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HUMAN FACTORS ISSUES IN PERFORMING LIFE SCIENCE EXPERIMENTS IN A 0-G ENVIRONMENT

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SPACELAB AND SPACE STATION FREEDOM

The Spacelab pressurized module is about 13 feet in diameter and 23 feet long, counting both the core and experimental segments. Because of the volume occupied by equipment racks the remaining central cross-section for crewmember movement is about 7 feet square, although it is narrowed near the ceiling. It provides a shirt-sleeve, sea-level pressure environment. Because of orbiter center-of-gravity requirements, access to the module is via a tunnel from the orbiter middeck.

The Space Station Freedom US Lab module will be approximately 14 feet in diameter and 44 feet in length. Allowing for racks, the remaining central open cross-section also will be about 7 feet square. An important contrast with Spacelab is in length and the full utilization of 4 rows of equipment and storage racks, to form the wall, floor and ceiling. The environment aboard Space Station Freedom also will be shirt-sleeve with sea-level pressure.

CONTAMINATION CONCERNS

The requirements in Freedom for cabin air contamination control are more strict than in Spacelab. Unlike Spacelab, which can be returned to earth in 14 days to be cleaned up, aired-out, and deodorized, Freedom will remain in orbit for 30 years. For this reason, Class 100K cabin air requirements are imposed, comparable to many clean room environments. For example, it is doubtful that Velcro can be used in Freedom because of the small breakage particulate matter it generates. This simple fact, alone, is already causing consternation among astronauts and human factors engineers.

While requirements are more strict for Freedom than for Spacelab, Life Science studies requiring active manipulations of any type must be performed in a carefully controlled environment, such as a glovebox. Lockheed developed and delivered to NASA the General Purpose Workstation to provide the glovebox environment for use onboard Spacelab. As the Life Sciences contractor for the Freedom US Lab, Lockheed also will develop and deliver to NASA the Life Sciences Glovebox with other Life Science support facilities & equipment, as well as the Maintenance Workstation which provides containment capabilities as needed. The required use of these facilities imposes restrictions not generally realized in an earth environment. For example, where a science laboratory open workbench or laminar-flow curtain workbench might be utilized on earth, a completely contained glovebox with full air-scrubbing capabilities must be utilized in space. The glovebox will restrict visibility, will have annoyingly limited volume and freedom of movement, and utilize power and consumables as needed to keep the glovebox functioning. Additionally, video and still cameras are typically utilized along with corresponding requirements for adequate illumination and desirable real-time communication to earth. There may be concurrent needs to utilize data entry and/or processing systems.

A corresponding requirement, especially for the long-term multiple-use Life Science Glovebox onboard Freedom, is for decontamination. The glovebox and apparatus must be decontaminated adequately to allow the removal of one set of specimens and apparatus and entry of a different set of experimental specimens and equipment. The complex merger of cost effective design and decontamination and requirements is still underway. There must, of course, be tradeoffs with other requirements such as structure and weight, design commonality, and productive time considerations. It is estimated that a half-hour may be needed to achieve required clean levels before changing out the glovebox.

These described functions and activities combine to represent a heavy burden on available resources. Utility and other consumable resources are a precious commodity in space. Freedom resupply flights will be very costly and must be limited. Utilities such as power must be allocated and budgeted to equitably support the broad spectrum of experiments and international interests onboard Freedom, especially. The same picture applies to Spacelab but perhaps not as severely.

Astronaut time is also a crucial resource. Working with a glovebox increases demands on strength, dexterity, and general staying power. Thus, we expect slower task performance and a sooner onset of fatigue than would occur outside the glovebox. Contamination concerns impose significant demands on both physical and human resources. Because of the associated requirement to manage resources, crew activity schedules must be developed and they must be closely followed.

MICROGRAVITY

The concept of zero or micro gravity is familiar to everyone. A closer look at this phenomenon, however, with respect to its affects on the dynamics of operating in this environment is of importance to adequate human factors engineering. Conceptually, there is a "fine-line" of true 0-g at the center of mass of the object in orbit, corresponding to the orbital path. Locations above or below that line will experience increasing degrees of microgravity (towards or away from earth) with increasing distance from the center. Practically speaking, this affect is negligible, although it may be of concern to some scientific experiments.

All unrestrained objects will "drift" in the direction of microgravity. Left untethered or otherwise restrained, small objects, especially, can drift away unnoticed, to be lost or perhaps to cause damage. Many small items, in fact, were lost onboard Skylab. Microgravity drift is compounded by the effects of air flow, especially with small items. Many items were eventually found on filters of air conditioning intake screens. It is relevant to note that gloveboxes include directed airflow.

Specifically, microgravity forces require that every object must be restrained in order to stay in one place.

On earth the luxury of space enables leaving certain equipment on the table for "next time." The workbench is reasonablely large and stowage of auxilliary items is provided nearby. Any new items brought to the table can be brought in bulk and setdown for setup. Something forgotten can be brought later.

In space, if there is any possibility of contamination due to nominal or accidental events, "table top" work must be performed within a glovebox for the safety of the crew and of specimens.

The planned Freedom Life Science Glovebox is about 40" wide, 30" deep, and 26" high.

The Spacelab General Purpose Workstation is about 28" wide, 23" deep, and 26" high.

Strict control of all equipment is crucial. On Skylab, some experiments were abandoned because all needed items could not be found. On Freedom an Inventory Management System will track every item of equipment. But in some form, it must be told what is being taken where by whom. That will take time. Means to automate this function are being investigated.

When two or more items are brought to the workplace/glovebox problems occur. Problems are compounded if the only way into the glovebox is via an airlock or similar passage. Envision one item in each hand. With one hand, therefore, the crewmember must perform the steps required to pass the first item through the airlock and into the glovebox and restrain it, therein. While so doing, he must restrain himself and retain safe control of the second item. Obviously, there are many variations on this scenario with alternative solutions but the point is at least partially made.

Without belaboring the issue it is important to recognize the corresponding requirements for item restraint during the performance of activities in or out of a glovebox. A quick routine movement, for example, during a dissection procedure could inadvertently leave a scalpel floating freely within a glovebox. Anything let loose by a bump, careless slip of a grasp, or a similar impetus represents a real hazard because in 0-g there is a strong interial tendency for things to keep moving, bouncing from surface to surface.

While good analysis and planning will lead to as many appropriate design provisions as possible, many will necessarily be "best guess." Also, it is expected that good habit-forming training in 1-g for a 0-g environment will be difficult.

BIOMECHANICS

Some of the effects on astronauts performance due to microgravity were introduced above. More specifically, crewmembers also must be restrained in order to stay in one place. "Staying in one place" is enough for most objects; it is not enough for the crewmember. People also must retain an orientation which is functional with respect to the task at hand. A 1-g orientation is desirable and in some tasks, essential, to make immediate sense of them. If forces must be applied the restraint scheme must provide the needed compensating support/restraint. Typically, therefore, a simple tether is inadequate. Also, typically, people must actively participate (flex muscles) to retain a desired position. This is achieved by use of the hands and/or fingers, the feet and/or toes, or virtually any part or parts of the body which can be used to wedge or grasp a secure hold on whatever is available to do so.

For example, if microgravity pulls crewmember away from a rack face (i.e., towards his heels) the force tends to remove his feet from the footloops. Thus, the crewmember will drift back and/or allow his feet to rotate upward, or the foot and toes must be lifted to retain their position. This unusual muscle flexion is fatiguing. To relieve this effort, one or both hands may be used to grasp a hand rail. If the hands are otherwise occupied, or should be otherwise occupied, the dynamics are at least distracting. Delay or error in the performance of a sensitive task could occur. In the case of a crewmember utilizing a glovebox, he might press against the hard edges of the gloveports as a means of restraint. This action could alternately aid or hinder the task at hand.

It is expected that an available foot restraint system on Freedom will provide a positive "grip" so that active foot and/or toe flexion is not needed for retention. Another area of important consideration is the adaptability and location of foot restraints. For example, the placement for a large person applying a pushing force within a glovebox can be reasonably low and close to the workstation face, in contrast to the higher and farther out placement needed for a smaller and weaker person. The anthropometric range for design of Freedom is from the 5th percentile Japanese female to the 95th percentile American male (extrapolated to the year 2000).

Another area of experience reported by astronauts is the awkwardness of performing certain tasks in the absence of the "reference force" provided by gravity. For example, typing is typically performed with the arms, hands and fingers in contact with nothing except the pressed keys during active typing strokes. On earth, gravity holds the arms down and muscles learn to flex from the 1-g reference point to locate and press the correct keyboards keys. The coordination and/or dexterity needed for the entire limb positioning, search and find and press action is learned, utilizing the opposing forces of muscles and 1-g on earth. In space the gravity reference is lost and holding the hands and fingers in place at the correct height, the proper location, exerting the appropriate forces, etc., are made more difficult by the loss of gravity. We understand that the use of a firm reference point, such as a bar against which to press with the heel of the hand, is a definite aid.

We have not had the opportunity to conduct adequate studies, but there are indications, at least, that appropriate measures should be made to support the performance of other sensitive tasks, such as specimen dissection. Such provisions may need to be optional and/or variable to accomodate different people and different tasks. With reference to the previously described issues in performing Life Sciences tasks in space, however, this concern adds another dimension to the human factors concerns.

SUMMARY

Sampling the Human Factors Engineering concerns, with reference to the performance of Life Science in space, provides an indication of the nature of some problems facing mission scientists. An accurate conception of these issues is needed in order to plan and design for effective missions. It is believed that only a well coordinated team effort of the scientific user community and program system designers can lead to missions successes.

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