

Nutritional Trends in Future Manned Space Flights

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Nutritional trends in manned space flights might best be discussed in terms of the recommendations relevant to food, water, and waste of the Space Medicine Advisory Group (SPAMAG) in their conceptual study of an orbiting research laboratory (ORL).

The SPAMAG is a working group of 19 consultants in medical and paramedical fields, each of whom is an outstanding contributor in his own speciality area. The Group was organized by the NASA Space Medicine Division, Office of Manned Space Flight, for the purpose of studying requirements for the ORL in order to lend support to other in-house and contractual ORL studies.

By way of providing a proper framework for this report, it would probably be worthwhile to spend a few minutes discussing the general method of approach employed by SPAMAG in this study.

Members of the Group are listed as follows:

John A. Buessler
Loren D. Carlson
Robert E. Forster
Edgar S. Gordon
Douglas Grahn
Ashton Graybiel
Milford D. Harris, Jr.
Andres I. Karstens
Edward C. Knoblock
Joseph F. Kubis
Edward A. Liske
Ross A. McFarland
Samuel Natelson

Herbert Pollack

Ralph Reitan

Scott H. Swisher

John C. Townsend

Sherman P. Vinograd

James V. Warren

G. Donald Whedon

Earl A. Wood

DOD/NASA coordination is effected by the attendance of Lt. Col. Milford D. Harris, Jr., and Dr. Edward A. Liske as DOD observers, and Col. Andres I. Karstens who is serving in the capacity of cochairman. Two-day meetings have been held at monthly intervals since the first meeting of the group in January 1964. Present estimates are that six or eight such meetings will be required to complete the study, after which the Group will meet three or four times a year in order to update its findings in the light of newer knowledge and further contemplation of the total problem.

The first morning of each 2-day session is devoted to briefings, chiefly by NASA personnel. These are designed to familiarize the Group with the unique constraints, problems, and developments of manned space flight. This is considered to be a highly important step toward significantly enhancing the value and applicability of recommendations made by the Group.

Prior to the first meeting, a 12-page format or working procedure was devised. This was adopted by the Group at the time of the first meeting. In general, the study falls into three

categories or phases: The first is the establishment of recommendations concerning the constant environment, or life support factors which are to be supplied the flight crew. The second is a definition of the medical experiments and measurements to be done aboard the ORL. Most of these are centered about environmental factors, or stresses, which are experimental unknowns; almost all of them concern weightlessness and combined stresses. The third phase is devoted to recommendations for actual vehicular and operational requirements in terms of the medical support of the crew, and the desired medical experiments and measurements. In effect, this phase is the translation of the first two phases into operational and engineering terms.

It is anticipated that the end products of the entire study will be:

- (1) Group of ORL medical experiments in format
- (2) Group of additional ORL medical measurements in format
- (3) Group of life support recommendations in format
- (4) Group of prerequisite ground based experiments
- (5) Group of prerequisite spaceflight experiments
- (6) Group of recommendations for research and development
- (7) General philosophy and recommendations for ORL experimental approach
- (8) Recommendations for general ORL decisions
- (9) Tentative flight plan
- (10) Reviews of work of four study contracts and ORL BEWG
- (11) Summary of possible uses of space environment for study and therapy of pathological states
- (12) Recommendations for future study effort

It can be seen from the scope of these products that their review and implementation will be the work of all NASA life sciences groups, since they cover the full range from prerequisite basic research to manned space flight support engineering and operations.

With regard to the present status of this activity, the first phase has been completed, and work on phase 2 is now in progress. Phase 1, life supporting environment to be supplied the crew, may be broken down into its major component categories for study as follows:

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|-------------------------------------|-----------------------|
| (1) Atmosphere | (7) Group integrity |
| (2) Suits | (8) Hazard protection |
| (3) Food | (9) Safety monitoring |
| (4) Water | |
| (5) Waste | |
| (6) Living conditions and standards | |

The Group addressed itself to these areas by dividing into five subpanels, each assigned to specific categories. The metabolism, or food, water, and waste, subpanel, whose work will be discussed, consists of Dr. Edgar S. Gordon, Lt. Col. Edward C. Knoblock, Dr. Herbert Pollack, and Dr. G. Donald Whedon. As is true of all the subpanel reports at this stage, their report is a preliminary one based upon an initial, although painstaking, exploration of the problem. These recommendations will probably be augmented and perhaps even altered throughout the course of the three-phased study, but some of the initial recommendations of the subpanel as approved by the full group are as follows.

Dietary recommendations are that the diet be kept as simple as possible with emphasis on the maximum use of natural foods which will provide balanced nutritional components. The form of the diet preferred by the subpanel is either a liquid formula, or one which can be readily reconstituted to a semiliquid or liquid form.

In attempting to set up particular caloric requirements, one of the first things the Group had to decide was a reasonable schedule of activity. The following schedule was suggested: 8 hours for sleep, 2 hours for eating, 2 hours for exercise, 4 hours for rest and relaxation, and 8 hours for work.

The caloric requirements which the group considered reasonable for a 150-pound man in a shirt-sleeve environment are:

Activity	cal/hr	Btu/hr
Sleep.....	70	280
Eating.....	1.5× Basal	420
Exercise.....	2.5× Basal	700
Rest and relaxation..	1.5× Basal	420
Work Program:		
Flight control.....	2× Basal	560
Reconnaissance.....	2-2.5× Basal	560-700
Scientific observation..	1.5-2.5× Basal	420-700
Repair.....	2-4× Basal	560-1120
Suited environment (unpressurized): Add increase factors in percent as follows:		
Sleep.....		+10
Eating.....		+50
Exercise.....		+50
Rest and relaxation.....		+50
Work.....		+50

For extravehicular work, a maximum of 2000 Btu per hour may be required. This is not tolerated for periods in excess of 1 hour. A steady state of activity is reached at approximately 500 calories or 2000 Btu per hour. Then oxygen debt develops. This maximum requirement should therefore be avoided except under emergency conditions.

Further recommendations are that natural foods of low fiber and low in laxative properties should be utilized and that no adjustment of bacterial flora of the intestinal tract should be attempted. A liquid or reconstituted diet utilizing coded cubes which are preweighed would facilitate the precision of recording food intake for purposes of balance studies. In addition, an oral exercise medium such as a gum or other suitable device is suggested for purposes of oral hygiene.

As to the composition of the diet, the following recommendations are made:

High quality protein, percent.....	12.5
Carbohydrate, percent.....	52.5 to 57.5
Fat, percent.....	30 to 35

This ratio would be used to provide 2700 to 3200 calories per day with a respiratory quotient of 0.8 to maintain a carbon dioxide to oxygen ratio which would spare the carbon dioxide scrubbing requirements of the environmental control system.

Anticipated metabolic degradation relates to muscle atrophy and bone changes which may result in calcium loss. Special attention should be paid to providing a balance of high-quality

protein and adequate calcium in the diet. The ratio of polyunsaturated to saturated fat in the diet will be dependent upon the conditions of preservation of diet during the flight program and the method chosen for reconstitution of the diet for feeding in space.

Recommendations concerning mineral and vitamin requirements are as follows:

Calcium—0.8 gram per day.

Phosphate—1.2 to 1.5 grams per day.

Sodium as NaCl for individuals who are acclimatized to the environment—4.5 to 5 grams per day.

Sodium for those not acclimatized, add 1 gram as NaCl for each liter of water consumed per day over 4 liters. This figure is tentative and the suggestion is made that in view of the possibility of adrenal stress, the potential use of 10-15 grams of sodium chloride per day be considered with corresponding reduction of potassium to approximately one gram per day, which might serve as a protective device for the adrenal glands. Accordingly, the water intake may need to be increased to 4 liters or more per day. This would also be useful for maintenance of heat balance.

Vitamin D—1000 units per day.

Other vitamins—the use of a standard minimum daily requirement type of polyvitamin preparation daily is advocated, but in no greater quantity than the minimum daily requirement as recommended by the NAS-NRC. (Nat. Acad. of Science—Nat. Res. Coun.)

Minerals—trace mineral supplements are strongly advocated if the food used is processed by chelation. This is one of the strong reasons for the recommendation for the maximum use of natural foods.

Water—2.5 liters per day (one cc per calorie of food). Water intake should be sufficient to maintain the urine at a specific gravity of 1.015 or less or a volume of at least one to one and a half liters per day to avoid the development of renal stones; urine should be maintained at a normal pH range.

With reference to water supplies, because of power, weight, and volume requirements, recycling of water is not considered practical for flights of less than 30 days duration, but should

be considered for flights in excess of that period of time. Water sources for reclaiming include metabolic water and that produced by the fuel cells. The recycling of urine is considered to be costly in both energy and volume-weight requirements. Ion exchange or millipore filters appear to be simple devices for reclaiming metabolic and fuel cell water and converting it to a potable supply. Metabolic water can easily be reclaimed for hygienic use.

With reference to urine and fecal waste, the following recommendations are made. On each voiding, the total volume must be accurately recorded and an aliquot separated for study. Aliquots according to aeromedical requirements can probably be stored in the walls of the cabin to provide additional radiation shielding until they are returned for analysis. Cryogenic preservation is recommended.

To reduce the quantity of fecal material, a low residue diet is recommended. Samples should be collected, adequately identified, and stored in sealed containers for analysis as with the urine. Desiccation and cryogenic storage, utilizing the conditions of space, might well be employed to facilitate this program. It should be borne in mind with reference to the storage of feces that drying without either freezing or sterilization may well introduce the danger of bacterial contamination of the atmosphere.

From the standpoint of metabolic considerations, medical selection for the ORL program should attempt to rule out those who have a tendency toward nephrolithiasis. It is also important to record any food intolerances and idiosyncrasies of flight crew candidates.

The subpanel's recommendations for research and development include the following:

- (1) A study of the nutritional acceptability and palatability of such foods as algae, and a reconstituted liquid or semiliquid diet of natural products for extended periods. With this is recommended an investigation of the possibility of extending a natural diet by means of a concentrated, high-density synthetic diet which can be fed periodically and interspersed at intervals during the flight program.

- (2) Studies to determine the possible occurrence of ill effects from prolonged maintenance

on a very low residue diet. As a part of this study, the exact weight and volume of fecal material produced, for a given diet, should be determined.

- (3) Continued work in the field of food packaging to enable the accurate measurement of intake of food constituents.

- (4) Continued development of improved urine and fecal collection devices.

- (5) Further research and development on the recycling of water, with purification to acceptable standards of potability.

- (6) Further research and development on the conversion of waste materials to carbon dioxide and water by means of free radical oxygen digestion (using a stream of oxygen through a very high frequency radio beam). The conversion of the carbon dioxide to carbon and oxygen also requires further research.

Recommendations for ground based experiments, and flight crew training preflight are as follows:

- (1) The study of calcium metabolism at various phases of training under various conditions preflight to establish baseline levels for each potential astronaut.

- (2) The provision of extensive training in the handling of special diets during the flight training program.

- (3) A study of the effects of centrifuge simulation of the flight launch profile on the anti-diuretic hormone (ADH) activity to provide parameters for comparison with both 1 g and zero g determinations.

- (4) The preconditioning of the ORL crew members to a low caloric intake is recommended, and their body fat stores should be normalized prior to flight. Metabolic studies to determine the caloric cost of activity should also be done.

Recommendations for space-flight experiments prior to the ORL are as follows:

- (1) To fly an animal metabolic cage to determine the effect of weightlessness on metabolism, by means of oxygen consumption and carbon dioxide output determinations, on H₂O balance, and on calcium balance. The effects of weightlessness on peristalsis and on muscle deterioration are also in need of exploration by means of animal flights.

(2) The determination of ADH activity during manned space flights by means of urinary assays. This determination relates not only to fluid requirements, per se, under weightless conditions, but also to blood volume and cardiovascular effects of weightless flight.

In conclusion, it should be mentioned that the

industry and the enthusiasm displayed by these busy SPAMAG members in applying their well demonstrated abilities to the problems of our national space effort, are deserving of special note and high praise. Their work has been most laudably representative of the best traditions of the American scientific community.