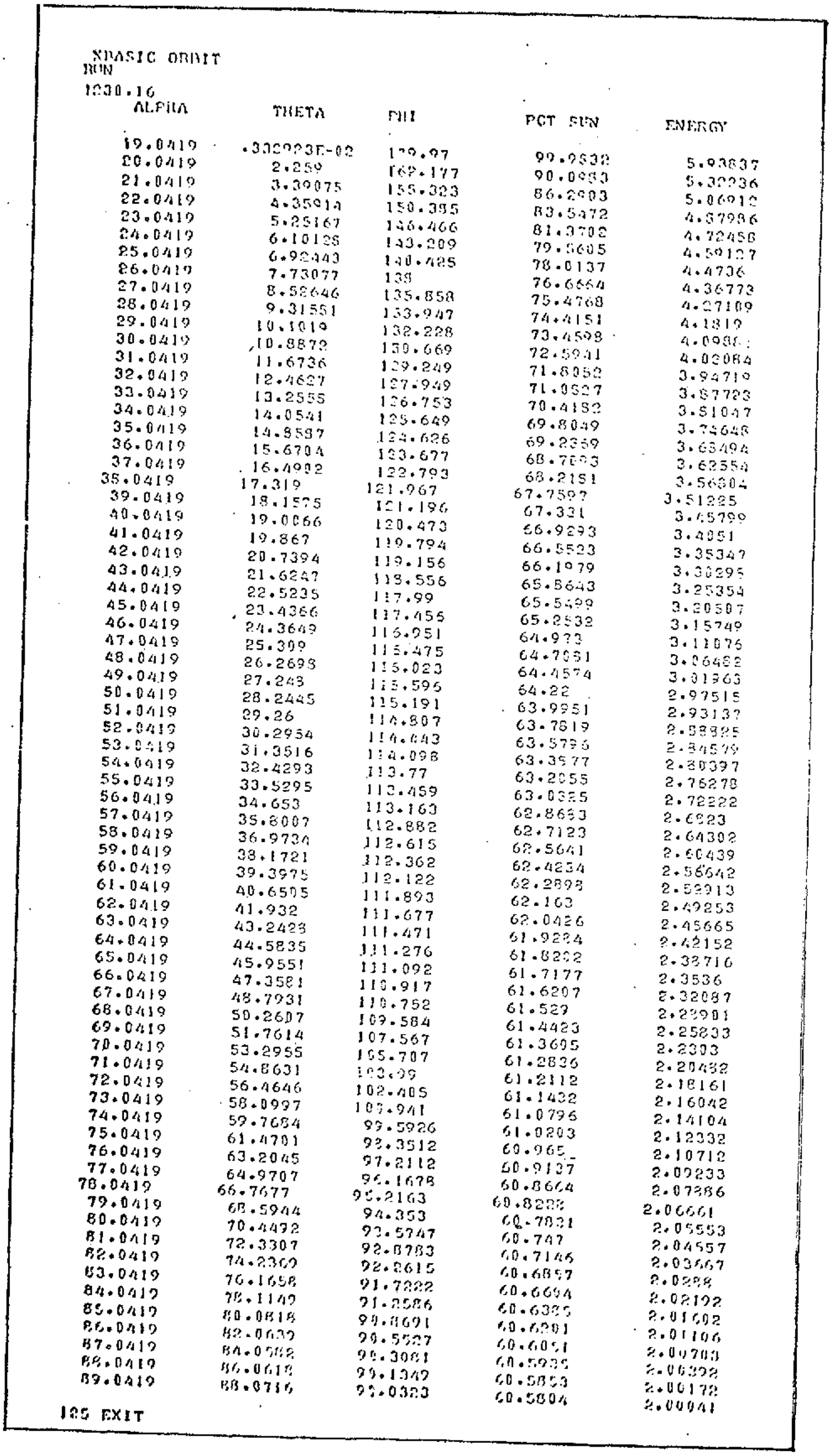
LIST,ORBIT

010 INPUT A
015 P = 3.141593
020 R = 3976
025 D = SQR((A+R)^2-R^2)/R
030 B = ATN(D)
035 B1 = 180*B/P
036PRINT,037
037FMT,X5,"ALPHA",X8,"THETA",X6,"PHI",X10,"PCT SUN",X6,"ENERGY
038 PRINT
040 FOR S1 = B1,90,1
045 S = S1*P/180
046S2=SIN(S)
050 K = SQR(1-(R/(A+R))^2)
055H = K/SQR(SIN(S)^2-K^2)
057 Q = ATN(H)
060 F = P/2+ATN(H)
070 Q1 = Q*180/P
075 T = 100*(180+2*Q1)/360
080 Z = SIN(F)*TAN(S)/F
085 Y = ATN(Z)
086 GO SUB 130
090 Y1 = Y*180/P
095 F1 = F*180/P
096 E=2*SQR(SIN(F)^2*SIN(S)^2+F^2*COS(S)^2)
100 PRINT S1,Y1,F1,T,E
110 NEXT S1
125 STOP
130E1=COS(S)*COS(Y)+COS(F)*SIN(S)*SIN(Y)
135IFE1>.001THEN150
140X=-1/TAN(S)/TAN(Y)
142X1=SQR(1-X^2)
143F0=F
144F=P+ATN(X1/X)
145IFF>F0THEN160
146M=2
147GOTO156
150M=1
156RETURN
160F=F0
162M=3
170GOTO156
```

TABLE 5-2. COMPUTER RUN PRINTOUT



```
XBASIC ORBIT
RUN
1030.16
   ALPHA        THETA          PHI          PCT SUN       ENERGY

  19.0419     .302923E-02     179.97        99.9532      5.93837
  20.0419       2.259         169.177       90.0953      5.32236
  21.0419       3.39075       155.323       86.2903      5.06912
  22.0419       4.35914       150.395       83.5472      4.87986
  23.0419       5.25167       146.466       81.3702      4.72456
  24.0419       6.10128       143.209       79.5605      4.59127
  25.0419       6.92443       140.485       78.0137      4.4736
  26.0419       7.73077       138           76.6664      4.36773
  27.0419       8.52646       135.858       75.4768      4.27109
  28.0419       9.31551       133.947       74.4151      4.1819
  29.0419      10.1019        132.228       73.4598      4.0986
  30.0419      10.8872        130.669       72.5941      4.02084
  31.0419      11.6736        129.249       71.8052      3.94719
  32.0419      12.4627        127.949       71.0527      3.87723
  33.0419      13.2555        126.753       70.4152      3.81047
  34.0419      14.0541        125.649       69.8049      3.74648
  35.0419      14.8597        124.626       69.2369      3.68494
  36.0419      15.6704        123.677       68.7093      3.62554
  37.0419      16.4902        122.793       68.2151      3.56804
  38.0419      17.319         121.967       67.7597      3.51225
  39.0419      18.1575        121.196       67.331       3.45799
  40.0419      19.0066        120.473       66.9293      3.4051
  41.0419      19.867         119.794       66.5523      3.35347
  42.0419      20.7394        119.156       66.1979      3.30295
  43.0419      21.6247        118.556       65.8643      3.25354
  44.0419      22.5235        117.99        65.5499      3.20507
  45.0419      23.4366        117.455       65.2532      3.15749
  46.0419      24.3649        116.951       64.973       3.11076
  47.0419      25.309         116.475       64.7051      3.06482
  48.0419      26.2698        116.023       64.4574      3.01963
  49.0419      27.248         115.596       64.22        2.97515
  50.0419      28.2445        115.191       63.9951      2.93137
  51.0419      29.26          114.807       63.7819      2.88825
  52.0419      30.2954        114.443       63.5796      2.84579
  53.0419      31.3516        114.098       63.3977      2.80397
  54.0419      32.4293        113.77        63.2055      2.76278
  55.0419      33.5295        113.459       63.0325      2.72222
  56.0419      34.653         113.163       62.8693      2.6823
  57.0419      35.8007        112.882       62.7123      2.64302
  58.0419      36.9734        112.615       62.5641      2.60439
  59.0419      38.1721        112.362       62.4234      2.56642
  60.0419      39.3975        112.122       62.2898      2.52913
  61.0419      40.6505        111.893       62.163       2.49253
  62.0419      41.932         111.677       62.0426      2.45665
  63.0419      43.2423        111.471       61.9284      2.42152
  64.0419      44.5835        111.276       61.8202      2.38716
  65.0419      45.9551        111.092       61.7177      2.3536
  66.0419      47.3581        110.917       61.6207      2.32087
  67.0419      48.7931        110.752       61.529       2.28901
  68.0419      50.2607        109.584       61.4423      2.25833
  69.0419      51.7614        107.567       61.3605      2.2303
  70.0419      53.2955        105.707       61.2836      2.20432
  71.0419      54.8631        103.99        61.2112      2.18161
  72.0419      56.4646        102.405       61.1432      2.16042
  73.0419      58.0997        100.941       61.0796      2.14104
  74.0419      59.7684         99.5926      61.0203      2.12332
  75.0419      61.4701         98.3512      60.965       2.10712
  76.0419      63.2045         97.2112      60.9137      2.09233
  77.0419      64.9707         96.1678      60.8664      2.07886
  78.0419      66.7677         95.2163      60.8228      2.06661
  79.0419      68.5944         94.353       60.7831      2.05553
  80.0419      70.4492         93.5747      60.747       2.04557
  81.0419      72.3307         92.8783      60.7146      2.03667
  82.0419      74.2369         92.2615      60.6857      2.0288
  83.0419      76.1658         91.7222      60.6604      2.02192
  84.0419      78.1149         91.2586      60.6385      2.01602
  85.0419      80.0818         90.8691      60.6201      2.01106
  86.0419      82.0632         90.5527      60.6051      2.00703
  87.0419      84.0582         90.3081      60.5935      2.00392
  88.0419      86.0618         90.1349      60.5853      2.00172
  89.0419      88.0716         90.0323      60.5804      2.00041

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magnetosphere particle composition collectors were both heavily contaminated during the SL-1/2 and SL-3 missions. Also some thermal control surfaces were degraded and the S190A window exhibited severe external contamination. Furthermore, analysis of SL-1/2 and SL-3 star tracer data indicated that 39 anomalies were exhibited by the startracker, eleven of which were identified as "false star" tracking of contaminant particles.

Figure 5-4 is a view of Sklylab locating various contamination sensors taken from reference 4. The 4 sensors located in the lower portion of the figure recorded the accumulated mass of contamination as shown in Figure 5-5. The sensor identified as CSM was pointed in the + X direction and was most exposed to the engine firings of the command and service module during docking. The sensor identified as OWS was pointed in the negative X direction looking at the Skylab dome and the 2 sensors XAM and X50 were along the Z axis and were temperature controlled. This data indicates that engine firings can cause sharp rises in contamination levels which are then reduced by desorption. It is important to note that the time period required for return to low contamination levels after engine firing can be on the order of days. It is therefore possible that an experiment which has been exposed in orbit could have had a higher level of contamination during exposure than the level measured after its return.

Table 5-2, Major Sources Summary, provides data from a recent shuttle contamination study, reference 5. These general sources of contamination are discussed briefly in the following paragraphs to provide some insight to the contamination factors that may affect the performance of an orbiter based experiment.

5.2.2 PROJECTION

On orbit engine firing is probably the greatest potential source of contamination for the experiments. There are forty 900 lb. thrust reaction control system (RCS) engines, six 25 lb. thrust RCS vernier engines, two 6000 lb. thrust orbital maneuvering system (OMS) engines, and three 470,000 lb. thrust main engines. From a contamination viewpoint the RCS and RCS vernier engines warrant prime consideration. External surface deposition can be expected from the use of OMS engines and from near orbit use of

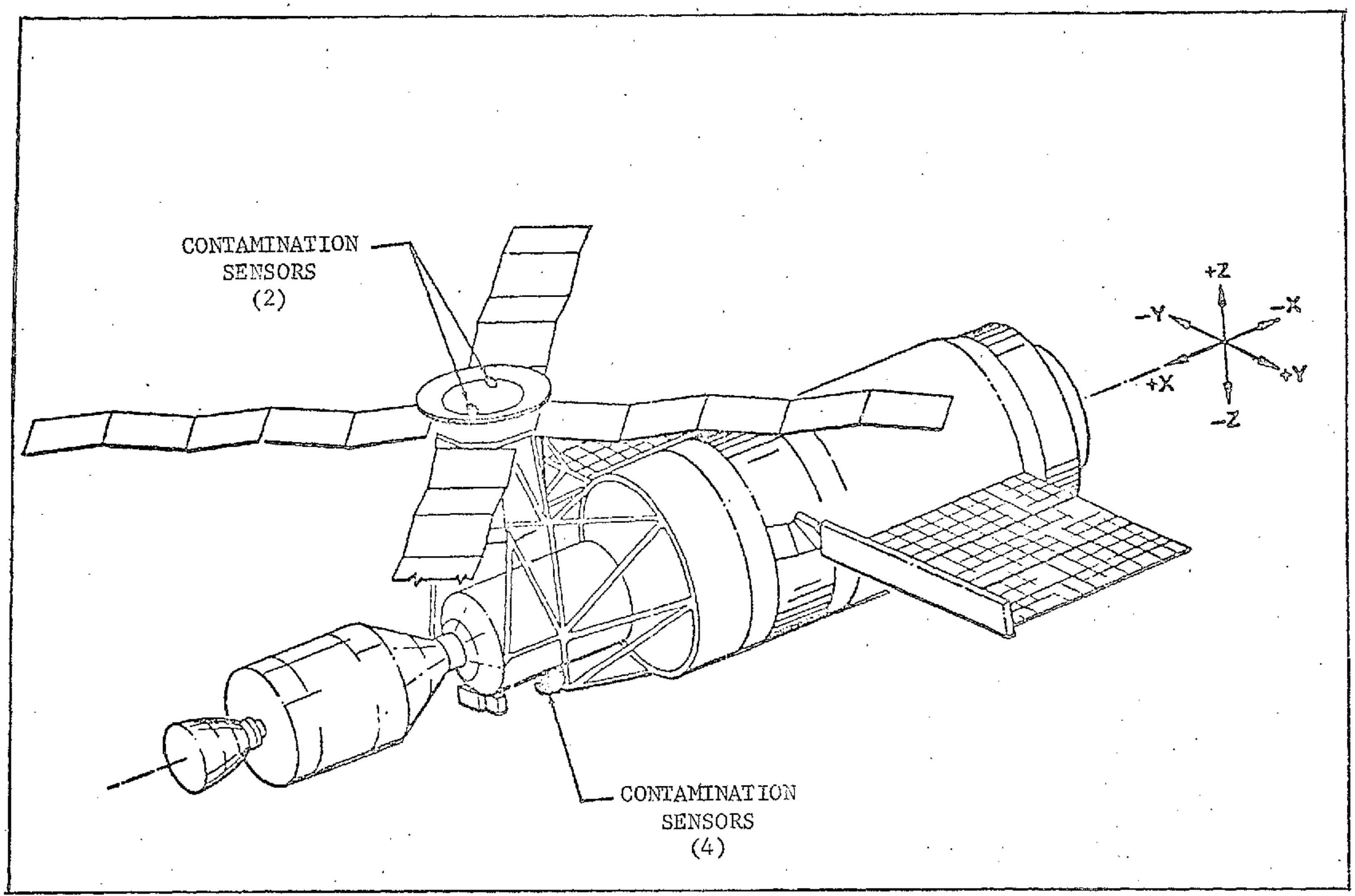

Figure 5-4. Skylab Sensors

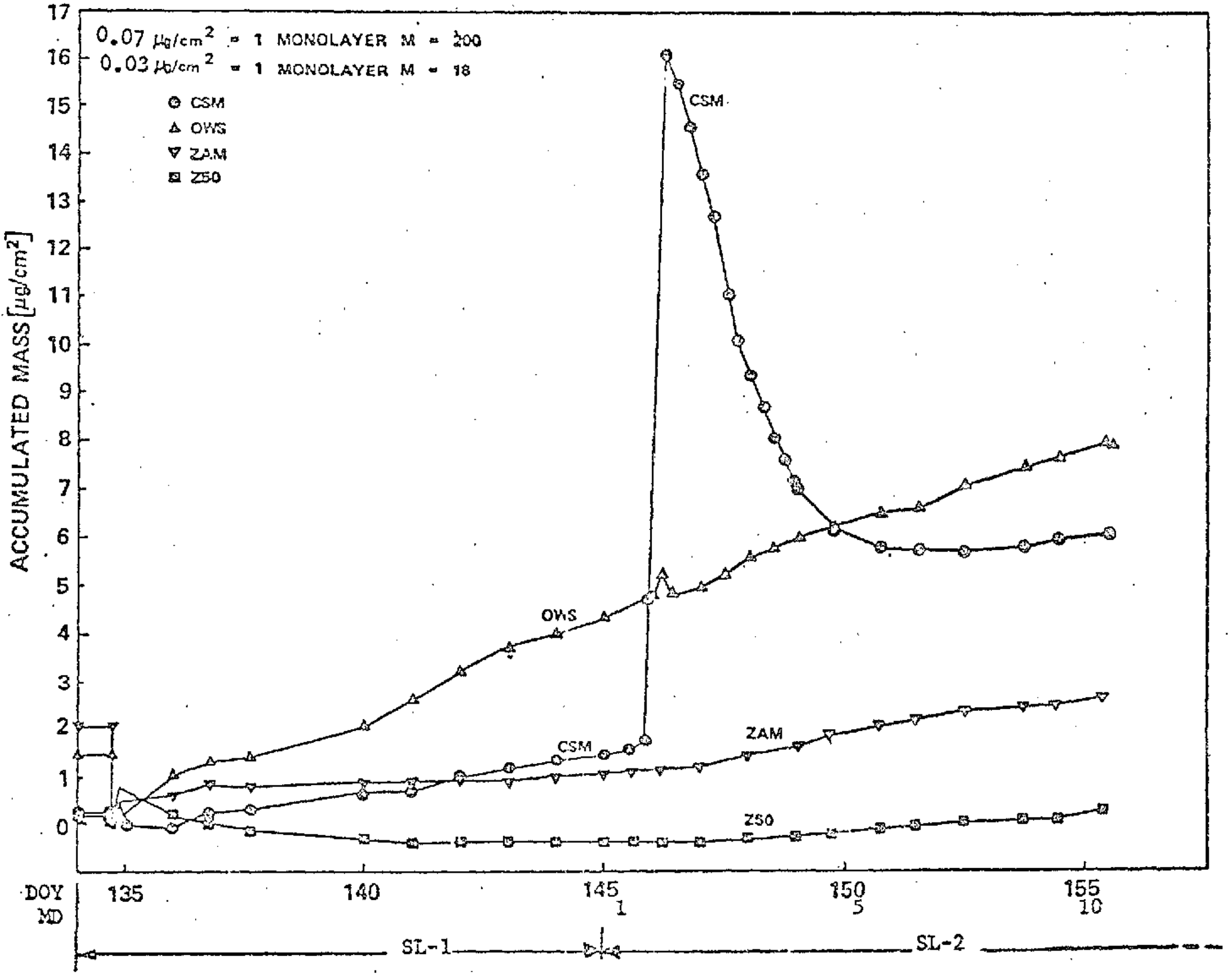

Figure 5-5. Contamination Profile

Table 5-2. Major Sources Summary

Major Sources	Duration/ Frequency	Flowrate	Constituents	Plume Shape Function	Velocity	Size Parameter
Outgassing	Continuous	$5\times10^{-10}\, e^{-t/4100}\, e^{(T-100)/29}$ g/cm^2/sec (10%)	Hydrocarbon chain fragments, RTV's, etc.	$\cos\theta/r^2$	$12.9\sqrt{T}$ m/sec	Molecular Avg. M = 100
Offgassing	Continuous for first 100 hours on-orbit.	$[.325e^{-.0714t} + .372e^{-.0105t}]\, e^{(T-100)/29}$ g/cm^2/sec x 10^{-8}	Water light gases Volatiles	$\cos\theta/r^2$	$30.4\sqrt{T}$ m/sec	Molecular Avg. M = 18
Evaporator (2)*	~60% of on-orbit Time	5.5 lb/hr/vent	Water	$(\cos\zeta)^{6.272}/r^2$	1003 m/sec	Molecular M = 18
Cabin Atmos Leakage	Continuous	7 lb/day	O_2 N_2 CO_2 H_2O	$\cos\theta/r^2$	$2220\sqrt{\frac{1}{M}}$ m/sec	Molecular Avg. M = 29
RCS Vernier Engines**	As Reqd.	3.0 lb/orbit Y-POP attitude @ 200 km	H_2O N_2 H_2 CO CO_2 H	$\frac{(\cos \frac{\pi}{2}\cdot\frac{\theta}{\theta_1})^{8.65}}{r^2}$ $0^\circ \le \theta \le 40^\circ$ $\frac{C}{r^2}$ $.0467(\theta-40^\circ)$ $40^\circ < \theta \le 140^\circ$ $\frac{C}{r^2}$ -4.67 $140^\circ < \theta \le 180^\circ$	3505 m/sec	Molecular
Ambient Reflection	~10 min per orbit	Varies with above sources & orbital attitude	Any of the above sources	$\cos\theta/r^2$ from collision points	7.65×10^3 m/sec	Varies with all above sources

* Plume reflections off of structural surfaces (e.g. wings, experiment bay doors) are equivalent to a source equal to the plume impingement rate with a $\cos\theta/r^2$ distribution and a velocity of $30.4\sqrt{T}$ m/sec from the surface where T = surface temp.

** RCS plume reflections off of structural surfaces are assumed to have a rate equal to the plume impingement rate with a $\cos\theta/r^2$ distribution and a velocity equal to $119\sqrt{\frac{T}{M}}$ where T = surface temperature.

the main engines. This surface deposition can desorb at a later time and contribute to the contaminant level in the induced atmosphere around the orbiter. Nonetheless the RCS and RCS vernier engines are more significant contributors because they will be exercised subsequent of deployment to the experiments.

The main RCS engines are used to effect a change in the attitude of the orbiter, while the vernier engines are used to maintain that attitude. The flight profile plan becomes an important consideration since changes in orbiter attitude are determined in advance to accomplish specific flight or experiment objectives. Consequently minimum contamination effect on an experiment due to engine firing will be associated with flights not requiring orbiter attitude changes during the deployed period. This is due to the absence of RCS firing while the experiments are deployed. If orbiter attitude changes are required during the deployed period then it may become necessary to protect an extended experiment by covering or enclosing it during RCS firing and for a suitable period of time thereafter. Because of the number of RCS thrusters and magnitude of thrust level, it does not appear that a contaminent-free position for an experiment exists within practical extension range of the orbiter. That is, extended experiments of any appreciable mass require structural booms or other extendable framework capable of sustaining orbiter maneuvers, such as attitude changes, following deployment without excessive oscillations of the experiment mass. Also the extension mechanism must be capable of sustaining temperature gradients without undue distortion that might compromise experiment pointing. Thus from a cost effective viewpoint, it appears that projecting an experiment much beyond about 30 meters from the orbiter is not a viable alternative.

The RCS vernier engine contribution to the contaminant environment is by far the highest of all potential sources assuming protection against the RCS engines is afforded. Based upon anticipated propellant usage, up to 48 lbs. could be expended per day of operation. The nominal duty cycle of these engines is in the order of 70 milliseconds. Assuming that the engines were fired at a uniform rate per day the resulting firing frequency would be once every 15 seconds. Therefore, considering direct plume contribution plus reflection deposition and subsequent desorption from orbiter surfaces, the vernier engines constitute a near steady state source of contamination. Consequently, it is important to avoid projection of an experiment into the plume envelope of these thrusters. At the same time, it is important to project as far as practical from orbiter surfaces.

Figure 5-6 graphically displays the various contamination constraints and capatibility of experiments for the baseline ATL-1 mission. The majority of the mission requires an orbiter position with the payload bay facing radially earthward. The nominal beta angle is 16° for the first day decreasing steadily to about 11° by the end of the 7 day mission. This accounts for the orbiter shadowing profile depicted. Combustion product plume envelopes (95°) are shown for the six vernier engines and, as seen, 4 plume are directed downward and 2 plume are directed sidewards. There are no upward firing verniers. The aft downward firing thrusters can, however, impinge on the orbiter wing and thereby create a weakened contamination zone in the upward direction. Sideward contamination is very much worsened by the variety of vented materials directed outward beneath the open payload doors and above the orbiter winds. The channelling effect created by these surfaces will likely intensify contaminant clouds below the payload doors and along the wing surfaces.

Consideration of two main sources of contamination, RCS vernier engines and vented materials, leads to the rough conclusion that locations for extended experiments are more favorable in the upward direction than in the sideward or downward direction. In the case of the experiment, shadowing and pointing considerations tend to trade off part of the advantages of the upward location. Placement of the experiment above and outboard the orbiter appears to provide the best combination of conditions of position. Approximately 40° off vertical appears to preclude shadowing of the experiment and affords minimal direct impingement of the experiment from reflected and desorbed flux.

In general, the contaminant contribution due to other sources such as outgassing, offgassing, leakage, particulate matter and miscellaneous

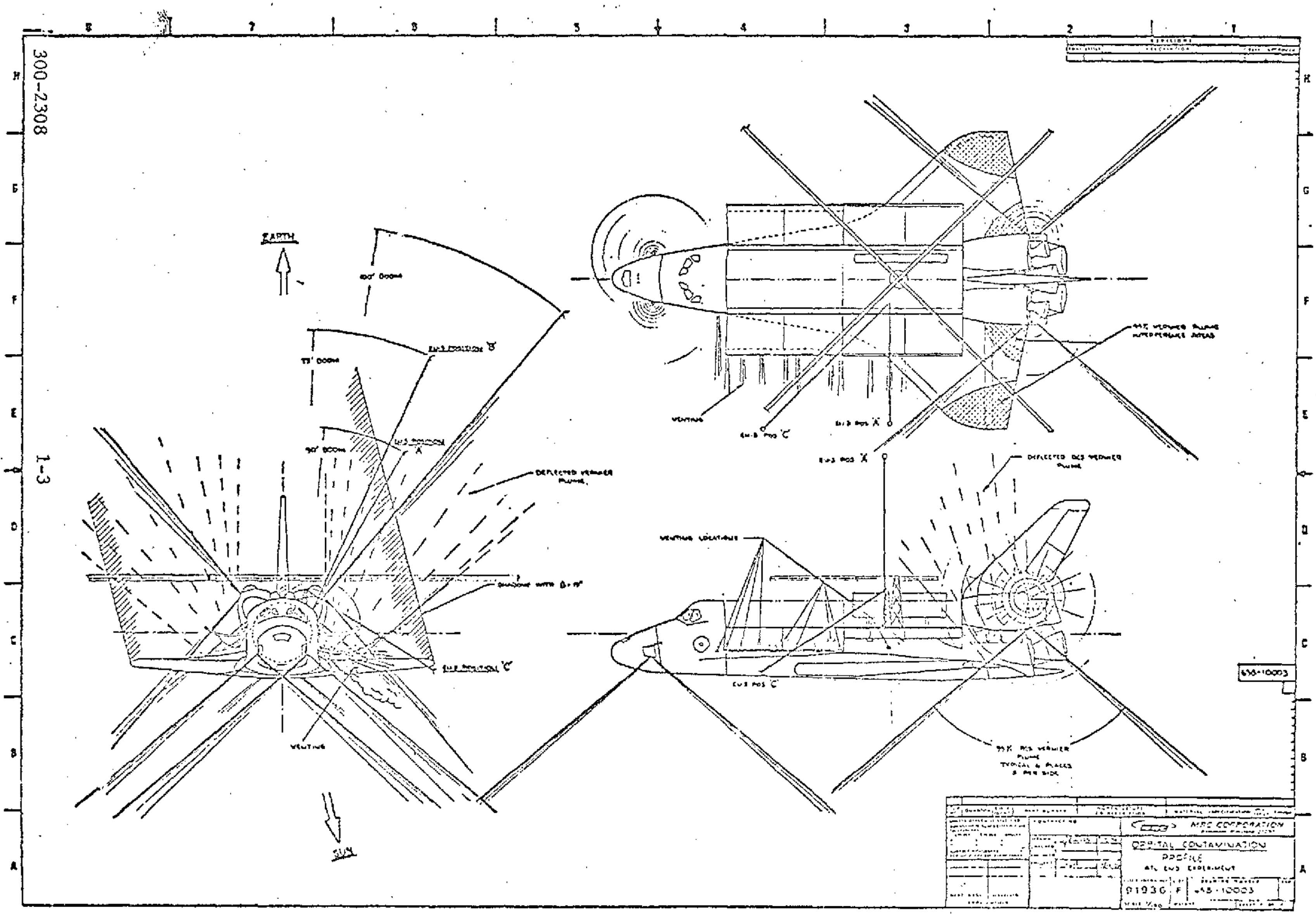

Figure 5-6. Orbital Contamination Profile

sources exhibit no strong tendency to favor one extended location over another. Consideration of these sources leads to the obvious conclusion that extension distance should be maximized and experiment pointing should minimize or preclude "seeing" orbiter surfaces.

In consideration of mission constraints and cost effectiveness it does not appear practical to project an experiment far enough from the orbiter to place it in an ambient atmosphere. Therefore, some consideration must be given to contaminant flux returned toward the orbiter as a result of reflection from the ambient atmosphere. The majority of contaminant flux generation occurs as known times; that is, (1) at orbit insertion due to offgassing and outgassing peak activity, (2) at payload bay door opening due to peak particulate matter release, (3) at thruster firings, (4) at vent releases, (5) during EVA activities, and (6) during periods where leakage is known to have occurred. If a suitable time period is allowed after the release of a contaminant to permit return flux to be reflected spaceward then a mission plan can be developed, assuming that a remote closure or seal-off capability is incorporated in the experiment hardware. Such a plan would integrate payload activity constraints with the detail mission profile. As mentioned earlier, the baseline mission profile for ATL-1 includes periods of local vertical orientation interspersed with periods of stellar inertial orientation, thereby requiring use of the RCS 900 lbs. thrusters. The desire to protect an experiment from this extreme source of contamination coupled with the advantage of protecting an experiment against peak periods of contamination leads us to the conclusion that sensitive experiments hould include the capability for retractable covers or seals capable of frequent cycles.

5.3 SELECTED LOCATION

The documents listed in the References and Bibliography Section of this report have been reviewed as they relate to the placement and protection of the polymeric materials experiment and the ATL-1 flight profile. The contaminant environment around the orbiter will exhibit fluctuating tendencies generally following predictable time lines. Projecting an experiment so far as to place it in the ambient atmosphere even during periods of peak contamination activity is judged to be impractical. By utilizing the known timelines associated with contaminant producing activity, it does appear practical to project the experiment to a position where ambient atmosphere is experienced during known periods of time. The position depicted in Figure 5-6 is felt to be such a location. The experiment container mechanism is designed for compatibility with a mission constraint program requiring periods of exposure and isolation of the experiment. Repeated retraction and deployment of the experiment to the specified location is neither recommended nor desired, since nothing is gained by bringing the experiment toward a more highly contaminated zone and also since mechanical retraction and deployment activity of a boom creates a new source of particulate matter contamination through abrasion and friction. It is concluded than, that a boom of approximately 30 meters length should be used to project the experiment at approximately 40° to the plus Z axis in a plane parallel to the YZ plane. The boom should be structural, designed to withstand the rotational and translational accelerations produced by the RCS engines. The boom must also consider deflections due to temperature gradient to preclude inadvertent pointing of the experiment toward the orbiter.

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Section 6

DEPLOYMENT

6.0 GENERAL

The primary factor limiting boom length is the bending strength and stiffness required to support the deployed container during RCS firing. While it may be practical to close the experiment container prior to an RCS firing to avoid contamination, it would be an impractical constraint on the mission to request that the boom be withdrawn. The maximum acceleration level predicted for the RCS system will be $2.05^{o}/sec^{2}$ rotational about the pitch axis with a superimposed translational acceleration of $0.94\ ft/sec^{2}$ (0.3 m). Accordingly, in order to remain within reasonable limits of size and cost effectiveness, it becomes apparent that the maximum feasible boom length attainable is about 30 meters. In that some of the boom designs evaluated are not suitable to support the deployed container 100 feet (30.5 m) out, a minimum acceptable boom length was established at 50 feet (15.25 m). Therefore, boom length evaluation parameters were established as 50 to 100 feet (15.25 - 30.5 m), with the higher end being the most desireable from a contamination standpoint.

The container for this experiment is estimated to weigh 15 to 20 lbs. (6.8 - 9 Kg). During a pitch maneuver, the boom must be capable of supporting the acceleration of the container up to $2.05^{o}/sec^{2}$. An offsetting factor to the implied load is in the location of the boom with respect to the pitch axis. As shown in Figure 6-1, Deployed Dynamics, the boom forms an angle to the pitch axis of approximately 50^{o} to 55^{o}. Hence the effective moment arm is 100 feet (sine 50^{o}) = 77 feet (23.5 m).

In roll, however, the effective moment arm remains 30 meters with applied acceleration of $1.48^{o}/Sec^{2}$. As a result, the roll maneuver establishes the design parameter for the boom.

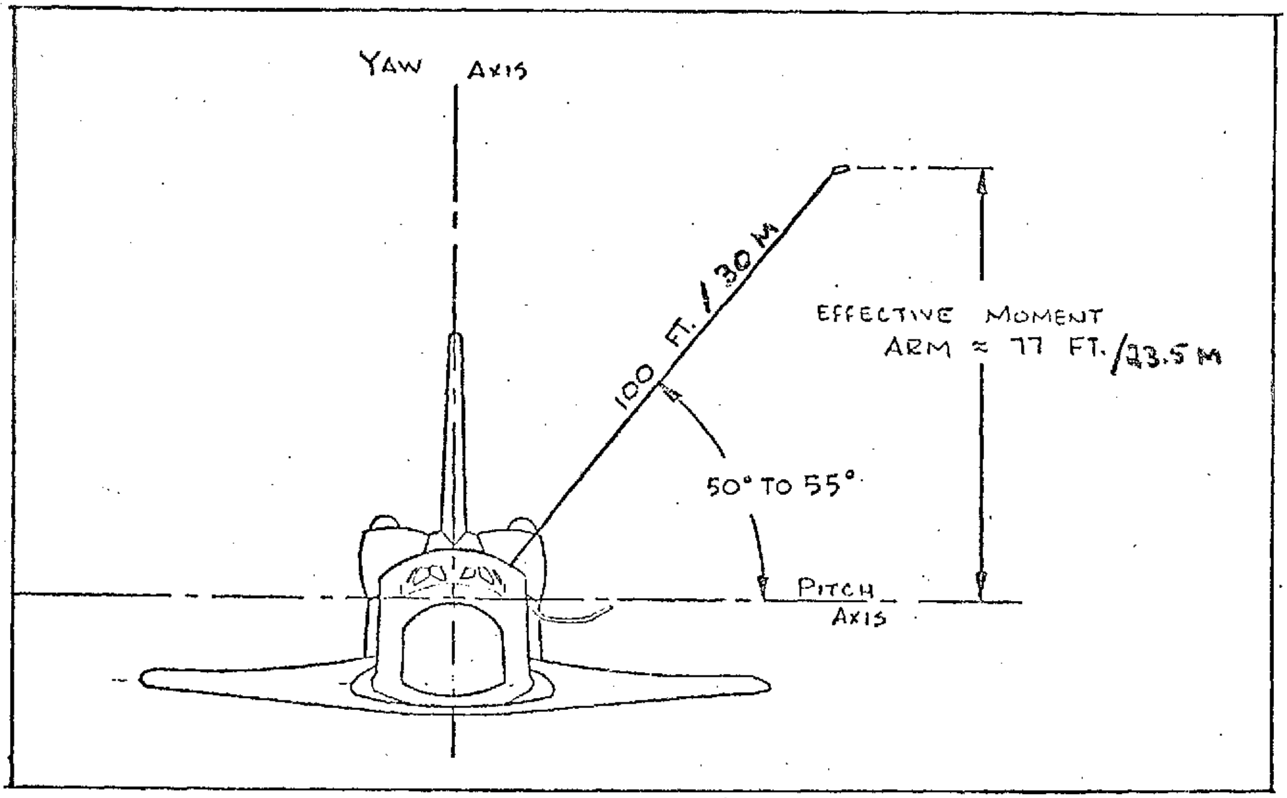


Figure 6-1. Deployed Dynamics

Due to the elastic structure of the boom, accelerating the combined mass of the container and boom will result in the development of an oscillatory motion. The maximum potential loads, therefore, will occur during deceleration, when the deceleration force is combined with the kinetic energy of the oscillating boom to produce a boom overtravel. Depending on the weight and stiffness of the boom under evaluation, the required bending strength of a 100 foot boom could be as high as 10,000 in. lbs. (1129 nm).

Although the primary load on the boom will result from RCS firing, attention must be paid to the frequency of RCS vernier firing. While the vernier develops only $.032^{o}/sec^{2}$ maximum acceleration, the acceleration on the boom could become cumulative to the point of destruction if the natural frequency of the boom approaches the vernier firing rate.

The other major consideration in the acceptibility of any boom design is in the thermal response quality of its structure. Due to the potential for extreme temperature variations between surfaces, the boom is susceptible to major thermal distortion which is a problem in systems requiring extreme accuracy.

6.1 REMOTE DEPLOYMENT

A number of different automatic deployment mechanisms exist which are potentially applicable to this experiment. These, along with an MRC developed concept, were evaluated principally on the dominate measures of bending strength, thermal response qualities, weight, cost and stowage dimensions. While the scope of this program did not permit a conclusive detail design and cost analysis of individual candidate booms, each category of boom was assessed for general applicability and comparative efficiency. The various mechanisms evaluated included:

1. A swingout, hinged boom design
2. Extendible tubular booms such as the Spar Aerospace 'Bi-Stem', and Fairchild 'TEE's
3. The Astro-Research Corporation's self-erecting 'Astromast' linear lattice structure
4. Fairchild's erectible 'boxbeam'

6.1.1 SWINGOUT BOOM

The swingout boom design, shown in Figure 6-2, was evaluated as a relatively low cost approach, intended primarily for placing the experiment in an over-the-wing position. Because of the large area the retracted boom would require in the orbiter, and the potential interference with other experiments during deployment and retraction, this approach was discarded in favor of the more compact, linear extension booms.

6.1.2 EXTENDIBLE TUBULAR BOOMS

The extendible tubular type booms evaluated included the Spar Aerospace Products 'Bi-Stem' and the Fairchild Industries 'Tubular Extendible Elements' (TEE). Basically, this type of boom is a tubular structure, composed of one or more thin metal strips formed into a cylindrical shape which is stored by elastically flattening the material into a spool would tape. The boom is deployed by rotating the spools, extending the elastically restored material through a nozzle.

The 'Bi-Stem' is composed of two elastically flattened strips which form into diametrically opposed circular sections, one inside the other, as shown in Figure 6-3. Each tape circumscribes an angle of approximately 330°. While both strips are open cross section, they derive some buckling and shear resistance properties from the friction between their overlapping surfaces. Fairchild has evolved tubular (TEE) boom designs which appear to be suitable for this application. Four basic configurations have been developed.

1. The overlap sear (STEM type) whereinthe edges of the metal strip overlap from 80° to 160° in the tubular shape.

2. The edgelock type, which is similar to the overlap except that its edges are scalloped with alternate long and short tabs. When the flattened element forms into a tube, the short tab on one edge is tucked under the long tab of the opposite edge, resulting in a zippered seam which supplies increased torsional and buckling strength. This approach also appears to be available from Spar Aerospace.

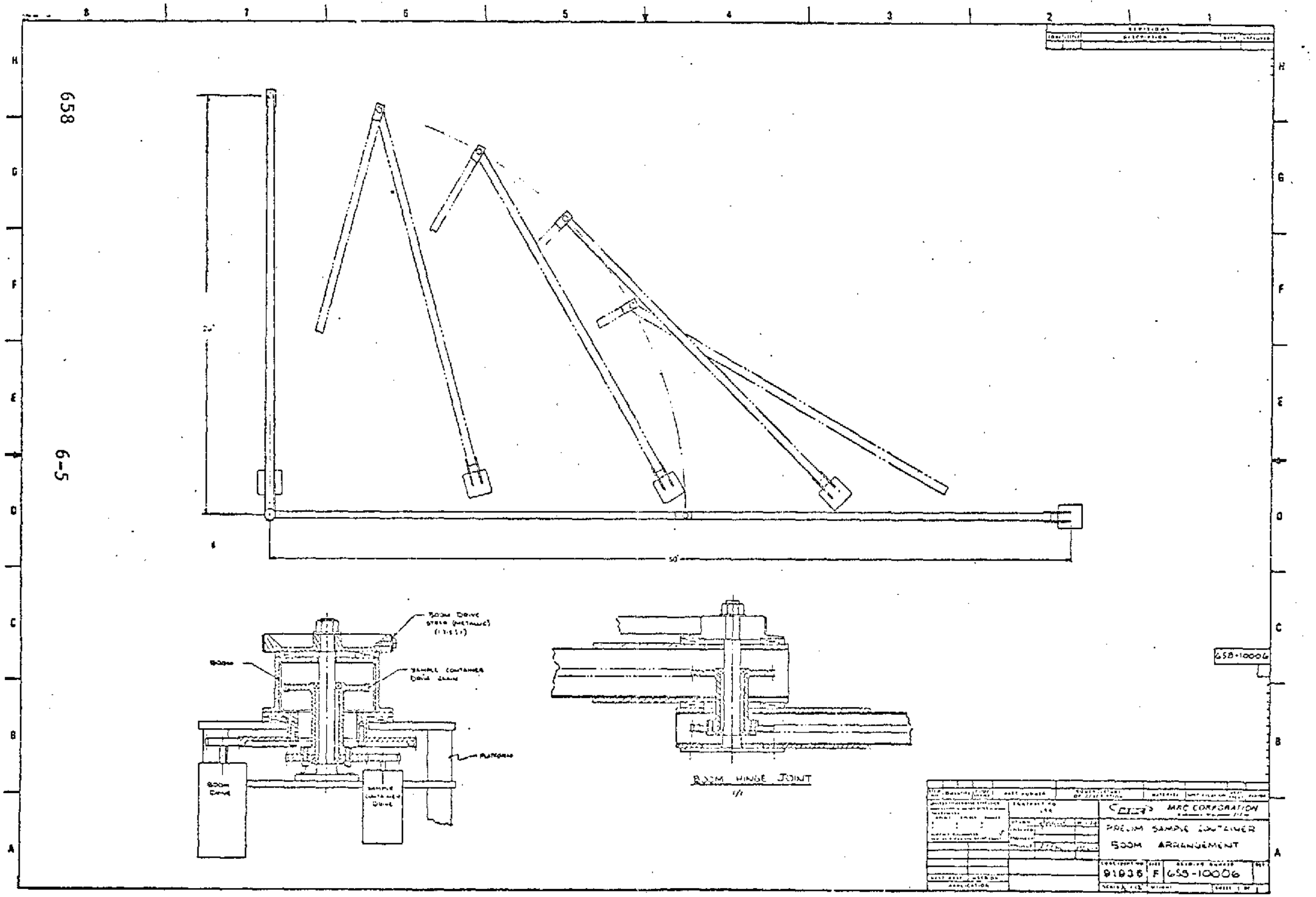


Figure 6-2. Swing Out Boom

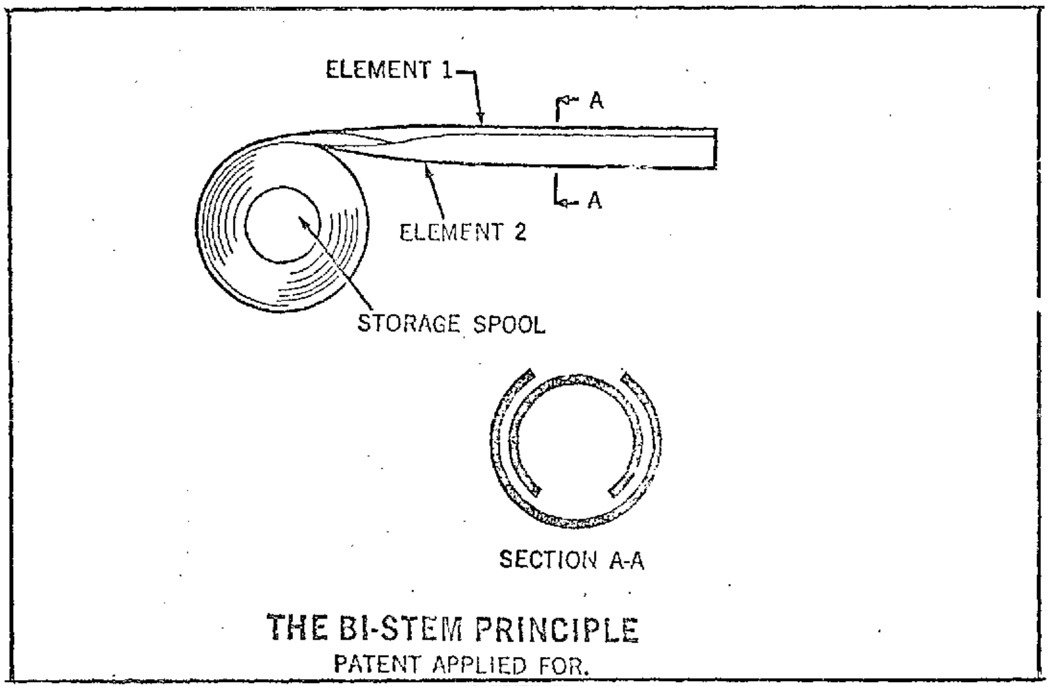


Figure 6-3. The Bi-Stem Principle

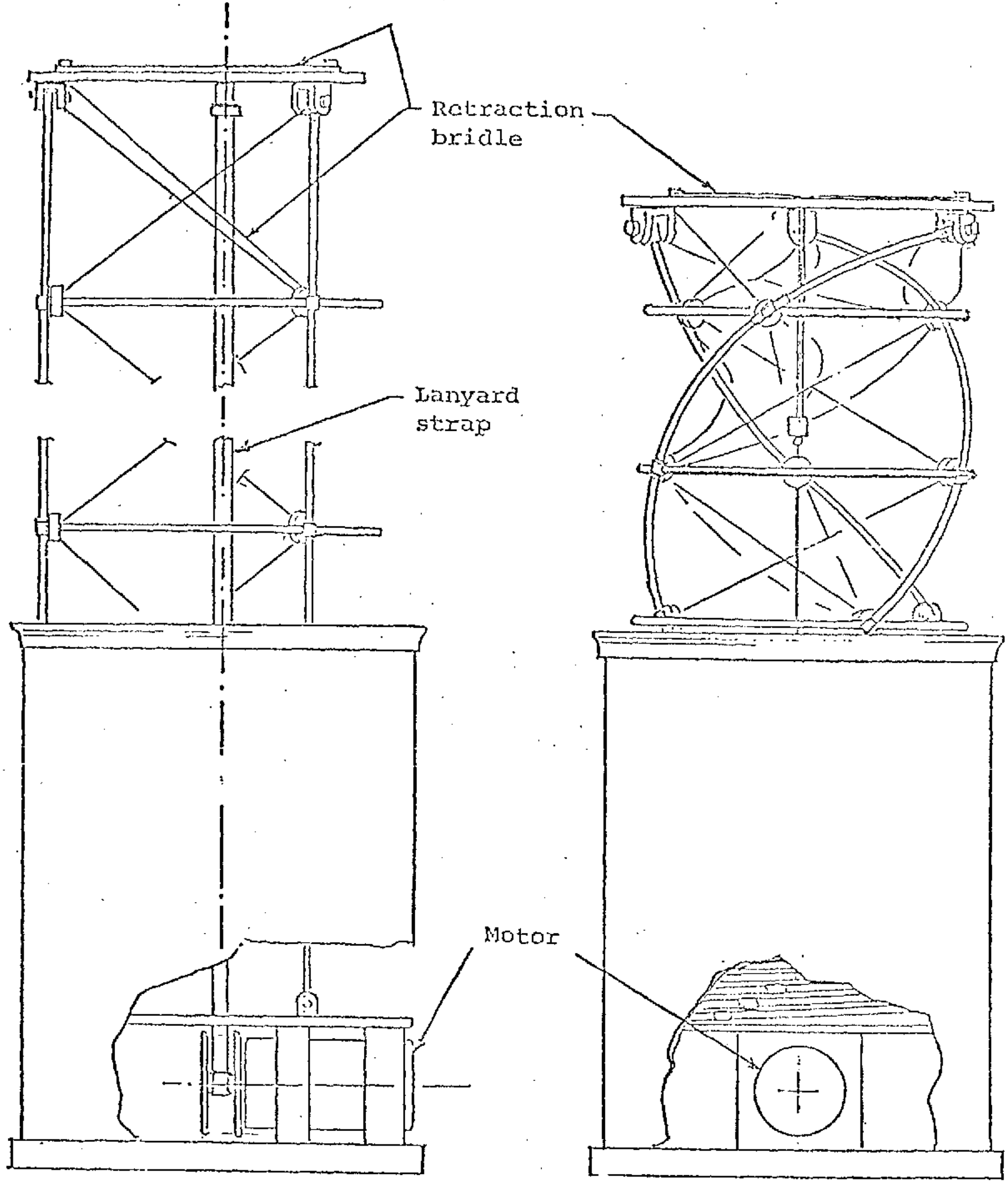
3. The hingelock type, which further improves the mechanical properties of the cylindrical boom. This boom is composed of two halves permanently joined along both edges in a tab-slot hinge line. This configuration is stored on a spool by flattening the two halves against each other, producing a stored width half as great as the original overlap. According to Fairchild, this boom has mechanical properties closely approaching those of a closed tube.

4. Twin Lobe type - Fairchild developed a twin lobe boom for the Skylab to transport a 125 lb. film cassette between the Apollo telescope mount and the airlock (approx. 30 ft.). This boom was designed in a twin lobe configuration (2 inch diameter lobes) to meet the bending moment requirements while maintaining a cross section which could be easily gripped by the astronaut. The twin lobe was capable of supporting a 2800 inch-lb ending load in its strong direction and 2100 inch-lb bending moment in its weak direction.

Thermal response qualities of the Twin Lobe boom is achieved by the combined use of thermal coatings and perforation. The boom has a polished, highly reflective outer surface and a coated, flat black interior. The walls are perforated to allow some of the thermal energy to pass through the sun side and be absorbed by the far side. The near side outer surface being reflective and the far side inner wall being absorbant, as well as the material being a very good thermal conductor, has reportedly achieved temperature gradients on one-inch-diameter booms down to as small as 1° C between the sun side and the dark side. Fairchild indicates that maintaining boom straightness in the space environment to within ±5° is within their capabilities.

6.1.3 LINEAR LATTICE BOOMS (ASTROMAST)

The lattice boom is a remote deployable structure which has a high strength to-weight ratio. It has been developed by Astro Research Corporation and is known as Astromast, Figure 6-4.



Lanyard Deployed 10-Inch Diameter Astromast in Fully (Left) and Partially (Right) Deployed Configuration

Figure 6-4. Astromast

The patented ASTROMAST tower is made of high-strength, corrosion-resistant parts throughout. It comes in four sizes from the 15-inch diameter A-15000 Series to the 34-inch diameter A-34000 Series, and in heights to 300 feet. When folded it measures only three to five percent of its deployed height. During erection of the Astromast tower you merely pay out the guylines under tension from the central mast area, thereby eliminating complex and time-consuming step-by-step guyline securing and tensioning procedures often necessary with other types of portable towers.

6.1.4 BOXBEAM

A new boxbeam concept has been developed by Fairchild. This is a recent development which may contribute to extendible member technology but was not considered in any depth for this study since it is in the early development stage.

6.2 MANUAL DEPLOYMENT

The use of extra vehiclar activity (EVA) for deployment of the polymeric materials experiment package requires identification of certain assumptions.

1. EVA capability is available to payload.
2. The time frame of availability is comparable to the times blocked out for initial deployment in the first cut ATL-1 flight plan.
3. The ATL pallet configuration includes translation and restraint points and possibly life support junctions.
4. The full potential of the 2 man, 6 hour, EVA capability is utilized.

Using these assumptions, it is expected that EVA performance will be enhanced beyond that demonstrated by the unscheduled installation of thermal shields on the Skylab mission. The following scenario is used to describe the potential use of EVA for experiment deployment:

The polymeric materials experiment has been designed and built as a sealed dish which is quick-coupled to a pole similar to the poles holding the twin-pole sun shade assembly used on Skylab, Figure 6-5. The experiment container itself is structurally mounted on the pallet with launch restraint clamps. The several sections of extension boom are mounted in close proximity and the boom mounting joint is built into the container launch restraint, Figure 6-6.

Upon reach this experiment location, the astronaut performs a visual inspection to ascertain any effects of the launch acceleration. Noting that all appears well, the astronaut actuates the restraining position. Permanently mounted to the container is a short section of boom complete with quick-couple. The first boom section is placed in the boom mounting joint, Figure 6-6), (a), latched and extended, Figure 6-6 (b), and the additional sections are quick coupled and extended, Figure 6-6 (c).

Opening of the container and exposing it to sunlight is accomplished by any one of several techniques. The major sealing clamps are incorporated into the launch restraints so that operation of the container outside of the launch restraints requires minimal force.

This force is applied either with a lanyard arrangement or by the astronaut manually going to the position and providing the opening force. An alternate approach would be to open the container as soon as it is mounted on the initial boom section and before moving it to its exposure position.

In this scenario the astronaut has applied the activation forces for: releasing a number of launch restraints; positioning the experiment; and exposing the experiment samples. Time required for the operation after the initial position has been reached is on the order of 20 minutes. Time required for retrieval and stowage would be on the order of 30 minutes. The cost of the operation must be compared against the cost of developing automatic equipment for accomplishing these functions.

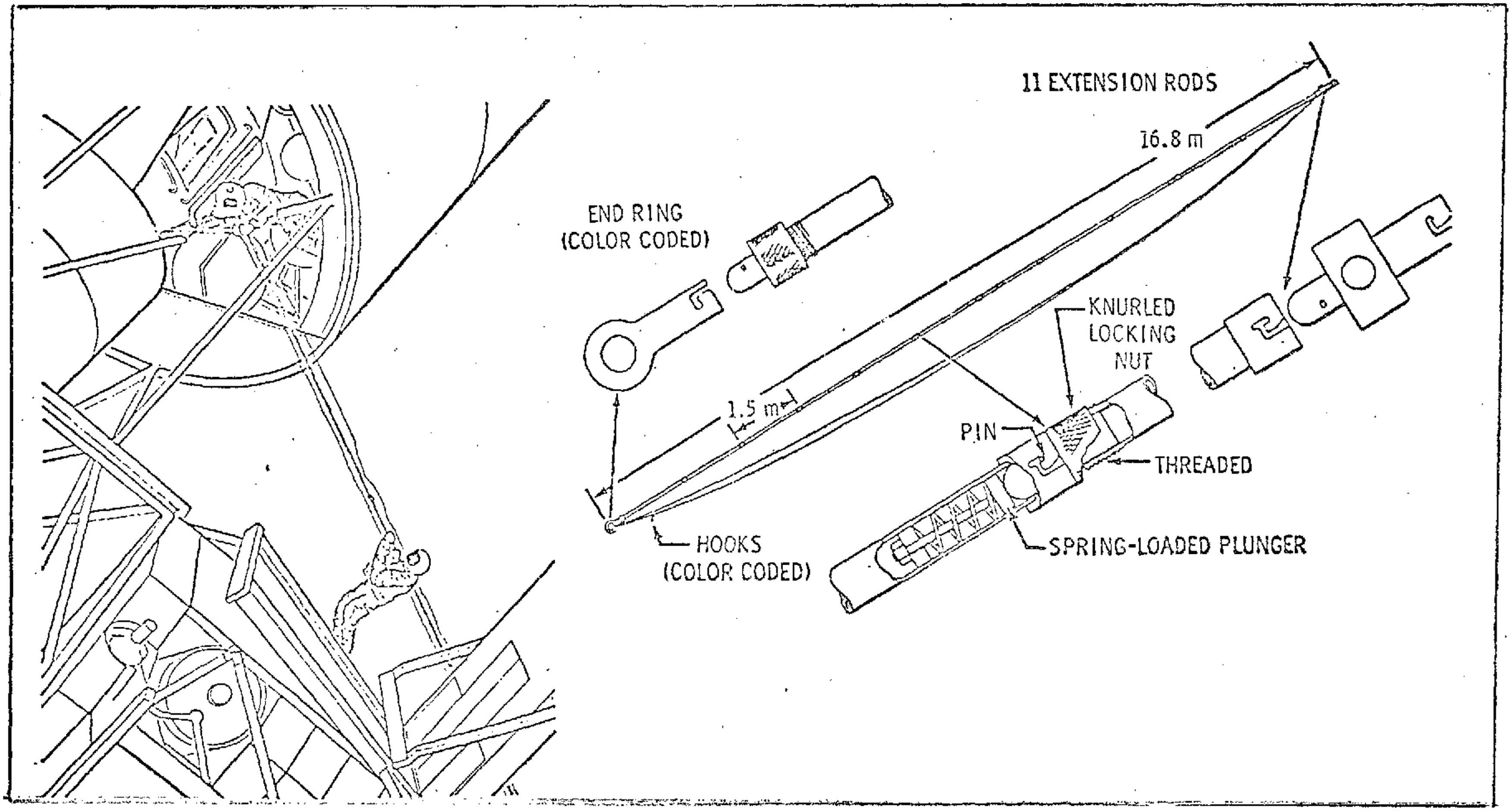


Figure 6-5. Skylab Pole Deployment

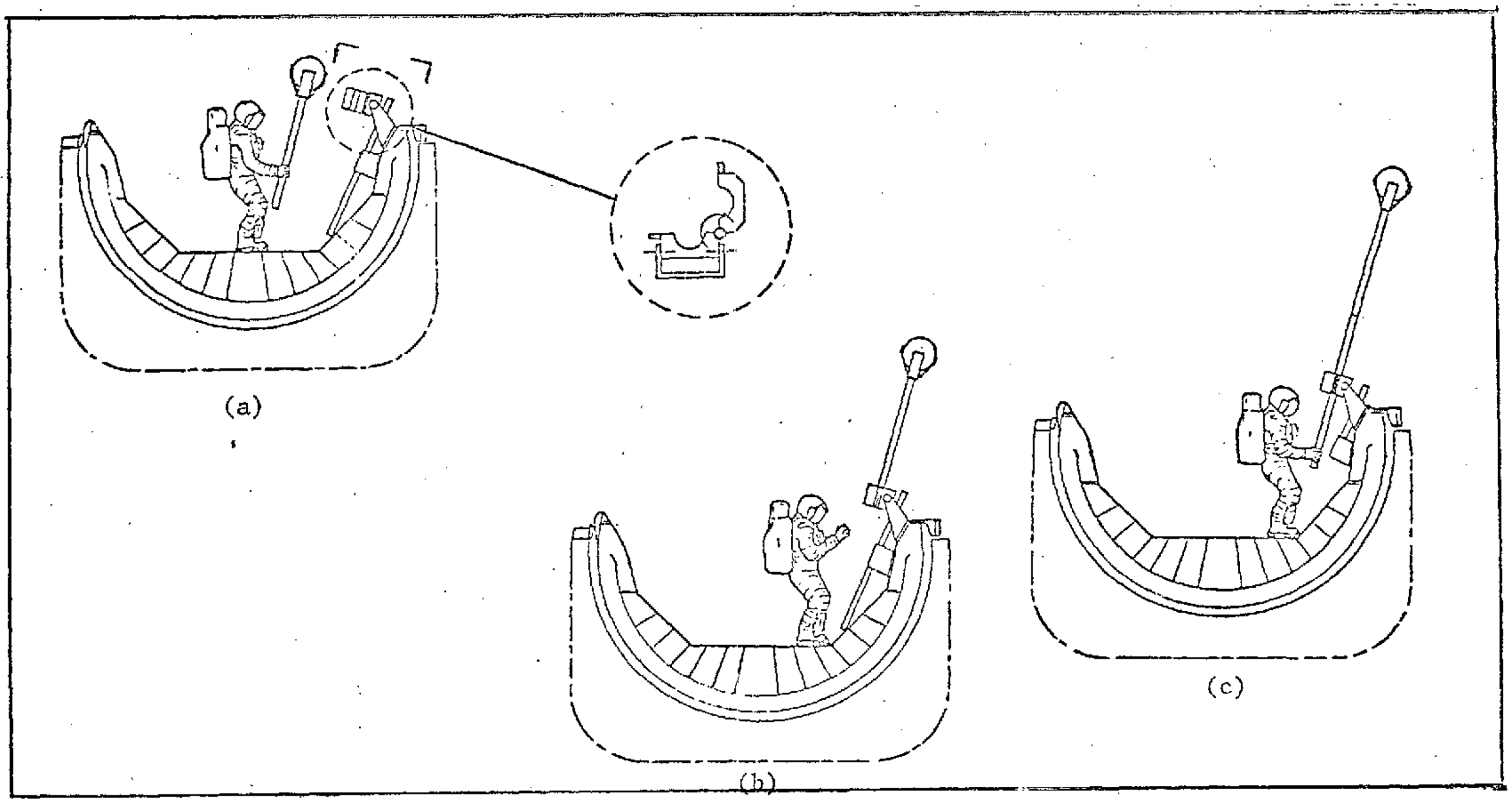


Figure 6-6. Manual Deployment

6.3 SELECTED TECHNIQUE

Table 6-1, Deployment Booms Analysis, compares the major characterustucs if the booms considered in this study. Figure 6-7, Deployment (development cost), is an educated guess of the cost vs deployment distance. The 30 meter deployment distance selected for this experiment in Section 5 of this report would be most reliably accomplished by a tubular type boom. A major weakness of tubular booms, thermal distortion, is not a major problem for this experiment.

Astronaut EVA participation in ATL operations is not well defined but could provide a cost saving especially as greater deployment distances are required.

Astronaut generated contamination will add to an already serious problem. However, deployment of this experiment to its functional position (extended from the spacecraft) prior to exposure of the experiment samples as shown in Figure 6-6, Manual Deployment, will minimize the problem. This astronaut generated contamination will be localized in the payload bay and will dissapate along with other contamination. However, until further definition of missions and astronaut participation, manual deployment cannot be recommended.

It is recommended that the optimum hardware for deployment of the Polymeric Materials Experiment is a remote deployable tubular boom.

TABLE 6-1. DEPLOYMENT BOOMS ANALYSIS

	PAST SPACE USE	STORED VOLUME	ACTUATION VOLUME	THERMAL DISTORTION	DEVELOPMENT COST 30 METERS
REMOTE					
SWINGOUT	SOME	MAX	MAX	HIGH	INTERMEDIATE
TUBULAR	MANY	MIN	MIN	HIGH	INTERMEDIATE
LATTICE	PROTOTYPES	INTERMEDIATE	MIN	LOW	HIGH
BOXBEAM	NONE	INTERMEDIATE	MIN	LOW	HIGH
MANUAL					
TUBULAR	NONE*	MAX	MIN	HIGH	LOW

*SKYLAB USED SIMILAR CONCEPT

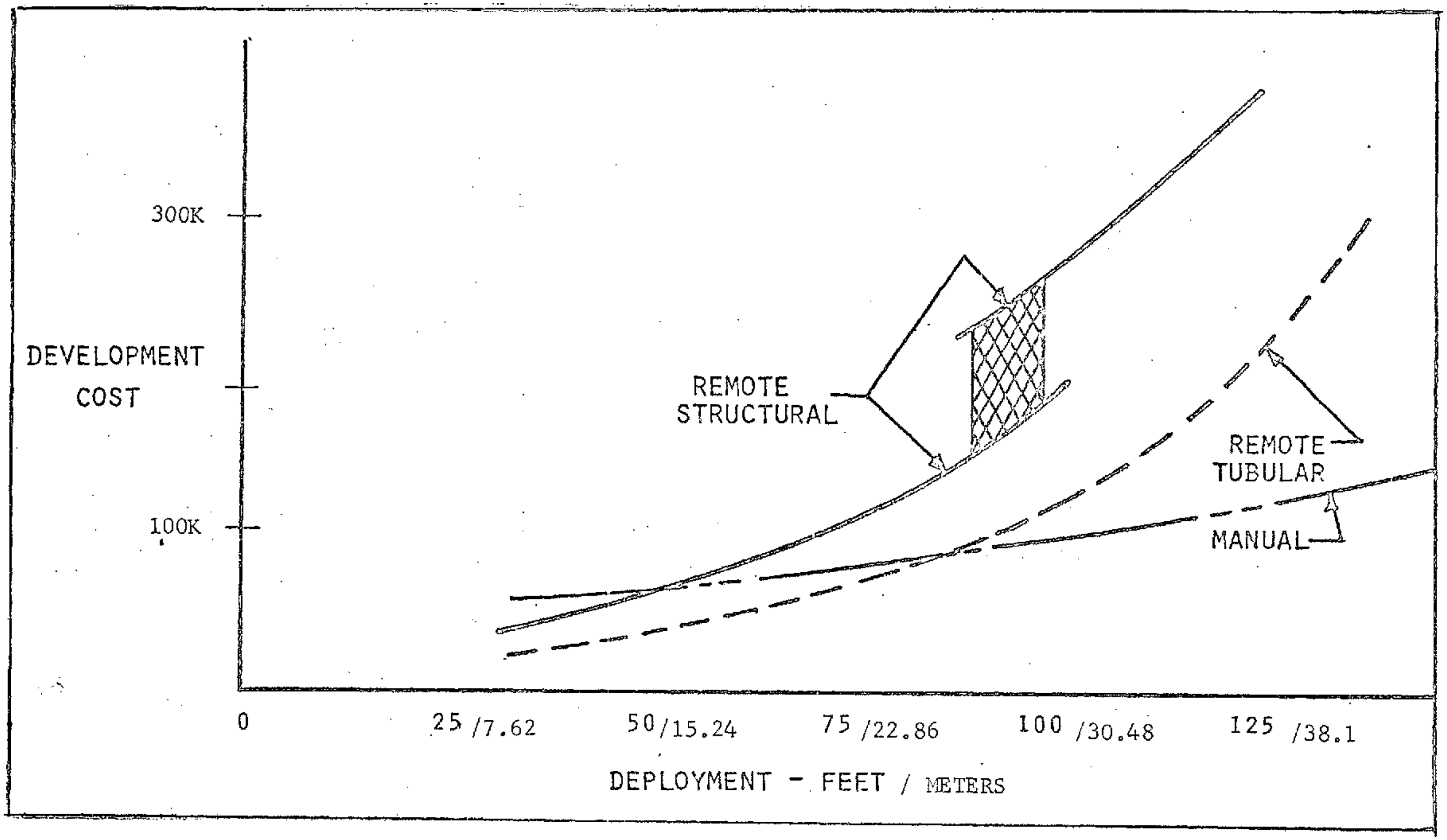


Figure 6-7. Deployment (Delopment Cost)

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Section 7

RECOMMENDATIONS

7.0 GENERAL

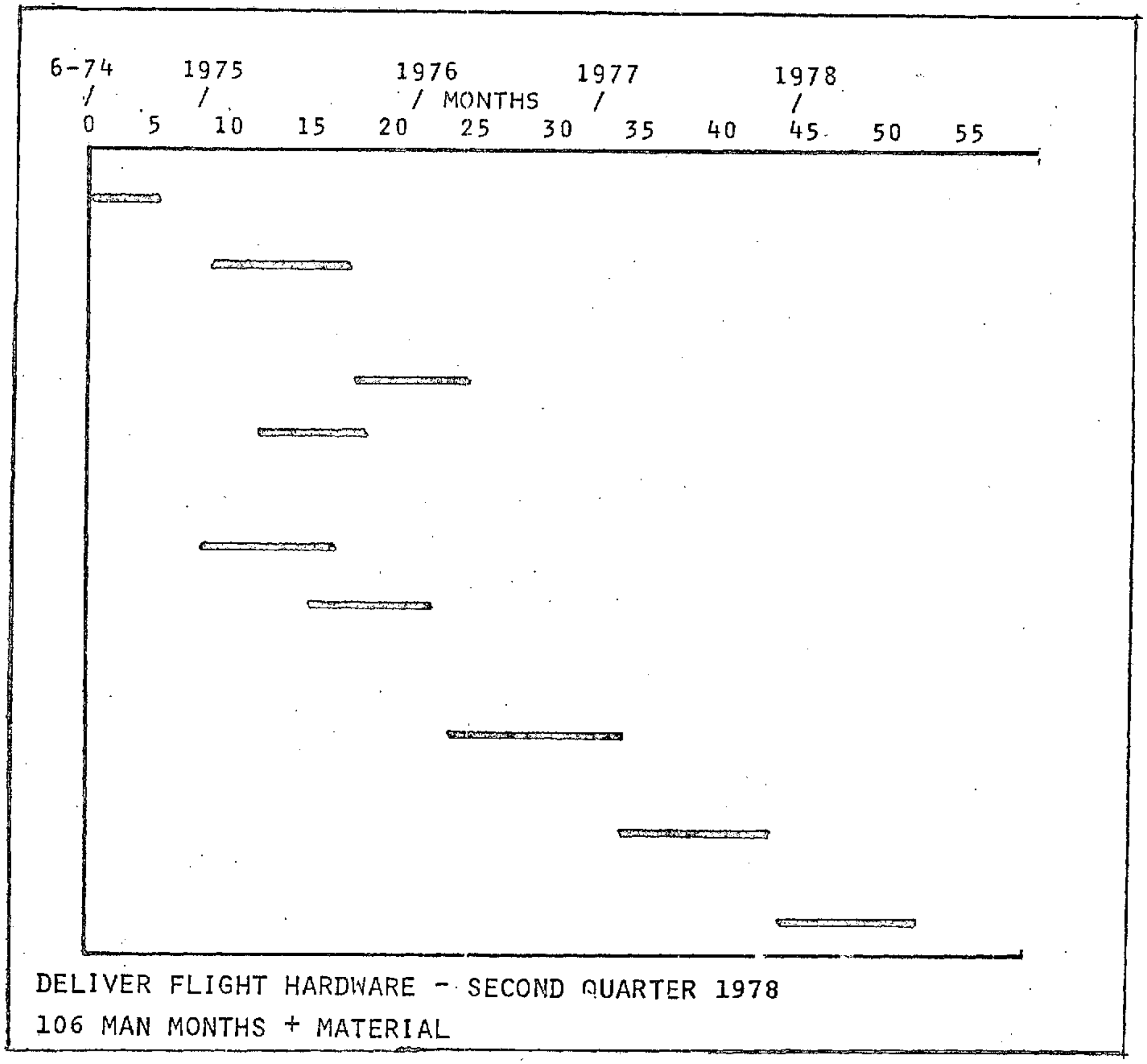
The preliminary design study of the polymeric materials experiment included investigations into the flight characteristics, the overall logistics of the experiment, and experiment hardware designs. In some cases, such as the experiment container and the vacuum system the preliminary design of the equipment is relatively free of the flight requirements. In other cases, such as the deployment mechanisms, additional information would be required of the orbiter and the flight prior to a preliminary design definition. Consequently this study has identified the design considerations and performed preliminary designs where possible. Our recommendations fall into two categories; recommendations concerning the experiment and general recommendations for the ATL flight.

7.1 POLYMERIC MATERIALS EXPERIMENT RECOMMENDATIONS

A program plan Figure 7-1 has been formulated to identify the experiment requirements and a level of effort to accomplish those requirements in the required time period. We recommend that this program be implemented in a timely fashion.

During the course of this contract it was determined that the contamination levels associated with the shuttle orbiter may be higher than originally anticipated. It is recommended that the polymeric materials experiment establish a contamination tolerance level which can then be matched against the orbiter contamination profile.

The shuttle orbiter reaction control system is one of the major contamination sources. In order to provide a protection against comtamination from this source it is recommended that consideration be given to



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106 MAN MONTHS + MATERIAL

Figure 7-1. Proposed Program Plan

closing the experiment container during maneuvers requiring the reaction control system.

7.2 ADVANCED TECHNOLOGY LABORATORY RECOMMENDATIONS

During the course of this study Advanced Technology Laboratory documents were referenced in order to provide a baseline for this experiment. The following recommendations would provide additional data which could be used to make a more complete design study.

There are extensive compatibility studies underway of the various shuttle payloads.

These studies are generally directed to the scientific value and requirements of the individual experiments and sometimes suffer from the lack of knowledge of the mechanical operation and properties of the experiment hardware. Similarily, a preliminary design study, such as this effort, suffers from a lack of knowledge of properties of adjoining experiments. Integration of such a group of experiments requires knowledge in both areas. A heuristic approach is recommended for experiment development. Studies, such as this effort, should be brought to the attention of the group conducting compatibility studies and conversely, the compatibility studies (1st iterations) should be made available to the experiment designers at the earliest possible date. Only in this fashion can true compatibility be achieved.

EVA participation is a case in point. Current studies of EVA identify a general astronaut availability and usefulness relative to a percentage of experiments. The individual experimenter and the flight group must have more information in order to consider astronaut participation. A scenerio of a flight must be written and the individual experiment deployment and operation must be specified. Only then can a realistic evaluation be made of astronaut participation. It is recommended that such a study be undertaken for a potential ATL-1 flight as soon as information is available from mission studies.

Since several of the experiments on the ATL-1 flight are sensitive to the anticipated contamination levels of the orbiter, it is recommended that consideration be given to a study of active contamination control for ATL flights.

In considering abort for the polymeric materials experiment, it appeared that there were several experiments that would require separation from the spacecraft in an abort situation. It is therefore recommended that consideration be given to grouping these experiments in one structural section which could be separated from the remainder of the pallet in an abort situation.

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