HABITABILITY FACTORS IN A ROTATING SPACE STATION

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Abstract. The ease with which a crew can habituate to rotation will be a major criterion in determining the habitability of an artificial gravity space station. The factors which contribute to that habituation include rotation rate, stability, and crew orientation. Problems associated with each of these factors can be alleviated by proper space-station design.

1. Introduction

Most designs of spacecraft interiors are laid out as though a gravity field were present. This is frequently done to facilitate prelaunch activities, but is often done because it is easier to deal with a force field to which man is accustomed. Artificial gravity is considered in space-station design for the same reason. Man is used to having coffee stay in a cup and being able to walk on a floor, and man can predict much more accurately what interior layout is the most habitable, if a gravity environment is assumed. Artificial gravity, of course, provides other benefits not directly connected with man's comfort and habits. Water separation, ullage, water and waste management, and the life support systems are, in general, easier to design when a force field is present.

Much of the skepticism about the use of artificial gravity originates from the time of the early rotation studies, when it was not known how to help man adjust to a rotating environment, and it appeared that an artificial gravity (rotogravity) environment was uninhabitable. From more recent experiments, it is now known that if man is taken stepwise into a rotating environment, he can adjust (without becoming ill) to spin rates above that required for maintaining an artificial gravity environment in a space station (Newsom et al., 1966). Little or no data are available, and much work remains to be done in the area of prehabituation and the rate at which habituation is extinguished. At least three factors must be considered in the design of an artificial gravity space station, and the factors directly affect the degree of habitability of the space-station environment. The three factors are rotation rate, stability, and coriolis force.

2. Rotation Rate

The magnitude of the centrifugal force is proportional to the vehicle spin radius and the square of the rotation rate. Early studies predicted a requirement for very long spin radii to keep the rotation rate down to 1 or 2 rpm (Dole, 1960). The problem is that of cross-coupled motions that a crewman makes when he turns his head. This is frequently termed coriolis, but in this report, the term coriolis is reserved for disorientation that results from changes in spin radius, and the head motion of a crewman is
examined on the basis of the interaction of two angular accelerations. If a person who is not yet habituated to a rotating environment makes a head turn out of the plane of spin, he will perceive a motion other than that which he would normally expect. The angular motion he perceives is in a plane orthogonal to the planes of vehicle rotation and his head turn. The sensitivity to this conflict in visual, proprioceptive, and perceptive senses can cause an undesirable sympathetic response. However, the response diminishes with experience, but interaction is required, or habitation does not take place. By progressing stepwise through 1-rpm increments every 12 h, it is possible to adjust to levels of 10 and 12 rpm, (Newsom et al., 1966; Graybiel and Wood, 1969), but it is likely that rotation rates of only half these values are necessary. Spin radii of over 50 ft would provide approximately 0.24 g.

The orientation of the semicircular canals is shown in Figure 1. When a man is standing in the upright position, it can be seen that no canal is aligned with the x-, y-, or z-axis. Numerous tests which position the head so the horizontal canal is in the horizontal plane have been run. Accelerations about the z-axis were then made by smooth changes in velocity which give an almost square acceleration wave. Canal sensitivity is found to be as low as 0.03 deg/s², with the average approximately 0.5 deg/s² (Clark and Stewart, 1968; Clark and Stewart 1970). This, however, does not represent the situation in the space station where a body or head turn is coupled to a constant rotation rate. Figure 1 shows that all canals are affected by the coupling of the head turn with the constant rotation rate, and the motion is a waxing and waning angular acceleration. In addition, the stimulus, in order to be perceived, must have a duration that exceeds the time constant of the cupula. One study has dealt with canal response threshold, and the canal sensitivities were found to be on the order of 3 deg/s² (Newsom et al., 1968) but this number depends greatly on the angular velocity at which the acceleration takes place for both ω₁ and ω₂. The point to be made is that

![Fig. 1. Head motion in a rotating space station. The acceleration experienced is sinusoidal and involves all canals.](image-url)