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# Space Platforms for NASA -Opportunity or Pitfall?

William J. Cuneo
*Lt/Col, USAF on Detail to NASA*

Dell P. Williams
*Director, Space Systems Division, NASA Headquarters, Office of Aeronautics and Space Technology*

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# SPACE PLATFORMS FOR NASA–OPPORTUNITY OR PITFALL?

William J. Cuneo, Jr.
Lt/Col, USAF on Detail to NASA
and
Dr. Dell P. Williams, III
Director, Space Systems Division
NASA Headquarters
Office of Aeronautics and Space Technology

## ABSTRACT

Described are the NASA efforts to determine if platform to pool payload services are cost effective. The platform concept originated from the short shuttle life on orbit, the shuttle capability to assemble aggregating structures, and the belief that economies might be obtained from shared services and repair. About eighty payloads in NASAs future were identified for consideration. Contractor and in-house studies have produced platform configurations. Comparative cost studies are currently being done. Results have been obtained, but enthusiasm is being reserved (as of March) until sufficient review has been achieved. The platform approach has a large intuitive following; if platforms appear to be cost effective, they are likely to become a very visible part of the NASA space effort.

## INTRODUCTION

One of the major potential applications of the capability of the Space Shuttle is the construction and maintenance of a platform, a location in space where space-peculiar activities are carried out with economies of scale. Grant Hansen of the National Research Council's Ad Hoc Committee on Technology of Large Space Systems has likened it to a terrestrial industrial park, where essential services for activity are provided reliably and economically. However, even those who are drawn to the imaginative appeal of such a concept are justifiably concerned with the potential pitfall: cost to develop, to operate, to integrate with, and to accomplish the mission in the face of orbit, view restriction, contamination, and other constraints which will accompany platform operations. Initial evaluation of such factors suggests that a platform can be favorable mode of operation and further review is underway. This paper will describe some of the highlights of the current platform studies and discuss how some technologies can improve the effectiveness of a platform.

## DEFINITION AND MOTIVATION

In the context of this paper, a space platform provides to a changing set of activities (payloads) basic services such as power, attitude control, communications, data management, and thermal control. The concept is not new. The many previous studies on space stations encompass the essence of platforms. For example, Disher[1] described such a concept in his discussion of the 1975-77 Space Station Systems Analysis Studies by Grumman and McDonnell Douglas for the NASA Office of Space Transportation Systems (OSTS) and Marshall Space Flight Center (MSFC). These studies synthesized a program for a permanent operational base and laboratory to support or enable several missions perceived to be of value: solar power system development, 0-g manufacturing, earth observation/communication/navigation, life science, and celestial/solar observation.

A platform to merely support payloads appears to be a narrow perception compared to the space stations envisioned in those studies. However, today, with shuttle operations only two years away instead of six, and the NASA payload planning horizon in the eighties more sharply defined than it could have been in 1975, a somewhat different set of factors drive planning for use of the shuttle. The difficulty of keeping the shuttle spaceborne for extended periods collides with the desire for longer duration by those experimenters who will transport their instruments to space cheaply on the shuttle. The presence of man on the shuttle encourages assembly, deployment, and repair to be considered at levels far beyond what has been possible with automated spacecraft. Efficiency of both transportation and orbital activity is expected to be greater if regular flights were made to a single point. Equipment failures should be repairable sooner if the equipment is concentrated at a point.

Together these facts and beliefs reinforce the rationale that there should be a place in space where payloads can be left by the shuttle. You will note that they all have a common theme of operational economics as contrasted with the heavier emphasis on vision in the earlier space station studies. In essence, the users are expected in the platform scenario to provide the vision, with the "space station" activity providing a minimum cost and constraint on the user for operating in space.

## PLATFORM EVALUATION ACTIVITIES

Over the past year there has been a major effort within NASA to evaluate the cost effectiveness of platforms. This effort has involved all of the offices of NASA: the users in Space Science (OSS) and Space and Terrestrial Applications (OSTA), the operators in Space Transportation Systems (OSTS), and the technologists in Space Technology (OAST). The major responsibility for conduct of the initial study effort was given by Deputy Administrator Lovelace to the Space Science Office because of their most obvious demand for longer observation time than the shuttle could reasonably provide and the high state of definition of their desired payloads. Several NASA Centers participated with the sponsorship of different Headquarters offices: Marshall, Johnson, Langley, and Goddard. The effort broke into three major parts: payload model, platform design, and comparative costing.

## PAYLOAD MODEL

The payload model had to be established with sufficient detail and with a time horizon about ten years hence to permit reasonably representative platform configurations to be defined. A first step was creation of a format which would insure that critical technical features were not overlooked. The format developed and generally used is presented in Table 1. With this data format in hand, the several discipline offices identified the future payloads which could be considered for platforms, and produced a Payload Data Package (PDP) of detail for each one. The disciplines were (OSS) Astronomy/Astrophysics, Solar/Terrestrial, Life Sciences; (OSTA) Climate/Environment, Global Resources, Materials Processing; and (OAST) Technology. The payloads identified are listed in Tables 2-4.

Note that not all NASA disciplines are included in these lists of payloads. Communications is omitted because the payloads would be geosynchronous. Planetary missions are omitted because they obviously are not low earth orbit. Further, within each discipline, payloads which must operate in unique (such as highly eccentric) orbits have been omitted.

When a set of payloads such as this is presented, the question naturally arises on its constancy. The answer is not simple, nor is it unique to NASA. An organization such as NASA which is mandated to operate on the forward edge of technology and uncertainty should not produce an unchanging edifice of detailed goals. This, however, is contrary to the desire and need for fixing goals to channel effort. A principal mechanism NASA uses to reconcile these opposite forces is the Five Year Plan The FY 1980-1984 plan was "frozen" in March 1979 and activity was begun to create the FY 1981-1984 plan. The process of creating such a plan is as valuable as the final document; the final product document, while eloquently expressive of NASAs overall goals, is outdated with regard to detailed plans, particularly the detailed schedule beyond two years. Most of the payloads listed in Tables 2-4 were identified from the Five Year Plan work during Fall-Winter 1978. New payloads were also identified. Some of these have entered the Five Year Plan as of March 1979. On balance, the payloads passed several tests of validity; they are technically possible; have a clearly or probably useful output defined by a user; are within reasonable budgets, albeit modestly increased; and have a constituency within NASA.

It is interesting to note that the payload model presented does not have men in orbit unattended by the shuttle until 1987 when a life sciences habitability module is proposed for addition to a platform. This module, presently envisioned as a derivative of the Spacelab, would provide quarters for a crew of four for 90 days. In 1990 another discipline, materials processing, is scheduled in this model to require man in the long duration MEM-II module, currently envisioned as a 100KW facility to advance the industrial use of space. While unattended manned operations on orbit are relatively far in the future under this mission model, there will be numerous manned flights of Spacelab between now and 1987. For instance, up to seven Spacelab flights are scheduled on the shuttle through early FY 1983.

Most readers are fully aware that the dates cited in these tables are approximate. Some will advance; many will slip under the pressure of technical and, particularly, budgetary factors.

## PLATFORM DESIGN

The NASA Centers cited above were involved in the design effort. Several contractors participated: Rockwell International Satellite System Division, McDonnell Douglas Astronautics, and Grumman Aerospace were the principal ones. Initially, the payloads in the model were sorted by their characteristics and requirements. Some payloads were given little consideration because of their large size or other unique features which forced subsequent design: examples are the 100-meter diameter, high power, atmosphere gravity wave antenna, and the pinhole camera with a 100-meter boom. Materials processing and life science payloads were not included in the bulk of the work because of their high power, low-g requirements, and later schedule. The technology payloads in Table 4 were generally neglected because they require operation in Spacelab. A new set of technology payloads which perform demonstrations for OAST is currently being defined to exploit the opportunity offered by the platform concept. Fifty-one candidates are being screened; an initial indication is that about half will remain technically and economically justifiable for flight on a few pallets under the OAST program.

After omitting the manned, large, and technology payloads, about 50 science and 20 application payloads were subsequently examined. Their orbit inclination requirements varied. Celestial observing instruments were generally content at 28°. Solar observations tended to favor 70° and higher. Earth observation payloads required near polar if the mission was "routine" (e.g., operational weather satellites) or a mid-inclination (70° or 57°) if a variety of suntime-location pairs were needed to enrich the range of variables observed. Materials processing and life science are indifferent to inclination. This variety of desired inclinations leads to a tendency to proliferate platforms; the economy of scale is weakened thereby. The consequence to the user of compromising on inclination is a matter requiring further study.

For the current platform studies, compromises on inclination had to be assumed. One extreme was to assume a 28°, 57°, 70°, polar, and sun-synchronous platform to meet the needs of the observational missions with little compromise. The other extreme was to assume two platforms, 28° and polar. To illustrate the mass-orbit characteristics of the platform concepts, a particular three platform scenario[2] (circa 1986) can be cited. A 28° platform would have a mass of 40K kg, half of which is user instruments, not including their pallet mounts. A 57° platform mass would be 30K kg, 40% of which is instruments. At 90°, a 25K kg platform would also have 40% of its mass in instruments. At this stage of the platforms, masses cited are likely to be low by several tens of percent.

The salient features of a platform can be seen in Figure 1, the 28° 40K kg platform cited above. The dominant feature of all the platform designs is the solar cell array, generally about 60 meters end to end for providing a nominal 25K kw. Its width is about nine meters to minimize obstruction of view angles. Compare this with Skylab which is about 40 meters long (workshop-adapter-orbital service module) and 30 meters across its workshop solar cells if both panels had deployed.

The radiator is the second dominant feature noted in the platform designs. It is unclear whether a single central radiator or radiators distributed among payloads is best. Distributed radiators complicate thermal independence of payloads in the compact platform designs. Central radiators require considerable plumbing but potentially offer more thermal freedom to the individual payload designs.

The next dominant feature is the strongback required to carry the payloads. All designs use a strongback; the concept of simply bolting pallets together has been rejected because of the number involved, in this case about 12. A variety of designs for strongbacks have arisen. One type involves erectable pentahedral elements such as in Figure 1. A deployable strongback concept is the "six-pack"[3] shown in Figure 2. Six instrument pallets are carried in this configuration, supported by three platform equipment pallets. Solar arrays and radiators would appear similar to those in Figure 1. Another type of strongback involves more columnar, extendable arms on which pallets are mounted. The most ambitious (sizewise) strongback uses beams manufactured on orbit to form an open structure up to about a hundred meters long with booms to mitigate the gravity gradient effects by equalizing the moments of inertia. In summary, there are numerous options for strongback construction. Their size and the size of the solar arrays and radiators for typical aggregations of payloads make a platform an imposing structure.

## COMPARATIVE COSTING

In parallel with the payload model and platform design work, several cost models were constructed to compare extended life shuttles, platforms, and dedicated spacecraft. Absolute numerical detail will not be given here because review of the results is incomplete as of this writing. It is probable that considerably more effort will be devoted to validating the models and their input data so that the question "are platforms worth it" can be answered with some unanimity of opinion. Some relative cost trends can be noted now, however.

A straightforward point is that the cost to a user will tend to be less on a platform by avoiding shuttle reflights to accumulate mission duration. Since science users desire much longer staytimes than even the 60 days proposed as an upper limit for the shuttle, the platform appears to have a decided cost advantage over the shuttle.

The significant cost competitor to a platform is the dedicated spacecraft exemplified by the Multimission Modular Spacecraft (MMS). The result of cost comparison between MMS and platforms is highly sensitive to the traffic model and size of the platform; more traffic and larger size favor the platform. Tentative results obtained so far suggest that an MMS operating in excess of two to three years is competitive with a platform in cost per unit payload-year; for shorter missions the platform operations are up to two to three times less costly, including amortization of the platform development and production. The base for amortization of the cost of pallet carrying platforms is on the order of 100 to 150 pallet-years over an initial six year period. A three-inclination platform family is assumed for the cost ratios cited.

In order to emerge from future cost tradeoff with MSS on the favorable side, platforms will have to be defined which can achieve acceptably low cost in the usual development, procurement, and operations domain. The platform designs to date do not reveal any features which make any component of a platform risky on fundamental technical grounds; hence, the cost risk associated with the components can be considered acceptable. It is the pecular aspect of platforms, the integration of varying payloads, which appears to many to be a significant cost pitfall which could appear if NASA decides to operate from platforms.

## THE INTEGRATION PITFALL AND APPROACHES FOR AVOIDANCE

We believe the integration pitfall will appear when platform design has progressed to the detailed design phase, where specific components, controls, and instrument groups are selected and their interaction with the total system predicted. The pitfall will consist of the cost of resolving the uncertainties by performance compromise, new design and development, and exhaustive integrated testing. An indirect cost will accrue if the compromises reduce performance or observation time of user instruments.

Such an integration pitfall is not peculiar to platforms, but we believe it can easily become worse than traditionally expected in the case of platforms. It is not possible to predict and solve all such integration problems in advance. However, there are some areas where early technology demonstrations can anticipate more obvious potential problems and provide confidence in some new techniques to suppress them. Some, but certainly not all, important areas for such technology demonstrations are instrument pointing, dynamic motion supression, assembly and deployment, data management, and propulsion.

## INSTRUMENT POINTING

The pointing needs of the various payloads vary over a wide range. Figure 3 describes the payload needs for accuracy (how absolutely the optical axis points) and stability (how much the optical axis can move during an observation time).[4] Pointing and stabilization of optical line-of-sight are strongly affected by other spacecraft characteristics, perhaps more so than any other function. Costly redesign and integrated component testing have traditionally been required in many spacecraft to achieve desired line-of-sight performance.

On a platform, a hierarchy of techniques appears necessary, ranging from whole body platform pointing, through gimbals and verniers for groups of instruments, to direct use of the observed image to provide pointing and stabilization signals. It would seem that the more that can be achieved at the coarser levels of the hierarchy, the less complex would be the entire platform/instrument ensemble because the finer levels involve more numerous units. However, there are limits to which each level of the hierarchy can be pushed before development difficulty becomes great.

Evaluation of platform structures indicates that whole body pointing can conservatively provide 0.3 degrees error in pointing to any instrument station on a platform such as shown in Figure 1. Thermal effects cause the bulk of this error. Wider use of low expansion graphite epoxy, particularly in the pallet, might permit 0.1 degree to be achieved.

However, it is not clear that such an improvement is useful because the pointing required by narrow field solar and astronomy instruments is three to 100 times finer. Instrument group gimballing using sun or stars as an external reference appears necessary. Two gimbal systems are under development: the Spacelab Instrument Point System (IPS) and the MSFC/Sperry Annular Suspension Pointing System (ASPS). Using star sensors to provide a reference, it is expected that these gimbals will provide one arc second pointing accuracy after mechanical biases of a few arc seconds between star sensor and instrument are accounted for by calibration in use.

After acquiring an object or field through the pointing process, stability of the line-of-sight is of critical concern. Both the ASPS and IPS gimbal are expected to achieve stabilities on the order of one-two arc seconds. However, many planned instruments which depend upon imaging have sub-arc second stability requirements. Generically, consider a one-meter aperture and one-micron wavelength telescope. A root-mean-square stability of 0.2 of the wavelength/diameter ratio is generally attractive in the design phase to achieve an optimum system performance. Stabilities of 0.04 arc second are thus indicated. This level of performance has been approached in laboratory tests of the magnetically suspended vernier on the ASPS.

There is often a need to achieve even higher stabilities, especially in astronomical instruments, such as the Deep Sky Ultraviolet Survey Telescope on Astronomy Pallet # 2 in the mission model. Motion compensation using the instrument's image is capable in principle of achieving stability commensurate with the instrument's resolution. An example of such image compensation can be found in the Space Telescope's fine pointer system which should achieve the desired 0.02 arc second rms stability. It is possible that the difficulty of developing such compensation can be lifted from the user, however. The ASPS venier is designed to achieve or exceed performance exemplified by the Space Telescope. Flight tests are necessary to test performance to the theoretical design limits, particularly when tracking. Flights of the IPS and probably the ASPS will occur in the early eighties on shuttle sorties. If theoretical performance is nearly achieved in these demonstrations, the ASPS and IPS will enable platforms to provide the users the critical pointing and stabilization functions. Payload traffic models suggest that about twenty such units would be necessary to support platform operations.

## DYNAMIC MOTION SUPRESSION

Solar and astronomical observations as a class are the most demanding of stability, and there is concern that their dynamic interaction will restrict their performance on a large multiactivity platform even though individual pointing platforms such as ASPS and IPS perform well. The large mass of the platform relative to a single instrument, the absence of required high accelerations, and the ability to shape accelerations should prove powerful in ameliorating instrument interactions. However, analysis of the platform dynamics has not been done yet, and hence the effects cannot be dismissed of disturbances such as those due to worn CMGs, pumps and valves, rotating joints, non-ideal slew profiles of instruments, and attitude control of the platform, turbulent coolant flow, etc. Should analysis and experiment reveal these to be of concern, then new techniques for active dynamic control now under development for flexible spacecraft offer solutions which can prevent costly platform component redesign or performance compromise. These techniques use either local absorption of vibratory energy by generation of counteracting forces in structure, or "global" absorption by observing and counteracting in concert at several points on the structure. A dynamic analysis of some platform point designs is in order to determine the magnitude of the problem.

## ASSEMBLY AND DEPLOYMENT

Platforms will require extensive assembly and deployment on orbit. There appears to be no reason why such operations are fundamentally unreasonable. Indeed, NASA planners assume that an age of on-orbit structure building will be enabled by the shuttle. The same planners and the operators also believe that such construction activity will require engineering development before it can be accomplished reliably. Recent tests in neutral bouyancy tanks support this belief. In the tests we have in mind, lightweight structural elements which were satisfactory for operational loads were broken by the loads imposed during assembly. Such difficulities do not imply that on-orbit assembly is excessively risky, but they do imply that assembly and deployment success will require vigorous iterations between demonstrations and design. The OAST sponsored Large Space Structures Technology program is now providing a base of such design and demonstration upon which systems builders can draw. We believe the platform represents an opportunity to gain the experience of demonstration in space as a step in the evolution toward more complex structures which are envisioned for the future, such as the Space Power System.

## DATA MANAGEMENT

The means by which data is handled on the platform is another area where technology can help reduce integration costs and deliver less costly data to the user. In the current Spacelab control and data system, a large central software package handles almost all functions. Its modification to accommodate different payloads is a costly process. In the early years of operations, a platform will have to present to many payloads the same interfaces as they had on Spacelab to avoid costly rebuilding of instruments. In time, though, it seems desirable to provide control and data interfaces from local processors and memory units. Each could be programmed to accommodate its particular payload, and each would be under much simpler central control. Such an approach would not only ease the software problem of modifying a large central processor, but would also permit the packaging of data in manners particularly efficient for the individual payload and its users. Such custom data packages could conceivably be sent directly to users who would be supplied with standardized low cost ground stations. Such stations appear possible with modest changes in existing communications hardware. For example, Goddard Space Flight Center has configured an x-band link, with an 0.6-meter space antenna, 2.3-meter ground antenna, and 44 watts RF power which could move 100 Mb/sec to a user. Such a link, except for antenna gains, is now used in the Landsat program. Most users with instruments on platforms would require far less data than provided by Landsat. It appears that a direct-to-user link can be designed for a platform which enables the low cost, proliferated ground stations. The platforms thus appear to offer an ideal opportunity for implementing a highly tangible aspect of the NASA End-to-End Data System, which has a goal of greatly decreasing the cost and increasing the speed of data acquisition by users.

## PROPULSION

The propulsion needs of platforms do not affect integration cost per se, but do impact the cost of platform operations which should lead to increased user charges. The platform designs studied to date require three-five thousand kilograms per year of storable propellant for drag makeup in 450 km orbits. It is currently suspected that electric propulsion drag makeup can be employed. Use of a noble gas should eliminate contamination and environmental concerns which attend the use of mercury. Further tradeoff of this alternative versus chemical propulsion is proceeding now. If electric propulsion proves favorable, its use on a platform can serve as a step in its qualification for orbit maintenance in other applications, particularly the geostationary communications platforms which are under study.

## THE FUTURE

The above discussion of the impact of technology on the performance and hence worth of platforms is only a sampling of the many areas where development is useful. OAST, in coordination with the other offices in Headquarters and with the Centers, has been evaluating new thrusts to improve the technology supporting platforms. As of this writing, the place of platforms in NASAs future is under review. If the decision is made to move vigorously toward platform operations, driven by such factors as the user need for longer observation times, then a first platform could be orbited as early as 1984. To impact the design of such an early platform, part of the technology efforts would have to be channeled immediately toward platform-specific demonstration items.

Because of the review activity currently underway, we cannot report a conclusion on whether the opportunities offered by platforms outweight the pitfalls. Our own belief, based upon such information as presented above, is that platforms will prove to be desirable. They appear to have sufficient cost advantage to offset the cost risk of their development. They appear to be useful not only in themselves, but also as a building block of experience toward even more visionary space operations. They can be (perhaps literally) a highly visible sign among the stars that free men are reaching for the heavens.

We are indebted to many individuals in NASA Headquarters and Centers, contractors, and users whose ideas and work we have used to compose this discussion and report on platforms. We have had the luxury of time to write while W. Snoddy, J. Rosendahl, C. Gillespie, S. Sadin, E. Huckins, H. Hill, R. Benson, T. Hagler, W. Kisko, R. Beranek, M. Nein, F. Digesu, H. Gierow, J. Ballance, V. Burton, L. Allen, L. Jenkins, A. Louviere, D. Krueger, A. Adelman, M. Townsend, J. Evans, G. Naumann, J. Allen, W. Boyer, and their colleagues in NASA and elsewhere have been and are assiduously producing the knowledge which has been barely tapped for this paper. We salute them and their efforts.

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3. "Deployable Orbital Service Platform Conceptual Systems Study Final Review," NASA/JSC contract NAS9-15532 with the McDonnell Douglas Astronautics Company, West Huntington Beach, Calif., February 14, 1979, p. 69.

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## TABLE 1
## ITEMS FOR PLATFORM STUDY PAYLOAD DATA PACKAGE

### GENERAL

Name

Status (operational, in development, planned start, planned but no funds, concept evolving)

Objective

Lifetime (planned/desired)

Type measurement

Date [launch date (real or firmly planned), start and launch date if start approved, earliest launch date if not planned and given a reasonable development time starting now]

Principal contact

Wavelength and bandwidth (or energy and Δ energy)

Active sources - if any

F/No

Aperture [diameter(s)]

### PHYSICAL

Dimensioned sketches of major mission equipment

Overall size (L × W × D)

Mass characteristics (give payload/spacecraft division, if possible) (weights, moments of inertia, expendables)

Unpressurized volume/pressurized volume

Identify deployable elements, internal moving parts (size, weight, speed, momentum)

Structural interface mounting locations

### ORBIT

Altitude desired, acceptable range

Inclination desired, acceptable range

Perigee location if highly eccentric

Synchronization with Earth or Sun, if any

Ephemeris accuracy needed

Time reference accuracy needed

## TABLE 1 (Cont.)

## ITEMS FOR PLATFORM STUDY PAYLOAD DATA PACKAGE

### POINTING

View direction (inertial, solar, Earth, other)
Total field of view during an operation
Pointing timeline
Pointing accuracy
Required pointing knowledge accuracy
Stability angle (error in angle allowed during a measurement period)
Integration time (time over which platform stability is to be maintained)

### POWER

Average power or energy per orbit
Peak
Standby
Desired voltage/frequency, if different from 28 Vdc
Peak power duration
Timeline

### DATA/COMMUNICATIONS

Type output (analog, digital, voltages)
Data rates
Allowable delay between acquisition and dumping (real time, minutes, hours, days)
Special uplink commands, if any
Duty cycle
Data processing, if any
Diagnostic telemetry points (number and rate)

### THERMAL

Temperature ranges (operational, nonoperational)
Type concept utilized
Cryogenic (load, temperature, duration)
Heater requirements
Heat rejection requirements

TABLE 1 (Cont.)

ITEMS FOR PLATFORM STUDY PAYLOAD DATA PACKAGE

## ENVIRONMENTAL SENSITIVITY, IF UNUSUAL

(Temperature limits, humidity limits, cleanliness limits, acoustics limits, conducted EMI limits/level, radiated EMI limits/level, radiation rate limit, operating acceleration limit, outgassing, pumps)

## PERSONNEL OPERATIONS REQUIRED/DESIRED, IF ANY

(Number crew, times, shifts, EVA)

## OPERATIONS

(On-orbit maintenance/checkout/calibration, if any)

## POTENTIAL HAZARDS AND SAFETY CONSTRAINTS

## SPECIAL CONSIDERATIONS, IF ANY

(Booms, isolation, etc.)

## TABLE 2

## POTENTIAL PAYLOADS FOR PLATFORM: OFFICE OF SPACE SCIENCE

| EXPERIMENT TITLE | PROJECTED FLIGHT DATE | INSTRUMENT(S) | OBJECTIVE |
|---|---|---|---|
| Astronomy Pallet No. 1 | 1982 | UV photometric polarimeter<br>EUV spectrograph | Time dependent event studies<br>High spectral resolution studies |
| Astronomy Pallet No. 2 | 1982-84 | Spacelab wide angle telescope | Full sky survey in UV |
| Astronomy Pallet No. 3 | 1987 | 3-5 m VLBI or submillimeter antenna | Test concepts for submillimeter astronomy or very long base-line radio astronomy |
| Astronomy Pallet No. 4 | 1983 | P.I. class pointed UV/optical instruments | Specialty experiments |
| Astronomy Pallet No. 5 | 1985 | 1.5-m UV/optical light collector | Photometry, spectroscopy, polarimetry studies |
| Spacelab II IR Survey Instrument | 1981 | 0.15-m IR telescope | Wide FOV IR survey |
| Unmanned SIRTF Follow-On (Shuttle Infrared Telescope Facilty) | >1985 | 1.2-m infrared telescope | Extension of manned SIRTF mission |
| STARLAB | 1987 | Meter class wide field telescope | Visible/UV observations of large angular extent structure |
| Astrometric Telescope for Planet Detection | 1988 | 1.5-m visible telescope | Search for extra solar planetary systems |
| Large Ambient Deployable IR Telescope | 1989 | 12-20 m near/far IR telescope | High resolution IR observations |

TABLE 2 (Cont.)

POTENTIAL PAYLOADS FOR PLATFORM: OFFICE OF SPACE SCIENCE

| EXPERIMENT TITLE | PROJECTED FLIGHT DATE | INSTRUMENT(S) | OBJECTIVE |
|---|---|---|---|
| High Energy Pallet No. 1 | 1983 | P.I. version of LAMAR (Large Area Modular Array of Reflectors)<br>Fe line spectrometer | Map extragalactic X-ray sources<br>Provide data for nuclear astronomy |
| High Energy Pallet No. 2 | 1985 | Cosmic ray instrument | Measure isotopic composition of Fe nuclei |
| High Energy Pallet No. 3 | 1986 | X-ray high resolution spectrometer<br>X-ray polarimeter | Study compact galactic and extragalactic sources |
| High Energy Pallet No. 4 | 1988 | Gamma ray burst detector/monitor | Establish location, spectrum, and time profile of bursts |
| High Energy Pallet No. 5 | 1989 | High energy gamma ray telescope | Study spectrum and spatial extent |
| High Energy Pallet No. 6 | 1984 | All sky X-ray monitor | Monitor long-term intensity changes |
| High Energy Pallet No. 7 | 1986 | Soft X-ray survey instrument | Extend HEAO-A survey<br>Measure luminosity function of sources |
| High Energy Pallet No. 8 | 1987 | Large area timing facility<br>Proportional counter and scintillator | Study time variability of compact X-ray sources with high resolution |
| High Energy Pallets No. 9 and No. 10 | 1988-89 | Low energy gamma ray spectrometer | Detect and measure nuclear lines from discrete objects and diffuse regions |
| LAMAR | 1986 | Large area modular array of detectors | Determine distribution of extragalactic X-ray sources |

## TABLE 2 (Cont.)

## POTENTIAL PAYLOADS FOR PLATFORM: OFFICE OF SPACE SCIENCE

| EXPERIMENT TITLE | PROJECTED FLIGHT DATE | INSTRUMENT(S) | OBJECTIVE |
|---|---|---|---|
| Solar Physics Pallet No. 1 | 1982 | Several Spacelab I and II and P.I. class instruments | Solar spectral and magnetic characteristics |
| Solar Physics Pallet No. 2A | 1983 | Solar gamma ray experiment | Study gamma rays from solar flares |
| Solar Physics Pallet No. 2B | 1983 | Hard X-ray imaging instrument | Study nonthermal particles and high temperature plasmas |
| Solar Physics Pallet No. 3 | 1984-86 | Lyman alpha coronograph<br>White light coronograph | Measure coronal temperature |
| Solar Physics Pallet No. 4 | 1985-88 | XUV spectroheliograph<br>X-ray heliograph | Study physical characteristics of coronal plasma |
| Solar Physics Pallet No. 5 | 1986-89 | Moderate resolution UV/vis telescope | Study solar magnetic and velocity fields |
| Soft X-Ray Facility | 1989 | Narrow field spectroscope | Study sun inner corona and transition zone |
| Solar Optical Telescope | 1984 | 1.25-m UV/IR spectroscope | High spatial resolution studies |
| 100-m Pinhole Camera | 1985 |  | Hard X-ray measurements of solar disk |
| 1-km Pinhole Camera | 1988 |  |  |
| Solar Cycle and Dynamics Mission | 1986 | 10 instruments in X-ray, XUV, UV, vis, radio regions | Long-term measurements of sun |

TABLE 2 (Cont.)

POTENTIAL PAYLOADS FOR PLATFORM: OFFICE OF SPACE SCIENCE

| EXPERIMENT TITLE | PROJECTED FLIGHT DATE | INSTRUMENT(S) | OBJECTIVE |
|---|---|---|---|
| Space Plasma Physics Pallet No. 1 | 1982 | Particle accelerators<br>Photometric camera | Study space plasma/atmospheric interactions<br>Measure atmospheric emission |
| Space Plasma Physics Pallet No. 2 | 1982 | Deployable diagnostic subsatellite | Measure plasma characteristics |
| Space Plasma Physics Pallet No. 3 | 1984-85 | Instruments from free-flyers | Measure plasma parameters, particle spectra, wave spectra |
| Tether Facility | 1984 | 100-km tether | Atmosphere and space plasma characteristics and dynamics |
| Wave Particle Interactions | 1984 | 300-m dipole antenna<br>10-km antenna using tether | Confirm occurrence of wave particle interactions and measure flux |
| Radiation Belt Dynamics Facility | 1985 | Three X-ray instruments | Study energy populations and distributions |
| Life Sciences Laboratory Module (manned with Shuttle tending) | 1986 | Animal, cell tissue holding units<br>Human research units<br>Low-g centrifuge | Medical, biological, and life systems research |
| Habitability Module (manned without Shuttle tending) | 1987 | Crew quarters | Study human factors, behavior |
| Logistics Module | 1989 | Gas/liquid storage<br>Waste storage and transport | Provide for resupply of expendables and extension of crew stay-time |

TABLE 2 (Cont.)

POTENTIAL PAYLOADS FOR PLATFORM: OFFICE OF SPACE SCIENCE

| EXPERIMENT TITLE | PROJECTED FLIGHT DATE | INSTRUMENT(S) | OBJECTIVE |
|---|---|---|---|
| Additional XRO Instruments | 1988 | Wideband imaging spectrometer | Measure continuum spectrum of discrete X-ray sources |
| University of Chicago Cosmic Ray Nuclei Detector | 1981 | Nuclear spectrometer | Determine charge composition and energy spectra from Li through Fe |
| Cosmic Ray Instruments from CRO | 1987 | Nuclear spectrometer | Measurement of continuum spectrum of discrete sources<br>Ultra-heavy cosmic rays<br>Electron, positron spectrum |

## TABLE 3
## POTENTIAL PAYLOADS FOR PLATFORM: OFFICE OF SPACE AND TERRESTRIAL APPLICATIONS

| EXPERIMENT TITLE | PROJECTED FLIGHT DATE | INSTRUMENT(S) | OBJECTIVE |
|---|---|---|---|
| LANDSAT | 1981 | 6 channel vis/IR 30-m resolution scanner | Earth resources observations, especially agricultural |
| Earth Resources and Atmospheric Processes Pallet | 1984 | Laser probes | Atmospheric composition and dynamics |
| Climate Research Satellite | 1986 | TBD | Climate observations and predictions |
| Atmospheric and Solar Studies Pallet | 1984 | Solar irradiance monitor | Measure total solar radiation |
| | | Laser heterodyne spectrometer | Distribution of atmospheric species |
| | | Composite tropospheric package | Tropospheric temperature/humidity profile |
| System 85 Operational Polar Satellite | 1985 | Camera, vis/IR scanners, sounder, IR radiometer | Operational weather satellite for climatology and water budget estimation |
| Passive Microwave - Multidiscipline | 1985 | 10 channel high resolution microwave spinning scanner | Studies in meteorology, geophysics, hydrology, polar studies, and ship routing |
| Ocean Circulation Satellite | 1985 | Radar altimeter<br>Others: TBD | Determine biomass distribution, ocean heat transport, and relationship to weather and climate |
| Coastal Zone Monitoring | 1986 | Radar altimeter<br>Others: TBD | Monitor near-shore environment, including biocontent, ice, and coastal transport conditions |

## TABLE 3 (Cont.)

## POTENTIAL PAYLOADS FOR PLATFORM: OFFICE OF SPACE AND TERRESTRIAL APPLICATIONS

| EXPERIMENT TITLE | PROJECTED FLIGHT DATE | INSTRUMENT(S) | OBJECTIVE |
|---|---|---|---|
| Global and Regional Atmospheric Monitor | 1988 | TBD | Regional and global environment studies |
| Precipitation Measurement | 1984 | Microwave radiometers | Global water budget and agricultural studies |
| Wind Measurement | 1987 | Radiometers, scatterometers | Monitor wind pattern, speed, and stress |
| Soil Moisture Radiometer - Mark I (fixed parabolic) | 1985-86 | 15-20 m diameter 1-2 GHz radiometer | Determine feasibility of making soil moisture measurements from space, aid in crop yield prediction, watershed management and climate studies |
| Soil Moisture Radiometer - Mark II (phased array) | 1987 | 10 x 10 m dual polarized 1-2 GHz radiometer<br>Thermal IR radiometer | Crop yield forecasting, watershed management and climate studies |

TABLE 3 (Cont.)

POTENTIAL PAYLOADS FOR PLATFORM: OFFICE OF SPACE AND TERRESTRIAL APPLICATIONS

| EXPERIMENT TITLE | PROJECTED FLIGHT DATE | INSTRUMENT(S) | OBJECTIVE |
|---|---|---|---|
| National Oceanic Satellite System | 1984 | Scatterometers, altimeters, AVHRR (visible & IR radiometer), microwave radiometer<br>Coastal zone color scanner | Provide global observations of ocean surface conditions |
| Earth Resources Synthetic Aperture Radar | 1985 | Dual polarized L-band SAR | Mineral and petroleum exploration<br>Develop SAR techniques |
| Lidar Temperature Sensor | 1982 | High power laser | Measure temperature profile in the troposphere |
| Lidar Pressure Sensor | 1984 | High power laser | Measure surface pressure, cloud top pressure/height, and pressure profile in the troposphere |
| Land and Atmosphere Profiling/Ranging Pallet | 1984 | High power laser<br>Microwave instruments | Detect Earth crustal motion<br>All-weather temperature/humidity sounding; ocean current and terrain mapping |
| Spaceborne Meteorological Radar | 1990 | TBD | Provide precipitation data for storm surveillance, natural disaster observation, and flood warning |

TABLE 3 (Cont.)

POTENTIAL PAYLOADS FOR PLATFORM: OFFICE OF SPACE AND TERRESTRIAL APPLICATIONS

| EXPERIMENT TITLE | PROJECTED FLIGHT DATE | INSTRUMENT(S) | OBJECTIVE |
|---|---|---|---|
| Cryogenic Limb-Scanning Interferometer and Radiometer | 1985 | Infrared instruments | Study stratosphere and lower thermosphere thermal emission measurements |
| Atmospheric Science Pallet No. 1 | 1983-84 | 11 P.I. class instruments | Multi-parameter data base of atmospheric phenomena |
| Atmospheric Science Pallet No. 2 | 1987 | A number of P.I. class instruments | Multi-parameter data base of atmospheric phenomena |
| Atmospheric Science Pallet No. 3 | 1990 | A number of P.I. class instruments | Multi-parameter data base of atmospheric phenomena |
| Subsatellite | 1986 | Maneuverable subsatellite with variety of instruments | General scientific support |
| Atmospheric Gravity Wave Antenna | 1988 | 100-m diameter antenna | Study properties of gravity waves and their role in atmospheric energy transfer |
| Chemical Release Module | 1986 | Release of substances in ionosphere, probably on probe vehicles | Atmosphere/ionosphere studies |
| LIDAR | 1986 | High power laser | Study atmospheric constituents |
| Particle Beam Injection | 1986 | Electron injection | Study ionospheric perturbations |
| Magnetic Pulsations | 1990 | 1-km antenna tc transmit ULF signals | Induce magnetic pulsations in magnetosphere |

TABLE 3 (Cont.)

POTENTIAL PAYLOADS FOR PLATFORM: OFFICE OF SPACE AND TERRESTRIAL APPLICATIONS

| EXPERIMENT TITLE | PROJECTED FLIGHT DATE | INSTRUMENT(S) | OBJECTIVE |
|---|---|---|---|
| Materials Experimentation Carrier | 1984 | High temperature furnaces<br>Containerless processing facilities | Low g experiments in materials processing |
| Space Vacuum Research Facility | 1987 | Molecular wake shield | High vacuum processing experiments |
| Materials Experimentation Module No. 1 | 1987 | Several automated payloads | Material processing with larger facility |
| Materials Experimentation Module No. 2 | 1990 | Various laboratory modules | Long duration man-tended material processing |

## TABLE 4

## REPRESENTATIVE PAYLOADS FOR PLATFORM: OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

| EXPERIMENT TITLE | PROJECTED FLIGHT DATE | INSTRUMENT(S) | OBJECTIVE |
|---|---|---|---|
| Drop Dynamics Module | 1981 | Cameras, audio equipment, liquid source and container | Observe free-floating liquids under acoustic excitation |
| Laser Heterodyne Spectrometer | 1983 | IR spectrometer | Demonstrate capability to measure trace atmospheric species |
| SEP Solar Array Flight Experiment | 1980 | Deployable solar array | Demonstrate advanced lightweight solar array technology |
| Feature Identification and Locating Experiment |  | Video system and IR camera<br>Data analysis system | Development of a landmark identification and tracking system |
| Annular Suspension Pointing System | 1983 | Gimballed pointing mount | High accuracy target pointing and tracking |
| Cryogenic Fluid Management Experiment | 1982 | Liquid hydrogen handling | Demonstrate on-orbit subcritical cryogen storage and supply |
| Solar Cell Calibration Facility |  |  | Verify calibration of present and advanced state-of-the-art solar cells |
| Two-Phase Heat Transfer | 1983 | Camera, pumps, liquid/gas injecting system | Develop propellant management methods<br>Conduct fluid mechanics and heat transfer experiments |
| Zero Gravity Combustion Facility | 1981 | Variety of man-operated experiments | Observe combustion in low gravity |
| Geophysical Fluid Flow Cells | 1980 | Shadowgraph and photochromic techniques | Provide data on spherical convection processes and test theories |

TABLE 4 (Cont.)

REPRESENTATIVE PAYLOADS FOR PLATFORM: OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

| EXPERIMENT TITLE | PROJECTED FLIGHT DATE | INSTRUMENT(S) | OBJECTIVE |
|---|---|---|---|
| Tribiology Experiment in Zero Gravity | 1980 | | Examine interaction of liquid lubricants and surfaces |
| SAR Processing Experiment | 1982-84 | Synthetic aperture radar processor | Investigate feasibility of real time on-board processing of SAR data |
| Phase Transition and Critical Point Experiments | | High speed camera, electronics | Fluid property measurement near gas-liquid critical point |
| Dynamic and Thermal Properties of Superfluid Helium in Zero Gravity | 1981 | Quantized surface wave experiment | Study properties of capillary waves |
| | | Bulk fluid experiment | Measure frequencies, damping, and temperatures |

# BASELINE CONFIGURATION—PLATFORM 1

- ERECTED IN A SINGLE SHUTTLE MISSION
- OPERABLE WITH OR WITHOUT SHUTTLE ATTACHED
- ACTIVELY STABILIZED
- EXPANDABLE TO LARGER SIZE

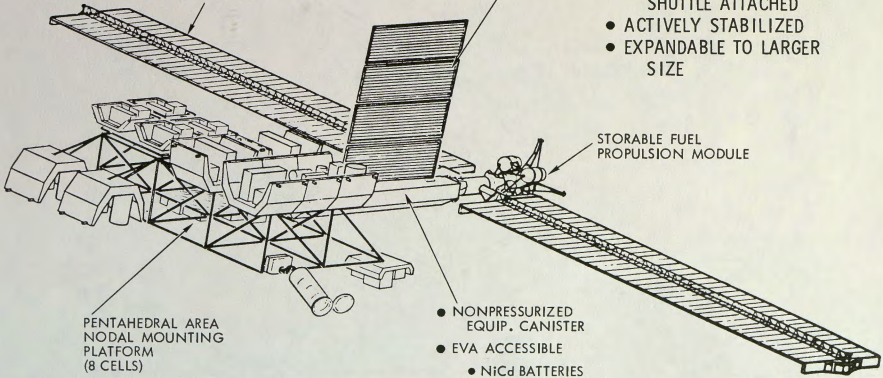

Figure 1.

# DEPLOYABLE PLATFORM STRUCTURAL CONFIGURATION

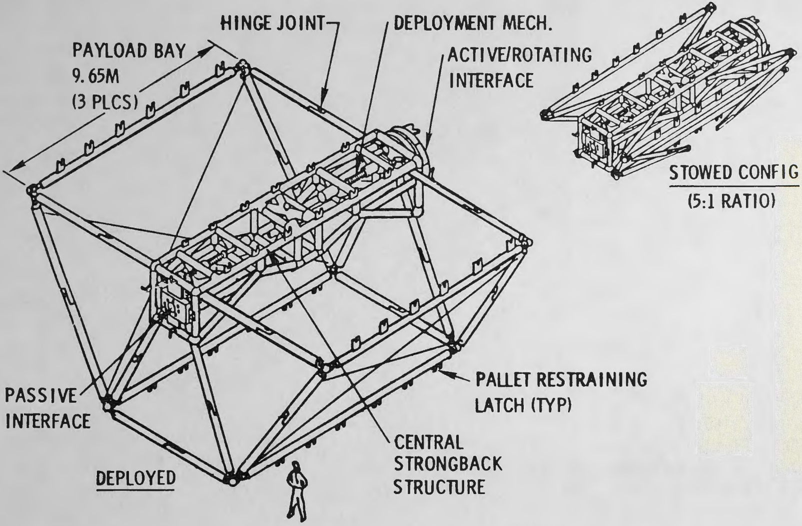

Figure 2.

# POINTING REQUIREMENTS AND POTENTIAL SOLUTIONS

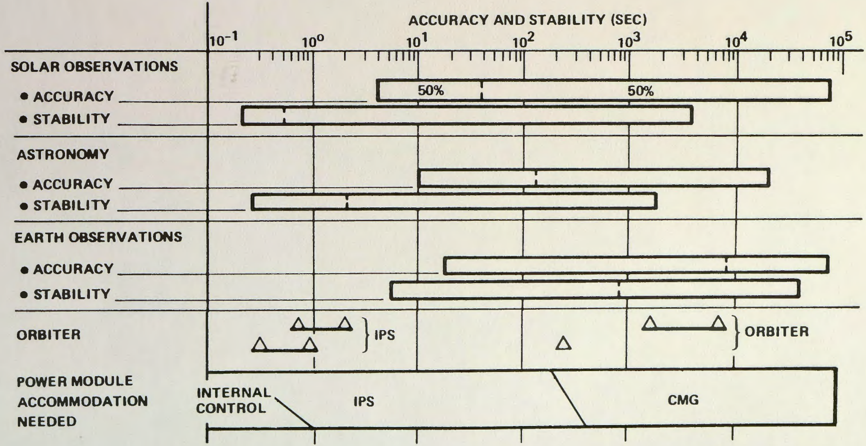

Figure 3.