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FINAL REPORT

for the

PLASMA PHYSICS AND ENVIRONMENTAL PERTURBATION LABORATORY

Volume I - EXECUTIVE SUMMARY

Prepared for

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ABSTRACT

This report describes the results of an eighteen-month study carried out to identify for NASA the controlled or active space physics and plasma physics experiments that can be performed from the space shuttle on sortie missions. We collected and analyzed potential experiment concepts, and derived requirements for an experiment facility. This type of laboratory appears to be extremely well-matched to the sortie missions capability, and a technically feasible facility can provide a base for an extensive and significant research program to be carried out during the 1980-1990 time period. The laboratory, known as the Plasma Physics and Environmental Perturbation Laboratory, or PPEPL, consists of a 33-foot pallet of instruments connected to a 25-foot pressurized control module. Two 50-meter booms, two subsatellites, a high power transmitter, a multipurpose accelerator array, a set of deployable canisters, and a gimbaled instrument platform are the primary systems deployed from the pallet. The pressurized module contains all the control and display equipment required to conduct the experiments,and life support and power subsystems. Missions are planned to last seven days, during which time, two to four scientists will perform the experiments from within the pressurized module. As many as four flights per year will be required for about ten years if all the experiments are to be completed. The laboratory design was largely based on approximately 180 experiment concepts received from scientists throughout the world in response to a questionnaire. In addition, the study group benefited from a number of reviews conducted with NASA-formed advisory panels, and many other members of the scientific community contributed ideas when invited talks were presented at several symposia.

THE PLASMA PHYSICS AND ENVIRONMENTAL PERTURBATION LABORATORY

I. INTRODUCTION

The present concept of the Plasma Physics and Environmental Perturbation Laboratory was developed with the widespread participation of the scientific community, and this extensive scientific input reflects the growing awareness of the need to carry out controlled experiments in the space plasma. In November of 1971 a questionnaire, together with a brief description of possible shuttle sortie mission capabilities, was circulated to 280 scientists in the United States and fifteen foreign countries. This solicitation yielded a large number of valuable responses, and to date letters describing more than a hundred and eighty experiment concepts in the PPEPL area have been received from scientists in the U. S. and elsewhere (Canada, England, France, Germany, Italy, the Netherlands, Sweden, Israel, Australia, New Zealand, Japan, and India).

II. STUDY OBJECTIVES

The primary objectives of this study as based on the statement of work are summarized below.

Study Objectives

- Development of the Plasma Physics and Environmental Perturbation Laboratory within current experiment area concepts, including conceptual designs for the laboratory, candidate layouts, and equipment.
- Definition of scientific instruments for experiments in experiment areas of the laboratory.
- Definition of payload complements for inclusion in early Shuttle sortie missions.
- Development of cost, schedule, and supporting research and technology (SRT) requirements for the laboratory.
- Design and fabricate a 1/50 scale model of the PPEPL.

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NASA plans for future manned Plasma Physics Environmental Perturbation Laboratory module

Throughout the study, the emphases noted below were used to form a guide and framework, and served as further objectives for the detailed work itself.

<u>Study Emphasis</u>

- Heavy emphasis on participation of the scientific community and heavy scientific liaison (MSFC/University Scientific Advisory Board, Working Groups, and questionnaire and letter contact).
- Generation of engineering data for RAM, SOAR, and Shuttle/Space Station studies, and maximum coordination with NASA, experiment investigators, related parallel on-going work (SOAR, RAM, Shuttle/Station studies), and OSS/OSMF planning for development of space physics experiments and technology.
- Maximum and effective translation of the Blue Book, LRC experiment program and requirements study, University of Maryland study, and other source experiment material information into the study work flow.
- Traceability of decision processes throughout sequential tasks.

III. RELATIONSHIP TO OTHER NASA EFFORTS

The information obtained from the initial questionnaire clearly indicated that a large number of experienced scientists are now seriously considering ways to carry out controlled experiments in the space plasma environment of the earth. The ideas for these studies first arose naturally when some early active experiments provided unplanned but invaluable information on cause and effect relations in the magnetosphere and ionosphere. For instance, the high altitude nuclear explosions of the early 60's gave new information on particle injection, wave generation, wave-particle pitch-angle scattering, and large-β effects, including turbulent diffusion. The Alouette and ISIS RF sounding experiments opened new fields involving wave resonances, wave-particle heating, wave-wave interactions, and parametric instabilities.

Similarly, the triggering of magnetospheric emissions by ground-based VLF transmitters suggests an obvious generalization to a controlled satellite-borne, wave-particle interaction study. In recent years, there has also been an increasing emphasis on the implementation of carefully-designed active experiment programs using ground-based transmitters, sounding rockets, and unmanned spacecraft. For example, electron accelerators were flown to produce artificial auroras, to study beam-plasma instabilities, and to analyze trapped particle orbits. In addition, radio waves were used to modify the ionospheric characteristics and artificial tracers were used to study field line topology and particle drifts.

Because of this extensive background, most of the elements of a Plasma Physics and Environmental Perturbation Laboratory are in an advanced state of development, and it is suitable to conceive of PPEPL as a laboratory facility in which standardized diagnostic instruments and data processing modules are furnished as core equipment. It is intended that the prospective investigators will be able to carry out many experiments using only core equipment, but provision will be made for the integration of certain experiment-unique equipment as well.

IV. METHOD OF APPROACH AND PRINCIPAL ASSUMPTIONS

The responses to the November 1971 circular letter were first organized into eight general areas of scientific interest. These areas and specific subtopics for each general experiment area are designated in Table 1.

Table 1

PPEPL EXPERIMENT SUB-AREAS

WAVE CHARACTERISTICS: 35 EXPERIMENT CONCEPTS, INCLUDING STUDY OF:

Linear and non-linear dispersion relations, damping, growth, $\underset{\sim}{k}\cdot\underset{\sim}{B}$, $\underset{\sim}{k}\cdot\underset{\sim}{U}$ dependence,
Generalized Bernstein modes (ion and electron branches) using resonance techniques,
Parametric instabilities,
Long-delay echoes,
Non-linear effects and 3-wave interactions,
Generation of low frequency electromagnetic waves from within the plasma at ULF ($f < f_c^+$)
ELF ($f < f_p^+$) and VLF ($f < f_c^-$),
Wave packets in a dispersive medium.

WAVE-PARTICLE INTERACTIONS: 18 EXPERIMENT CONCEPTS, INCLUDING STUDY OF:

Cyclotron resonance instabilities, pitch angle diffusion, acceleration,
Turbulent resistivity,
Generation of electromagnetic waves by phased electron or proton gun arrays.

PROPULSION AND DEVICES: 22 EXPERIMENT CONCEPTS, INCLUDING STUDY OF:

Problems of Langmuir probes, Faraday cups, dc electric-field probes in space,
New techniques for measuring small plasma drifts (Doppler effects), dc electric fields,
other devices,
MPD arcs in large volumes,
Plasma beam-ambient plasma interactions, for ultimate propulsion applications.

MAGNETOSPHERIC MODIFICATION: 21 EXPERIMENT CONCEPTS, INCLUDING:

Radiation belt precipitation by changing wave growth rates,
Generation of high-power VLF waves to trigger precipitation events,
Ionospheric heating and spread F studies (parametric instabilities, RF heating),

PLASMA PHYSICS IN SPACE: 15 EXPERIMENT CONCEPTS, INCLUDING SEVERAL OF THE ABOVE, PLUS STUDIES OF:

Neutral gas-plasma beam interactions,
The generalized Ohm's law,
Levitron-type confinement devices (deployed magnet),
Motion and configuration of a spinning conducting fluid.

BEAM-PLASMA INTERACTIONS: 23 EXPERIMENT CONCEPTS, INCLUDING STUDY OF:

Beam instability and turbulence, return currents, neutralization, collisionless dissipation
and acceleration mechanisms,
Artificial auroras,
Response of the ionosphere to controlled fluxes of suprathermal particles, modification of
ionospheric conductivity,
Artificial mid-latitude SAR red arcs,
Models of solar flare radiation mechanisms, and mode-mode coupling.

ENERGETIC PARTICLES AND TRACERS: 20 EXPERIMENT CONCEPTS, INCLUDING STUDIES OF:

Field line topology,
Parallel and perpendicular electric field,
Charged particle orbits and life histories.

WAKE AND SHEATH: 29 EXPERIMENT CONCEPTS, INCLUDING STUDY OF:

Wake and sheath regions around known targets,
Validity of current theories (size, shape of perturbed region, potential distribution,
Cerenkov cones in wakes),
Stability of W-S regions: variation when body is biased. Effects of different surface
materials, body shapes,
Effects of W-S on antenna impedance, particle probes,
Generalized Terrella experiments with large magnets.

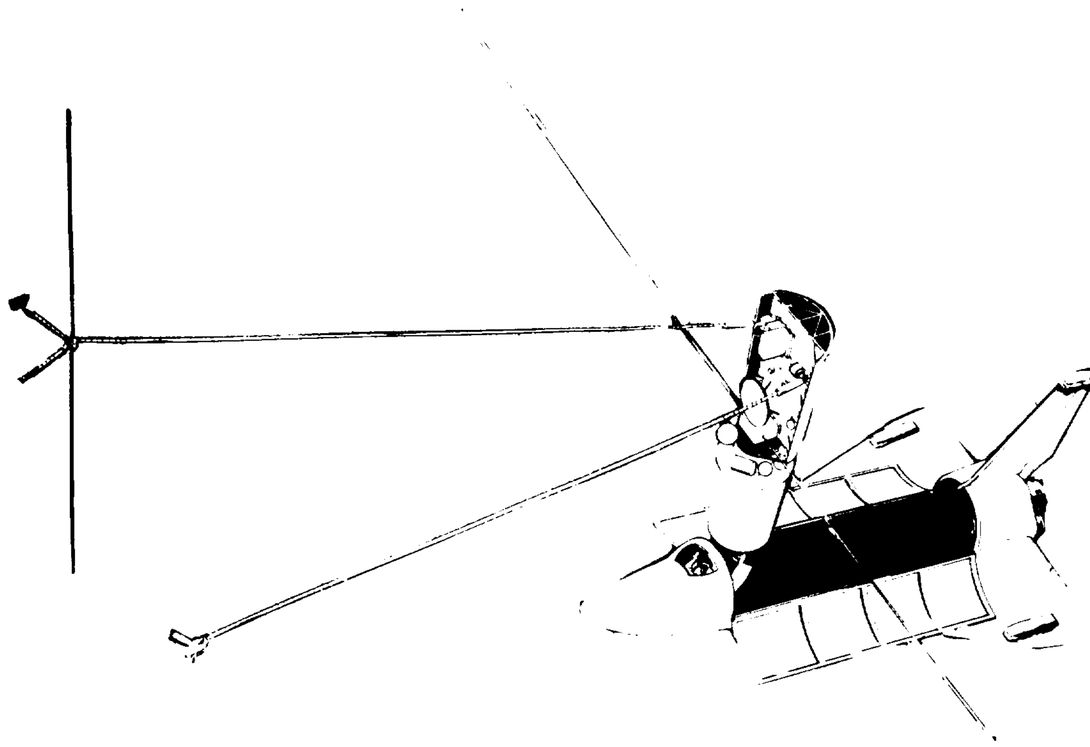
The initial responses from the scientific community outlined in Table 1 provided a very important technical baseline for development of preliminary PPEPL configuration concepts, instrumentation specifications, and other significant mission requirements. On May 8, 1972 a second circular letter was sent to all scientists who responded, and in many cases there were additional direct contacts to clarify technical points.

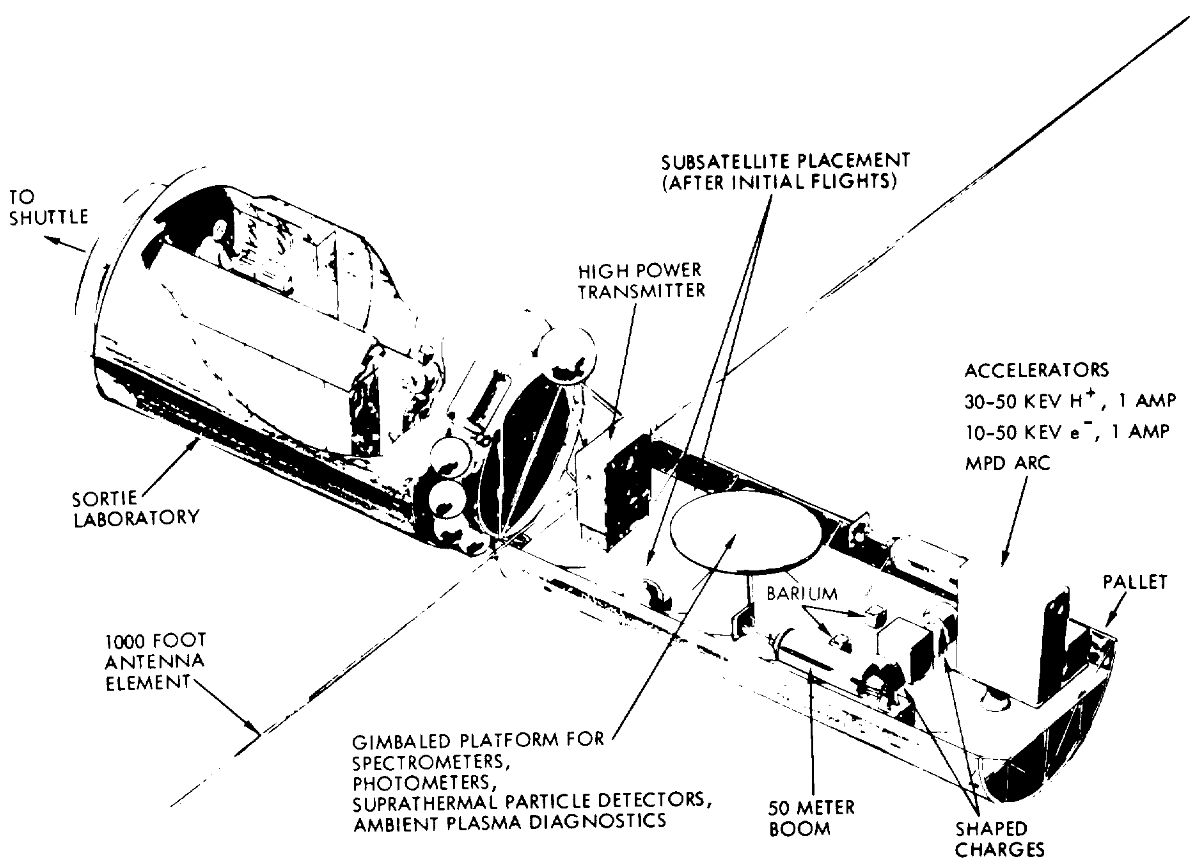
During the course of this study we also had continuous interactions with several NASA-formed advisory panels concerned with PPEPL and the sortie missions. Marshall Space Flight Center established a PPEPL Science Advisory Board (SAB), and three discipline-oriented working groups were formed by members of the SAB to examine certain problems in greater depth. The PPEPL concept was also discussed at meetings of the Atmospheric and Space Physics Working Group, a NASA Headquarters advisory body concerned with several possible future missions. Finally, the PPEPL concept was widely discussed at open scientific meetings. Invited talks on this topic were presented at the American Physical Society Meeting of the Plasma Physics Division (Monterey, California, November 1972); the AAAS Symposium on Space Shuttle Payloads (Washington, D. C., December 1972); the Spring Meeting of the American Geophysical Union (Washington, D. C., April 1973); and at the Seventh ESLAB Symposium (Saulgau, W. Germany, May 1973).

These discussions of the PPEPL program at the advisory panel meetings and at scientific symposia provided many additional informal suggestions for experiment concepts, and in several areas the material in Table 1 (taken from the original questionnaire) does not adequately document the depth or variety of science likely to be proposed for a flight program. For instance, in the Energetic Particle and Tracer area, the initial suggestions for release experiments involved release of Barium or Lithium to measure dc electric field distributions and to study particle entry into the magnetosphere. More recent suggestions, not listed in Table 1, include use of Helium releases to trace the Polar Wind, and release of electron acceptors (such as sulfur hexafluoride) to disrupt ionospheric currents so that magnetosphere-ionosphere coupling can be studied in a controlled way. Another example involves alternate uses for the magnetoplasma dynamic (MPD) arc proposed by the Princeton Group (experiment PD-16) for flight on PPEPL. The original experiment concept, in the Propulsion and Device area, was proposed so that a convection-free arc source could be tested in the unbounded space plasma; the propulsion capabilities could then be evaluated without concern about wall effects that always enter in ground-based laboratories. However it has been noted that this very high power device provides a unique capability as a plasma source for many other kinds of experiments, and we include the MPD arc as a baseline plasma accelerator for PPEPL. In general, we have tried to generalize the PPEPL concept to provide a facility capable of conducting many more experiments than the ones listed in Table 1.

V. BASIC DATA GENERATED AND SIGNIFICANT RESULTS

The Plasma Physics and Environmental Perturbation Laboratory concept described here [bottom of Figure 1] is housed in a fifteen-foot diameter twenty-five foot long pressurized version of the Sortie Lab. Attached to the end of this laboratory is a pallet thirty-three feet long and about twelve feet wide. The pallet is unpressurized, and during the experiment phase of the mission it is exposed directly to the ambient environment. It has been assumed that during this experiment time the Sortie Lab and its associated pallet are deployed





SUBSATELLITE PLACEMENT
(AFTER INITIAL FLIGHTS)
TO
SHUTTLE
HIGH POWER
TRANSMITTER
ACCELERATORS
30-50 KEV H+, 1 AMP
10-50 KEV e−, 1 AMP
MPD ARC
SORTIE
LABORATORY
BARIUM
PALLET
1000 FOOT
ANTENNA
ELEMENT
GIMBALED PLATFORM FOR
SPECTROMETERS,
PHOTOMETERS,
SUPRATHERMAL PARTICLE DETECTORS,
AMBIENT PLASMA DIAGNOSTICS
50 METER
BOOM
SHAPED
CHARGES

Figure 1

out of the shuttle bay to assume a position 90° [see top of Figure 1] to the shuttle bay while still attached to the shuttle. Although this deployment mode is extremely beneficial for PPEPL, it is not a mandatory requirement; it is possible to redesign the pallet package for the undeployed mode. The Sortie Lab is accessible to the shuttle through a pressurized tunnel, and the far end of the pallet is about fifty-eight feet above the shuttle bay in the deployed mode.

Near the far end of the pallet two 50-meter deployable booms which can be articulated are mounted. There is a gimbaled platform at the end of each boom, and instruments are mounted on each of these remote gimbaled platforms. These instruments include antennas, particle detectors, magnetometers, and other equipment to be used for many experiments, particularly those in the areas of wave-particle and beam-plasma interactions, wave characteristics, devices, and wake and sheath measurements.

Mounted on the far end of the pallet are high-power, electron-ion accelerators complete with power supply. The guns themselves are of several types, but it is contemplated that they will operate from a common power supply. On the opposite end of the pallet nearest the Sortie Lab is mounted a variable transmitter and power supply with associated dipole antenna. The dipole antenna may be extended to about 1000 feet per element once the PPEPL is deployed. [The Wave-Particle Interaction Working Group suggested that for high frequency wave experiments it might be desirable to include other types of antennas, such as dishes, on the pallet.]

About half-way between the antenna and the electron-ion beam guns, a gimbaled platform approximately eight feet in diameter is mounted. This gimbaled platform contains optical and particle detectors requiring pointing. These sensors are used for a number of experiments, especially those in the areas of beam-plasma interactions, magnetospheric modifications, and energetic particles and tracer experiments.

The pallet provides sufficient area to accommodate other experiment items. For example, cannisters containing lithium, barium, or other chemicals may be mounted on the pallet and ejected to carry out ionospheric wind studies, field line tracing, and electric field investigations. In a similar manner, cannisters containing inflatable "wake bodies" may also be ejected, as may maneuverable subsatellites (such as the Atmospheric Explorer). It can be seen that with the concept illustrated in Figure 1, considerable space for growth is provided.

Inside the pressurized Sortie Lab are located the control and display consoles for the instruments, booms, subsatellites, transmitters and receivers for the RF and VLF experiments, electron and ion beams. In addition, a computer, spectrum analyzers for near real time data evaluation, additional power supplies, general work areas, and recorders are also located in this module.

VI. STUDY LIMITATIONS

Study described herein originated with a study for a Plasma Physics and Environmental Perturbation Laboratory (PPEPL) solely devoted to research dealing with the earth's ionized medium. In July of 1973, the U. S. National Academy of Sciences conducted a general study on scientific uses of the space shuttle, and the participants discussed a single sortie lab facility that would combine the requirements of the scientists interested in PPEPL and the requirements of scientists concerned with remote sensing of the atmosphere between 30 and 120 km. In the summer of 1973, some shuttle-sortie lab engineering developments forced a second significant modification in the PPEPL planning; it became apparent that problems associated with shuttle landing weight limits and with center of gravity considerations would restrict the total sortie lab payload weight to about 32,000 pounds, and would restrict the payload bay volume available for the pressurized laboratory and pallet.

It appears that a combined sortie laboratory facility for the controlled space and plasma physics experiment area and for the atmospheric science area can readily be configured to fit within the revised shuttle guidelines.

The atmospheric physics requirements do, however, involve a significant expansion of the remote sensing capability planned for the pallet mounted gimbaled platform to include

- High resolution airglow observations
- Measurement of vertical distributions of constituents
- Lidar probing of lower atmosphere
- Measurement of light absorption using subsatellite.

The top part of Figure 2 shows a tentative sortie mission configuration that provides a suitable location for the center of gravity, assuming that all instrumentation is uniformly distributed within the lab module and on the pallet. Immediately behind the orbiter cabin there is a docking module (DM), and this is followed by a transfer tunnel to a small pressurized module. The pallet shown here is almost the size of the original one depicted in Figure 1 and for a seven-day mission 12,000-13,000 pounds of scientific instruments and subsystems can be mounted on the pallet and within the pressurized module (this weight allocation is for scientific instrumentation; basic subsystems for life support, power, thermal control, and some data handling and communication are furnished with the baseline support module and pallet).

The bottom part of Figure 2 shows a very preliminary layout for a possille combine Atmospheric, Space and Plasma Physics Facility, consistent with the dimensions given at the top of the figure. In order to accommodate the Lidar system and the more elaborate remote sensing unit, power supplies are mounted below the pallet surface. A subsatellite similar to the Atmospheric Explorer is shown beside the accelerator, and the undesigned Lidar system is simply represented as a

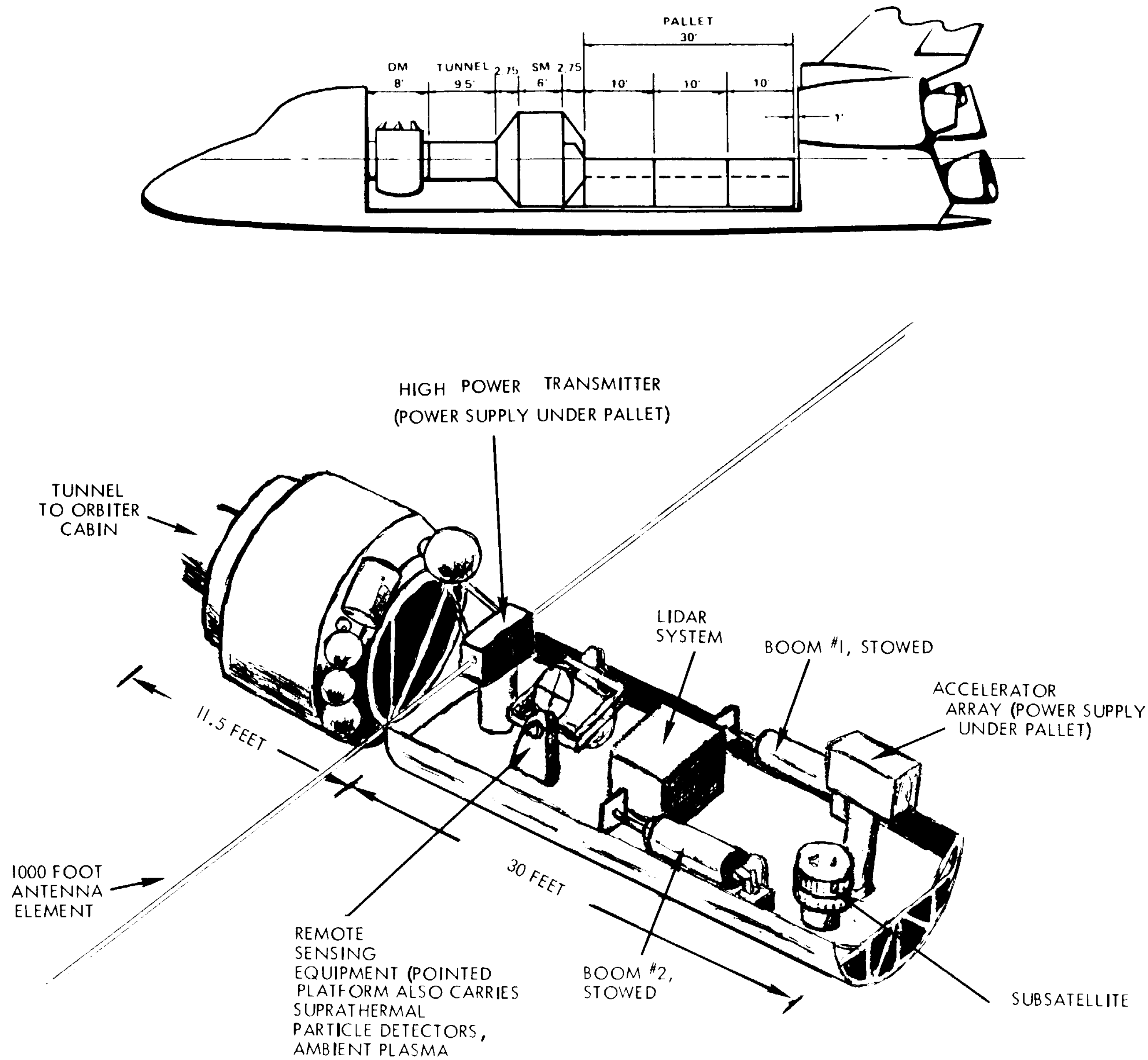

PALLET
30'
DM
8'
TUNNEL
9.5'
2.75
SM
6'
2.75
10'
10'
10
1'
HIGH POWER TRANSMITTER
(POWER SUPPLY UNDER PALLET)
TUNNEL
TO ORBITER
CABIN
LIDAR
SYSTEM
BOOM #1, STOWED
ACCELERATOR
ARRAY (POWER SUPPLY
UNDER PALLET)
11.5 FEET
30 FEET
1000 FOOT
ANTENNA
ELEMENT
REMOTE
SENSING
EQUIPMENT (POINTED
PLATFORM ALSO CARRIES
SUPRATHERMAL
PARTICLE DETECTORS,
AMBIENT PLASMA
DIAGNOSTICS)
BOOM #2,
STOWED
SUBSATELLITE

Figure 2

large package with no specific features. The remote sensing system shown here is based on the preliminary design of the Main Instrument Cluster and Gimbal unit studied by Martin Marietta in their analysis of an Atmospheric Science Facility. This unit is approximately 10 feet across, 8 feet wide, and 8 feet high. The additional support requirements for the atmospheric instrumentation is summarized in Table 2.

Table 2

Optical Instrumentation

PPEPL Planned

- Gimbaled Platform
- TV System
- Photometer Bank
- Camera

Additional for Atmospheric Observations

- Lidar (phased array)
- XUV Normal Incidence Spectrometer
- UV-VIS-NIR Normal Incidence Spectrometer
- Hi-resolution Fourier SWIR Spectrometer
- Cryo IR Fourier Spectrometer
- IR Radiometer
- Fabry-Perot Interferometer

Weight:	580 kg + Mount	Pointing:	$\pm 0.02°$
Power:	345 W	Data:	2×10^6 + ? bps

If the pallet is not to be deployed out of the payload bay, there must be some way to move the high voltage units (transmitter and accelerator array) away from the shuttle itself. A very preliminary and simple scheme is indicated in Figure 2. The high voltage units are mounted on pedestals that can be extended to obtain adequate clearance.

The increased display and control requirements coupled to a smaller available pressurized module make mandatory the requirement for developing a method of increasing the interior space utilization efficiency. One such method is depicted in Figure 3 in which the control and display equipment is located radially around the module walls. Two chairs, mounted on separate longitudinal poles or columns would be indivudually controlled by the on board scientists. Such an arrangement would provide for more efficient utilization of the reduced volume available but integration and test procedures on the ground would be more difficult.

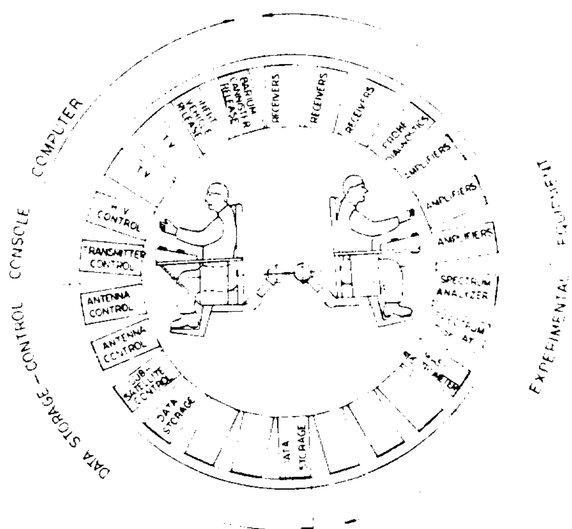


Figure 3. Cross Section of Pressurized Module Equipment Layout

It should be evident that no detailed technical analysis of the combined Atmospheric, Space and Plasma Physics Laboratory has yet been carried out; however, the initial evaluation does suggest that it will be feasible to design a combined facility that is entirely compatible with the new shuttle sortie mission restrictions.

VII. IMPLICATIONS FOR RESEARCH

The original grouping of experiment concepts into the eight areas of Table 1 was motivated by the need to define instrumentation requirements so that commonality studies could be conducted. However, from a broader point of view, a more suitable grouping involves the science objective, rather than the experimental techniques. From this viewpoint, we would classify the suggested science into the two broad but overlapping disciplines of space physics and plasma physics.

The most significant space physics experiment concepts involve natural follow-ons to the present phase of magnetospheric-ionospheric exploration based on use of unmanned spacecraft. It seems to be widely recognized that after the completion of the International Magnetosphere Study (1976-1978), the major dynamical phenomena that occur in nature will have been classified, and there will be general knowledge of where and when important events take place. For the decade of the eighties, many scientists now appear to feel that the field will be ripe for a new stage of research, in which the primary objective will be to understand the detailed mechanisms and the physical interactions which bring about the observed dynamical phenomena. Many controlled experiments in the Energetic Particles and Tracers area are designed to provide unambiguous answers about magnetospheric configuration, particle entry, relative energization and loss processes, distributions of electric fields, and magnetospheric convection. A number of experiments in the Beam-Plasma and Wave-Particle Interaction areas are designed to study basic magnetospheric plasma instabilities that can limit the stably-trapped flux, provide the wave-particle scattering that leads to anomalous resistance (and hence parallel electric fields), modulate auroral phenomena, and introduce coherence effects into magnetospheric radiation processes. Other experiments in these areas, and in the Magnetospheric Modification area, are aimed at studying the mechanisms that drive large scale dynamical processes (coherence effects in auroras, triggering of substorms, energy transfer in red arcs, magnetosphere-ionosphere coupling) by introducing major controlled perturbations that can generate the phenomena in a known way (e.g., the artificial aurora), or can vary the natural process (e.g., by modifying ionospheric conductivity, injecting waves to scatter particles, injecting cold plasma to modify instability growth rates).

The Shuttle sortie missions also provide a unique opportunity to investigate fundamental and applied plasma physics phenomena that are not necessarily or specifically related to geophysical problems. All the Shuttle orbits are immersed within a natural, magnetically-confined plasma in a high vacuum, with scale lengths that can be enormous in comparison with those available in ground-based plasma laboratories. It is possible to investigate important phenomena free of the sometimes dominant influence of walls. The weightless orbital conditions can be extremely important to the potential experimenter who may wish to study such diverse phenomena as long-term plasma confinement in a field produced by a levitated magnet, the interaction of a spinning conducting fluid with the ambient geomagnetic field and plasma, or the behavior of convection-free plasma arcs; in the ground-based laboratory all of these studies would be strongly affected by gravity.

In some general areas it appears that the availability of one or more of these unique space laboratory conditions is of vital importance. For instance, some information on low frequency electromagnetic wave modes in a magnetized plasma (whistlers) can be obtained in a ground-based laboratory, but the conventional experiment is generally restricted to near-field analysis for the specific wave modes allowed in the fixed and finite plasma chamber. Because of this, it is not possible to study the complete warm plasma dispersion relations or generalized radiation processes and wave-wave coupling effects in the ground-based laboratory. In some cases the finite chamber size restrictions limit the accessible interactions and preclude study of basic plasma phenomena that are known to occur in nature. For instance, while it may be stated that non-linear beam-plasma interactions have frequently been studied in ground-based laboratories, the finite scale size dictated by laboratory chambers means that the short wavelength electrostatic waves play a predominant role in these experiments. However, the various beam-plasma dissipation processes that occur in nature appear to give rise to intense electromagnetic radiation fields (auroral hiss, solar radio bursts, Jovian decametric radiation, pulsars, etc.), and these mechanisms cannot be studied adequately in small plasma chambers.

In the plasma physics area, the sortie laboratory missions can also provide the scientific community with significant opportunities to carry out short-term experiments involving development and test of new diagnostic devices and investigation of new techniques for plasma propulsion. Long-standing questions involving the plasma physics of the wake and sheath and the behavior of various probes in earth orbit can be studied.

Our analysis of the response from the scientific community suggests that the Shuttle sortie mission capabilities are very well matched to the needs in the space physics and plasma physics area for a meaningful experimental program to be conducted in the eighties. The region outside of the shuttle is a natural plasma laboratory (collisionless at the higher shuttle altitudes over the poles, and collision-dominated at lower shuttle altitudes nearer to the equator). The scientists on-board can conduct true, controlled experiments from within the pressurized sortie lab chamber, because the shuttle weight and power capabilities will allow massive and high power perturbation sources to be carried. The polar shuttle orbits also traverse directly the important auroral and ionosphere-magnetosphere coupling regions of prime interest to space scientists.

The present NASA planning for sortie missions is based on the concept that selected scientists will receive moderate flight training (2 to 3-months duration) so that two to four experimenters will actually ride on each sortie mission to conduct their own experiments. The presence of man in the laboratory will make it possible to carry out true experiments rather than data-gathering exercises based on use of inflexible automated rocket or satellite payloads. Moreover, the fully-equipped laboratory facility will provide much more comprehensive information than any series of rocket launches, but the experiment costs can be kept low with use of the facility concept and with the relatively short duration of the mission.

Although the science objectives in the plasma physics and geophysics disciplines are somewhat different, our analysis of the proposed experiment concepts suggests that a single shuttle laboratory can be designed to satisfy the needs of both groups of scientists. Moreover, it appears that the science requirements in these areas lead naturally to the concept of a fully-instrumented laboratory because most of the proposed experiments will have to utilize

60-75 percent of the full PPEPL instrument complement in order to achieve the desired objectives. The facility concept is also especially appropriate for PPEPL because technical problems will be encountered in developing and integrating several high voltage systems, controlling spacecraft interference, etc. Thus, it is appropriate to design a preliminary PPEPL configuration based on the assumption that a dedicated pallet will be available.

The science requirements, as presently visualized, can generally be satisfied by a facility with the following features:

a) Complete diagnostics for thermal plasma distributions and plasma wave spectra.

b) Two 50-meter booms; one or more subsatellites for remote mounting of instruments.

c) Photometer array and other directional instruments on gimbaled platform with accurate pointing.

d) Standardized accelerators

30-50 keV protons, up to one ampere

10-50 keV electrons, up to one ampere

5-20 eV electron gun

High power MPD plasma accelerator.

e) High powered transmitters (routine for $f \gtrsim 10^5$ Hz; carefully tested in-flight for $f < 10^5$ Hz) 1000' dipole elements; electrostatic wave generators.

f) Lower power transmitters for VLF and below.

g) Shaped charges, barium canisters, other releases.

Although a number of scientists proposed experiments that would require cryogenic systems on PPEPL, it was decided to defer implementation of these requests for the present, and we do not include provision for large superconducting magnets, etc. in the baseline PPEPL design for early flights. The remaining sections of this report describe a baseline PPEPL module capable of carrying out almost all of the proposed science. However, it should be kept in mind that the Sortie Lab missions will have to be supplemented by use of other observing platforms (e.g., ground-based rockets, unmanned spacecraft in orbits such as synchronous) if the full science benefits of PPEPL are to be realized.

VIII. SUGGESTED ADDITIONAL EFFORT

Some significant technical problems will have to be studied in the next few years in order to develop a successful Plasma Physics and Environmental Perturbation Laboratory facility. The important problem areas that need attention are the following: electromagnetic interference: general conducted and radiated interference control and potential problems associated with pulsing of high-powered transmitters and accelerators; outgassing and contamination; cooling of high voltage supplies; reflected light problems, particularly from deployed booms and antennas; accelerators: space charge forces, stable neutralization, purity of proton beam, cathode contamination by outgassing, electrostatic and magnetic "contamination" for the low energy gun; and cabling in booms.