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WORKING GROUP REPORT ON BEAM PLASMAS, ELECTRONIC PROPULSION, AND ACTIVE EXPERIMENTS USING BEAMS

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I. OVERVIEW

THE JPl Workshop addressed a number of plasma issues that bear on advanced spaceborne technology for the years 2000 and beyond. Primary interest was on the permanently manned Space Station with a focus on identifying environmentally related issues requiring early clarification by spaceborne plasma experimentation.

Five Working Groups were convened, each with a charter to identify specific issues, their relative importance, associated gaps in existing knowledge, and requirements on theory and experiment necessary to advance our understanding. The "Beams" Working Group was specifically asked to focus on environmentally related threats that platform operations could have on the conduct and integrity of spaceborne beam experiments and vice versa. Considerations were to include particle beams and plumes. For purposes of definition it was agreed that the term "particle beams" described a directed flow of charged or neutral particles allowing single-particle trajectories to represent the characteristics of the beam and its propagation. On the other hand, the word "plume" was adopted to describe a multidimensional flow (or expansion) of a plasma or neutral gas cloud. Within the framework of these definitions, experiment categories included:

(1) Neutral- and charged-particle beam propagation, with considerations extending to high powers and currents.

(2) Evolution and dynamics of naturally occurring and man-made plasma and neutral gas clouds.

In both categories, scientific interest focused on interactions with the ambient geoplasma and the evolution of particle densities, energy distribution functions, waves, and fields.

II. A PERSPECTIVE ON TECHNOLOGY LEVELS

The Beams Working Group adopted a general perspective on the planning and development of future experiments to be conducted on large spaceborne platforms (as will be the case on the Space Station). That perspective can be stated as follows:

> The basic-plasma, geoplasma, and astrophysical-plasma communities can be strong supporters of the Space Station as a uniquely useful laboratory in space <u>if and only if</u> induced environmental effects of the primary platform and its subsystems are reduced to noninterference levels in the conduct of the scientific experiments, and <u>if and only if</u> support subsystems provide a substantially broadened capability in power, telemetry, operations, and information technologies than currently available on Shuttle and dedicated satellite missions.

With this perspective, initial concerns reviewed Level-1 technologies (Table 1), including: (1) the dynamics and control of large structures, (2) fluid management, (3) energy systems, (4) information technologies, (5) automation and robotics, and (6) in-space operations. Of all Level-1 technologies, energy systems and in-space operations received the most attention. It was generally agreed that current plans for 25 to 50 kW power levels as primary support on the Space Station would hinder more creative scientific advances in the era beyond the year 2000. One such example includes the possible use of positrons as unique probes of the magnetosphere (Dawson, 1986). Such an endeavor requires a large energy resource, with 10 to 20 GeV a nominal requirement for the production of a single positron. While the total number of positrons would be low, the volume of space to be probed would easily tax the planned Space Station power system–a not too unfamiliar situation in which technology would lag the scientific requirement.

Panel attention to "in-space operations" quickly moved to Level-2 concerns on the "local scientific climatology" (Table 1), defined as the sum total of all prevailing conditions that affect and/or contribute to the integrity and merit of the scientific mission in question. These concerns, detailed in Level-3 considerations, involve the availability of free-flying or tethered satellites, the naturally occurring and induced environments, and the platform adaptability to sensor requirements.

Free-flying satellites were viewed as an important asset that would allow multipoint measurements in space with guaranteed observational perspectives free from possible contamination by the presence of the Space Station itself. Similar assets were attributed to tethered subsatellites, with applications including those geared to the development of an "Ionospheric Weather Station" (Szuszczewicz, 1986) and innovative approaches to power generation and propulsion (Purvis, 1986; Hastings, 1986; and Taylor et al., 1986).

A number of special issues were identified within the context of tether technology and associated applications. These included: (1) the very difficult problem of tethering to large separations (hundreds of kms), (2) extraordinarily high $\bar{V} \times \bar{B}$ potentials (Szuszczewicz, 1986; and Hastings, 1986), (3) requirements for new "in situ" measurement capabilities, (4) the necessity for large current contact with the ambient ionosphere and control of subsatellite potentials through the use of plasma contactors (Szuszczewicz, 1986; and Hastings, 1986); and (5) waves generated by large spacecraft configurations (Hastings, 1986; and Barnett, 1986). These all represented issues of special concern to the execution of beam and beam-related experiments in space (Winkler, 1986; Raitt, 1986; Szuszczewicz, 1986; and Murphy, 1986).

III. GENERIC ISSUES AND ENVIRONMENTAL IMPACTS

In terms of environmental influences, it was determined that the following generic categories could provide an encompassing description:

(1) Particle effluents.

(2) Electric and magnetic field emissions.

(3) Uncontrolled surface and body effects, including surface potentials, structure currents, and wakes.

Within the context of the working group charter, environmental issues were identified with specific concerns for the impact on the execution of a planned experiment, and alternatively, the potential threat of experiment execution on platform subsystems. Those results are summarized in Tables 2 and 3.

In keeping with the general position advanced in the opening of this summary report, it was agreed that unless substantial care was taken with regard to platform environmental controls many experiments would not meet full scientific accommodation on the Space Station. Gaseous effluents, power systems, and structures and surfaces of the Space Station and tethered subsatellites could have a degrading effect on the performance of beam and plume experiments. As Table 2 delineates, these environmental issues can impact not only the physics of the process under study but the integrity of the optical and electrical sensors being used for diagnostics in the investigation.

It was determined that environmental impacts could work both ways and that there exists the possibility that the execution of a number of experiments could lead to deterioration of several of the on-board subsystems. Table 3 delineates relevant interactions, not the least of which includes EMI, surface damage by energetic particle impact, and degradation of optical sensors used for spacecraft positioning and guidance.

IV. OVERALL RECOMMENDATIONS

Several issues in Tables 2 and 3 presented themselves as having serious gaps in our current understanding, giving rise to concern for concentrated efforts to relieve the deficiencies in the near- to mid-term. These issues include:

(1) The generation of waves and plasmas by large structures, plumes, and beams.

(2) Current systems in vehicle-plasma interactions, including $\vec{V} \times \vec{B}$ effects, surface and body currents, and vehicle charging.

(3) Effectiveness of plasma contactor technology to satisfy safety concerns relevant to vehicle charging and to perform the safety function on a noninterference basis with planned scientific programs.

An immediate and aggressive program of investigation is recommended, with synergistic approaches of theory, laboratory simulation, and spaceborne experimentation. Initial efforts should focus on large structures, their wave fields, differential potential and current systems, and adaptability to control with developing plasma contactor technology. In parallel, there should be a continuing development of strong scientific requirements for control over the generic areas of environmental impact so that negative influences can be eliminated, mitigated, or controlled. Where attitude control gases are viewed to have degrading effects, alternate technologies should be pursued – perhaps in some cases requiring a substantial research and development initiative. Similar approaches should be adopted with respect to the application of plasma contactors. While protection against high charging levels is one issue in contactor development, the possibilities for distortions of the natural particle and wave fields are abundant (Szuszczewicz, 1986). There should be serious concern with the latter aspect of contactor development and alternate technologies should be explored or plasma contactor noise-reduction-techniques developed. Overall the time frame to the year 2000 is short, and nearsightedness on the approach to the "scientific climatology"of the Space Station could render it as a relatively unattractive platform for future scientific endeavors.

IV. REFERENCES

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Table 1. Hierarchy of Space Station Plasma Technology Issues

Level 1

- Dynamics and control of large structures
- Fluid management
- Energy systems and thermal management
- Information systems
- Automation and robotics
- In-space operations

Level 2

- Advanced life-support systems
- Orbital transfer vehicles
- Local scientific climatology
- Propulsion
- Maintenance and repair

Level 3: Local scientific climatology

Prevailing conditions affecting and/or contributing to the scientific mission

- Availability of free-flying or tethered subsatellites
- The natural, induced, and controlled space environments
- Platform adaptability to sensor requirements

Table 2. Environmental Issues Resulting from Subsystem and Platform Operations With Potential Impact on Beam Experiments

Subsystems and platform operations (cause)	Scientific program execution (effects)
Gaseous effluents	Lifetime and evolution of processes under study (e.g., chemistry and dynamics of expanding plasmas)
• Controlled releases (e.g., thrusters, waste ejection, and thermal subsystems)	Degradation of optical sensors
• Uncontrolled sources (e.g., virtual leaks, real leaks, and outgassing)	Dielectric material deposition on critical electrical surfaces
	Generation of perturbing plasmas and waves
	Distortion of ionospheric currents to the platform and triggering of anomalous charging/discharging events
Power	Uncontrolled fields (electric and magnetic, dc and ac) and currents
• Solar arrays	
• Ac and pulsed-power systems	
• Ground loops	
• Power levels	Duty cycle of high-power beam experiments
Structures and surfaces	Large differential potentials (e.g., $\vec{V} \times \vec{B}$)
• Large structures	Uncontrolled and unknown potentials
• Tethered subsatellites	Wakes and resulting wave fields

Table 3. Environmental Issues Resulting from the Conduct of Beam Experiments With Potential Impact on Subsystem and Platform Performance

Scientific program execution (cause)	Program performance (effects)
Particle beam experiments	EMI
	Surface damage/erosion by energetic particle impact
	Spacecraft charging
	Potential interference with optical/attitude sensors
	Possible interruptions of C^3 systems
	Explosive release of stored energy
Heavy-particle "plumes"	Surface deposition and contamination
• Plasma injection	• Solar arrays
• Neutral gas cloud releases	• Optical surfaces
	• Thermal surfaces
	Possible interruptions of C^3 systems
	Safety of high-pressure systems