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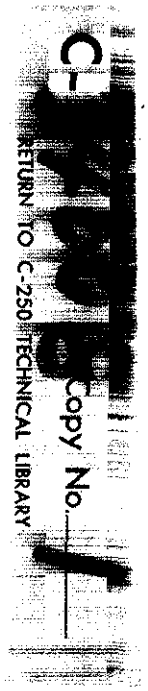

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INTRODUCTION

What does habitability mean? This word is commonly used and is bandied about as a thing which is necessary and desirable for all manned flight vehicles. But what does it really mean?

A serious examination of the meaning of the term soon leads to attempts at definition into discussions of the interplay of such factors as the mission, the size and makeup of the crew, the jobs within the mission, the flight duration, the stress loads, the vehicle to be used, the comfort, and the deprivations inherent in the mission, the flight environment, et cetera. In other words, habitability might be considered the resultant of the interplay of all of the factors related to the man, his machine, his environment, and the mission to be accomplished. It is more easily visualized as the state of being at the completion of the interaction of all of the factors rather than a discrete entity itself. Therefore, the provisions made to meet the habitability requirements can contribute to or be detrimental in meeting the program objectives. The requirement placed upon the space vehicle may be eased if necessary through the proper selection and training of the crewmen. The motivation of the crew may be an additional aid in providing a satisfactory solution to the habitability needs. The design and development of the space vehicle should avoid depending upon special selection and unusual training to meet the basic provisions needed to support the men in the space environment. The vehicle provisions should stand upon their own merit. Difficult and hazardous missions can be made more tolerable through augmentation of the provisions for habitability. For the sake of this discussion of habitability in a space station, this concept will be considered. This paper will emphasize a discussion of the interplay of some of these broader and little discussed factors as they reflect themselves in the development and operation of the space stations, rather than represent a list of items which have been established as essential for crew provisions. Ignoring these allied factors can lead to a successful mechanical system that will operate in space, yet a complete failure in providing the working, relaxing, and living areas so necessary for man if he is to maintain his productivity.

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THE MISSION

The mission being accomplished on the space station will vary widely as the station moves through its flight life. The requirements will vary with the mission phases as well. As an example, the early flight tests of the vehicle may be of shorter duration and will require smaller numbers of crewmen. Therefore, each segment of the flight program should be studied thoroughly in order that the essential and adequate provisions will be present. This variability in the mission will require extreme flexibility in the crew support area in order that lessons learned on one flight can be turned into flight qualified hardware by the next launch of the station or the logistics vehicle. For better understanding of the effects of mission, a discussion of the variations in the phases of mission which could produce effects upon the habitability requirements seems appropriate. For this discussion, the mission can be divided into three phases: space station establishment phase, the experiment or study program phase, and the maintenance phase.

Space Station Establishment Phase

This phase of the mission will be characterized by wide variation of program and maximum flexibility in activity as the station passes through the development and early test flights. Like any new vehicle, there will be a period of proving the design and the adequacy of the equipment provided for operation of the station. Safety of flight will be of prime concern and optional equipment will be seriously questioned as to its need. The crew makeup during this period will probably be limited to pilots, navigators, engineers, and station technicians. The crew complement on each flight will reflect the complications encountered during early flights. The goals to be achieved during this phase will be the demonstration of the safe and reliable operations of the space station systems and the establishment of the operational and maintenance procedures to keep the station active during the rest of the flight program. Such important things as what should be repaired at the component level and what should have modular replacement will be demonstrated. This period should be successfully completed before large numbers of additional personnel are ferried to the station for work. The validation of the maintenance and operational procedures, which will be a product of the test program, will permit the development of the final training of the personnel awaiting transport to the station. Further definition of the number and types of housekeeping personnel can also be made. For example, the number of men needed for such things as station puncture repair and the tools and procedures needed by these men can be studied. Just as the modern city could not provide all the services needed at the moment of its origin, the space station must be allowed to develop its routine services and shake down the procedures before the influx of the scientists and experimental apparatus is begun. Once the services are available, problems can be absorbed easily.

The length of the space station establishment phase will be influenced by the approach selected for placing the station in orbit. For example, if the approach is that of a single launch prefabricated system, the station establishment period should be considerably reduced. However, if the approach is that

of a multiple launch with assembly of units while the station is in orbit, this phase may be extended by the complexity of the tasks. Such a flexibility in approach should be possible by the time the space station program is undertaken because the demonstration of rendezvous by manned vehicles will have been accomplished and the decisions concerning the assignment of portions of the rendezvous tasks to manual, automatic, and combination of the two will have been made.

The Experimental or Study Program Phase

The arrival of the scientists and their special equipment starts the second major phase of the station life. These men will be exposed for the first time to a society which is different and perhaps strange even though it has been discussed and studied on the earth as thoroughly as exact duplication will permit. The scientist, however, will have had little actual rocket flight experience and certainly will not have taken up tenure in a space station before. For the first time, he is in a situation where there is no turning back because his unscheduled return would cause another man to stay at the station twice the intended duration and would result in his experimental program being markedly reduced or abandoned. The scientist will find that he must fit all of his activity into the established society and command structure of the station. This event will be the true test of the success of the selection and training program of both the housekeeping and the scientific crew. The penalty of failure in the crew selection program for the station will be severe and will cause serious jeopardy to all other crewmen and to the mission. This space vehicle design must reflect maximum flexibility for the performance of experimental programs, and as such, the scientific crew should be of diversified background.

The Maintenance Phase

Between periods when the scientific groups are not at the space station, the required housekeeping and maintenance will go on. During these periods, there will be requirements to ferry in new men and train them in the operation of the vehicle to preclude shutdowns and to minimize emergency periods during the scientific phases. In addition, consideration may be given to abandoning the station during inactive periods followed by a resupply and reopening period before the next scientific phase. The experience gained with rendezvous and the ability to handle logistic loads will influence which of these operational procedures is used. If the housekeeping personnel stay on, they will have the problem of readjusting to the new arrivals. This influx and integration of the new crew might be likened to the crew rotation seen in combat during World War II. The new personnel had to earn their position in the society. The crew support facilities available for such things as recreation, relaxation, eating, and entertainment during this period of change will be a critical consideration.

The Size and Makeup of the Crew

The crew has been discussed along with the mission. This is as it should be because they cannot be separated. However, there are some special factors which bear mentioning that relate to the crew because they too will determine what is needed to assure that the crew needs will be met.

The housekeeping and scientific crew should be held to the minimum required to do the job. It has been found that the person in any such undertaking who is not needed or rarely used is a problem to himself and to all others. The unnecessary person will soon be resented and will become an irritant to other crewmen. The ground preparation, the training, and the checkout periods of the space station should give high priority to establishing the number of personnel needed and the areas where more than one job can be handled by one individual who has proper crosstraining. In many instances, the housekeeping or scientific personnel could serve in several capacities if they are not critically needed simultaneously for their principal duties. For example, the scientist may be trained to perform the medical support for the station as well as his scientific tasks. The maintenance engineer might be able to set up and operate some of the scientific equipment or, conversely, the scientist could do specialized instrument maintenance as an additional duty.

The crew should be selected by using social compatibility and psychiatric stability as criteria as well as each man's recognized acumen in his special area. The crewmen's ability to like and to work with other people, their ability to accept station discipline, and their ability to work as a part of a team activity should be thoroughly established before they begin training. Man is also a widely variable entity. The characteristics required for astronauts must be defined as experience is gained. Equally important is the thorough understanding of the man in order that his psychiatric makeup will fit into the mission needs. Elimination of the incompatible must be done to prevent the flight of men with detectable problems. Observation of these men should be continued right up through their training and final selection. Elimination of personnel from the program should be continuous and be made a part of the program because the cost of carrying a man who has a small chance to fly is expensive and could affect his contemporaries negatively.

All members of the crew should be physically, as well as mentally, healthy. However, if overriding considerations occur that require a man with physical limitations to fly, for example, the only person available to perform a particular task has such limitations, then the effect of his inclusion in the program must be studied closely. In many cases, the placing of a man with physical limitations on such a mission will require the assignment of at least one other crew member to care for him. Such a problem could create resentment and act as a space station irritant which could lead to a discipline problem. Serious study should be made to find, if possible, physiologically young and healthy men for the scientific phase of the space station. In most cases, such selection can be made if the experimental program is identified early and preparation, including the crew, is started early. When the selection of the experiments to be carried out are being made, the crew considerations should have equal weight with the value of the information to be obtained.

Provisions for the Crew

If man must live under austere conditions, then the provisions made for him can greatly affect his ability to mold himself into the station life. As an example, the proper planning and scheduling for work cycles, time off for relaxation and recreation, and time for rest can become strong supports for

man in a strange environment. It must be recognized that each crewman may have a different work schedule, and provisions for this should be made where possible. Further, the provisions within each of these periods can greatly influence him and his effectiveness in meeting the next phase.

The work cycle has been discussed at great length in the literature. The answer is not obvious because the debate is still active. We have accepted 8-hour work days for earth labor but admit that frequent "breaks" increase attention and efficiency. It has also been learned that monitoring tasks cause one of the most severe challenges to man over long periods. This diversity in tasks to be done and in the participation of man in the tasks emphasizes the need for detailed and continuous analysis of each task and the working conditions under which the task must be performed. This will assure that the work area, the warning systems, the instruments, the data provided, and the work environment will be ready to make man an asset in the flight control loop.

The requirements for sleep are still to be determined. There is serious debate as to the sleep needs and the efficiency and depth of sleep in refreshing the astronaut while weightless or in a partial gravitational force if it must be provided. It has been reported that the Russian cosmonauts have slept a normal 8 hours without difficulty. This may be encouraging, but data are still too sparse for definitive planning. Again, quiet, privacy, and comfort must be considered in planning this area. The variable shift periods of the crewmen will cause waking, dressing, and movement of personnel at odd intervals. Experience with air crews has shown this to be quite disturbing in transient quarters when proper sound and noise treatment of the facilities have not been adequate.

Man is a marvelous adaptive system and can give considerable aid to the engineer in meeting the habitability needs. This ability should be used only after the engineering solution has been shown to cost too great of an amount in weight, power, and efficiency of other systems. If the adaptive ability is held in reserve it does permit some broadening of the limits of operational procedure.

The kinds and type of provisions for relaxation can be of prime value in making the period a truly relaxing one. Television will be of great benefit to some but quite repugnant to others. A library of good books could be an excellent method of relaxing for many of the crewmen who do not care for television. A daily two-way television chat with the family could also be of value. Games especially suitable for the space station might be devised or existing games might be modified to fit the new environment. Many desire periods of privacy or quiet as an important way of relaxing. All of this can be summarized by the statement that each activity provided must be seriously considered, and that each person going aboard must be seriously studied to be sure that provisions have been made to meet the needs of the man.

Diet is another example of a single area giving multiple types of crew support. It is easy to state the nutritional values considered important in the diet even though we can disagree on caloric needs for man in space. However, we talk little about the psychological support that an acceptable diet

can provide. In fact, variety of flavor and individual likes and dislikes must take on equal importance as that of caloric requirements, including the carbohydrate, fat, and protein content. As an example, there was no disagreement as to the nutritional value of the various field rations in World War II, but there was considerable debate concerning the variety, flavor, and acceptability. Conversely, it has been rare indeed to hear complaints from the men in the field about turkey dinners on Thanksgiving and Christmas even though it was difficult to deliver them to the men. The thoughtful planning of these provisions can modify a "spartan like" existence from barely tolerable to near enjoyable.

The comparison of space station life to that of the mountain camper is often made; however, it should be remembered that the camper can move and can change his existence. In contrast, the space station occupant is confined and must live with what he brought or what is provided.

Along with these general and specific factors mentioned for the crew, it is assumed, for this discussion, that extensive study and development of equipment will have been made for the successful provision of the environmental needs in the gaseous environment such as total pressure, partial pressures of gases, temperature and humidity control, positive handling of decompression, toxic materials and bacterial growth. Provisions will have been made for the acceleration environment such as noise, vibration, launch, reentry, investigation and control of the crew's physiological processes as they relate to long-term weightlessness and artificial gravity; and the orientation environment such as the need for visual, proprioceptive, vestibular and aural cues to provide comfortable working conditions in various force fields. The human engineering needs to provide for the work, rest, relaxation, and sustenance environments for man will have been made. All of these areas are obvious and must be provided as reflected in the extensive literature accumulated in the long history of aviation and space research. Man and his needs have not changed. However, these specific items and requirements cannot be considered alone because they interact one upon another. Compromise of any or all of these areas will influence other provisions. In fact, the space station will be a flying compromise. Adequate crew provisions will result in a very successful operation and inadequate provisions will lead toward a more difficult operation.

SUMMARY

Habitability is summarized as the resultant state accomplished through the interaction of all of the provisions furnished to aid the men in the achievement of a successful mission while in a hostile environment. Serious consideration must be made to surround the men with well selected equipments and provisions, other personnel, and a community government that will enhance the operation. Critical review of these items must be carried on throughout the program to assure that those items selected for each flight will be the best to assure mission accomplishment. The price of failure to make the proper selection is severe and can jeopardize the entire space station mission. Habitability is a difficult state to define materially and to achieve

successfully. The best method is to review consciously all factors such as the mission, the crew, the provisions for crew, the vehicle, et cetera, to assure that no area has been overlooked.

No attempt has been made here to restate the long list of specific man requirements and provisions and the range of tolerance by man of these items because they have been discussed frequently in the past. It seemed more appropriate to state the case for dynamic review for the accomplishment of habitability during all phases of the design, development, and flight programs in order that the best compromise for this mission can be reached. Many of these points appear obvious on first review, but have been regularly omitted in the past during aircraft and spacecraft design and flight. Many times the obvious is easiest to overlook, therefore, it needs to be stated as energetically as the specific demands by man.