"Scientific Uses of Space Station"

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Abstract

A permanently manned Space Station is now under "definition study" by NASA and, in parallel, by Canada, Japan, and the European Space Agency (ESA). As these studies mature, it is expected that an international partnership will be formulated with participation by some or all of these organizations and with shared operations once the station is established.

A most important aspect of this definition study is the incorporation of the needs of the scientific community. To assure that NASA is properly advised of the requirements of various research disciplines a "Task Force on the Scientific Uses of Space Station" has been organized under the leadership of Prof. Peter Banks at Stanford. Many of the suggestions made in this paper are the conclusions of this Task Force, which will eventually be documented by a formal report to NASA.

There has been widespread interest in participation in Space Station research, from many countries and from a number of disciplines. In particular, the life sciences (human and animal physiology, biology, plants) and microgravity sciences (materials science, fluid physics) have heavy demands for crew time and long duration operations. Astronomy and earth observations often need free-flying platforms for remote operations, but with the capability of return to the Space Station "core" or visits from an Orbital Maneuvering Vehicle, for maintenance and repair activities. The needs of these and other disciplines will be outlined.

The current status of NASA's definition study will be described and projections made concerning the conduct of science operations from an international Space Station.

Definition and Preliminary Design

At the present time, the Space Station Program is approximately half way through the designated Definition period, with Preliminary Design to follow in the latter half of 1986. A number of innovative suggestions have been made for modifications of the "Reference Configuration" established prior to the beginning of this program phase. For example, removal of radial docking parts from the pressurized modules will make substantially more interior volume available for laboratory and habitation functions. Location of EVA airlocks and scientific airlocks for equipment exchange externally to the pressurized modules will also retain the maximum volume for laboratory and habitation functions. To accomodate these changes, additional "interconnect nodes" have been conceived, which may attach to the end of any module and have five other possible locations (on the other five sides of a cube) for docking ports, hatches or windows. The original Reference Configuration has now been modified to incorporate these new features and to refocus the NASA and contractor studies in these directions.

Minimum acceleration level is a most important parameter for investigators in microgravity research, such as crystal growth, fluid physics and some areas of the life sciences. Although one may think of the entire station as being "weightless" in free-fall, in-fact, the acceleration level only approaches zero along the flight path of the station center-of-mass. For a station maintained in a local-vertical attitude, gravity gradient forces exert a little less than $0.4X10^{-6} g_o$/meter for all objects above or below the center-of-mass. In other words, the laboratory of the Space Station must be within about ± 2.5 meters vertically (or 3 times this distance out-of-plane) of the center-of-mass to remain at acceleration levels of less than one micro-g (about $10^{-5} m/s^2$). The Reference Configuration has again been modified to locate the pressurized modules more nearly at the center-of-mass, allowing experiments and operations close to the level of one micro-g_o.

From these examples, it is clear that the Reference Configuration is a dynamic description and one which is being modified as various alternative options are compared. It should also be clear that these modifications have come about almost entirely from the needs of the "user communities" in science, technology and commercial applications.

Still other changes to the Reference Configuration will certainly be made before the Definition is complete. While it is generally considered that the longest possible pressurized modules are desirable, the exact length has yet to be set. The number of modules, the degree of outfitting prior to launch, the hatch size, degree of closure of environmental control system, the assembly sequence, are some of the subjects still under consideration.

Other elements of the Space Station complex are also being reviewed, such as the capabilities of low inclination and polar platforms, their operational and (possibly different) servicing altitudes, and the mode of servicing them. The Orbital Maneuvering Vehicle (OMV) might service them at an operational altitude (polar orbit), or it might return them to the Orbiter's lower altitude for service, or the polar platform might maneuver independently to lower its altitude to that of the Orbiter.

Another essential element of the early planning is the consideration and incorporation of international participants. The European Space Agency, the Japanese and the Canadians are all embarked on parallel planning efforts and we are coordinating our efforts with their representatives at the NASA Program Office in Houston. We expect the final configuration to incorporate some or even all of the plans of these international organizations and countries.

Science Operations

To help answer questions concerning the utility of a Space Station and to advise NASA regarding means of enhancing its usefulness, a "Task Force on the Scientific Uses of Space Station (TF/SUSS)" has been organized, chaired by Professor Peter Banks of Stanford University and composed largely of academic members from a broad spectrum of scientific disciplines. The Task Force is formally a subcommittee of the Space and Earth Sciences Advisory Committee, but operates independently and provides advice directly to the NASA Advisory Council, to the Space Station and to the Science and Application Offices, as appropriate. Coordination with the international science community has been established by inviting a number of foreign scientists to participate in Task Force meetings and by joint meetings with its European counterpart, the Space Station User Panel.

From the core elements, it is expected that many experiments utilizing weightlessness (or "microgravity") will be performed. The expanding potential for research and even commercialization is becoming more evident from the early Spacelab flights and mid-deck experiments in the Shuttle/Orbiter. Protein crystals much larger than obtainable on Earth have been grown in space, with applications to cancer research and many other life science disciplines. Characterization of their molecular structure by X-ray diffraction techniques has already begun with the objective of devising the "key" to their functioning in living organisms. Crystals of interest to the physical sciences for use in X-ray and infrared detectors and spectrometers are grown either in fluids or by vapor deposition. Various hormones and drug related substances have now been purified by electrophoresis and are approaching the time for tests on humans.

As these experiments are still in a developmental stage, they are run most efficiently with a crewmember in attendance. Adjustments, modifications, oversight and repair, if required, have all been important elements on these early flights. Many more experiments will be possible when Space Station arrives, with weeks of continuous operation possible, with adequate power and crew attendance to maximize the productivity of the operation.

Human, animal and plant studies in long term weightlessness are also expected. They will extend Skylab and Salyut investigations of the adaptive mechanisms operating in weightlessness in such areas as vestibular function, bone demineralization (and countermeasures), cardiovascular modifications, immune response and many others. A large centrifuge for variable-g exposure may well be required, to permit in-flight comparisons at various acceleration levels.

The physical sciences expect to use the core station for control of a number of "attached payloads" in solar-terrestrial physics and astronomy (solar, stellar and planetary). A good many experiments require coordination between observations made on board the core station and simultaneous measurements from platforms or free-flyers in the vicinity of space station. "Tether" operations, in which a long, lightweight cable (usually conductive, but insulated from the surrounding plasma) may be extended upward or downward for tens and even several hundred kilometers. They may be used in a number of different ways--for power generation, modest thrust for orbit maintenance and for deployment of instruments remotely from the core station, as examples. In addition, the core station will eventually be used as a staging base in space for the build-up and check-out of spacecraft for planetary missions.

Platforms and free-flyers "co-orbiting" with the core station will be used for experiments which may need isolation from a manned station, yet desire the flexibility of an occasional manned visit for repair and maintenance. Examples presently envisaged include the Hubble Space Telescope, Gamma-Ray Observatory, Solar Maximum Mission and Space Infra-Red Telescope Facility. The ability to service hardware in nearby orbit as well as aboard the core station may well develop into one of the most important functions of the manned element.

Extensive use of sun-synchronous polar orbit is needed by various disciplines, but often at different local times of ascending node. For example, solar observers may require (0600 and 1800) local times to achieve continuous sunlight, while ionospheric physicists need (1200 and 2400) local times to obtain good day-night coverage, whereas many in the Earth resources community need mid-morning for minimum haze and clouds. All these orbits will need service from Orbiter, with an Orbital Maneuvering Vehicle used for transport between Orbiter and their observing altitudes.

In all of these applications, a new mode of communication between ground investigator and his or her space sensor is contemplated. It has been called "telescience" to imply the control of his experiment remotely, perhaps from a home university location or perhaps from a central operations control center with appropriate coordination between ground and space-borne crewmembers. The accent will be on a team approach, with some members at remote control centers and other team member(s) near the sensors in space. Considerable effort must be expended to insure a satisfactory end-to-end data and command flow and a design which will allow modernization of the data management system as technology evolves over the next ten to twenty years.

The response of the science community in the U.S. and internationally to this Space Station opportunity has been generally positive and enthusiastic. Having their "voices heard" at this early stage and with substantial evidence that the definition phase has been responsive to their needs, is especially encouraging to those with previous experience in similar major space endeavors. As the TF/SSS Summer Study Report concluded, "There is a consensus that the Space Station can be of great value to the advancement of space research."