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SOLAR TERRESTRIAL AND PLASMA PROCESSES EXPERIMENTS ON SPACE STATION

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ABSTRACT

This paper outlines the currently planned utilization of the Space Station to perform investigations in solar terrestrial physics and plasma physics. We will describe the investigations and instrumentation planned for the Solar Terrestrial Observatory and its associated Space Station accommodation requirements. In addition, the planned placement of the STO instruments will be discussed along with typical operational scenarios. In the area of plasma physics, we will outline some preliminary plans for scientific investigations and for the accommodation of a plasma physics facility attached to the Space Station called the Plasma Processes Laboratory. These preliminary experiment concepts use the space environment around the Space Station as an unconfined plasma laboratory.

INTRODUCTION

The Space Station will offer new opportunities to the scientific community by providing a long duration manned platform with sufficient electrical power, data rate, thermal control, servicing, and other capabilities to host several large observatories and research facilities. These observatories and research facilities will be attached to the manned Space Station and will make use of the provided resources. In addition, the presence of a science crewman to control and interact with the experiments and observations will provide additional capabilities for the conduct of new and unique types of research not previously possible.

In the following sections, we will describe two such attached payloads.

SOLAR TERRESTRIAL OBSERVATORY

Over the past ten years concepts for a Solar Terrestrial Observatory (STO) have been developed, including a space platform concept, a geosynchronous platform concept and a high inclination Manned Space Station concept. Now that the Space Station program has been initiated, the concept for the initial version of the STO is being more fully defined.

The STO is a specific, problem-oriented instrument payload structured to investigate and acquire an understanding of the physical processes that occur in, and couple, the major regions of solar terrestrial space. The STO encompasses investigations of the sun, the interplanetary medium, the Earth's magnetosphere and ionosphere, and the atmosphere of the Earth. The initial STO involves the use of a number of large instruments, originally designed for Shuttle Spacelab missions. These instruments will be placed on the Space Station elements to take advantage of: (1) long duration in orbit; (2) high power availability; (3) in-orbit servicing; (4) multidirectional pointing; and (5) coordinated operations.

The STO will also make use of data from other missions such as the International Solar Terrestrial Physics (ISTP) Program, Advanced Solar Observatory, the Environmental Observation System, and the Upper Atmospheric Research Satellite.

The STO will consist of instrument groupings on the Space Station top and lower keels and on the polar platform. The instruments for the initial Solar Terrestrial Observatory are shown in Table 1 along with their planned initial placement. Since the instruments for the initial STO are (with few exceptions) currently under development for flight on Shuttle/Spacelab missions, it is expected that the STO offers a cost effective and realizable payload for the initial Space Station.

Studies are currently underway to determine what modifications and upgradings of these instruments will be required to effectively use them on the Space Station. The initial selection and placement of the STO instruments will enable scientists to begin a program of interactive, cause-and-effect experiments which will be directed toward acquiring a better understanding of the Earth-space system. The upper boom of the manned Space Station will incorporate a solar cluster of instruments which will conduct long-term studies of the solar irradiance output and its variability. This data will allow us to develop a data base of the solar output as an input to the Earth-space environment. The solar cluster is planned to remain on the manned Space Station for a number of years. The solar cluster data will be augmented by data from the Advanced Solar Observatory, and may actually be replaced by the ASO as the ASO approaches its evolutionary maturity.

The active instruments and their supporting diagnostics (WISP, SEPAC, Tether, RPDP, and TEBPP) are placed on the

Table 1.

Solar Terrestrial Observatory
Implementation on Space Station

Instrument	Location	Discipline
Tether	Space Station (top)	Space Plasma Physics
White-Light Coronagraph (WLC) UV Coronal Spectrometer (UVCS) Active Cavity Radiometer (ACR) Solar UV Spectral Intensity Monitor (SUSIM) High-Resolution Telescope and Spectrograph (HRTS) Soft X-Ray Telescope (SXRT)		Solar Physics
Wave Injector (WISP) Particle Injector (SEPAC) Plasma Monitor (TEBPP) Recoverable Plasma Diagnostics Package (RPDP)	Space Station (bottom)	Space Plasma Physics
Imaging Spectrometers (ISO) Atmospheric Emissions Photometric Imaging (AEPI) Wide-Angle Michelson Doppler Imaging Interferometer (WAMDII)	Polar Platform	Atmospheric Physics
Magnetopheric Multiprobes (MMP) Vehicle Charging and Potential (VCAP)	Polar Platform	Space Plasma Physics
MMP/CHEMSAT	Coorbiting Platform	

manned Space Station to initiate a program of controlled, active experiments at low inclinations. The experiments to be performed by these instruments include beam-plasma interactions, wave-particle interactions, wave propagation, ionospheric sounding, plasma physics, and short-duration interactive experiments between the manned Space Station and the Polar Platform STO atmospheric and magnetospheric instruments.

The STO free flyer, the Recoverable Plasma Diagnostics Package (RPDP), will be deployed to operate in conjunction with other instruments on the manned Space Station. The RPDP will provide diagnostic data not only to support the active experiments, but also to provide information on the space environment within 10 km to 1000 km from the Space Station. The RPDP will be controlled and serviced from the Space Station. Figure 1 shows a tentative location of the STO solar cluster and tether on Space Station, and Figure 2 shows the expected placement of the STO active instruments.

The STO Polar Platform will initially host the atmospheric and auroral imaging instruments (AEPI, ISO, and WAMDII) plus a small electron accelerator package and a set of ejectable probes. Figure 3 shows a concept of the initial STO Polar Platform. The atmospheric instruments will operate continuously to acquire and establish a corollative data base on global atmospheric dynamics. When experiments are performed by the active instruments, or when a solar event occurs to trigger enhanced atmospheric response the atmospheric instruments will be commanded (perhaps automatically) to operate in the high resolution and therefore high data rate mode. Periodic experiments will be conducted in conjunction with the electron accelerator (VCAP), and the ejectable diagnostic/chemical release probes (MMP/CHEMSAT).

The currently planned STO operations require nearly continuous monitoring of atmospheric, ionospheric and magnetospheric constituents, and dynamics. In order to better understand the processes which couple the Earth-space regions, controlled, active experiments are also planned which introduce perturbations that simulate or stimulate natural phenomena. These controlled experiments will be performed periodically during the STO missions as campaigns. These campaign modes may be scheduled well ahead to perform a series of experiments to investigate specific physical processes. Alternatively, the campaign modes may be triggered by specific solar events which require experiments designed to investigate the evolution of naturally occurring processes.

Solar Terrestrial Observatory

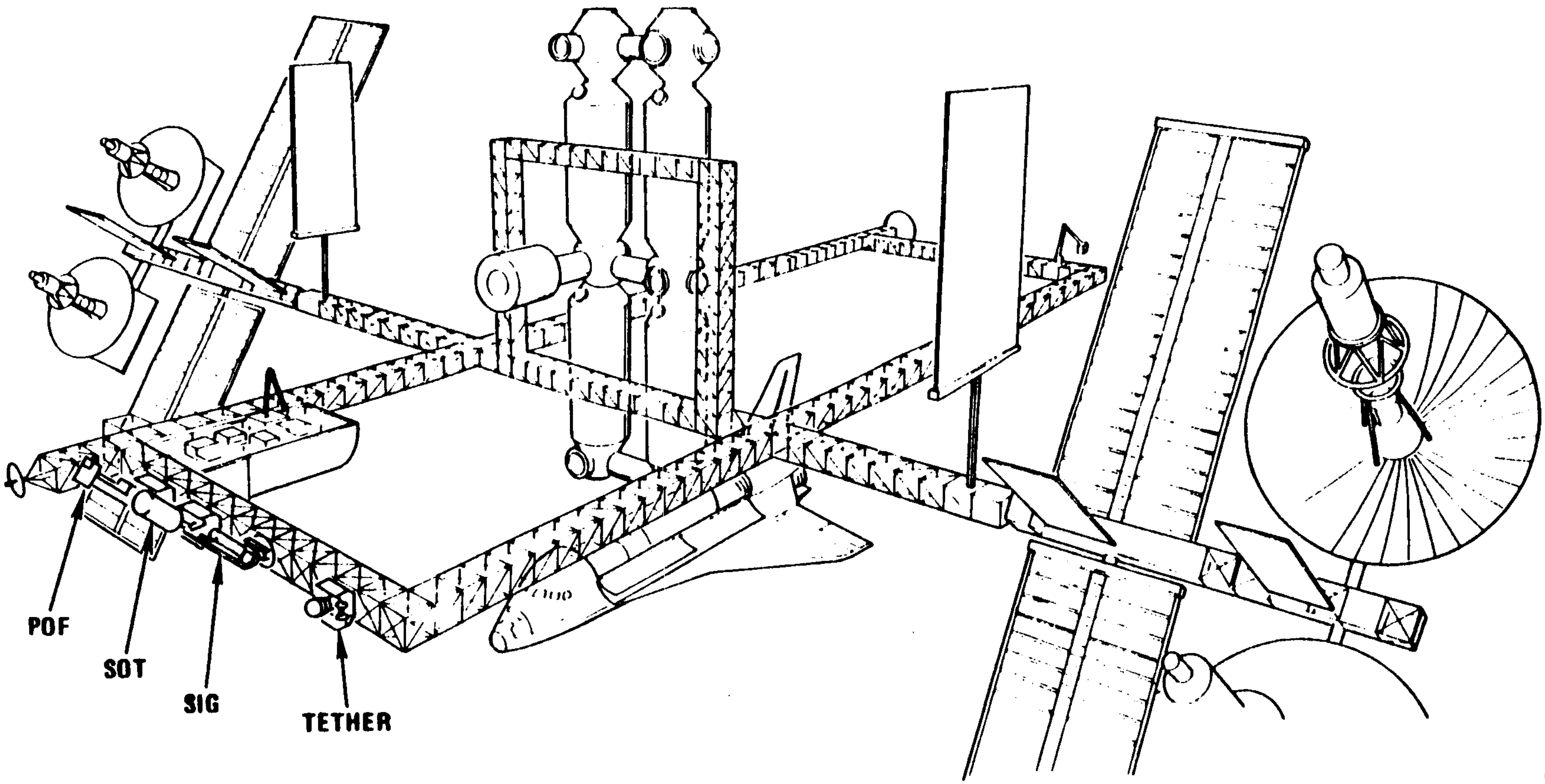

Figure 1. STO Tether and Solar Cluster

Solar Terrestrial Observatory

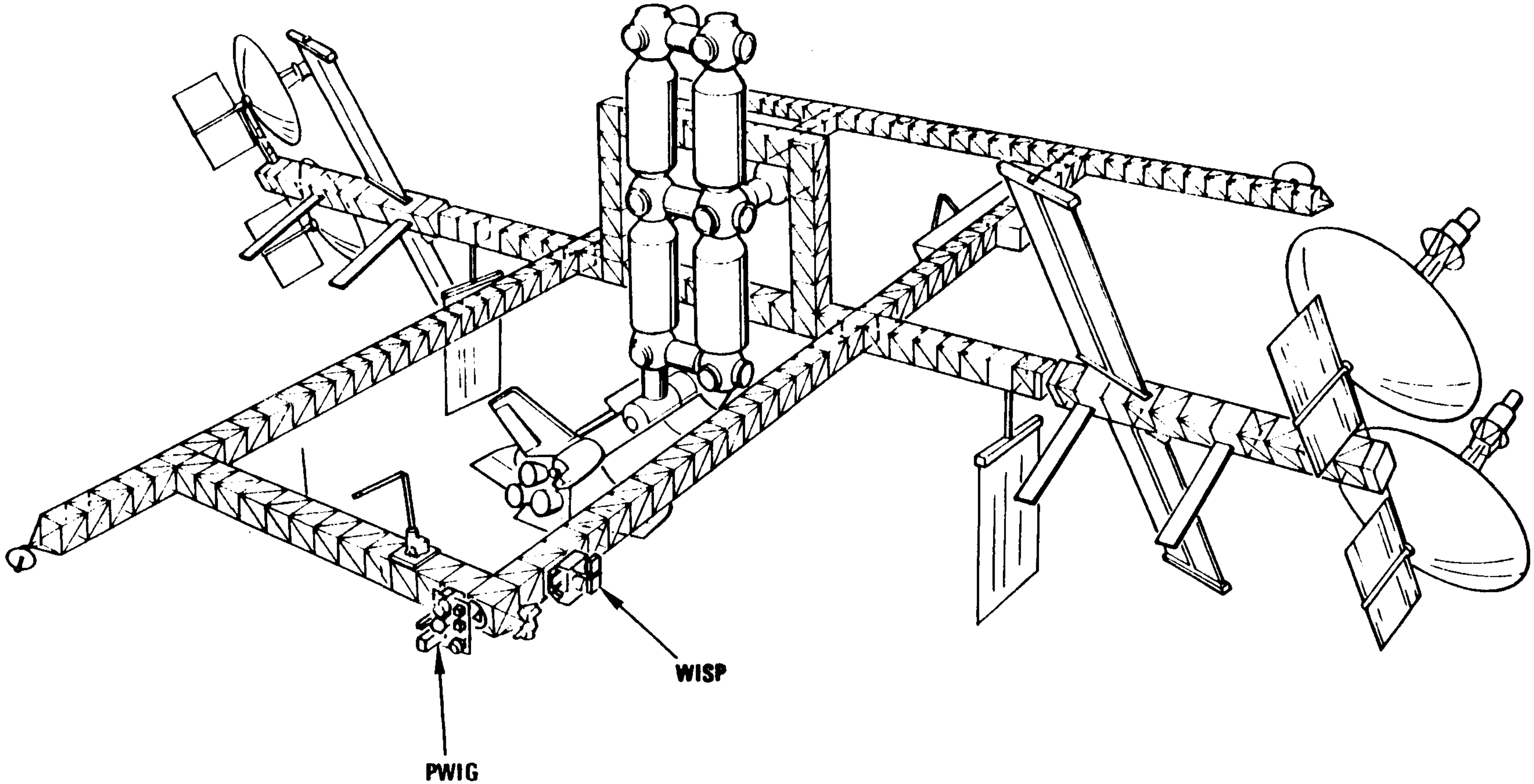

Figure 2. STO Active Instruments

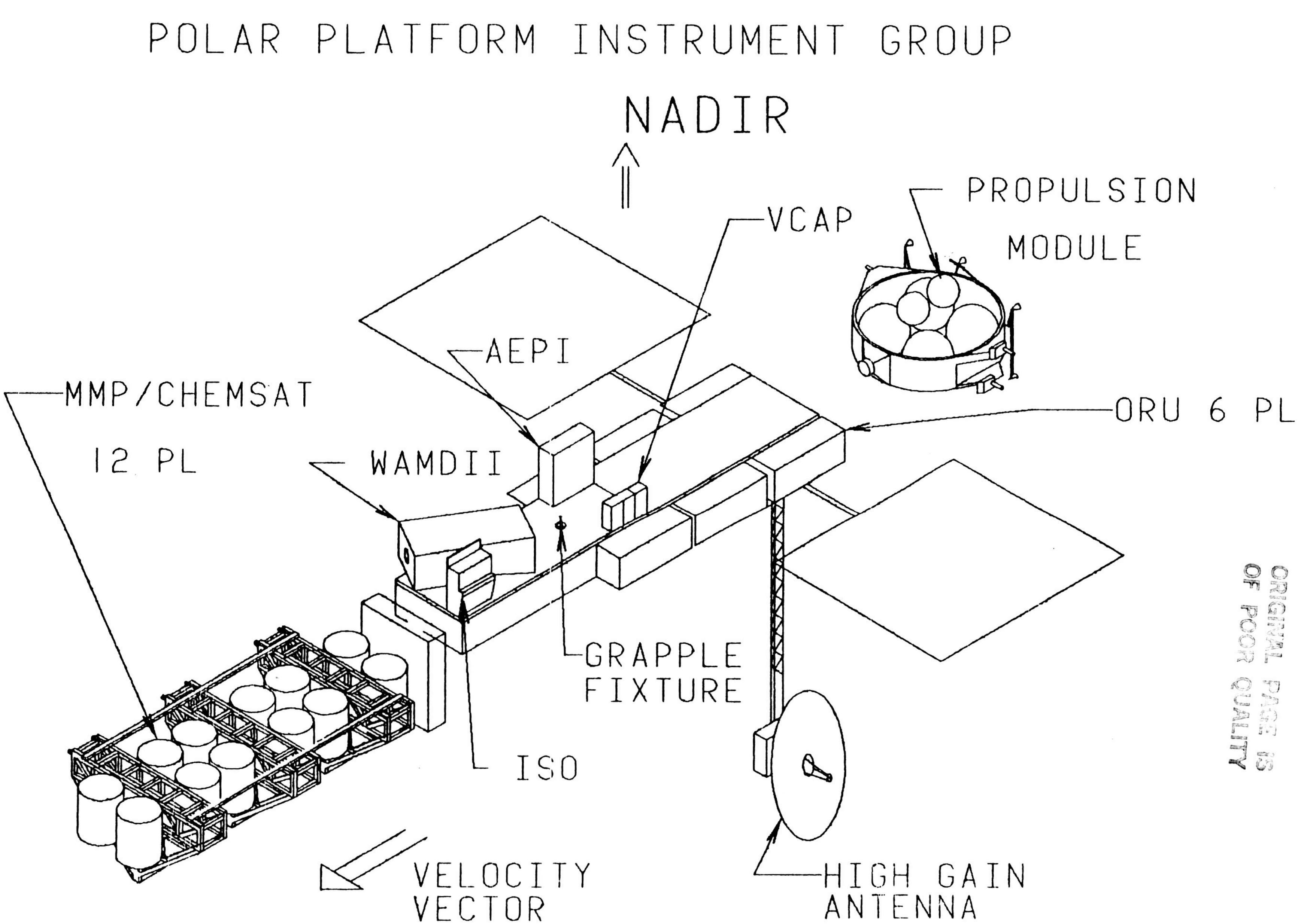

Figure 3. STO Polar Platform

Some STO operational modes could be scheduled for times when the manned Space Station and the Polar Platform orbits cross the same geomagnetic lines of force. Although this conjugate situation will only occur for a few seconds, the opportunity afforded for coordinated experiments between the Manned Station and the Polar Platform will be unique and valuable.

Figure 4 shows an example of the timeline for a typical campaign mode of operation. Usually these timelines will be scheduled well in advance. Prior to the start of the campaign mode, the electrodynamic tether will be deployed and the ejectable probe(s) will be released (from the platforms). The tether diagnostics will be operated for the full time that the tether is deployed, but the use of the tether in its electrodynamic mode will be performed in conjunction with the wave injector and the particle accelerators. Wave injection and particle accelerator operations will require some coordinated operations and some independent operations. For example, off-on modulation of the electron accelerator will generate waves which may be detected by the wave injector instruments. This would be an opportunity to perform coordinated investigations of the use of the electron beam as a virtual antenna. Likewise the wave injector using high frequency sounding techniques will be needed to detect and monitor ionospheric disturbances caused by the operation of the particle injectors. Numerous other examples of coordinated experiments involving the simultaneous operation of the wave injectors and the particle accelerators could be discussed. Typically the wave injector operations will have a duration of about one orbital period (90 minutes) whereas the typical duration for a particle injection experiment is about five minutes.

There are also classes of investigations in which the wave injectors and the particle accelerators do not want the disturbances caused by the other system. Time is therefore scheduled for WISP only, and for SEPAC only, operations.

During the seven days of the typical campaign mode of operation, one day will be devoted to analysis of the data acquired in the first three days, and to perform any replanning necessary for the remaining time. The daily experiment operations will be planned to be accomplished within one 12-hour shift each day. This will leave adequate flexibility for the analysis and allow replanning for the following days' activities. This operational scenario has been derived as a result of our Shuttle/Spacelab experience which demonstrated the need for analysis and replanning, and also maintains the effectiveness of the flight and ground operations personnel.

Solar Terrestrial Observatory
Operating Strategy

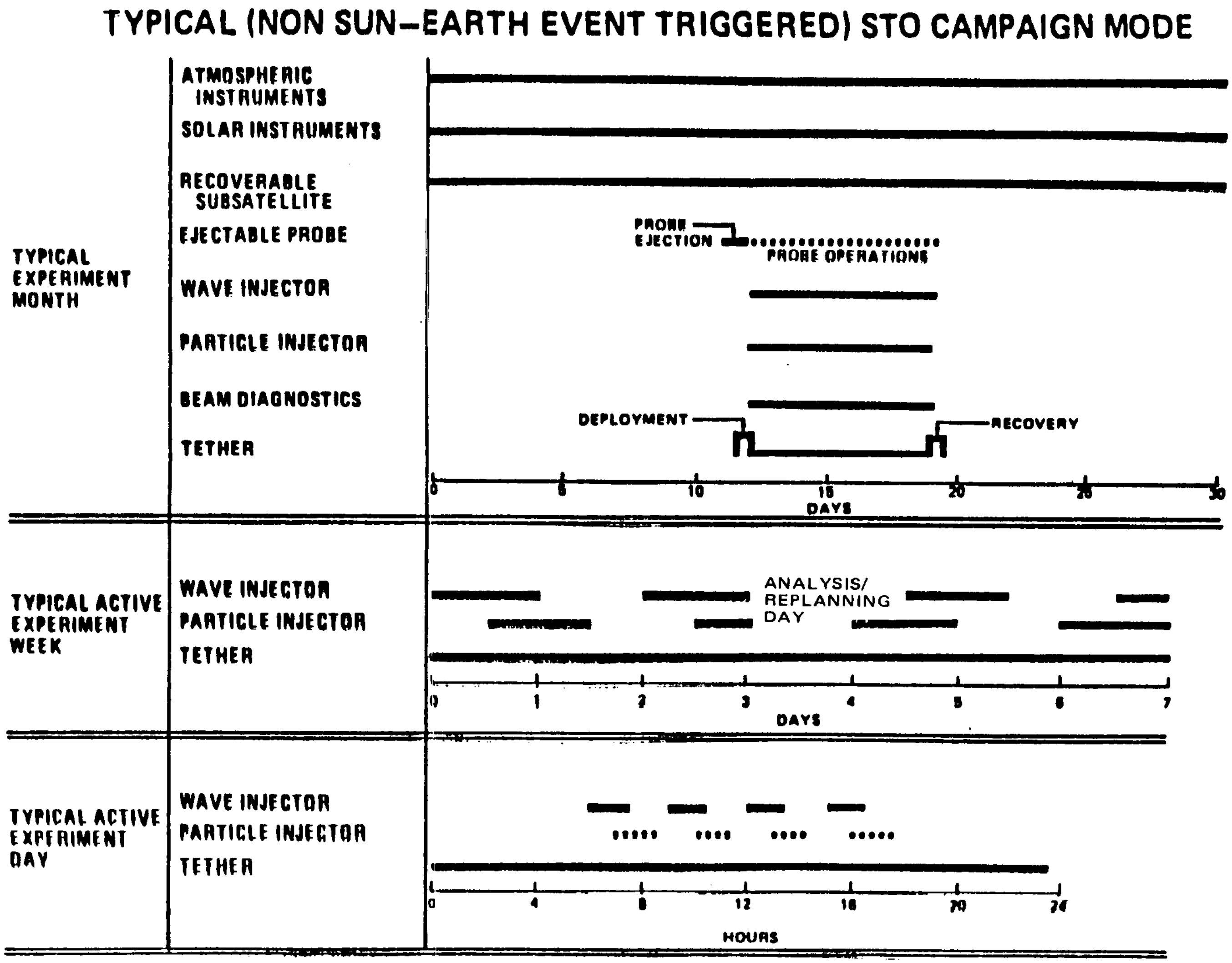

Figure 4. STO Typical Operations

The second class of STO campaign mode operations -- solar event triggered campaign modes -- is shown in Figure 5. This figure shows what would occur if a particular type of solar event (coronal hole) is observed on the Sun, triggering the subsequent operational timeline. The solar instruments would be operated in a high data rate mode as will the atmospheric instruments. Data from other programs would also provide critical information during these times. For example, data from the International Solar Terrestrial Physics (ISTP) Program satellites would be particularly important for solar wind and magnetospheric data. Data from the Upper Atmospheric Research Satellite (UARS) and the Earth Observing System (EOS) would also be very useful to determine atmospheric effects. Ejectable diagnostic and chemical release probes may be deployed from the polar platform to aid in the investigations of particle and field effects in the magnetosphere/ionosphere system. Likewise the particle accelerators could be used to detect and investigate the occurrence of parallel electric fields. The wave injector would be very useful in mapping traveling ionospheric disturbances resulting from the deposition of energy into the auroral zone and other sources.

This type of campaign mode, unlike the campaign mode discussed earlier, will require full operations 24 hours per day. This does not say that all instruments will be continuously operated, but rather that the operational scenario will accommodate single and coordinated operations of all the STO instruments and experiments 24 hours per day. In this way, the flight and ground crews will be available to perform detailed experiments and support continuous monitoring of the evolution of the solar terrestrial processes as they occur.

Ultimately we expect the STO active instruments initially placed on the manned Space Station to be moved to the Polar Platform. This will be done to accommodate the scientific goals of performing cause-and-effect experiments which study the coupling of the interplanetary environment to the Earth's magnetosphere, ionosphere and atmosphere.

The vacancy left on the manned Space Station will be adequately filled by a follow-on payload, the Plasma Processes Laboratory.

PLASMA PROCESSES LABORATORY

In 1985 a workshop was held to explore the feasibility of the Plasma Processes Laboratory for Space Station. Scientists from plasma and fusion research laboratories from throughout the United States attended and participated in this

Solar Terrestrial Observatory
Operating Strategy (Continued)

SOLAR TERRESTRIAL OBSERVATORY
SOLAR EVENT TRIGGERED CAMPAIGN MODE
CORONAL HOLE

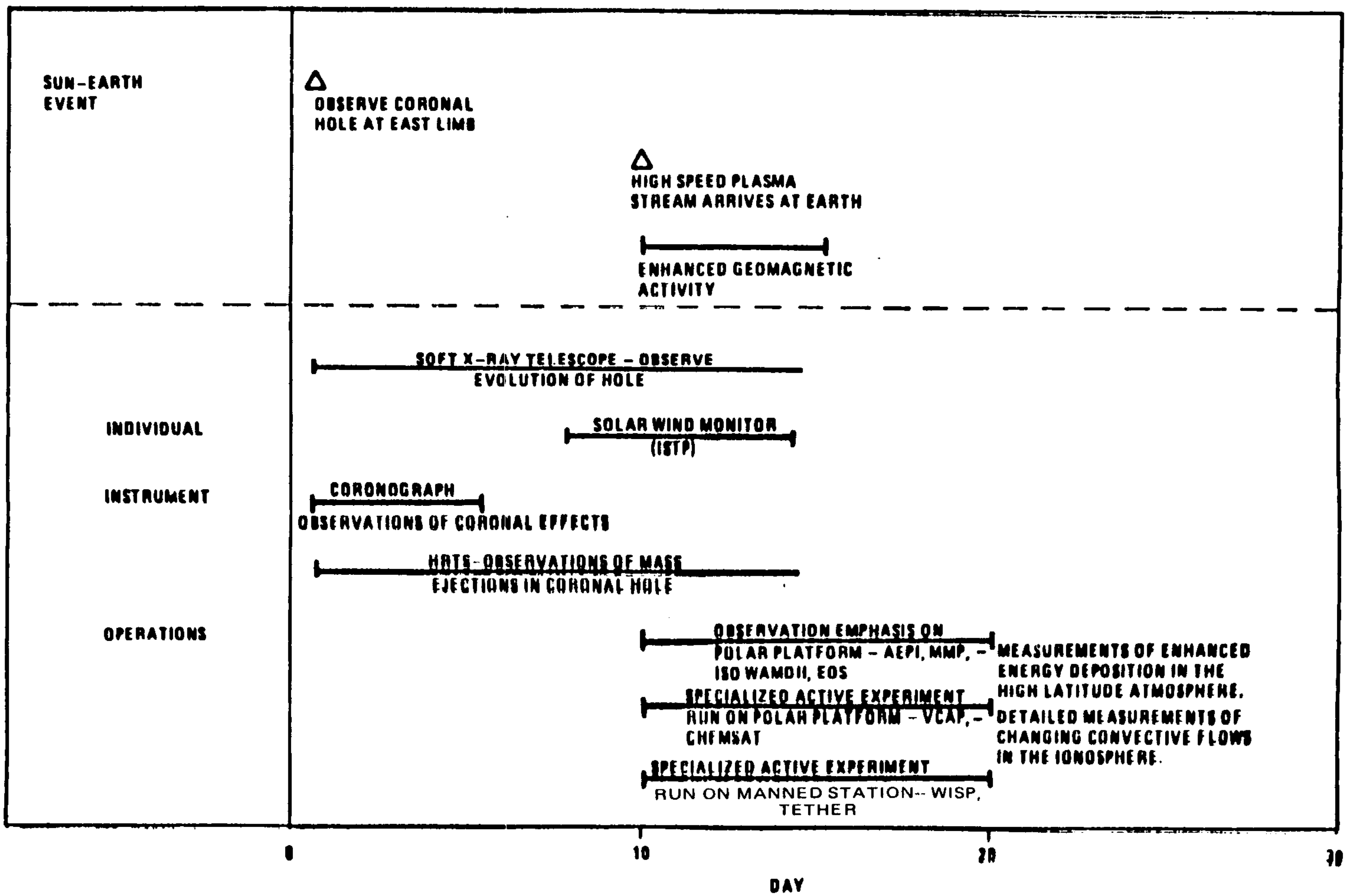

Figure 5. STO Solar Event Triggered Operations

workshop. For many of the participants this was a new interaction with NASA programs.

After three days of vigorous and intense discussion, the workshop participants identified a number of interesting ideas for basic scientific and technological experiments on the Space Station. In each case there is a solid scientific reason for pursuing the concepts developed on the Space Station as opposed to laboratory based experiments. Also, plasma physics as a discipline has much to offer the Space Station complex in understanding the plasma environment that surrounds it, and the interaction of a large electrically conducting structure (like Space Station) with this environment. The development of the basic technologies that would enhance the capabilities of future Space Station investigations is also important.

The Space Station will be a large structure, with large electrical power systems, a significant neutral gas outflux in a plasma and traveling at 7 km/sec through the geomagnetic field. It is reasonable to expect that this condition will create new and unique problems of plasma interactions. The Space Station will certainly cause significant perturbations to the natural plasma environment, and it is not unreasonable to expect that the plasma and magnetic field environment will effect the Space Station. For these reasons, it has been proposed that the Space Station develop a set of diagnostic instruments (a Plasma Interaction Monitoring System) to be attached to various places on the structures to measure and understand the nature and extent of this problem. The initial placement of these diagnostics should accompany the very first on-orbit station elements. By acquiring an early data base on possible deleterious effects of these plasma interactions, it may be possible for subsequent elements to be reconfigured to minimize the effects. Also this Plasma Interactions Monitoring System will hopefully be designed to provide data on environmental modifications resulting from Shuttle rendezvous and docking, station reboost, and possible venting from modules (the so-called "smokestack effect").

The advantages of the Space Station to plasma processes experiments per se may be categorized into two areas -- environmental and operational.

The environmental considerations include:

- The possibility of creating ultrahigh vacuum over a large volume. This may be accomplished by shielding the desired volume from the ambient neutral and plasma flow, creating a high-vacuum wake region.

- An ambient plasma environment uniform over large scale lengths. This makes it possible to perform experimental studies of processes requiring homogeneous background conditions over interaction lengths attainable only in space.

- The absence of walls and accompanying effects, such as impurity injection, wall currents, and field shorting.

- The large scale steady plasma flow past the Space Station due to its orbital velocity. This condition is difficult to achieve in the laboratory.

- Combinations of plasma parameters in the Space Station environment that are ideal for qualitative scaling of space phenomena.

- The absence of gravity. This permits a class of experiments which are difficult on Earth, involving colloidal or dusty plasmas as well as certain technology studies involving such effects as breakdown of insulation in mists. Additionally, levitation of components for achieving various boundary conditions or magnetic fields is simplified, possibly leading to previously unattainable field topologies.

Operational considerations include such factors as:

- Long-duration data bases. In contrast to Shuttle-borne missions one will have the ability to explore wider variations of experimental and environmental parameters with correspondingly more comprehensive investigations. Experiments which would yield too little data during a Shuttle flight may be contemplated.

- The ability to modify experiments during the course of an investigation. The scientific return from Space Station-based experiments can be qualitatively greater because of an investigator's ability to respond to unanticipated results or to modify (to some degree) the experimental configuration as new objectives are indicated by interim data. This mode of operation will lead to a hands-on laboratory-like capability.

- Maneuverable platforms, tethers, and other adjuncts. These will allow great flexibility in experimental configurations and diagnostics.

- The large scale sizes available in space, already mentioned above in the context of enabling experiments involving long interaction lengths, will also permit much greater diagnostic access than in ground-based experiments.

The workshop participants, after developing basic evaluation criteria, described nine very broad experiment categories which could effectively be addressed by the Plasma Processes Laboratory.

1. Investigations of the interaction of the large Space Station with the surrounding plasma environment.

2. Investigations of charge buildup causing high potentials on objects in the space plasma environment.

3. Studies of the plasma flow about objects.

4. Investigations of the basic mechanisms of nonlinear particle and wave interactions.

5. Studies of plasma shocks.

6. Investigations of beam-plasma interactions.

7. Investigations of plasma toroids.

8. Studies of the fundamental physics of dusty plasmas.

9. Studies of the physics of plasmas in a microgravity environment.

In general the Plasma Processes Laboratory (PPL) will require three types of facilities on Space Station: (1) a Core Facility, (2) an Exposed Experiment Facility, (3) a Remote Experiment Site.

The Core Facility, shown in Figure 6, will include a capability for data acquisition and processing and for control of the experiments. This shirtsleeve facility also includes a workbench and storage area to which specific instruments may be brought for on-orbit repair, servicing or up-grading and modification. This manned module may also include experimental microgravity chambers. A large airlock will also be needed.

Figure 7 is an artist's concept of the PPL Exposed Experiment Facility. This facility is attached to the Space Station and provides a pallet on which the PPL instruments may be mounted. Experiments in basic plasma physics, plasma interaction experiments and beam plasma physics may be conducted from this facility. The facility will be operated from the Core Facility.

Finally, Figure 8 shows the requirement for a PPL Remote Experiment Site. Some of the Plasma Processes Laboratory

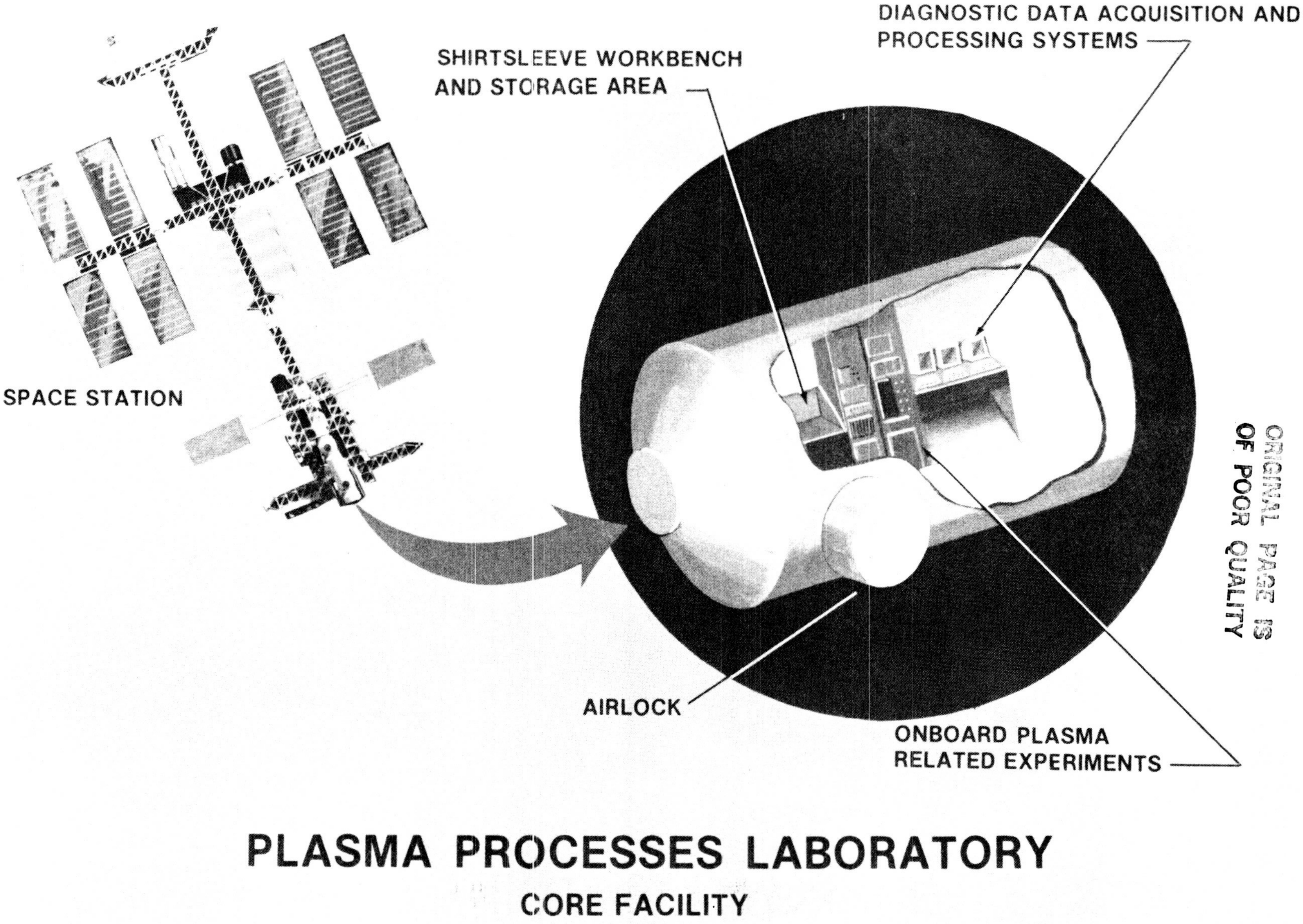

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Figure 6. PPL Core Facility

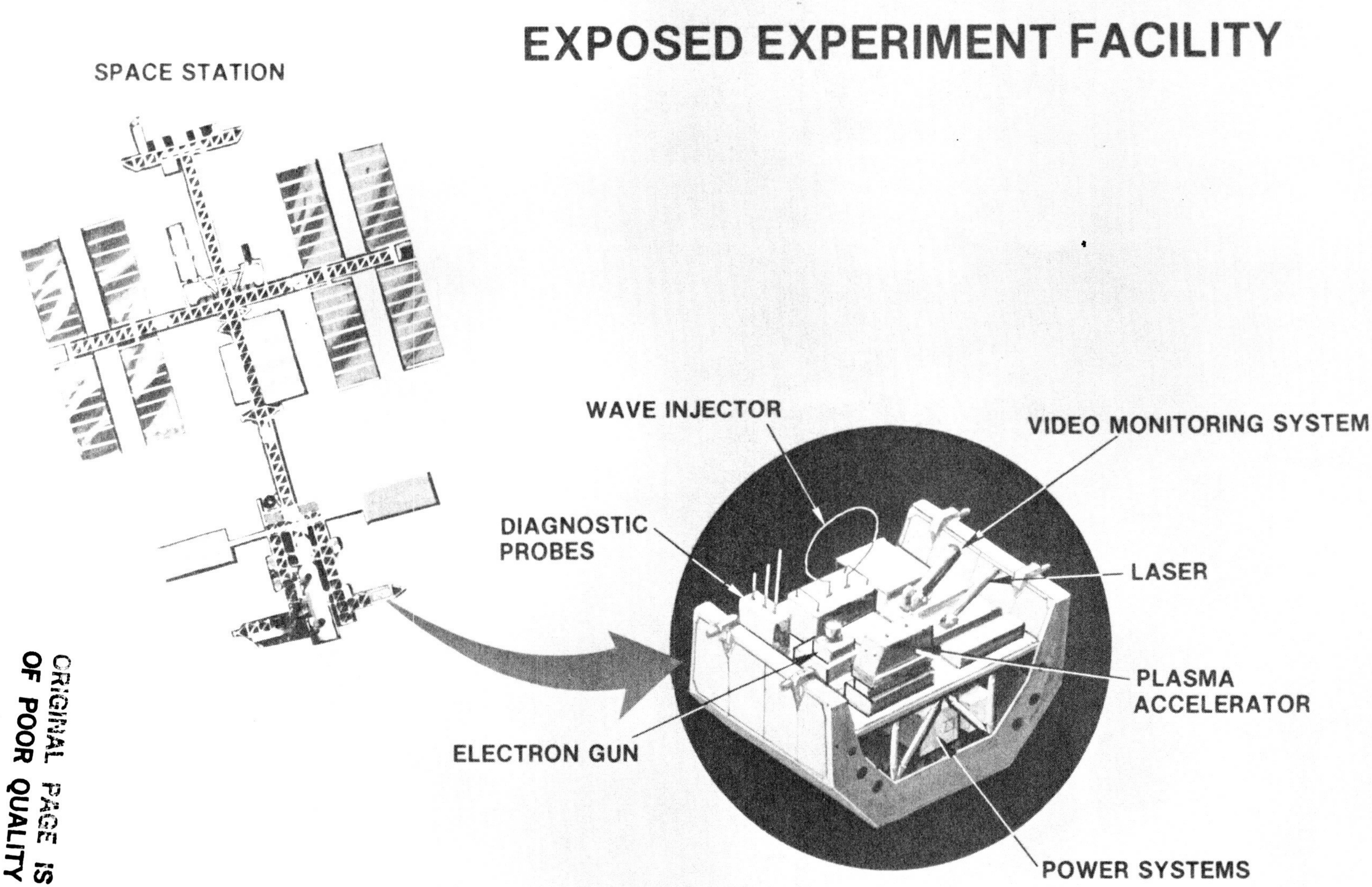

Figure 7. PPL Exposed Experiment Facility

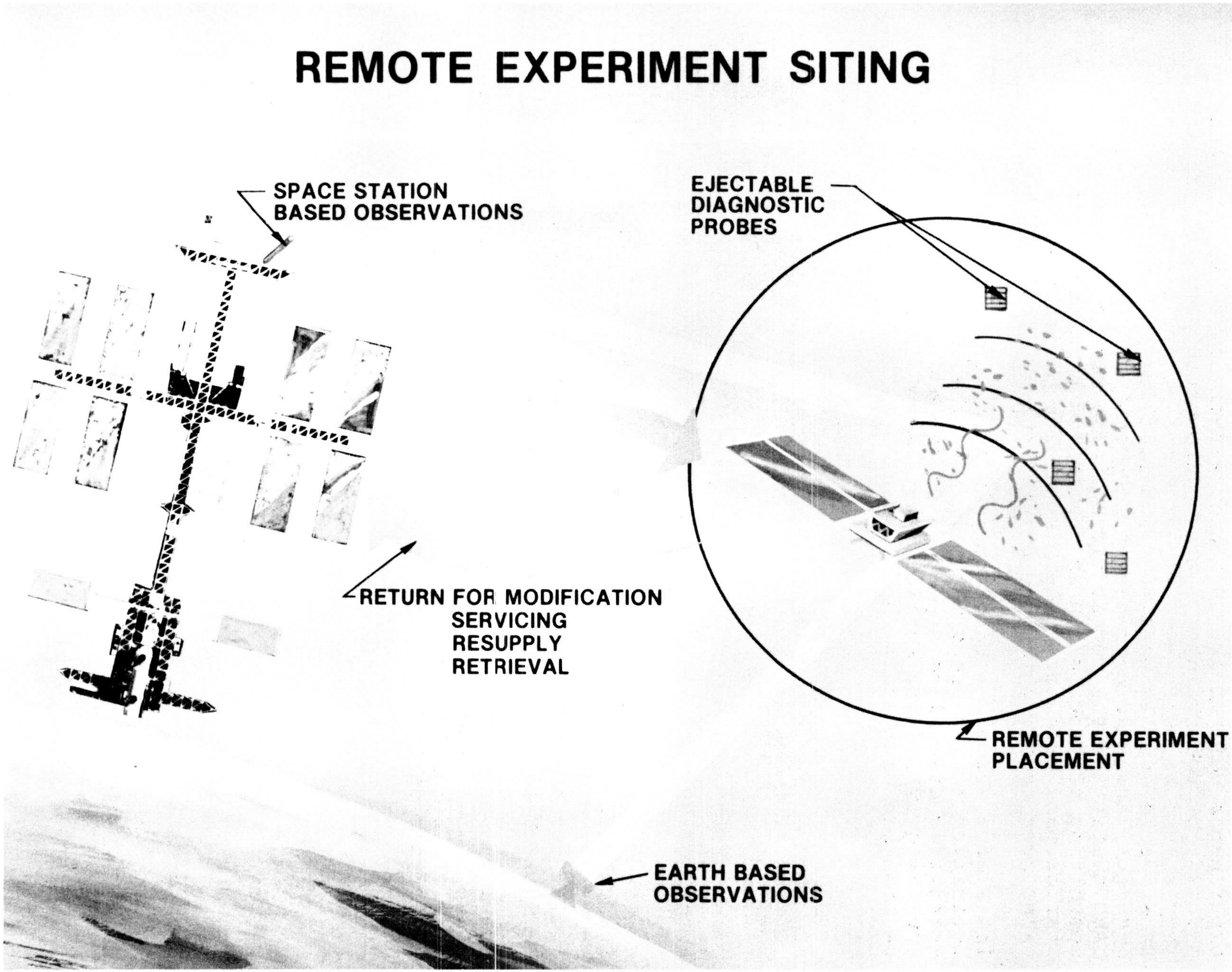

Figure 8. PPL Remote Experiment Siting

experiments defined are such that either due to environments induced, or uncertainty of the environmental loading effects, they should be performed away from the manned Space Station. Experiments such as nonlinear interactions, plasma toroid dynamics, and some beam-plasma interaction experiments are best suited for the remote siting. The remote site may be a coorbiting platform which is controlled from the Space Station, and uses the Space Station for periodic servicing, experiment reconfiguration, and instrument repair.

The Plasma Processes Laboratory is in a very early stage of definition at the present time. Nevertheless, this scientific discipline appears as a new and exciting customer for the growth Space Station -- a discipline that would not be possible without the Space Station.

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