# 4. Architectural Studies for a Space Habitat

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Before one can reasonably speculate on what the environment of a space habitat might be like, it is essential that the function of that habitat within the total system of the space colony be defined. Hence this presentation, tempting as it might have been to the architects in our group, is not full of images of the fabulous interiors of space habitats; such an approach would be premature and even misleading.

This report, of preliminary work in progress, is concerned largely with defining the function of the architectural environment within the total system of the space colony. From that definition, we attempt to delineate areas and methods of research necessary to arrive at a detailed design program. Only with such a program in hand may one begin to consider the full range of design tasks, from environmental systems to hardware specifications, for the construction of space habitats.

In considering the architectural aspect of space habitats, we should start with the question: In what sense is the function of the environment significant to the total colonization effort? If one can solve the difficult technical problems of constructing a satellite at L5, placing it in permanent orbit, and providing it with a self-sustaining ecological system, then aren't the problems involved in architectural design less critical? It might be assumed that in order to determine the architectural requirements of the colony at L5, all we need to do is to assemble its prospective population, have them decide what kind of environment they would prefer – high Alpine or subtropical island, for example – and then proceed to solve the technical problems of simulating such preferences. What could be more idyllic, or, if you wish, utopian, than the prospect of an existence in pollution-free environments, with weather made to order and landscapes on demand? While contemplating such a prospect is attractive, it is far too simplistic a view of the actual challenge.

Our fundamental concern is with the creation of an environment which is wholly artifical, and therefore inevitably more limited than anything encountered on Earth. This environment must not only be capable of attracting colonists to live in space, but also must be able to sustain their non-heroic day-to-day existence for years at a time. It is our basic assumption that unless one can provide such an environment, the solution of all other technical issues upon which this project rests will be in vain.

The architectural environment, as we conceive it in broadest terms, must include all the physical elements which are to occur between the shell of the satellite envelope and its population. This comprises not only shelter, but also furniture, utensils, even clothing. The shell and the population each represent a set of "givens", and each responds to certain requirements of its own, which must be brought together into one functional system. It is the primary task of the architectural environment to mediate and adjust these two sets of requirements to each other. To clarify these requirements, we should first consider some of the salient characteristics of the population and the shell, and the kind of constraints they are likely to impose on each other.

While later models are projected to accommodate much larger populations, which in their composition would be more representative of our urban societies, Model 1 clearly imposes the most constraining conditions with regard to population characteristics. Not only does it host the smallest population, but that population will be living in the greatest isolation, and in what can only be considered an experimental situation. Admittedly Model 1 may appear to distort the conditions of later models, but still it offers the best basis for our environmental criteria. Its inhabitants, or their children, are among us; we know their life-styles and values. Furthermore, since the success of Model 1, socially as well as technically, is essential to the construction of later models, the selection of its personnel and the establishment of their modes of interaction are perhaps more critical. For these reasons we will deal with the characteristics of Model 1, while observing its relationship to later models.

In certain significant respects, we might expect the characteristics of the population of Model 1 to differ from those of later models. To begin, the motivation and commitment which they bring to the colonization effort will have to be strong. They will be the first to engage in such an enterprise and they will be alone. They will have to be highly skilled and in all likelihood possess a multiplicity of skills. They are therefore likely to be well-educated, with a wide range of interests and experiences; in short, people who demand variety from their environment, and who might subsequently take adversely to a non-stimulating, regimented existence. The daily social life and the industrial tasks assigned to the colony will impose routine and social structure, which are likely to prove significant in the way the colonists adjust to life in space and to each other.

The satellite population will be confronted with a range of unprecedented perceptual phenomena, the effects of which will have to be examined systematically in a series of model experiments. To mention only a few:

- The internalized space and its scale distortions
- The cylinder curvature, which at least in Model 1 will be relatively perceptible
- The almost unpredictable quality of the light, reflected by the solars into the interior, which will probably, more than anything else, determine the visual perception of the shell configuration and of the imposed environmental elements
- The composition of the atmosphere and its proposed pressure of 2-3 psi, which is likely to affect hearing
- The mechanically controlled day-and-night cycles and the artificial climate, which will have an impact, even on a physiological level.

As we have suggested, the role of the architectural environment is to mediate between the given conditions of the shell and the existential requirements of its population. This role needs clarification, since certain characteristics of the shell, its atmosphere, gravity, etc., were already introduced in response to specific physiological requirements which have to be met in order to maintain a population in space. There are, however, other requirements of primary concern to us, which relate to the individual as an effect-responding, cognizing organism; in other words, which reflect the totality of his physiological, social and cultural endowments.

Conceptualizing the role of the architectural environment as a mediating mechanism, we can say, to the extent that the satellite environment is perceived as different from the native environment of its population, the potential exists for the development of stress reactions. We understand stress, following Glass and Singer's definition, as "the effective behavioral and physiological response to adverse stimuli." In man, the interpretation of stimuli as adverse may involve higher cognitive processes, as he is not responding exclusively to stimuli, but relies as much on his interpretation of associated information or cues. In any case, a major source of potential stress is the extreme novelty of the environment, reinforced by the perceived isolation of life in space.

All reactions to stress constitute a process of adaptation, which may be accomplished either by physiological adjustment, by cognitive mediation, or finally, by the alteration of the environment itself, so as to remove or diminish its stress-producing effects. These alternatives may be employed simultaneously, with a considerable amount of interaction between them. It is clear, however, that each alternative represents different kinds of potential costs, in terms of reduced performance, personnel replacement, or in remedial construction of the environment.

The given shell, an unadorned, large void, is obviously a potentially stressful environment by virtue of its initial lack of environmental stimuli. To be sure, the structures necessary to house and maintain the population, the facilities for agriculture and manufacturing and the variety of people themselves are sources of stimuli. However, in this wholly artificial environment, stimuli will have the desired effect only if all major environmental components are developed and programmed with this end in mind. The question which this unique environmental situation raises is, therefore, how it should be supplemented in order to alleviate the potential for stress.

The most immediate answer might seem to be to take the Earth environment most agreeable to the prospective satellite population and simulate that environment in space. The implicit assumption behind such an approach is that an Earth-like environment, especially an ideal Earth-like environment, far from being stress provoking, would act as a positive inducement for space colonization. This may be true, but the validity of this assumption cannot be accepted out of hand. Aside from the technical problems, the simulation of an Earth-like environment raises a number of conceptual questions: should it be attempted down to the last elusive detail? If we cannot achieve total simulation, what is really essential in an environment and what is considered by its inhabitants as extraneous? Must we simulate it literally, with real spreading oaks where the scenario calls for it, or can we substitute a styrofoam oak or perhaps a stylized one made of titanium mined on the Moon; perhaps a hologram of an oak will do? These alternatives are raised only half in jest, for they convey the very serious problem of any form of simulation, and that is, how will the satellite inhabitants react to it? Will it indeed provide an environment which alleviates the sense of estrangement that comes from living in such isolation from the Earth? Will it provide sufficient variety to keep its inhabitants' perceptual and cognitive processes "in tune"? It may well be that the very artificiality of such a simulation approach would be a source of stress in itself – the stress of a schizophrenic existence in which the inhabitant is asked to accept the illusory as the real.

While this question awaits an empirical answer, let us consider a completely different approach to the stress adaptation problem. Rather than attempting to adjust the physical environment to suit the conceptions and habits of a population raised on Earth, why not shift the process of adaptation to the cognitive level? That is to say, we might train people to adapt by fully utilizing their physiological and cognitive resources. There is an array of modern techniques and old techniques at our disposal, from bio-feedback (to alert people to the development of stress); to transcendental meditation (to cope with it); or, if you prefer, operant conditioning (to adjust to it). Such an approach might not only be attractive in terms of avoiding the inherent problems of simulation, but also in terms of providing optimal predictability about the behavior of the inhabitants, and therefore the greatest relability in designing facilities which could meet their needs satisfactorily. However, this approach also raises the specter of creating a society designed to fit the constraints of life in Model 1, but potentially ill-suited for life in larger models or on Earth, not to mention the negative influence on the recruiting of future satellite populations.

While both approaches may have a place in the process of stress reduction, and hence in environmental design, their effectiveness appears limited by too many preconceptions. Man does not necessarily respond to an unprecedented situation with innovative solutions, and we have therefore tried from the beginning to neutralize preconceived ideas and established formulas in order to remain as open as possible to new approaches. The one we favor at present does not involve the literal transplantation of stimuli, but would generate them out of its own creative potential in great variety. This approach considers the architectural environment as an open-ended opportunity system, one capable of facilitating the greatest number of activities in space with the greatest amount of flexibility in time. It offers, in our opinion, the closest possible fit between the habitat and its population, which will undoubtedly undergo continuous changes in number and composition.

From the construction phases to the time of full occupation and possible emigration to new satellites, we can always count on a population of high mobility. Accordingly their environmental requirements are likely to change over time; for example, in the initial periods the pressure to adjust to the new situation is such that an environment with the least additional variety may be the most desirable. After a time, however, the unavoidable routine of their isolated existence may prompt a need for change and variety to maintain optimal interest and vitality. Equally significant, however, is the flexibility with which the open-ended approach can accommodate the various social systems that are likely to develop in the satellite colonies.

Obviously, the basic production task which the colony will perform, be it manufacturing or energy production, will in itself generate sets of social interactions, which, together with other manifestations of social life, will ultimately result in social systems. The architectural environment must not only support their functioning, but insofar as these systems evolve over time, provide the opportunities for their emergence and establishment. To be precise, the role of the environment in this respect is not deterministic but only facilitating, inasmuch as the presence of certain kinds of spaces may invite the occurrence of certain kinds of activities. Conversely, the absence of certain spaces – for example, informal public space – may act to discourage certain activities. In keeping with an open-ended opportunity approach we would suggest that, rather than attempting to plan a single environment which anticipates and details all possible needs, we should allow for the development and alteration of space over time. The realization of such an open-ended system imposes reciprocal requirements on both the mechanical infrastructure of the shell and the social interaction of the population. On the other hand, mechanical details must be designed to accept flexibility needed in relocating facilities, and on the other, social governances must be developed to direct and control the alteration of the environment.

Considering the technical requirements to support a flexible environment (in particular, of creating difference-sized spaces), flexibility suggests some form of modularization and standardization. Modularity may be further assumed on the basis of transferring structural loads to the cable network of the shell. Similarly, standardization of construction may be assumed on the basis that most of the components will have to be manufactured at the colony under restricting circumstances. There is, by the way, no reason why an environment assembled from standardized elements must be monotonous, as the contrary has been demonstrated by a sufficient number of cases. Finally, the open-ended system has the particular advantage of providing an ideal experimental situation, which would allow us, by continuously monitoring the Model 1 evolution, to obtain a maximum of information about the design requirements for future colonies.

To summarize our argument at this point, we have defined the role of the architectural environment as a mediating mechanism adjusting the needs of the population to the characteristics of the shell. Mediation has been considered in terms of stress reduction and environmental opportunities. Areas of potential stress range from physiological to social reactions to the environment. The adjustment process of adaptation may take three forms, physiological, cognitive, or environmental. Our concern has been primarily with the design of the architectural environment as a means to alleviate stress and to maintain the health and vitality of the space colonists. While several design approaches were explored, emphasis was placed on one, which treats the satellite environment as an open-ended system.

This paper in no way constitutes a program for design; it merely indicates areas of research upon which such a program must be based. While the experimental literature dealing with psychological reactions to large-scale novel environments, or with social interaction under conditions of isolation, is substantial, much of it is only indirectly related to the actual conditions of space colonies. Further insights may be gained from historical analogies with other colonizing efforts, and specific data obtained from contemporary task communities working in isolation, where one could draw particularly on the subjective experience of the individual members.

While this survey of environmental data sources is underway, other research efforts will be made in specific areas, such as structural engineering, where we will seek information about the behavior of various construction materials and the suitability of various construction methods under space conditions. As a by-product, we intend to compile a catalogue of questions, which although unanswerable at present, indicate areas requiring further research in other disciplines. Our main objective, however, is the formulation of a detailed program for the design of an L5 satellite environment, and the development of precise criteria for the execution of such designs, which we ultimately hope to commission from a number of architects.

## DISCUSSION

*Q. I think that your approach is unduly pessimistic, because the first ten thousand people aren't going to be average people. They will be the people who want to go the most; and there are considerable more than ten thousand people in this country alone who would just love to go.*

A. I'm sure that the number of adventurous people is as unlimited today as it has been in past periods of history; there is certainly a substitute in space for gold in California. But it was our approach to see the problem as a whole and in its full range, not only in view of Model 1. And even with Model 1 you have not only the initial motivation, but the subsequent periods of routine, where the whole stress situation will slowly make its impact.

*Q. It would seem to me that the idea of an "open end" approach is absolutely necessary. What is the minimum rate of change of the various responses necessary to keep the economics of the situation from becoming a cost and still satisfy the population? Are there any terrestrial analogies in various modern societies that would give some guidance to the rate of change of the various individual and psychological problems? Does the rate of change of such phenomena as rock music or dance variations in New York versus that in a small town give some handle on this? Is this a field of research?*

A. It is certainly a field of research. The question cannot really be answered at the moment, because of so many unknown factors. We don't know what kind of system we'll adapt; it depends upon the manufacturing facilities that might exist on the colony. On the other hand, to establish a proper rate of change, we will have to go much deeper into the composition of the population and their mobility.

*Q. There is an analogy in history: Pitcairn Island. People landed, they sunk their ship, and they kissed the world goodbye. A group of people just moved in, adapted to what they had, and built an idyllic existence for some time. Are there any corollaries like that in your field that would help?*

A. As I pointed out in my paper, there are historical analogies which will give us some clues, but there isn't really anything comparable in terms of the environment. Even in Pitcairn Island there was air, a horizon, Earth soil and fauna, and many other things we take for granted.

*Q. Has there been more than just cursory thought given to how people respond in different specific areas or how people change which would have relevance to the question here?*

A. Not to my knowledge.

*Q. When you talk about the isolation factor, have you taken into full account the probability of a communication network and the possibility of frequent travel between Earth and the colony?*

A. We have been speculating on the relation between each cylindrical colony and its other twin satellite, and what differences there should be in their environments. It should have a completely different environment. But the initial isolation is still a sensation which nobody really knows – to be in a container with nothing but space around you. It is not like being in a space vehicle in process towards a goal. You will, however, still have a lot of links with Earth, so it isn't a simple problem to evaluate.