

Nutrition-Waste Complex— A Pressing Problem in Manned Space Exploration

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Space nutrition and waste handling have in the past been treated in the same context—however, as separate problems. In early manned space flight, much attention was given to space feeding and nutrition, but the problem of waste handling was eliminated by eliminating elimination. With the advent of mission requirements up to 3 years and beyond, it becomes evident that nutrition and waste subsystems requirements will contribute appreciable weight and volume requirements to the total manned vehicle complex. At the present state of the art, for example, with mission times of 1 year, the weight requirement for nutrition and waste handling is equal to one-half the total required for meeting all of man's life support needs, including his thermal control. As we look beyond to 3- and 10-year missions, variables as aging and adaptation are introduced which further contribute to the penalties associated with nutrition and waste. It may be argued that boost capability may eliminate the necessity for sophisticated weight-savings approaches to meeting man's requirements. For long-duration multimanned missions, weights for waste and food are extremely large and will remain a pacing item in maintaining man in space for unlimited time. For example, a 10-man year mission utilizing conventional storage methods for providing nutrition, breathing gases, and storing all wastes could require on the order of 70 000 to 90 000 pounds, and volumes of approximately 1800 cubic feet. If we consider a 50-man year mission, which is not

great, on the order of 300 000 to 350 000 pounds would be required for nutrition and waste, and volumes on the order of 9000 cubic feet.

Thus, any long-lived manned space system may well have to rely on the use of waste along with a high-energy-density energy source for the synthesis of required nutrients.

In addition, a 10-man year mission requires rejection of approximately 1×10^7 kcal of heat at relatively low temperatures. Reduced convection under reduced gravity conditions and the absence of an easily utilizable heat sink in space also contribute to the expenditure of more energy for the task of rejecting human thermal energy. The point here is that the problem of nutrition and waste in space is not solved. As a matter of fact, it is not even defined.

Of great importance to the definition and solution of this problem is the approach that we take during the planning phases. In the course of planning, space waste and nutrition should be treated as a complex which interfaces with all the other vehicle subsystems. The complexity of waste in low-leakage-rate long-duration sealed cabins for both space and under-sea operations further suggests this approach.

A simple illustration is shown in figure 1. We may consider man as a chemical thermodynamic system which converts usable chemical energy in the form of usable nutrients to useful work. In this process, energy is degraded and results in the generation of chemical and thermal waste. In the closed sealed cabin the nu-

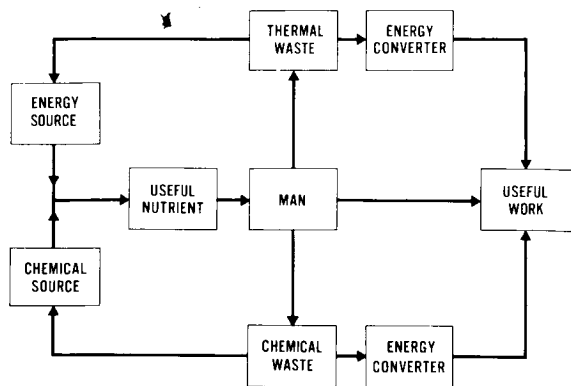


FIGURE 1.—Nutrient-waste complex.

trients must include oxygen for metabolism, foods, and water; the foods consist of fats, carbohydrates, proteins, and essential vitamins and minerals, and so forth.

The chemical wastes include the products of metabolism: gaseous products, such as carbon dioxide, and solids that consist of many forms of molecules from the very complex nonionic type, such as cellulose, to the inorganic ionic atoms, such as calcium and sodium. In addition, chemical wastes include water in different physical states, in the vapor state and the liquid state.

The thermal wastes associated with man are also in various states, and we have to consider these wastes in the latent and sensible form.

When we consider all these factors, we must also consider the fact that there are many ways to provide nutrition and control the waste in the manned space environment. The problem is in the selection of the right method, and this method must result in optimum systems weight, volume, power requirements, human efficiency, and utility at a specific time in a specific mission phase. All of these have to be considered in the selection of the right weight.

We might consider many approaches to the problem of nutrition and waste, but three representative approaches which suggest themselves include:

(1) Storage of all the required foods, water, and breathing gases and collection and storage of wastes.

(2) Storage of conventional nutrients and the use of thermal waste for either generation

of power by appropriate thermoelectric converters or as a heat source for the conversion of chemical waste to more easily handled materials.

(3) The use of synthetic or natural nutrients which are generated from waste materials in a closed cycle. Chemical wastes may be used as raw material for generating simple inorganic molecules which can be processed to form complex nutrients. Thermal waste can be used as energy sources for these and numerous other life support processes. An alternate approach is the use of chemical wastes as fuels for the bioelectrochemical generation of electrical energy or for the generation of thermal energy, which, if utilized, may result in systems weight savings and thus permit the provision of conventional foods and other nutrients.

Each of these approaches must be specific to the task. Future studies will show that an entire spectrum of methods will be required for a particular long-duration mission. For example, in the establishment of a lunar or Mars colony, many functions must be considered requiring several methods for provision of nutrients in a controlled manner. Such a colony would conceptionally include a fixed permanent shelter, mobile emergency shelters, one-man operating protective systems for exploration phases and vehicles.

Each of these facilities must be considered in the total system, and also in the waste-nutrition complex. We have to remember, however, that the specific approach to meeting each of the requirements must be consistent with the fact that the total colony is still a vehicle payload, and the critical logistic factors must be considered in any methodology that we develop for the selection of a particular waste-nutrition system to meet the requirements.

For example, a partial loss of nutrients in long-duration manned missions would result in critical logistic problems, and we must give attention to such factors as the direct contamination of the nutrients by waste, or the indirect contamination of the nutrients by the generation of toxins which result from improper choice of nutrition for a specific mission profile.

Thus, critical factors in the selection of a particular waste-nutrition complex include the following:

(1) The toxicity of the materials used in the spacecraft structures, the containers, and the waste processing equipment.

(2) Considerations of the possible generation of toxins as a result of interactions between spacecraft materials at various temperatures and pressures with the normal atmospheric components, such as oxygen and nitrogen.

(3) Interactions must be considered between metabolic products, such as water vapor, carbon dioxide, and hydrogen sulfide, with chemical atmosphere purification equipment used in atmospheric conditioning or regeneration.

(4) Consideration of possible modes of origin of toxic materials from normally nontoxic reactants under stressful environmental conditions.

(5) Origin of toxic contaminants that may be generated in the interaction of the products of food reconstitution, waste conversion, and reclamation systems, including all types—physical, chemical, and biological. These systems include the water reclamation system, waste reactors, and gaseous conversion systems, includ-

ing those for the generation of breathing oxygen.

In summary, it may be understated that much work remains to be done before extraterrestrial space becomes a new habitat for man.

Several areas require some immediate attention:

(1) Study of nutritional and waste handling methods for controlling the origin of toxic contaminants.

(2) Continued research and development of components and subsystems which can be used for the containment and conversion of wastes to nontoxic materials as usable constituents in nutrition cycles.

(3) Establishment of standards for allowable concentrations of synthetic nutrients in varied gaseous and thermal atmospheres over extended periods of time.

(4) Study of instrumentation methods for the detection and analysis of toxic precursors or usable chemical precursors in various physical states.

(5) Study of advanced concepts in metabolism which may permit the nutrition and rejection of waste in a manner consistent with man's new environment, space.