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# Human Factors in Space Station Architecture I

*Space Station Program Implications  
for Human Factors Research*

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# Human Factors in Space Station Architecture I

*Space Station Program Implications  
for Human Factors Research*

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**NASA**  
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## SUMMARY

*The space station program is based on a set of premises developed from mission requirements and the operational capabilities of the Space Shuttle. These premises will influence the human behavioral factors and conditions on board the space station. These premises include: launch in the STS Orbiter payload bay, orbital characteristics, power supply, microgravity environment, autonomy from the ground, crew make-up and organization, distributed command and control, safety, and logistics resupply. The most immediate design impacts of these premises will be upon the architectural organization and internal environment of the space station.*

## INTRODUCTION

The space station program rests upon a group of premises based upon mission requirements and the operational capabilities of the existing Space Transportation System (STS) Orbiter. These premises will influence profoundly the human behavioral factors conditions on the space station. The most immediate design impacts will affect the architectural organization and internal environment of the space station.

This article describes two sets of premises in the space station program. The first set, conceived by the Space Station Task Force (SSTF), **affects all aspects of the program, including design, operations, and mission capabilities.** The second set, engendered by the Space Station Concept Development Group (CDG), affects environmental design and human factors in particular. Each set of premises contributes to structuring a situation in which the human-factors advocate is given a clear role and a formidable task. Both sets of premises were groundwork for the "Skunkworks" at NASA Johnson Space Center from May through July 1984 and are manifested throughout the Phase B Request for Proposals that was the product of the Skunkworks (Systems Engineering and Integration Space Station Program Office: *Space Station Reference Configuration Description*, JSC-19989, NASA JSC, Houston, 1984).

Some of these premises, particularly those established by the SSTF, are made explicitly as program guidelines. Others are more implicit, and while not necessarily appearing as guidelines, underlie more visible recommendations. Both explicit and implicit premises should be recognized as foundation stones upon which to construct a development program and a system architecture. Human factors considerations must be equally a foundation stone of the space station program.

Before it is possible to advocate the human factors case, it is essential to evaluate the implications of these program premises. And this examination of program implications

must be carried out before research objectives are selected and certainly before design recommendations are made.

## SPACE STATION TASK FORCE PREMISES

The four basic premises of the space station program have been established by the Office of Space Station (Code S) at NASA Headquarters, under the leadership of Phillip Culbertson and John Hodge. These four premises pertain to launch, orbit, power supply, and microgravity.

### Launch in STS Orbiter Payload Bay

All parts of the initial space station will be launched into orbit in the STS Orbiter payload bay. The dimensions of the "dynamic envelope" for cargo in the payload bay are 4.27 m in diameter and 18.3 m long. When the docking tunnel is installed, the allowable payload is reduced to approximately 14.25 m in length and may be further constrained by center of gravity considerations. However, length is not as critical a dimension as diameter. The interior clear diameter is estimated at 4.06 m. This interior dimension represents a profound constraint in a confined environment and is significantly smaller than Skylab, which had a clear interior diameter of 6.5 m (ref. 1). Although the space station will have multiple volumes in four or five modules, the 4.06 m clear interior diameter will impose similar constraints on each module, no matter how many modules there are. These dimensional and volumetric constraints lead to serious concern for human performance levels over extended periods of time. The relationship between spacecraft cabin volume and human performance has served as one of the earliest measures of habitability (Celentano, J. T., Amorelli, D., and Freeman, G. G.: *Establishing a Habitability Index for Space Stations and Planetary Bases*, NAA-593-0, Space and

Information System Division, North American Aviation, Downey, CA, June 1963, p. 39). The concern for habitable volume increases with crew size and mission duration.

### **Low Earth Orbit at Low Inclination**

The station will probably fly in low Earth orbit at an altitude of approximately 370 to 580 km, the operational upper range of the STS Orbiter. The station will probably be placed in a low-inclination orbit of approximately 28.5°. Orbital altitude and inclination are partially dictated by mission and operational requirements, but they are also influenced by and have consequences for meteoroid, space debris, and radiation exposure. These potential hazards have significant meaning for crew safety (ref. 2). Radiation in particular presents a special case of a human-factors issue in crew safety, with long-term consequences for astronaut careers and human productivity on orbit.

### **Solar Photovoltaic Power Supply**

The power supply for the Initial Operating Capability (IOC) station will be a solar-powered photovoltaic array, providing a goal of 75 kW bus power, with the specific conditioning to be determined. In addition to some possible orbital fluctuations in peak power supply, human-factors implications include the likelihood that installation of the solar arrays may be extravehicular activity (EVA) labor-intensive, and long-term maintenance might impose additional demands on EVA time. However, the use of solar power rather than nuclear power appears to avoid a larger range of potential human-factors problems, including system safety, radiation hazards, and shielding that would be associated with a nuclear reactor on a human-inhabited space station.

### **Microgravity Environment**

The station will have a "zero gravity" or microgravity environment. There will be no attempt to produce artificial gravity by rotating the space station, because no requirements for artificial gravity have come forth from the aerospace or scientific user communities for this space station. In fact, the major attraction of the space station for scientific work and commercial materials-processing is microgravity. In terms of human-factors considerations for microgravity, ongoing research will continue in the area of physiological effects (ref. 5), health and safety (ref. 6), human-machine interaction (Bond, Robert L.: *The Methods and Importance of Man-Machine Engineering Evaluations in Zero-G, Skylab Experience Bulletin No. 26*, JSC-09560, NASA JSC, Houston, 1976), neutral body posture (ref. 5), work stations in

wieghtlessness (ref. 6), anthropometrics (ref. 7), and design guidelines (Griffen, Brand N.: *Design Guide: The Influence of Zero-G and Acceleration on the Human Factors of Spacecraft Design*, JSC-14581, NASA JSC, 1978). Additional research may be required in personal restraints, exercise, locomotion, and spatial orientation.

## **SPACE STATION CONCEPT DEVELOPMENT GROUP MODEL**

From May 1, 1983, to May 1, 1984, a Space Station Concept Development Group was chartered to meet at NASA Headquarters in Washington, D.C. The head of the CDG was Luther Powell of the NASA Marshall Space Flight Center in Huntsville, Alabama. People detailed from the various NASA centers met in small study groups to establish a CDG straw-man or baseline configuration. Within this baseline frame of reference were several premises that are critical to human-factors engineering for the space station, particularly the autonomy baseline, safety model, crew model, and command and control system. Many of these CDG premises were adopted into the Phase B Reference Configuration that subsequently was developed at the Skunkworks in Houston. For the purposes of this analysis, it is valuable to address these premises in their original form, before becoming enmeshed in specific design schematics.

### **Autonomy From Ground**

In developing the Autonomy Baseline, the CDG focused principally on autonomy from the ground, specifically from Ground Control or Mission Control. It is important to distinguish between NASA Mission Control and user or experimenter control on the ground, which will ideally be able to uplink instructions and downlink data with a high degree of independence from Mission Control or other NASA monitoring functions. The key points of the Space Station Autonomy Baseline are as follows (Hodge, John; Herman, Daniel; and Craig, Mark: *Space Station Program Briefing at Ames Research Center*, NASA SSTF, Washington, D.C., Feb. 24, 1984, p. DSG-320):

1. Ninety days in orbit without an STS orbiter revisit for resupply or rotation of crew. This baseline has implications for crew training and scheduling and for the organization of logistical support. The nominal tour of duty for the crew is implicitly set at 90 days. This nominal period of 90 days is based principally on logistical resupply criteria for volume and weight characteristics of a common module modified as a logistics module (ref. 9), and Shuttle launch and module ground-processing schedule considerations (Opresko, Greg; and Keenan, T.: Study No. 3: Operations and Logistics

Philosophy, *Space Station Concept Development Group Workshop Briefing Charts, Volume I*, NASA SSTF, Washington, D.C., Dec. 5-9, 1983).

2. Twenty-one days of survival time in "safe-haven" mode, in the event of some accident or catastrophe that requires rescue by the Space Shuttle. This 21-day figure is based on an assumed 19-day turnaround time for putting the next Shuttle back into orbit to carry out a rescue, with a margin of safety (ref. 10).

3. Five days in orbit without routine ground support from mission control in the form of advice, information, or instructions. This baseline implies that the station will have on board an extensive database about station construction, operations, and maintenance. However, in the event that some vital information is not available on board, the capability will be in place to uplink it rapidly. Ground control will provide "bellringer support," a continuously open channel that will acknowledge a call in 5 min and supply expert consultation within 4 hr (Holmes, William: Study Task No. 1: Autonomy, *Space Station Concept Development Group Workshop Briefing Charts*, description of Ground Responsibilities, NASA SSTF, Washington, D.C., Dec. 5-9, 1983).

4. One day in orbit with no communication from the ground, including the uplink and downlink of data. This baseline implies a 24-hr data-storage capability on the space station.

It is important to note that while points 1 and 2 of this Autonomy Baseline are derived from anticipated system operational constraints, points 3 and 4 represent goals to be achieved. One long-range goal of this Autonomy Baseline is to reduce the large staff at Mission Control to a small staff that will "provide manned routine-operations support on a noncontinuous basis (2 to 5 days/week, 8 hours/day)." This reduction in staff would hopefully lead to a reduction in overall program operating costs for a program that will be permanently in orbit. The Autonomy Baseline, if fully implemented, would free many NASA personnel to engage in activities more productive than simply maintaining the space station in orbit.

However, this transfer of decision-making responsibility from the ground to orbit will yield a new set of human-factors issues. This decision-making and problem-solving role will change the role of the crews from the Skylab experience in far-reaching ways about which it is possible to only speculate. The increase in self-reliance will contribute to the formation of a more coherent micro-society on board the space station.

## Crew Makeup and Organization

The crew of this initial station is projected at six to eight people. The crew of the post-IOC growth station is projected to double the initial crew to the range of 12 to 16 people, perhaps by the year 2000. There will probably be a fairly heterogeneous mix of backgrounds and talents among the space station crew. Typically, the crew might consist of two "classical" astronaut-pilots; two or three mission specialists; and three or four payload specialists from the scientific, international, or commercial communities.

The space station crews would train together for a period of time to be determined before commencing their nominal 90-day tour of duty on the space station. As a corollary to the Autonomy Baseline, part of the training for the space station crews may include working as mission ground controllers for other crews, not unlike the current practice of astronauts working as communicators in the STS mission control (ref. 11). However, payload specialists would probably receive much more limited training than other crew members, which will contribute to the heterogeneity of the crew makeup in possibly unforeseen ways.

One major variable in crew training and crew scheduling is the strategy to be selected for the rotation of crew members through their tours of duty on the space station. An assumption has prevailed throughout the space human-factors community that a likely model for space station crew rotation would be that of submarine crews. The principal reason for this assumption is the belief that full blue-gold crew rotation would lead to better crew cohesion and teamwork. However, a broad-ranging literature search of small group research turned up nothing definitive to show the value or validity of extending the blue-gold system beyond the relatively unique context of a submarine. On a submarine, the isolation from the outside world is far more extreme than would be the isolation on the space station, where regular, protected communications with family and friends would be encouraged. If the rotation strategy follows the "blue and gold" team approach of submarine crews, the entire crew will be exchanged at one time with an overlap period for turning over the station of approximately 4 to 5 days which is comparable to the turnover time for nuclear submarine crews (Essex Corporation presentation to the CDG at NASA HQ, Oct. 26, 1983. Background based on discussion following the Essex presentation). In submarines, the turnover occurs at dockside, with one if not both of the crews living on land, while both gold and blue crew members review their equipment and responsibilities together in the process of one crew handing over the job to the other.

But the space station is not a submarine. There is no "dockside." On the space station, the only other place to house the second crew during changeover will be the orbiter. But with a crew of eight for the space station plus two orbiter crew members, living for a week on the orbiter with 10 people will be an exercise in severe residential crowding.

Also, this load would probably approach the limits of the current orbiter's life support and other systems, indicating some possible modifications to the orbiter itself.

The first alternative is to house both full crews on the space station itself for 5 days. This approach could impose excessive loads on the station life support system, or require that it be oversized for a double load for approximately 5% to 10% of each crew rotation cycle. Actually, there may be no alternative to sizing the life support system to the 5% of the time/double load because of the need to hand over equipment and work responsibilities with both crews on board, and also to be able to support both crews in the event of some emergency.

The second alternative is partial crew rotation, where half of each crew of eight would be changed out at roughly 45-day intervals. This alternative strategy, while reducing the crowding problem on board either the orbiter or the station, introduces two new difficulties. First, it will break up the unity of whole-crew training and will possibly introduce an element of "old-timer versus greenhorn" or "us versus them" syndrome between the two crew factions. Second, this alternative will require a variation in the autonomy baseline for the 90-day independence from Shuttle revisit, and will put the crew rotation partially out of phase with the proposed logistical resupply strategy. *However, it must be recognized that on the growth station with a possible crew of 16, or on larger space stations to follow, it is unlikely that it will be practical to change out an entire crew for every tour of duty.* Therefore, despite some of its programmatic difficulties, this second alternative of partial crew rotation may prove to be the most realistic one over the long term. The research implication that flows from this alternative is that it will be necessary to find crew training, management, and operational measures to mitigate the potential adverse effects of split-crew rotation.

The crew selection, training, teaming, rotation, and scheduling strategies will be influenced by mission and operational requirements which are just beginning to crystalize, so it is premature to speculate further about these crew issues. However, it is essential to recognize the significance of these space station crews being more diverse and creating a more complex micro-society in a more complex environment than any previous spacecraft.

### **Distributed Command and Control**

One of the more radical ideas to come out of the CDG was that the command and control system be entirely distributed to every habitable, permanent module on the space station. Unlike virtually all previous space station proposals, this concept contains no centralized command module. There will be nobody in the role of Captain Kirk sitting on the bridge of the starship Enterprise eight hours a day with a staff of subordinates monitoring all the vital functions of the

spacecraft. In fact there will be no bridge at all. Instead, in every module, there will be a basic command, control, and communications console from which all the vital functions of the space station can be monitored and controlled. And the station commander, if there is such a position, will be free to move about the station and perform other tasks, never being more than perhaps 20 ft from a command and control console.

The station itself will be highly automated so as not to require constant human monitoring. While the CDG did not go so far as to explicitly recommend distributed command and control, the space station crew responsibilities for automation/human-machine interaction present a logic that leads to decentralized command and control. The key points of these functional requirements for both the station and ground control are as follows:

1. Maintain station in operational status.
2. Monitor station status and implement station configuration.
3. Take any actions necessary for station safety or station integrity.

Functional requirements specifically allocated to machines include these automated functions:

1. Perform "overhead" activities.
2. Perform repetitive, boring, dynamic, or dangerous tasks.
3. Provide automatic fault detection, isolation, recovery, and/or corrective actions, including switch-over to redundant units.
4. Provide for crew override of critical functions.

Functional requirements specifically allocated to the crew are as follows:

1. Overall supervisory control.
2. Perform interesting tasks.
3. Handle contingencies.
4. Supervise machines.
5. Conduct on-board experiments.
6. Make immediate judgments, evaluations, adjustments, and corrections.
7. Make immediate modifications and repairs.

With the exception of periodically scheduled system checks, the station ideally will fly itself. Unplanned human intervention will be required only when an alert or alarm is annunciated on the system. When an alert in the form of a buzzer, light, or voice alarm does occur, the crew must be able to respond in conformance to the immediate requirements previously described. In a contingency situation requiring immediate response, the crew must be able to turn to a command console no matter where they are. Therefore,

every module must have a command console. Whether this console should be dedicated to perform command and control functions exclusively, or whether it should be configurable with video display terminals that can serve a variety of functions is a systems design decision that cannot be made as yet. A set of critical research implications flows from this level of automation: how to design a human-matched command and warning system, how to maintain vital skills that will not be called upon except in a contingency situation, and how to conduct on-board training to pass on the command and control responsibilities to the following crew.

In addition to these distributed command consoles, the IOC station will have one or two proximity-operations (prox-op) work stations which will probably be located in an observation station or cab. These prox-op stations will be used for rendezvous, docking, berthing, EVA and teleoperator monitoring, and other functions that may require direct visual observation. These prox-op stations should be distinguished from the command and control consoles, although in those modules having prox-op stations, they may be associated by adjacency with the command and control consoles.

This concept of distributed command and control suggests profound implications for crew organization and for the space station architecture. A discussion of crew decision-making process and management is beyond the scope of this paper, but the space station architecture must consider the command and control system, including crew implications. **The primary implication of distributed command and control for space station architecture is that all the other critical systems likewise should be decentralized or distributed.** These systems include life support, electrical power, thermal control and cooling, communications, and a host of others. These subsystems are all architectural elements that shape the habitable environment, which will interact with the crew organization and the command and control system.

### Single Perceived Level of Safety

Distributed command and control will have enormous implications for space station crew safety. Just as the vital utilities are distributed to every module, so can emergency provisions be decentralized as "safe havens" to each module (ref. 10). Each safe haven will contain all the necessary supplies to support the entire space station crew of eight for the period of 21 days indicated in the Autonomy Baseline until a return and rescue by the Space Shuttle is possible. The safe haven will contain food, water, clothing, life support, and emergency waste management, and will be located in each module in a standard safe-haven pack that will be part of the common module.

The strategy of highly decentralized and distributed safety preparations led to the logic of a single perceived level of safety on the space station (meeting with Luther Powell at CDG offices, Washington, D.C., June 24, 1983). This logic

means that each module will be designed to be equally as safe or secure as every other module. And just as no work station in any specific location will be considered more essential or safer than any other (at least among the command and control consoles) neither will any crew member be considered more or less essential than any other. The implication for crew teaming and training is that there will be no nonessential personnel on board the station for the standard 90-day tour of duty. There may be some exceptions to this ethical/safety precept for people visiting the station for short periods of time, as in a brief Shuttle rendezvous.

It is important to point out that the safety strategy developed by each of three groups, the CDG, the Phase B Skunkworks, and the Space Station Crew Safety Alternatives Study by the Rockwell International Crew Systems Safety Group (ref. 12), are somewhat at variance with each other. These differences will give rise to some healthy dialogue about crew safety strategies.

It is also important to note that each crew safety strategy is predicated on various and differing assumptions about space station configuration. These differences become most manifest in the emergency life support and safe-haven strategies. For example, in the Space Station CDG-1 configuration, with most of the modules having only one means of passage to and from the multiple-berthing adapter module, a complete safe-haven package would be mandatory in each module (fig. 1).

In comparison, the Phase B Reference Configuration, which features a "racetrack" circulation-loop pattern, would tend to alleviate the need for a safe-haven capability in every module, with perhaps only as few as two complete safe havens required (fig. 2). The synthesis of the crew-safety aspects of these studies appears to support a racetrack configuration in which there are two means of egress from every module. But perceived requirements for safe-haven provisions, even with the racetrack in place, vary between the three approaches. Even with the racetrack, it might be deemed advisable to provide a safe-haven capability to every module.

### Logistics Resupply Strategy

The logistics resupply strategy is one of the mediums through which the Autonomy Baseline will shape the architecture of the space station. To the extent that logistics resupply is linked to a specific module, it is described here as an example of how a given module type may be shaped by different definitions of its function. Basic resupply will be provided in a special logistics resupply module, based on the common module, that will be brought up to the space station in the Shuttle payload bay, presumably at the same time as crew changeout. Thus each crew will start its tour of duty with its own 90-day supply of food, clothing, water, and other consumables. One of the most dramatic findings of



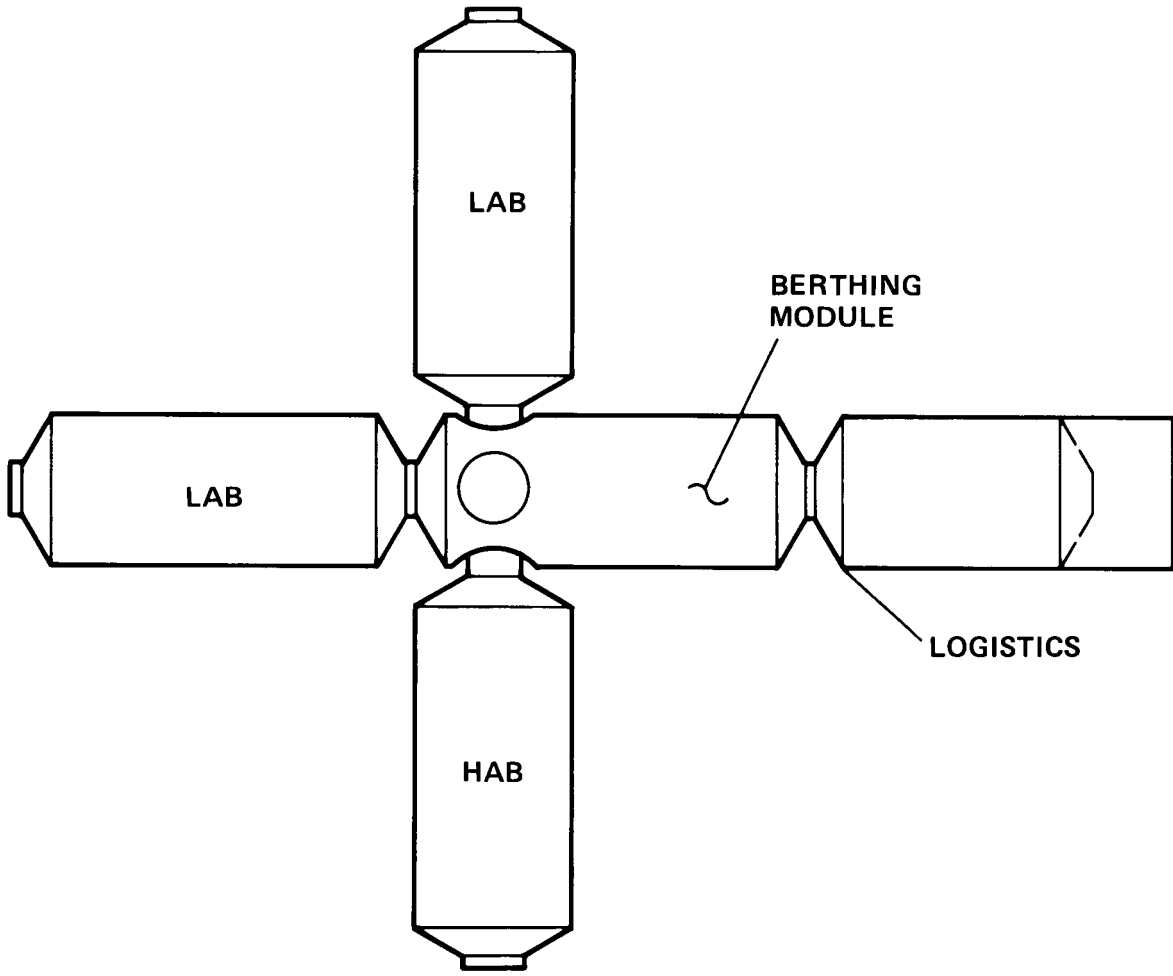


Figure 1.- "Phase A - CDG-1" Baseline configuration module connection pattern.

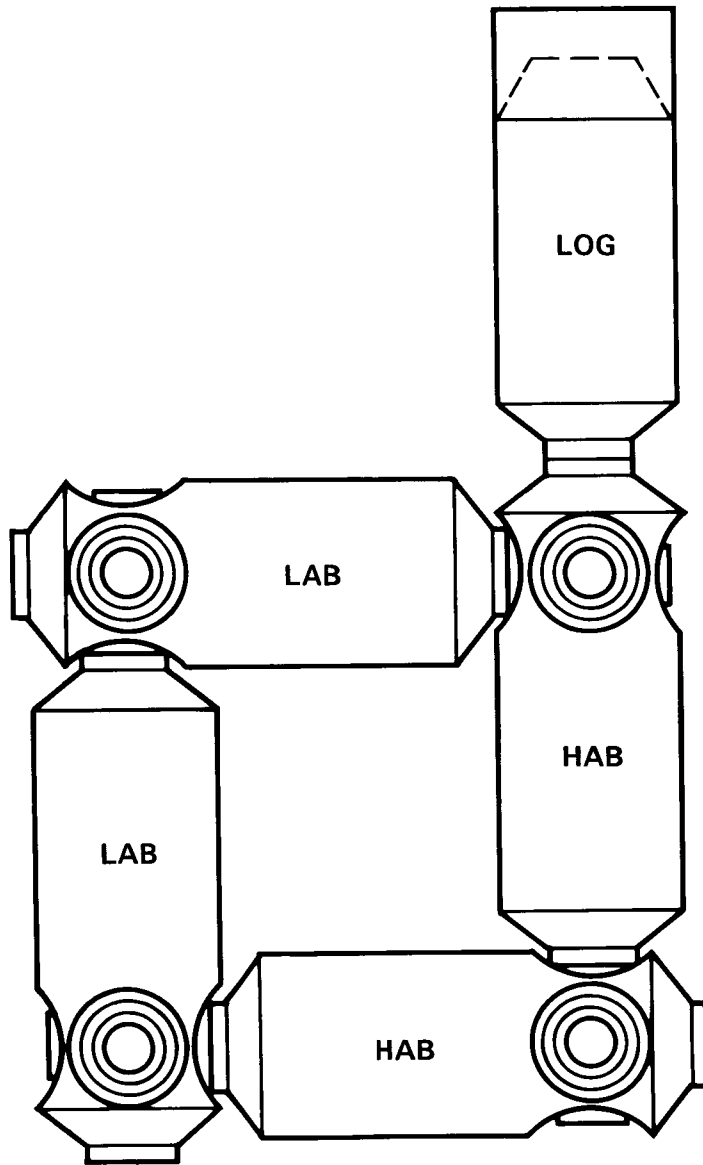


Figure 2.— “Phase B” reference configuration module connection pattern.

the Logistics Study Group was that closure of the water loop on board the station as a primarily recycling system could reduce logistics launch loads by as much as 8200 kg/launch (ref. 8). Although the cost savings which might derive from closing the water loop at first seems obvious, when the actual cost of providing the recycling equipment on the space station is compared to the actual cost delta of launching all the water in an already dedicated logistical Shuttle launch, the cost-benefit analysis may become more difficult.

The degree to which it will be possible to recycle water, launder clothing, or perform a whole range of renewable-capability functions will require considerable further study. The ultimate long-range goal of this avenue of research will be a bioregenerative life support system in which plants are used to revitalize the atmosphere, process wastes, and to grow food for the crew. As the space station evolves both before and after IOC, ongoing trade studies will be performed between logistics resupply requirements and on-board renewable capabilities.

This example of the logistics module and resupply strategy shows how the definition of this one module can affect a broad range of functions including safety considerations in the rest of the space station. It should not be surprising that logistics has such a far-reaching influence on potential space station design decisions; many habitats and settlements on Earth have been virtually created around "logistical supply" trade routes. In fact, an entire discipline of economic geography has developed to study the role of the economics of supply and transport in relation to the growth of human settlements (ref. 13). Just as access to the Great Lakes through the Erie Canal led to the development of New York City as the primary port of entry, trading, and distribution center of the United States in the nineteenth century, so will the commerce in logistical resupply influence the growth of the space station. Logistical resupply and transit considerations will play an ever-increasing role for space station as humankind establishes permanent bases in geosynchronous orbit and on the moon.

### Hygiene Facility Case Study

This case study is a continuation of the previous example of the logistics module, taking the hygiene facility as a representative habitability function. The CDG model called for the personal-hygiene facility, including the waste-management system, to be contained in the logistics module. This location would facilitate the return of solid waste to Earth in the empty tanks on the logistics module, and also would provide the opportunity for regular cleaning of the facility, at the most probably point of origin for microbial contamination. This cleaning is difficult to perform on the space station because all effective cleansing agents present potential toxic hazards to the life support system. Thus, cleaning the hygiene and waste-management facility using

current technology is quite difficult in orbit, especially in terms of maintaining it over a 20-year to 30-year space station lifetime.

The proposal to locate the hygiene facility in the logistics module presents both advantages and disadvantages. The principal advantages are the ability to clean it regularly and to refurbish it periodically. Also, having the hygiene facility in a module separate from the sleep quarters will help reduce noise problems. Noise problems must be viewed in the broader context of structural vibroacoustics of the entire space station. The principal disadvantages of placing the hygiene facility in the logistics module are a lack of convenience from the crew living quarters, and the possibility of complete separation of the hygiene facility from the space station during the change-out of the logistics module. If the berthing of the replacement logistics module was delayed for any reason, the crew could be forced to use a contingency hygiene and waste-management system, perhaps part of the safe-haven package.

However, the Phase B Reference Configuration places two hygiene facilities on board the station itself, one in each of the habitation modules, with some auxiliary services in the laboratory modules. This approach of multiple, decentralized, personal-hygiene facilities appears to overcome the problems inherent in the earlier CDG Logistics module proposal. However, if the system operations require the return to Earth of solid and liquid wastes, the requirements for pumping those wastes from the hygiene facilities into holding tanks in the logistics module will have significant impacts on plumbing throughout the station, particularly at the berthing-port interfaces, and the on-orbit cleaning problem will demand a clear solution.

In this respect, the hygiene-facility issue is representative of many functions for which decentralization or distribution present some operational and contingency advantages. However, the penalty for this type of distribution of functions is a far more extensive and elaborate utility piping and cabling network, which will tend to bottleneck at the berthing-port utility interfaces. The human-factors aspects of assembling, maintaining, repairing, and modifying these utility connections have been virtually unexplored to date, but they will have a profound effect on the long-term performance of the space station as a whole. Those few studies that do exist posit remote actuated pin assemblies either within the pressurized standard-berthing port (ref. 14), within a specially designed berthing port (ref. 15), or external to the pressurized volume, possibly carried on external truss structures (ref. 16).

Preliminary investigations of human-factors aspects of module berthing and utilities conducted at NASA Ames Research Center have revealed a wide range of unexamined issues which are affected by space station configuration. In addition to geometric, mechanism questions and possibilities with human-factors ramifications, utility connections arise as an early testing ground for decision making about which

functions should be automated and which should be conducted by direct human involvement (ref. 17). An analysis of the human-factors and operational aspects of these questions should ultimately feed back into each architectural design criterion (ref. 18).

To the extent that these examples of the hygiene facility and utility connections raises questions about automation and on-board crew construction and repair capability, it closes the loop back to the fundamental CDG premise of autonomy from the ground. The ability of the space station to maintain, renew, repair, and even expand itself will probably be major tests of station autonomy. The human-factors implications of all these elements and issues are fertile ground for further research.

### **Other Space Station Program Assumptions**

The Space Station Program as embodied in the *Space Station Reference Configuration Description* includes a number of issues besides those evaluated above that will influence human factors on board the space station. The difficulty with these other questions is that they are too preliminary, involve too many unknowns, or are much too lively to permit a characterization as a program premise. Among these other issues are maintainability, operations, berthing, and mission requirements. All these topics will be subjected to

extensive further scrutiny during the Space Station Phase B studies which will be conducted in 1985 through 1986.

### **Summary**

The extent to which this set of premises shapes the entire space station program cannot be overemphasized. The volume limitation posed by modules designed to fit the orbiter cargo bay will emerge as an overriding human-factors concern. The Autonomy Baseline affects the entire design process for every subsystem. The ideas drawn from the CDG studies may well shape particular systems and subsystems to a great extent.

The key challenge for human-factors advocates is to recognize these assumptions and to understand the effects that they will have on the overall space station architecture and operations. The human-factors advocate must be able to argue his or her case to the hardware engineer with full comprehension of the complexities of the space station program, and to explain the human-factors causes and effects of design decisions. This comprehension must rest on the ability to recognize genuine needs for research and the ability to implement that research effectively.

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Moffett Field, Calif., June 14, 1985

## REFERENCES

1. Skylab Program Office: MSFC Skylab Mission Report – Saturn Workshop, NASA TM X-64814, 1974.
2. Peercy, Robert; Raasch, Robert; and Rockoff, Lisa: Space Station Crew Safety Alternatives Study, Final Report and Final Oral Presentation, May 8, 1984, NASA CR-NAS1-17242, 1984.
3. Parker, James F., Jr.; and West, Vita R., editors: Bioastronautics Data Book, NASA SP-3006, 1973.
4. DOE/NASA Satellite Power System Concept Development and Evaluation Program, Assessment of Zero Gravity Effects on Space Worker Health and Safety, NASA TM-82330, 1980.
5. Jackson, John; Bond, Robert; and Gunderson, Robert: Man-Machine Engineering Data Application of Skylab Experiments M407 and M516. Neutral Body Posture in Zero-G, Skylab Experience Bulletin No. 17, NASA TM-85593, 1975.
6. Gunderson, Robert T.; and Bond, Robert L.: Zero-G Workstation Design, JSC Internal Note No. 76-EW-1, NASA TM-80000, 1976.
7. Webb Associates, Staff of Anthropology Research Project, eds.: Anthropometric Source Book, NASA RP-1024, 1978.
8. Cohen, Marc: Space Station Concept Development Study Workshop, Summer. NASA TM-85891. (Fall, 1983 and Winter, 1984 workshops are available at the Office of Space Station, NASA Headquarters.)
9. Kaplan, David: Logistics Resupply, Space Station Concept Development Study Workshop, NASA TM-85891, Part 14, Task 13, 1983.
10. Cramer, Bryant: Multiple Berthing Adapter: Alternative Safe Haven Concepts, Space Station Concept Development Study Workshop, NASA TM-85891, Part 9, Task 8, 1983.
11. Rockoff, Lisa: Space Station Crew Safety Alternatives Study – Final Report, Volume III, NASA CR-3856, 1984.
12. Peercy, Robert; Raasch, Robert; and Rockoff, Lisa: Space Station Crew Safety Alternatives Study, Final Report and Final Oral Presentation, May 8, 1984, NASA CR-NAS1-17242, 1984.
13. Yeates, Maurice; and Garner, Barry J.: Urban Growth and Urban Transport, The North American City, Second ed., Harper & Row, 1976.
14. Rockwell International, Space Operations and Satellite Systems Division: Space Operations Center Shuttle Interaction Study Final Review, NASA CR-167822, 1981.
15. Boeing Aerospace Company: Space Station Needs, Attributes and Architectural Options Study, Vol. 4, Architecture Options, Subsystems, Technology and Programmatic, NASA CR-17333, 1983.
16. Goldin, R. W.; Jacquemin, G. G.; et al.: Power System Interface and Umbilical System Study, NASA CR-161521, 1980.
17. Cohen, Marc M.: Space Station Architecture, Model, Berthing Hub, Shell Assembly, Berthing Mechanism, and Utility Connection Channel. U.S. Patent ARC-11505-1, No. 588,036, March 1984.
18. Cohen, Marc M.: Overview: Human Factors Issues in Space Station Architecture. Seminar on Space Station Human Productivity, NASA TM-86673, 1984.

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16. Abstract  The space station program is based on a set of premises based on mission requirements and the operational capabilities of the Space Shuttle. These premises will influence the human behavioral factors and conditions on board the space station. These premises include: launch in the STS Orbiter payload bay, orbital characteristics, power supply, microgravity environment, autonomy from the ground, crew make-up and organization, distributed command and control, safety, and logistics resupply. The most immediate design impacts of these premises will be upon the architectural organization and internal environment of the space station.			
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