NEUTRAL ENVIRONMENT WITH PLASMA INTERACTIONS MONITORING SYSTEM ON SPACE STATION (NEWPIMS)

Elden C. Whipple
Center for Astrophysics and Space Science
University of California at San Diego
La Jolla, CA 92093

and

Joseph N. Barfield
Southwest Research Institute
San Antonio, TX 78284

ABSTRACT

The U. S. Space Station Freedom will be the first large-scale, permanent, manned space operation. The size of the Station, variety of materials and resources, and the many different vehicles and payloads in its vicinity will present significant perturbations to the ambient environment. In addition, Station operations will be affected in yet undefined ways by the environment.

A system to provide comprehensive environmental and interaction measurements on Space Station is planned. This system, called the Neutral Environment With Plasma Interactions Monitoring System, or

"NEWPIMS"

will monitor the impact of the Station on the environment and vice versa. NEWPIMS will supply a long-term database and interaction models to the Space Station community that can be employed to analyze Station/environment interactions and to unfold natural from induced changes in the Station environment. The system will include neutral environment instruments, electric and magnetic field sensors, charged particle detectors, and remote sensing of radiation and particulates. Sets of instruments will be provided by the international community and permanently deployed at strategic locations on the Station.

I. THE SPACE STATION

The Space Station will present unprecedented challenges in U. S. space activities. It will be the first large-scale, permanent space operation. The Space Station will provide structural support, electrical energy, data processing, communication and life-support resources. It will serve as a vehicle fueling and repair facility. Proximate traffic will include the Space Shuttle, the Orbital Maneuvering Vehicle, and other as-yet undeveloped space vehicles. Thus, the Space Station will be a large, complex, busy structure in space. The size of the Space Station, the variety of materials and resources, and the many different vehicles and payloads in its vicinity will present significant perturbations to the ambient environment. Additionally, the operations on the Space Station will be affected in yet undefined ways by the environment.

Operationally, the large scale of the Space Station, the inclusion of many high-current electrical paths, and the large number of simultaneous communications links will produce many environmental perturbations, the nature and magnitude of which are quite uncertain. As a result, the environment of the Space Station will need to be verified as the Station is constructed, and as operations commence and continue. A comprehensive set of measurements of the resulting environment of the Space Station will be needed for the life of the Station, to aid in compensating for perturbations experienced and for design guidance in Station growth.

Users of the Space Station will have a critical need for knowledge of the actual environment within which measurements will be made. For instance, electrical noise levels may exceed the sensitivity of many instruments at various locations on the Station structure. Telemetry and sensor signals may be masked by the noise, leading to false conclusions due to defective data. Thus, a continuous ongoing data base that characterizes the environmental parameters of and around the Space Station as functions of time and location is critically needed.

In addition to the above needs, there also is a strong need for the monitoring of the Space Station "weather". That is, the operators and users will require an ongoing characterization of the environmental conditions within which events occur and are measured. Such a characterization will be required to separate the natural episodic changes at the Station from induced changes.

II. ENVIRONMENT/SPACE-STATION INTERACTIONS

1. Release of gases

The Space Station will release gases by outgassing from materials, by venting, by leakage from pressurized volumes, by the operation of engines and thrusters, by extra-vehicular activity (EVA) and the use of airlocks. Additional gases will be released during shuttle and orbiting maneuverable vehicle (OMV) rendezvous. As a result there will be a more-or-less continual gas cloud around the Space Station which will have a much higher concentration than the natural environment at the Space Station altitude. The gas cloud will also have a composition different from the natural environment.

This cloud of gas will scatter and absorb light. It will also emit radiation by spontaneous and induced emission processes. The gas can be ionized by sunlight and by energetic particles to produce ions and electrons. The constituents in the gas will react with each other, with the surface of the Space Station, and with the constituents in the natural environment.

2. Release of particulate matter

In addition to releasing gases, the Space Station will also release copious amounts of particulate matter in the form of dust swept along with the venting gases. Released water vapor can condense and freeze into ice grains. These particles will also absorb, scatter, and emit light. They can become electrically charged and then re-attracted to the Space Station where they can impact, react with, and adhere to surfaces and change the surface properties.

3. Impact of environmental matter

Environmental particulate matter including orbital debris as well as micrometeors will impact the space station, causing erosion, sputtering, and deposition. Again, the surface properties of the

Space Station can be modified by these impacts. The impact of environmental atoms, especially atomic oxygen, can produce surface reactions, cause surface erosion, and induce emissions such as the "ram surface glow". Environmental ions, electrons, and neutral atoms can also react chemically with the outgassing material in various ways such as by charge exchange, attachment, disassociati n, ionization, etc. Energetic ions and electrons from the environment can penetrate the surface, erode materials, and be deposited in sub-surface layers.

4. Electrical interactions

The Space Station itself will charge electrically because of the impact of ions and electrons from the natural and induced environment, and because of photoemission from its surfaces. There will be a plasma sheath around the Space Station and a plasma wake behind it caused by its orbital motion through the plasma environment. Surfaces such as the solar arrays which may be charged to large electrical potentials will interact strongly with the local plasma. There will be leakage currents across insulating surfaces and possibly arcing and multipacting.

The motion of the Space Station through the earth's magnetic field will induce an electric field of approximately 0.25 volts/meter in its vicinity which will distort the plasma sheath and wake. This electric field will accelerate local charged particles to energies comparable to the potential drop across the Station, i.e. to energies on the order of tens of electron-volts for singly charged particles, and to higher energies for particles with multiple charges.

5. Electrical noise

The Space Station will be a source of electrical noise from the power, communications, and other electrical activity on board. As a result there will be a large electromgnetic noise field in its vicinity which will interact with the local plasma, possibly interfering with experiments, causing plasma waves, and accelerating charged particles.

6. Long-term changes

The presence of the Space Station for many years in orbit could possibly induce long-term secular changes in the environment. The release of gases over many years could represent a significant source of new material for the earth's ionosphere. The release of particulate matter could contribute significantly to the accumulation of orbital debris at spacecraft altitudes.

III. THE PIMS STUDY

1. Initial study phase

The "Plasma Interaction Monitoring System" (PIMS) study was originally formed in February, 1988, under the auspices of the Space Station Plasma Interactions and Effects (SSPIE) Working Group chaired by Dr. Carolyn Purvis of the NASA Lewis Research Center. The PIMS study team interacted closely with that working group and derived the basic PIMS charter with inputs from SSPIE.

They were charged with five tasks:

(1) To define the objectives of environmental monitoring at SSF;
(2) To identify environmental measurements required to monitor the plasma environments at SSF;
(3) To recommend instrumentation necessary for SSF environment monitoring;
(4) To identify possible system mechanical configuration, module placement, and deployment sequence;
(5) To initiate and coordinate the international "NEWPIMS" program.

2. The PIMS Study Team

The PIMS study team members were selected to provide guidance to the study from many perspectives. The team has collective in-depth experience in measurements of space plasmas and fields, neutral gases, and particulates; design and development of space flight instrumentation; and modelling of the space environment. Team members were also selected who have extensive backgrounds in simulation of space environment interactions and laboratory experimentation with basic plasma physics processes.

Table 1 shows the PIMS team members and the additions to the team for Phase 2 when the study was renamed "NEWPIMS".

3. Evolution of the PIMS/NEWPIMS Study

June 87	Space Station Plasma Interactions and Effects Working Group was Established
October 87	Space Station external contamination study was started focussing on neutral gases and particulates, and visible and infrared emissions.
February 88	Original PIMS study focussed on charged particles and fields.
July 88	PIMS team and External Contamination Study team agreed that the PIMS system should include measurements of neutral environment interactions.
February 89	PIMS Phase 2 study was initiated. Study team expanded to include selected External Contamination Study members and international representatives.
August 89	PIMS name changed to NEWPIMS
October 89	First international NEWPIMS workshop in Tokyo, Japan.

4. Present NEWPIMS Objectives

(1) Space Station:
- -Verify Space Station environment specifications;
- -Satisfy requirements for external environment monitors for individual work packages;
- -Develop a long-term environment data base.

(2) Experiment Support:
- -Monitor environment perturbations created by active experiments;
- -Monitor environment in support of experiments;
- -Monitor environment for unacceptable contamination levels.

(3) Experiment Operations:
- -Monitor experiment problems;
- -Provide real-time information on contamination levels.

(4) Space Station/Environment Interactions:
- -Study electrical charging of large space structures;
- -Study wake and sheath;
- -Study electromagnetic field interactions.

(5) Historical Analyses:
- -Study environmental variability;
- -Assess environmental change;
- -Analyze environmental response.

(6) Problem Detection and Location:
- -Detect and locate leaks in coolant loops;
- -Detect and locate seal failures in modules and nodes;
- -Detect and locate power system arcing and corona;
- -Detect and locate material degradation.

(7) Instrument Design:
- -Improve instruments for environment extremes;
- -Improve instruments based on perturbation levels;
- -Design instruments for baseline background;
- -Design to identify and locate contamination sources;

(8) Space Station Growth Development:
- -Provide information on material/system deterioration;
- -Provide perturbation variability;
- -Provide models of environment and interactions.

IV. THE PROPOSED NEWPIMS SYSTEM

The NEWPIMS system consists of sets of instrument packages; their deployment and operation on Space Station; acquisition of data and its distribution and archiving; and modelling of the Space Station environment and of the environment/Space Station interactions.

Table 2 shows the set of instruments which have been identified for NEWPIMS instrument packages and the allocation of instruments for the first three instrument packages.

Figure 1 shows the first three NEWPIMS units and Figure 2 shows the proposed placement of the first three units and the possible locations for two later units on Space Station. Five NEWPIMS units are now envisioned for Space Station Freedom. The placement of the units will be in two phases, three units in the initial phase, and possibly two additional units in a growth phase. The placement is such that instruments may be directed toward both solar arrays, laboratory and habitat modules, into and orthogonal to the velocity ram and velocity wake, and may scan through payload attach points. Additionally, a NEWPIMS unit is proposed for the Japanese Experiment Module Exposed Facility and will obtain environmental information from this location. It is highly desirable to include a sixth NEWPIMS as a mobile system (which may be maneuvered by the Mobile Service Center) that can be moved along the truss structure and deployed some distance away from the truss itself.

The NEWPIMS concept will impose minimum requirments on the Space Station and its systems. Each unit has a mass of about 100 kg and will require about 100 watts of power and 100 kilobits per second for data. Thermal control will be handled by the NEWPIMS units themselves. A preliminary assessment has shown that the units may be attached at the truss nodes using a simple screw adapter and plate. Periodic command rates of 1 kilobit per second or less will be required to rotate the units and to change instrument settings. Special autonomous, low-data-rate configurations are being studied for possible deployment in the early launch phase of Space Station when no power or data resources will be available.

Figure 3 illustrates the NEWPIMS system consisting of the instrument packages on the Space Station, the data base, the environment and interaction models, and the various users. The data base must have sufficient flexibility to provide environmental data despite changing Space Station configurations and payload manifests, operational perturbations, and natural events. The data base must also provide for the long term archiving of data so that environmental trend analyses may be performed. It is therefore important that this system be addressed and a first order definition established early.

V. NEWPIMS STATUS

Discussions are being carried out with possible international partners.

Costing studies are in process.

OSSA and OSS are discussing possible NEWPIMS implementation.

STUDY TEAM

NAME	AFFILIATION	PRIMARY INTEREST
• JOE BARFIELD	SOUTHWEST RESEARCH INSTITUTE	MAGNETIC VARIATIONS
• JIM BURCH	SOUTHWEST RESEARCH INSTITUTE	SPACE PLASMAS
• GEORGE CARIGNAN	UNIVERSITY OF MICHIGAN	NEUTRAL SPECTROMETRY
• NICK EAKER	SOUTHWEST RESEARCH INSTITUTE	SYSTEM ENGINEERING
• IRA KATZ	S-CUBED	ENVIRONMENT MODELING
••• DAVE KENDALL	CANADA	ATMOSPHERIC CHEMISTRY & EMISSIONS
•• BILL KURTH	UNIVERSITY OF IOWA	SPACE PLASMAS
••• BERNT MAEHLUM	ESA (EUROPE)	SPACE PLASMAS
• GERALD MURPHY	JET PROPULSION LABORATORY	ELECTROMAGNETIC WAVES
• RAY RANTANEN	SCIENCE AND ENGINEERING ASSOC	ENVIRONMENT MODELING
••• SUSUMU SASAKI	ISAS (JAPAN)	SPACE PLASMAS
•• JIM SPANN	MARSHALL SPACE FLIGHT CENTER	NEUTRAL COMPOSITION & DYNAMICS
• JIM SULLIVAN	MIT	DATA MANAGEMENT
• BILL TAYLOR	TRW	ELECTRIC & MAGNETIC FIELDS
•• MARSHA TORR	MARSHALL SPACE FLIGHT CENTER	NEUTRAL COMPOSITION & DYNAMICS
• HUNTER WAITE	SOUTHWEST RESEARCH INSTITUTE	SPACE PLASMAS
• ELDEN WHIPPLE	UCSD	THEORETICAL STUDIES
• DAVE YOUNG	SOUTHWEST RESEARCH INSTITUTE	ION SPECTROMETRY

• Original PIMS Team
•• U.S. Representative added for Phase 2
•••International Representative added for Phase 2

TABLE 1

NEUTRAL ENVIRONMENT WITH PLASMA INTERACTION SYSTEM (NEWPIMS)
INSTRUMENT DEPLOYMENT SCHEDULE

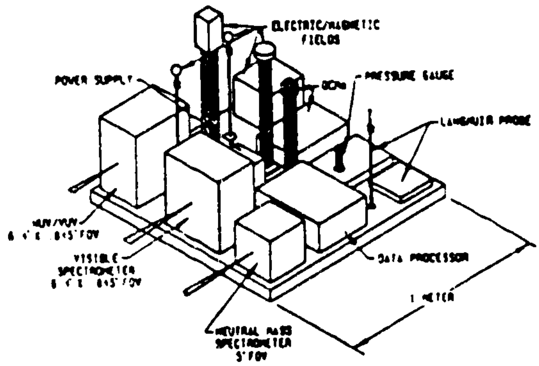
INSTRUMENTS	UNIT 1	UNIT 2	UNIT 3
LANGMUIR PROBE (electron density and temp)	Δ	Δ	Δ
PRESSURE GAUGE (total pressure)	Δ	Δ	Δ
QCM (6/UNIT) (deposition rates)	Δ	Δ	Δ
NEUTRAL MASS SPECTROMETER (neutral gas)		Δ	
ELECTRON SPECTROMETER (energetic electrons)		(LOW E) Δ	(HIGH E) Δ
THERMAL ION MASS SPECTROMETER (ions)			Δ
MEDIUM ION MASS SPECTROMETER (ions)			Δ
MAGNETOMETER (magnetic field)	Δ	Δ	
ELECTRIC FIELD MONITOR (electric field)	Δ	Δ	
ION/NEUTRAL MASS SPECTROMETER (ion/neutral)	Δ		
ENERGETIC PARTICLE DETECTOR (radiation)		Δ	
NUV/VUV SPECTROMETER (ultraviolet)	Δ		
VISIBLE SPECTROMETER (visible)	Δ		
NEAR IR SPECTROMETER (infrared)			Δ
LASER RADAR (particulates)		Δ	

TABLE 2

NEWPIMS UNITS

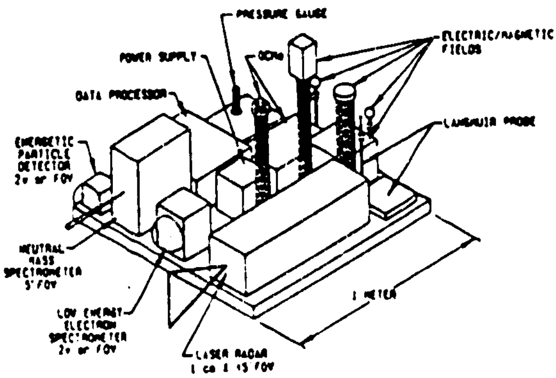
NEWPIMS Unit 1

THERMAL CONTROL COVER NOT SHOWN



NEWPIMS Unit 2

THERMAL CONTROL COVER REMOVED



NEWPIMS Unit 3

THERMAL CONTROL COVER REMOVED

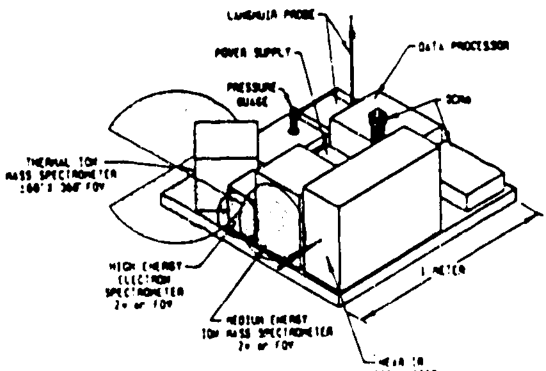


Figure 1

newPIMS With 3 Units Provides Adequate Measurements Of The Space Station Environment

MAXWELL

Objective : Determine minimum units necessary to monitor the SpaceStation environment.

Solution : 3 initial units with fields of view covering

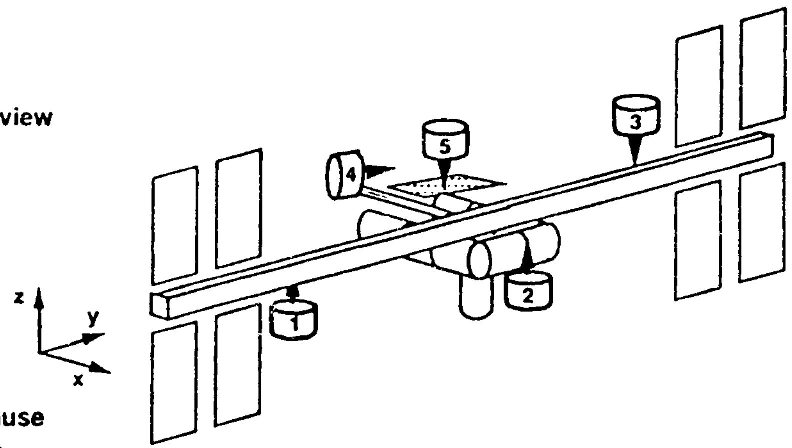
- left, middle, & right
- top & bottom
- solar arrays & habitats

2 units later on to measure

- JEM
- habitat wake region

Rational : Multiple units required because

- station so large (100+ meters) that single location would give misleading results.
- multiple units necessary to correlate with global models of station environment
- 2 axis platforms reduce numbers of units by increasing fields of view



newPIMS will combine neutral and plasma monitors on pointable platforms to monitor both contaminant levels and locate their sources

PIMS 8-89

Figure 2

NEWPIMS DATABASE AND MODELLING SYSTEM

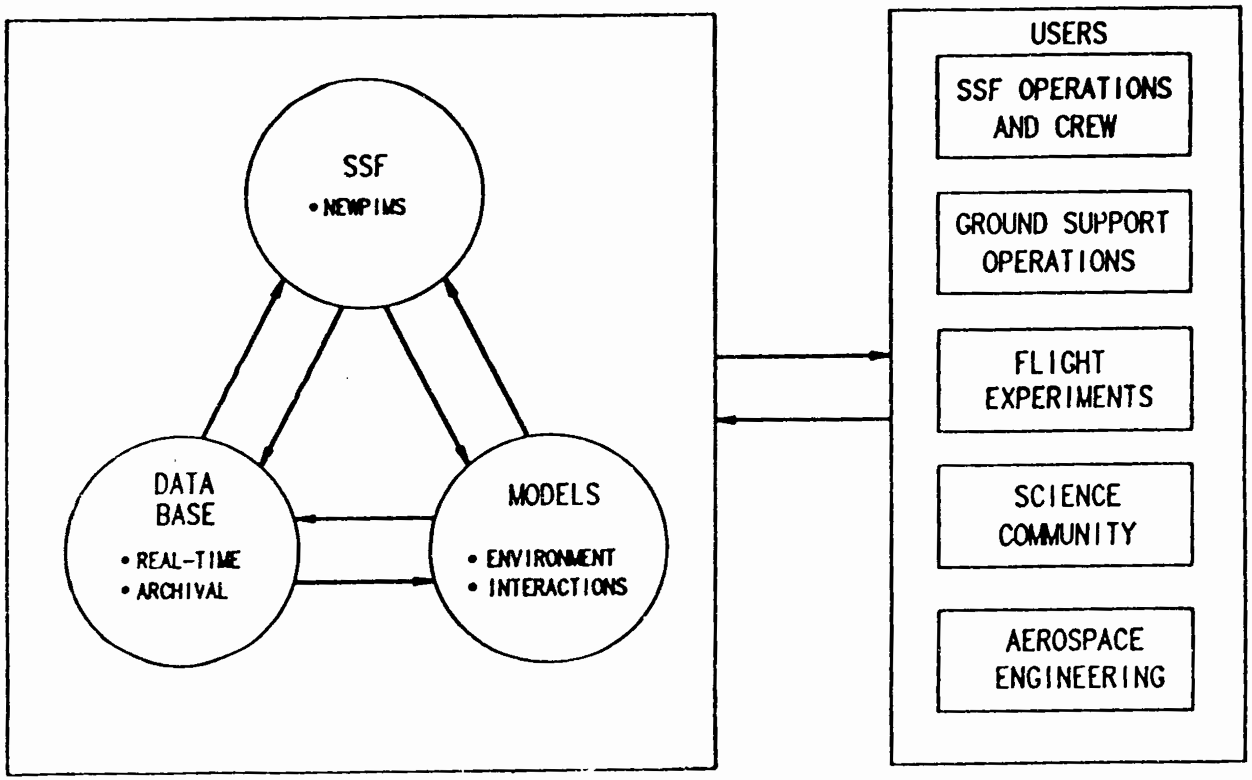


Figure 3