NASA Conference Publication 2370

Food Service and Nutrition for the Space Station

Proceedings of a workshop held at the Nassau Bay Hilton Hotel Houston, Texas April 10-11, 1984

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Food Service and Nutrition for the Space Station

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Proceedings of a workshop sponsored by
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PURPOSE AND SCOPE OF THE WORKSHOP

Significant activities are being initiated to study and define various operational and design requirements for a space station. These efforts include the definition of requirements and concepts for environmental control and life support systems.

A Workshop on Food Service and Nutrition with participation of representatives of NASA, federal government agencies, academic institutions and industrial organizations who could define these requirements and develop food service concepts was organized by Arthur D. Little, Inc. on behalf of the NASA, Johnson Space Center.

The purpose of the Workshop was to accomplish the following:

1. Define food supply and service requirements for a space station and develop concepts for food service systems which meet these requirements.

2. Identify and/or define the potential knowledge gaps associated with the implementation of a fully-integrated food service system in a space station.

3. Consider the need for experiments to resolve the previously identified knowledge gaps.

4. Develop detailed test objectives for the experiments which could be performed during future space shuttle missions which would provide the information to guide the design of the space station food service system prototype.

The scope of the Workshop included:

1. Review of the current concepts and uses of the space station.

2. Definition of food service requirements and concepts.

3. Identification of knowledge gaps.

4. Description of research and in-flight demonstrations to fill these knowledge gaps.

5. Development of a detailed agenda to guide the discussion and activities during the Workshop.

These Proceedings constitute the output of the Workshop and are made available to the Workshop participants and other interested parties.

OVERVIEW OF SPACE FOOD SERVICE SYSTEMS

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We have a lot of work to do in the next 8 years to place the Space Station into operation. We do not know exactly when the initial operational capability will be achieved. This workshop will provide us with leading ideas and indicate what the requirements are going to be for Space Station food systems and how we are going to get there. The current space shuttle food system is based on technology developed for the Gemini, Apollo, and Skylab missions. For the most part, reliance was placed on a food warming capability only. We provided a number of food items for these missions. This afternoon, when we go on our tour, we will show you specific examples of this food.

Our early space shuttle food package was virtually an Apollo food package; flexible and containing rehydratable food. It is no longer used. Astronauts are able to eat food with a spoon more or less gracefully. The surface tension of the food will cause it to attach to a spoon or fork or any appliance. If the person moves too quickly, it will separate and come off. The types of food include thermally stabilized, natural form, irradiated, and rehydratable. The rehydratable container has an injection-molded base and thermally-formed flexible lid. The food is vacuum-packed so that when it is rehydrated with water in flight an excess amount of gas is not ingested with the food. This reduces the separation problem the astronauts would have with gas in the food if it were not vacuum packed. We use an intermediate moisture package, dried fruits, etc. and fruits in natural form. We buy commercially as many food items as are available such as fresh fruits, dried fruits, natural form foods and dehydrated food items. Freeze-dried vegetables for the most part are not available commercially; we prepare them here. We buy dried fruits directly off the shelf as well as all the thermally stabilized foods in either cans or flexible pouches.

For the first time we are able to supply fresh food, e.g., bread, bananas, fruits, etc. This fresh food along with the other food is packaged in trays that fit into the mid-deck lockers. The mid-deck lockers are in the front part of the vehicle. A food-eating tray is provided that can be used as an eating surface. There is one tray dedicated to each astronaut. It can be carried to any place in the space craft where an astronaut would like to eat. There is no dining table in the Space Shuttle. It is closer to camping out; the astronaut goes to a corner to brace himself, or anywhere else where he or she wants to eat. They use eating utensils that can be attracted to a magnetic surface or the eating tray.

The food items include a breakfast, dinner, and lunch meal. The lunch meal, meal B, has been relegated to a snack type. We provide a standard six-day menu. Menu food is packaged in the trays by itself. Other food is stored in a pantry. In the event that the astronaut does not like a particular food item that is on the menu, he or she can go to the pantry and can substitute other foods for it. On the next flight, the astronauts will have more of a direct selection on the menu but the impact of this program has not yet been totally evaluated. In addition to supplying the menu and pantry food, two days of contingency food are supplied in the event that NASA extends the mission.

A water dispenser assembly is used when we do not have a galley onboard for food rehydration. This device provides chilled water or ambient water. We do not have hot water available if we do not have a galley onboard. The dispenser device gives us incremental amounts of water depending on the selection of two-, four- or eight-ounces of water.

The food package to be rehydrated has a septum into which a needle can be inserted and water introduced to the beverage powder or dehydrated food inside the package. The package is then removed and a straw allows the astronaut to suck the fluid from the container in the case of a beverage or the lid is cutt out by scissors or knife in the case of a food item to permit the food to be eaten.

The food warmer allows us to heat food or warm food on a mission when there is no galley. It is a briefcase with an internal heating element which sandwiches the food against the centrally located heating element. It is two-sided, beverages are placed on one side and food items on the other.

The galley is installed in the mid-deck area in the Shuttle when there is room. The galley provides food tray storage for assembling meals allowing one person at the galley to assemble up to seven meals. A food warming capability is provided by a forced air convection oven. A water dispensing post allows the water to be dispensed into the beverage packs and the rehydratable food packages. In addition, there are dispensers for condiments such as mustard, ketchup, etc. We use commercially-packed items for these.

A personal hygiene station is integrated with the galley. This provides a sponge bathing capability and minimal free-water washing of the hands. The galley has a hot water temperature indicator. There is a hot or cold water dispenser and a selector for the amount of water that goes into each food package. A needle interfaces with the package septum to allow rehydration.

Pepper or salt cannot be shaken onto foods in space. Salt is dissolved in water and the astronaut squeezes the solution onto a food item. Pepper is put into an oil suspension and similarly applied to the food.

The galley oven will hold meal items for up to seven people. The thermally stabilized food items are placed in the top portion and are heated by conduction. The packages and the rehydratable beverage containers are heated by forced air convection in the lower portion of the oven. The beverage straws are provided with shut-off clamps because in zero gravity some of the liquids through surface tension forces would crawl out of a straw. Containerless drinking with a straw was an experiment on the last flight. We also started to grow plants for food purposes in space. Seeds were packaged and rehydrated in space to grow sprouts. The idea was to provide food variety for sandwiches in space. A humble beginning, but the type of activities which could lead to Detailed Supplemental Objectives (DSO) experiments for the Shuttle.

A Detailed Test Objective (DTO) is not necessarily an experiment but a demonstration that is performed to support the Shuttle. DSOs are flown on the Shuttle to support advanced missions like space stations.

In this workshop we will be discussing primarily DSOs. The food service systems that we wish to develop will undoubtedly also support the Shuttle. We are looking to the workshop discussions to develop new ideas and DSOs that will be important to meet Space Station food service requirements.

THE CONTEXT FOR FOOD SERVICE AND NUTRITION IN THE SPACE STATION

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INTRODUCTION

Space is part of humanity's continuing evolution and an integral part of man's capabilities to fashion a better future for this and succeeding generations. There is no turning back; space is the arena where U.S. industry has the opportunity to achieve a competitive edge and restore the vitality of industrial innovation.

As in any emerging field with bright promise, skeptics can point to major obstacles to space operations, including the high cost of space transportation and space activities, the risks of new ventures and the timing of entry into the space market. Commercial activities in space represent diverse markets where international competitors will be motivated by economic, technical and political considerations. Although the technical details, costs and benefits of these activities can only be conceived in broad outline, it is time to take a constructive view of the attainable economic returns from space endeavors.

President Reagan directed NASA to develop a permanently manned Space Station within a decade to demonstrate U.S. leadership in space and to stimulate commercial exploitation of space.(1) " A Space Station," declared Dr. James M. Beggs, NASA Administrator, "provides a logical stepping stone to the exploration and exploitation of space."(2)

THE SPACE STATION PROGRAM

The Space Station opens a door for American industry. This will be crucial to the future of U.S. businesses because the successful development of commercial products and services is essential to exploiting "the enormous potential of space commerce."(1) Space commerce will be as significant in determining political and commercial relationships in the twenty-first century as developments in aviation, electronics, and computers in the twentieth century are in determining economic growth, industrial expansion, and international influence.

The Space Station will pay off because it is not just a technological challenge. It will be worthwhile because it makes many other projects in space science, telecommunications, manufacturing, and exploration possible. It clears the way to tap the inexhaustible energy and material resources of the solar system. It is the next step we are ready to take.

The Space Station will have an important role in support of a broad range of scientific and commercial activities, which may be performed either in the Space Station or in free-flying satellites tended by the Space Station.

The Station will permit extensive facilities in orbit to be built up gradually and equipment to be maintained and repaired leading to major improvements in capabilities to perform scientific investigations, to manufacture products and to reduce project costs. It could be a support base for transportation of payloads to higher Earth orbits and eventually provide routine access to the Moon and to the planets. The building of a lunar base, where materials could be processed for use in the construction of more extensive space projects in Earth orbits and in support of scientific explorations, would provide a major mission for the Space Station. This base would give an open-ended aspect to the development and growth of an industrial infrastructure that could support an increasing variety of commercial activities designed to make the most effective use of the inexhaustible energy and materials resources of the solar system. The Space Station is "The Right Stuff" to ensure that U.S. industry will be in a position to meet the competition from other nations in exploiting the opportunities for commercial activities in space.

INDUSTRIAL PARTICIPATION

From the onset the Space Station program will involve industry to ensure that industrial organizations can make the most productive use of the unique environment of space. This is in keeping with one of the President's objectives "to encourage industry to move quickly and decisively into space." Appropriate Federal government policies and cooperation between the public and private sectors can develop the necessary industrial infrastructure. An indication of the commitment to increased participation by the private sector is the February 24, 1984 Executive Order authorizing the Department of Transportation to coordinate a program to allow private corporations to launch their own satellites into space. President Reagan said, "...and if our efforts in space are to show the same energy, imagination and daring as those which made our country great, we must involve private enterprise to the fullest."

POTENTIAL BENEFITS OF COMMERCIAL ACTIVITIES IN SPACE

The direction and scope of commercial activities in space are already being defined as a result of the wide ranging experiments being performed on the space shuttle. Unlike the Shuttle, the Space Station will be designed to accommodate experiments performed over periods of weeks and months in a nearly gravity-free environment. The strategy for near-term commercial activities must be planned and coordinated with long-term space industrialization goals, such as establishing a lunar base and obtaining energy from space for use on Earth. The Space Station program brings these industrialization goals into sharper focus. Areas of potential commercial interest with near-term benefits include:

1. A "fee-for-service" laboratory where industrial organizations could rent space to perform experiments.

2. Observations of the Earth and atmosphere.

3. A platform for a space-based communications program including the maintenance and upgrading of communications satellites.

4. New materials developed in space for use on Earth or in space-based production.

The Space Station will provide opportunities to engage in experiments and pilot plant operations in order to gain experience working in space. Participation in Space Station activities by industrial organizations could be an integral part of business planning strategies for organizations interested in space ventures.

Incentives for industry participation in commercial activities could be provided by services supplied to Space Station users. If NASA would provide long-term guarantees and service contracts, companies might be interested in providing facilities and services charged to the users in ways analogous to similar services provided in terrestrial industrial facilities. Examples of such services are power supplies; housekeeping and life support including equipment, consumables and waste management; habitability features including crew accommodations, recreational facilities, and food preparation and service.

The return on industry investments to provide commercial facilities and services to a Space Station would be negotiated between participants in a competitive environment, with industry taking the lead to develop and provide the necessary facilities and services on a business basis. These commercial activities could be planned from a modest and embryonic start to encompass future major investment in space industrialization.

FOOD SERVICE AND NUTRITION

Habitability

The establishment of a permanently manned Space Station places the focus on habitability. Habitability could be achieved by complete food resupply from Earth, by partial recycling of air and water, and possibly by growing a few selected food resources and in the future, by a completely controlled ecological life support system. The key to achieving acceptable habitability will be providing adequate food in a form that meets the physiological and psychological needs of the crew members when exposed to the Space Station environment. The habitability goal is to maintain crew members in the physical conditions approaching those considered normal by Earth standards.

Effects on Physical Condition

There is a growing understanding of the effects of space missions on the physical conditions of crew members. For example, protein metabolism will be altered, so optimal protein levels in the diet will have to be determined. Current indications are that protein levels may have to be reduced because of effects of calcium metabolism. Carbohydrate and fat level fluctuations do not seem to have adverse effects within the limits of currently acceptable diets. Total energy requirements may increase slightly because of an increased workload and/or decreased efficiency of utilization. Calcium requirements are not known to a desirable degree; they will probably increase in an effort to reverse the loss of calcium from the bones. Even more important may be the ratio of calcium to phosphorous. Requirements for some vitamins may be altered by stress, gravitational changes and extended periods of food storage. Vitamin supplements may have to be made available to the crew members.

Dietary Goals

Dietary goals have been established to form a bridge between nutritional needs and the food service system which meets these needs. These dietary goals include the following:

- Establishing access to a variety of foods
- Determining and maintain ideal weight for the crew
- Avoiding too much sodium by eliminating highly-salted foods
- Reducing protein intake
- Reducing the calcium to phosphorous ratio

The food service system for a Space Station must meet several requirements. It must

1. Fulfill dietary goals by delivering of appropriate nutrients.
2. Deliver acceptable foods with desirable sensory attributes.
3. Maintain health and safety standards.
4. Meet unique crew needs imposed by the Space Station environment and the expected activity levels of the crew.
5. Provide potable drinking water.

Food Preparation

Techniques will have to be developed to prepare acceptable meals from foods stored in the Space Station and resupplied by the space shuttle.

Constraints on cooking devices in the Space Station environment include the absence of convection, the need to keep foods contained and the difficulty of weighing, measuring, and transferring materials. The three major forms of cooking or thermal processing are (1) fluid immersion by pressure cooking or deep fat frying, (2) roasting and baking with a combination forced convection/ microwave oven with an attached browning unit, and (3) direct contact and/or radiant heating for grilling, pan frying, and other stove-top operations.

Meal Service and Food Handling

Meal service will have to be adapted to the mission and the crew size. Individualized preplanned meals may be practical with increased crew size and some type of food service operation may be warranted. The menu may be varied and cycled, with choices offered as needed. Food monitoring systems may be used for inventory purposes and to insure adequacy of diet.

Options for meal service include solo, group or fast food "vending" with equipment to be developed for this purpose. Food packaging and handling techniques will have to meet sanitary and health requirements. It will be important to minimize waste in packaging and food processing at every step of a functioning food service system.

DEVELOPMENT TESTS

Considerable information on food service and nutrition has been obtained in past Skylab and Space Shuttle missions. The food service and nutrition requirements for a Space Station will require evolutionary advances which will have to be based on new information. Terrestrial laboratory tests can provide only part of this information because the space environment will influence food service requirements. Detailed test objectives and detailed supplementary objectives for Space Shuttle experiments must be defined to develop new concepts and approaches for food service systems and nutrition for the Space Station.

The participants in this Workshop met to exchange knowledge on the state-of-the-art of food service system and nutrition in space flight, and to explore areas where additional knowledge will have to be gained to guide the development of food service systems. There are no text books or handbooks which can be consulted to select optimized approaches. Working together, learning from each other and sharing in the creative process during the Workshop will provide the opportunity to lay the foundation for future advances of food service systems and nutrition in a Space Station.

References

1. The State of the Union Message, January 25, 1984.

2. NASA Press Conference, January 26, 1984.

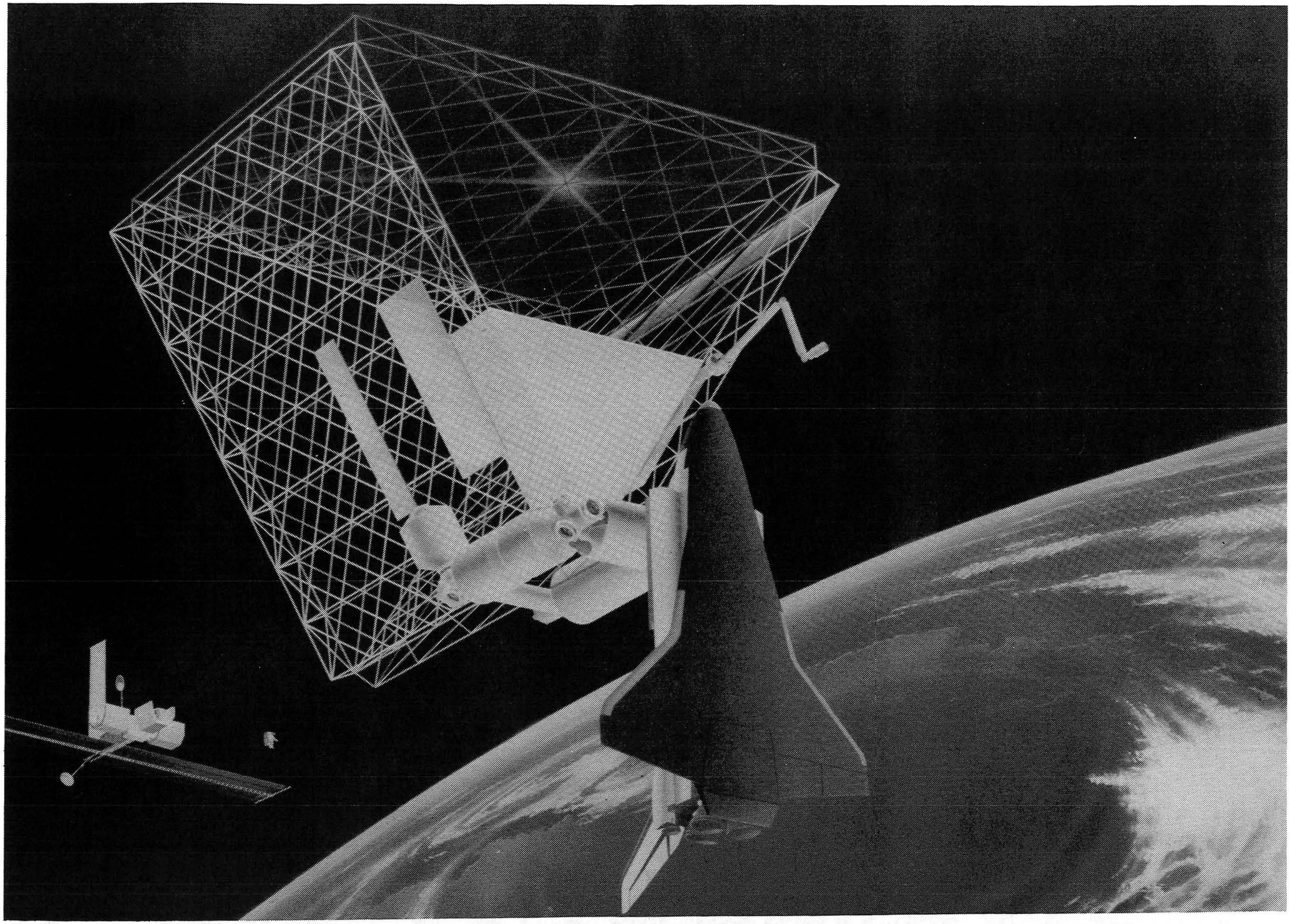

Figure 1

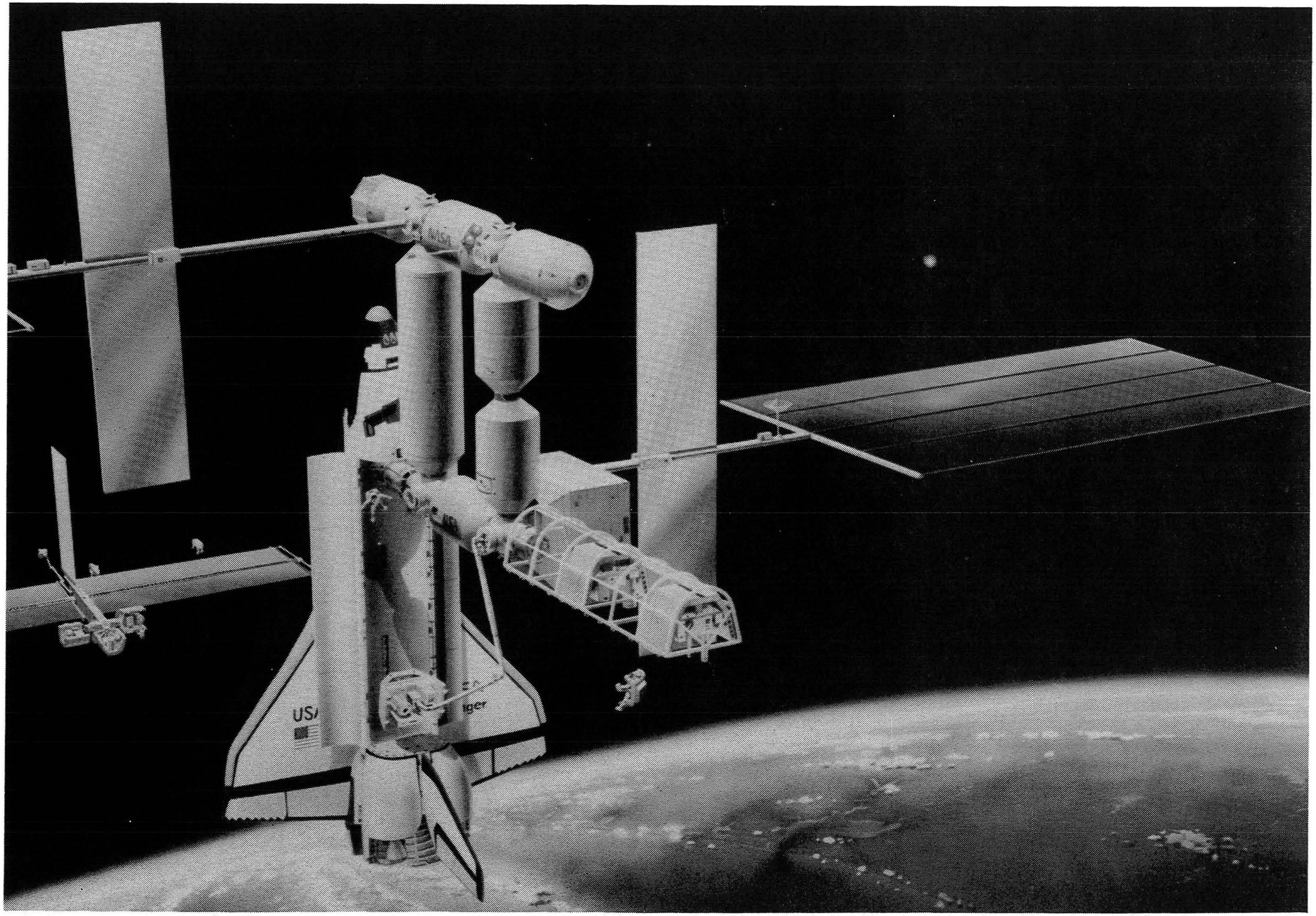

Figure 2

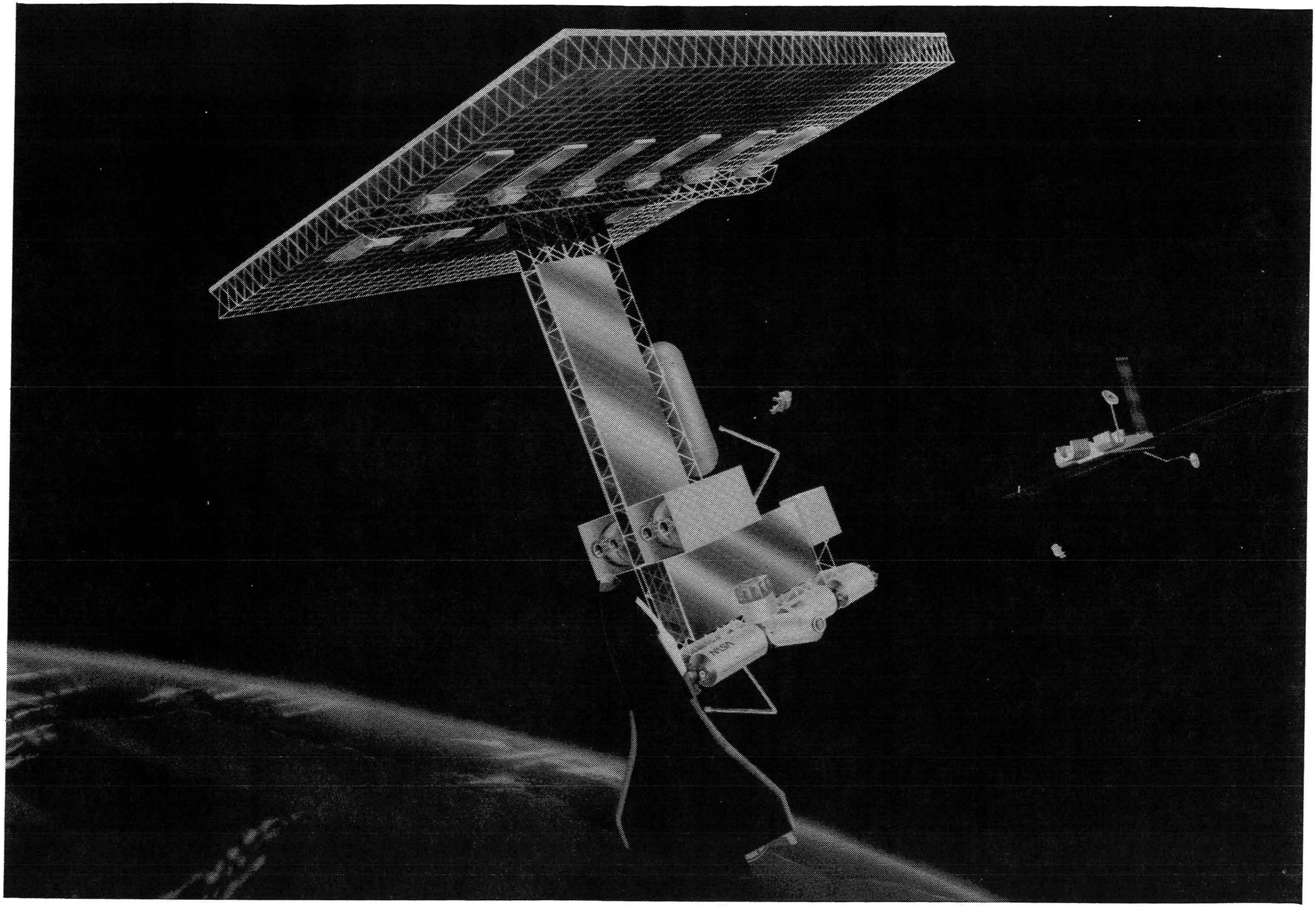

Figure 3

NASA PLANS FOR A SPACE STATION

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In the State of the Union Message, January 25, 1984, the President stated "Tonight I am directing NASA to develop a permanently manned Space Station and to do it within a decade. A Space Station will permit quantum leaps in our research in science, communications, in materials science and life saving medicines which can be manufactured only in space."

The Space Station forms part of the growing space infrastructure, which includes the Space Shuttle. Other components will be added in the future. The Space Station is an operational base which includes a number of modules for living quarters, logistic supplies and support, laboratory facilities, utility services, and berthing and assembly activities. The Space Station can grow by the addition of additional modules for laboratories, construction, assembly, and orbital transfer vehicle support. Pallets also can be attached to the Space Station and appropriate equipment mounted on them.

The Space Station also provides a base for maintaining, servicing and controlling unmanned platforms where microgravity experiments and processes, remote sensing and scientific observations of Earth, the solar system and the universe beyond could be performed. Such unmanned platforms could be free flying or tethered to the Space Station and maintained and serviced by extravehicular activities using orbital maneuvering units and orbital transfer vehicles. There are several possible orbital locations for the Space Station and associated platforms. The Space Station is envisaged as a multipurpose facility which can serve a wide range of scientific and technology development activities. It would serve as an in-orbit laboratory, a permanent space observatory, and a node in the space transportation system (which may be extended to other orbits or planets in the solar system). Finally, it would serve as a communications and data processing center between men and equipment in space and data acquisition facilities on Earth. The Space Station could also serve as a manufacturing and assembly facility to service free-flying satellites and as the storage depot for food, equipment and supplies needed to perform various missions.

The rationale for developing a Space Station includes the following:

- Ensure U.S. leadership in space during the 1990s.
- Stimulate development of advanced technologies.
- Develop fully the commercial potential of space.
- Provide a versatile, efficient system for space science and applications.
- Couple maturing international space programs to U.S. space systems and provide a vehicle for international cooperation in space.
- Enable the U.S. to function more efficiently in space and build on previous national investments.
- Increase prestige abroad and pride at home.
- Stimulate interest in scientific and technical education.
- Maintain the continuity and focus of the nation's civilian space program.
- Provide options for future national endeavors in space.

The decision to develop a Space Station in 10 years recognizes that the development program will take time, that the Shuttle is becoming operational, that the Soviet threat to U.S. leadership in space is real and that the U.S. economy requires investment in new technology.

A number of alternative approaches to the Space Station have been considered, including:

- A Space Shuttle with expanded capabilities and extended stay times in orbit. However, it would be costly to design and refurbish a Space Shuttle for this purpose and it would be less capable of performing the needed functions than a Space Station. The Space Shuttle does not represent a needed step towards Space Station design. Further, refurbishing the Shuttle would compete with other future Shuttle improvements.
- An unmanned Space Station. A Space Station would require development of sophisticated automated equipment. Even if equipment could be developed during the next 10 years, it would be less capable to meet the goals for the Space Station than a manned facility and it would not assure obtaining the objective of leadership in space.

The Space Station development program is not expected to crowd out science programs. Space science prospered during the Apollo program. The funds which were made available for the Space Shuttle development would not have been appropriated for science. Scientific activities just as the Space Station development must be approved by the Office of Management and Budget and Congressional on their own merits. Although the Space Station is not essential for current space science programs, it would be an effective system for the future, enabling scientific investigations not now possible.

The Space Station is designed to serve civil requirements, but it is likely that the Department of Defense may conduct R&D aboard a NASA Space Station. The notion that the Soviet Salyut Station employs second-rate technology and represents no threat is misplaced. The Soviet space program is growing quantitatively and qualitatively, so Salyut and its successors represent a threat to U.S. leadership in space.

International interest in the U.S. Space Station program is growing. This interest derives in part from existing contributions to the Space Shuttle, past and present cooperative activities with NASA, recognition that a U.S. Space Station is the next large development program, the maturity of U.S. and other countries' aerospace industries and the winding down of Spacelab development in Europe.

Several countries have already asked how they can be involved in NASA's planning for the Space Station. The European Space Agency, Germany, France, Canada, and Japan are conducting separate, parallel mission requirement studies to complement NASA's studies. Both the European Space Agency and Japan are examining elements that they could develop for a U.S. Space Station. Italy's present satellite systems study includes possible application of a tether to a Space Station.

So far, no other nations have made commitments to participate in the Space Station program. Potential partners must be sensitive to U.S. concerns pertaining to national security, technology transfer, exploiting jobs, and efficient management. NASA is presently undertaking initiatives including visits to Europe, Canada, and Japan for high-level discussions on international participation in the Space Station. The plan for international cooperation will be developed based on these discussions. A target date of early 1985 has been set for completion of an agreement on management relationships and the definition of specific cooperative programs.

Planning guidelines have been established for the Space Station development. The management-related guidelines include

- A 3-year extensive definition phase (5 to 10 percent of program costs).
- NASA-wide participation in Space Station development.
- Development of funding to be made available in FY 1987.
- Initial operations of the Space Station are being planned for the early 1990s.
- Cost of obtaining initial operational capability (IOC) estimated at $8 billion.
- Extensive user involvement in science applications, technology and commercial activities in international participation.

Engineering-related guidelines include the requirements that the Shuttle will

- Be continuously habitable.
- Be Space Shuttle dependent.
- Contain both manned and unmanned elements.
- Be part of an evolutionary development.
- Be maintainable and restorable.
- Be capable of autonomous operations.
- Be customer friendly.
- Be technology transparent.

The Space Station program schedule milestone include the issuance of the request for a proposal for Phase B, "Definition Studies" in the summer of 1985, the start of the definition phase of the Space Station in February 1985, and the election of contractors by the end of 1984. The budget for Space Station development in FY 1985 is $170 million which, at the present time, includes:

Item	$ Million
Utilization requirements	14.1
Supporting studies	5.8
Focused technology	54.2
Advance development	20.2
Flight experiment	11.0
Systems definition/integration	58.3
Program support	6.4

The Space Station program assumes a NASA budgetary framework of 1 percent real growth per year and identifies 600 NASA personnel in direct support of Space Station development.

The Space Station program utilization philosophy is strongly motivated to be customer friendly. Throughout the Space Station evolution an ongoing process will

- o Develop an informed customer community.
- o Influence Space Station capabilities with realistic requirements.
- o Accommodate flexible customer schedules and use profiles.
- o Provide total accommodation requirements to achieve an operational performance envelope.
- o Specify an evolving customer accommodation requirement that will support an evolving space market.
- o Provide requirements traceable back to the source.
- o Provide a forum to resolve conflicting design, operational or utility issues.
- o Establish communications between basic research, technology development, applied research, and applications communities.

The Space Station will be geared to commercial use because space is already commercialized by the communications industry and encouraging private sector activities in space is part of U.S. national space policy. Several NASA activities already have a commercial dimension, including expendable launch vehicles and the Space Shuttle. The Space Station could provide laboratory and servicing capabilities to private sector endeavors in space. Materials processing has already been identified as a particularly promising area.

The Space Station planning process includes commercial working groups and contracts to nonaerospace industries. Commercial requirements are expected to influence Space Station design, particularly requirements to protect proprietary data, and provide required power and other support activities.

To realize the commercial potential of a Space Station no quick sell is envisaged. On the contrary, commercial utilization of a Space Station will require considerable early success as a result of research and experimentation. Some of this research could be conducted with NASA's ground facilities such as drop towers, aircraft, and the Space Shuttle.

NASA realizes that it must reach researchers and management in industry. Therefore, it will nurture contacts with industry because otherwise the enterprise will sour. Continuity and consistency plus patience are the essential ingredients. NASA believes that commercial endeavors that use a Space Station involve risk but that the potential benefits are both real and large. The challenges faced by NASA in the development of the Space Station are fully recognized and include the need to

- o Design for "permanence," maintainability and growth.
- o Build to cost and schedule.
- o Conduct systems engineering/integration in-house.
- o Orchestrate the international dimension including politics, technology, development and operations, and management.
- o Maintain customer focus when time, money and engineering begin to pinch.

The Space Station represents determined steps by NASA to build a space infrastructure. Figures 1, 2, and 3 indicate possible Space Station designs which will be further defined, modified, and developed. The Space Station is a major U.S. effort designed to lay the foundation for expanded space activities in this and the next century so that "We can follow our dreams to distant stars, living and working in space for peaceful, economic, and scientific gain." (President Ronald Reagan, State of the Union Message, January 25, 1984.)

FOOD SERVICE MANAGEMENT

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We conducted a study to design a food service system using current technology to serve a small scale Space Station. We made the following assumptions:

- Population of Space Station is eight crew members
- Length of stay is 90 days
- Microgravity of environment in all areas of the Space Station
- Food resupply every 30 days
- Emergency requirement that a 90-day food supply be kept in the Space Station
- Emergency rations equal to 57.2 percent of the normal 90-day food supply

We investigated the psychological, sociological and nutritional factors affecting feeding in microgravity conditions, and identified and evaluated the following system components:

- Demand forecasting
- Menu planning
- Purchasing
- Receiving
- Packaging
- Delivery
- Storage
- Issuing
- Production
- Service
- Sanitation
- Logistics management

The first step in organizing a food service system is demand forecasting, which dictates the menu. A food service planner should know the market or the system as well as astronaut preferences. We recommended a survey of the astronauts and the increased number of astronauts now offers a sample large enough for survey purposes. For missions involving international crews, cultural differences should be considered.

The next step is menu design because all aspects of the food service are affected by the menu. Psychological and sociological needs should be considered. Nutritional needs of astronauts on extended missions are still being studied. When this information is developed, it should be incorporated into the menu. In our system, we used the four basic food group rules as guidelines when developing meals.

A major psychological need for Space Station users will be variety. A reasonable variety of food types should be incorporated into the menu without requiring excessive storage space. Attention can be paid to food characteristics. For instance, flavor is a combination of aroma and taste. The ability to smell food aromas is impaired in microgravity conditions due to the lack of normal air convection. In light of this, other food characteristics can be emphasized. Taste can be improved by flavor enhancers like condiments. Food colors, shapes, consistency and textures can be varied without affecting storage requirements.

The sociological aspects of eating can affect the morale of the crew. We recommend provisions for the group to eat together. Dining ambience can be provided or improved by providing a small inventory of flatware and china. However, this would necessitate sanitizing and recycling. In addition, pleasant lighting and music can make the meal more enjoyable as can theme meals planned for special occasions like Thanksgiving.

The dinner menu we designed has 30 different, complete meals for a one-month cycle. With the 90-day emergency supply, we can offer a choice of three different meals each day. This way the meal appears as a choice three different days in the month, yet an astronaut can choose something else all three times if he or she does not particularly like that meal. Resupply at the end of 30 days replenishes 30 days worth of meals eaten out of the 90-day supply. Luncheon meals are organized in a similar fashion.

For breakfast, we designed a limited a la carte menu, keeping in mind that Americans tend to prefer less variety in their breakfast items from day-to-day than for lunch or dinner. Therefore, we offer a smaller variety of foods but the astronauts can choose each item from the breakfast menu rather than having to choose complete meals.

The next step in organizing the system is selecting food preparation methods. Currently, menus are largely made up of combinations of preserved foods and food preparation involves reconstitution and warming or chilling. Adding fresh foods to the menu will involve more cooking from scratch, which calls for standardized recipes and more sophisticated preparation techniques. It also may involve growing some vegetables there. Experiments should be conducted to determine:

- Chemical reactions in cooking methods such as baking, broiling or frying.
- Ways to bake bread.
- Ways to grow vegetables in space, e.g., hydroponics.
- Ways to portion food from bulk packages for service and to mix recipes.
- Ways to store leftovers.

As knowledge grows it can be incorporated into the Food Service System.

In our study, we used available technology, so food purchasing, receiving, preparation and packaging is done on earth. Methods of preservation include:

- o Dehydration
- o Thermostabilization by canning, retort pouch and irradiation
- o Intermediate moisture
- o Freezing
- o Not preserved

For packaging we recommended single serving packages like the ones currently used for shuttle missions, where the crew numbers only eight. A breakoff point must be established as to how large a crew can be before individual packaging becomes impractical. Consideration should also be given to the development of a less labor intensive, more easily opened package and the reduction of package weight.

Our delivery and storage functions begin at the ground based commissary. It handles purchasing, receiving, preproduction delivery and storage of raw materials, and pre-flight post-production storage of prepared foods. The main ground based activities for the Space Station food service system are: initial food delivery, food resupply and food inventory monitoring (which is performed via a communication link with the Space Station).

In our system, when the initial delivery of the 90-day food supply is made to the Space Station it will be stored in three separate locations. This is a safety precaution. In the event that one storage location becomes inaccessible, food will still be available from the other two storage locations.

Food will be resupplied every 30 days. Computer feedback from the Space Station to earth, available on a daily basis, will monitor which meals and what food is needed for resupply. Food service functions aboard the Space Station are to take the order, get the food, prepare it, serve it and clean it up.

We have designed a storage system that dictates even depletion of food from the three storage locations. This is necessary to meet safety requirements. Food is stored so that it is taken from the storage locations on a daily rotating basis.

In our system, each day each astronaut will place his or her meal orders for the following day. Available selections will be displayed on a computer screen, the astronaut will type in meal choices and the choices will be stored in the computer. The next day, approximately one and a half hours before meal times, the computer will provide the following information: What meals the crew ordered and what storage area contains the food for that day. An astronaut will get the food from that location and the computer will delete the meals from inventory for Earth-based supply records. Each crew member can prepare his or her own meal or one crew member can prepare all meals. For the production function we use the Galley System designed by General Electric, which is currently in use for the Shuttle System. Food items are reconstituted by the crew member(s) according to directions on the packages.

Meal trays are assembled in the galley area. From this point the astronauts can serve themselves or food trays can be carried to the table and served to them. Cafeteria-style procedures could be developed for large crews.

Cleanup affects the waste management system. It is designed to accommodate housekeeping, body waste and food waste. Individual portion disposable serving packages could generate large amounts of waste relative to bulk packaging or reusable dishware. However, problems associated with bulk packaging and portioning must be considered also.

The logistics of the Food Service System must be defined. Factors include the need for:

- A centralized food production facility on Earth.
- Food demand forecast.
- A production plan that indicates which food items are to be produced, when these items are needed, and what quantities are needed.
- Inventory planning and control, both on earth and in the Space Station.
- Quality and performance control.
- System user feedback.

FOOD ACQUISITION: FOOD INGREDIENTS, RAW MATERIALS AND SUPPLY

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My objectives are to consider the kind of food supply system that will serve the space station in coming years and to identify detailed supplementary objectives related to questions we must answer to make the system work. Thus we will consider the direction and rate of evolution of space food service systems, and ask, what do we need to know to supply appropriate food to space station crews?

Naturally, the food supply system cannot be considered in isolation since it depends on other elements such as the preferred food preparation system, the types and variety of food desired, packaging and preservation technologies, and so on. These and other issues are discussed in other sessions of this workshop, and we will need to keep these issues in mind as we consider the food supply system.

The current approach to feeding the shuttle crews is a "heat and eat" feeding system, like a TV dinner with "mix and match" selectable components. Is this the best long-term approach? We have heard the Shuttle missions referred to as "camping trips," where inconvenience is tolerable because duration is limited, but will the crew members want to eat TV dinners for months on end?

It appears that a system improving on both the quality and variety of menus available will need to be developed for the space station. This will require innovations in food sourcing, recipe development, pre-preparation, packaging, preservation, preparation, presentation, consumption and waste disposal.

With the long-term development of space activities a more self-contained, self-sufficient system may have to be developed. We are not going to be able to supply fresh-baked loaves of bread and crates of fresh vegetables from Earth. Regenerative systems will be necessary. The question is, how soon do we have to think about doing that? What are the steps to get to that regenerative system? What can we do on the shuttle to move in that direction? Steps taken now, perhaps as part of the food service system for the space shuttle or only as experiments, will lay the groundwork for regenerative long-term solutions.

A few food items which would fill unmet needs by the current system include salads, which would give a "fresh" character to the diet. A start has been made in this direction with the on-board generation of salad sprouts from seeds. These efforts should be expanded as much as possible. Larger-scale hydroponic gardening probably will have to be the subject of considerable experimentation in the shuttle and in the space station itself. There are a number of unanswered fundamental questions in this field so this research probably should be the subject of larger-scale experiments rather than a DSO.

It may be possible to prepare corn flakes with dehydrated milk to which only water is added, which may be better than no corn flakes at all. However, they are not likely to be as appetizing as a crunchy breakfast cereal product developed with the needs of the crew and the space station food service system in mind, and served with real milk. How important is it to be able to do this? "Camping" food may be tolerable for a while, but will long-term dependence on such a style and quality of eating experience interfere with crew morale or performance? We believe the answer is yes.

In considering the nature of the food supply system, we can look at the major categories of solid and liquid foods comprising the crew's diet:

- o Water
- o Just add water and heat or chill, e.g., freeze-dried items, powdered beverages and soups.
- o Add water and prepare, e.g., pancake mix.
- o Complex items, e.g., jams, ketchup, peanut butter, etc.
- o Frozen foods, e.g., meats, "made" dishes, vegetables.
- o Vegetables, etc., that can not be freeze-dried or frozen.
- o Alcoholic beverages.
- o Fats.

We can also look at the various methods of preparation available to us. We need to establish which of these can and should be employed in the space station:

- o Eat it raw
- o Drink it from a container
- o Add water to it
- o Heat frozen items
- o Put together frozen parts and heat
- o Produce it onboard
- o Spread it on thawed breadstuffs
- o Fry it
- o Bake it
- o Boil it
- o Cook it in a microwave
- o Broil it
- o Others?

We need to consider which combinations of food types, food preparation methods, and food packaging and delivery systems will best fit the needs of the space station crew and the constraints on the space station and its supply system. In addition we need to consider such issues as housekeeping, pest control, tools, condiments and other aspects of eating in space. All of these issues are candidates for the design of detailed supplemental objectives which can be carried out on the space shuttle.

As currently envisioned, the food service system for the space station will rely on frozen food items, to the extent possible, to provide the highest possible quality of food. These items, and the packaging and preparation systems required to deliver high quality, should be designed specifically for the space station and its conditions. The technology required appears to be available.

To augment these items a carefully-considered and tailored selection of condiments and fresh items will be required. Most of the fresh items, especially fruits and vegetables, will be supplied in the normal resupply cycle, with packaging or pre-preparation to provide long storage life in the space station. Other ancillary items, to give character and fresh quality to the diet, may be produced on-board.

Specific DSOs which should be designed and executed in development of the space station food system involve experimentation with simple, self-contained systems to generate fresh salad items. These would include sprouts, mushrooms, miniature carrots and the like. How can these be produced onboard and how can they best be transferred from their production medium to the food in which they are to be consumed? What demands will the production of such supplemental items make on crew time, space, and other resources? Experiments must be carried out to learn about these issues.

Questions about means of portioning bulk-packaged materials, such as cereals, condiments, spreads, drinks, and so on need to be addressed in DSOs. Bulk packaging and portioning will reduce the amount of packaging waste.How can loose materials, such as breakfast cereals and drink mixes, be handled in the space station? Experiments with such materials will tell us whether we need to stay with single-serving packs or devise dispensers for such materials.

To add fresh character to the diet it is important to provide fresh-baked bakery products routinely in the space station. To determine whether these will have to be supplied in long shelf-life form in the normal resupply cycle (which would make significant demands on cubic capacity in the resupply modules) experiments with on-board baking need to be devised and carried out. Use of frozen or refrigerated doughs seems feasible, although systems designed with the requirements of the space station in mind will have to be prototyped and tested. The baking of frozen breads or rolls will be an important model for on-board preparation of fresh foods. Dough formulations need to be tested to address problems of crumbling, as well as adaptation to acceptable thermalization methods.

In these and related DSOs attention needs to be paid to the development and validation of preparation systems and ingredients which minimize demands on crew time, while providing maximum eating enjoyment. We recommend that DSOs testing these principles be executed as early as possible in the development of the space station food service system.

PREPARATION METHODS: PAST AND POTENTIAL METHODS OF FOOD PREPARATION FOR SPACE

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The long-standing objective for a food system for manned space flight has been to provide the crew members with appetizing, safe, nutritious and convenient food which is light in weight, small in volume and compatible with the mission.

There has been a logical progression of development of space food systems during the Mercury, Gemini, Apollo, Skylab and Shuttle programs. Preparation methods have ranged from no preparation to heating, cooling and freezing. The food system for each program will be reviewed briefly.

MERCURY

The Mercury flights were of short duration and the food systems were simple and experimental. The orbital Mercury program flights of astronauts Glenn (Mercury 6), Carpenter (Mercury 7), Schirra (Mercury 8) and Cooper (Mercury 9) demonstrated for food system planners that man could consume and digest solid and liquid food in space. The experience gained in food packaging and in-flight handling led to the evolution of the Gemini and Apollo food systems.

Foods developed for the early Mercury flights were pureed-type foods packaged in collapsible tubes. Pontubes attached to the containers were inserted through an opening in the face plate of the pressure suit helmet. Later in the Mercury program, bite-size foods were developed and tested. These foods were fabricated as cubes coated with an edible coating to reduce the possibility of crumb formation in the spacecraft and to alleviate the problem of stickiness or greasiness. Freeze-dried foods were used in the last Mercury mission.

GEMINI

Mission length increased during the Gemini program, requiring a more complex food system. Approximately 726 grams of packaged food providing 2800 calories were allocated per crew member each day. The volume provided for food stowage was restricted to 2130 cubic centimeters (cm^3) per crew member per day. The diet was designed to provide 16-17 percent protein, 30-32 percent fat and 50-54 percent carbohydrate.

The Gemini food system included bite-sized compressed and freeze-dried (dehydrated) foods, rehydratable beverages and solid/semi-solids, and intermediate moisture foods. The stability of intermediate moisture foods is controlled primarily by adjusting water activity (a_w). Water activity is usually expressed as a decimal derived from the ratio of water vapor pressure of the food to the vapor pressure of pure water at a given temperature. Dehydrated and intermediate moisture foods, which included bite-size cubes of meat, fruit, dessert, and bread products, were consumed directly from the package without dehydration. Their uniform shape, high caloric density (5 calories/gram), and variety of flavors made them ideally suited to the engineering requirements of space flight. Rehydratable foods and beverages are dehydrated products that must be rehydrated before consumption. Rehydratable fruits, beverages, salads, desserts, meats, and soups were developed during the Gemini program. These foods were packaged in a laminated plastic bag with a valve for water insertion tube through which the foods could be consumed. The 1.9 cm^3 diameter of the tube restricted the maximum food particle size to 0.3 by 0.6 cm^3.

Packages of food were arranged in meal units. Each meal was overwrapped in an aluminum foil plastic laminate which also served as a garbage bag for in-flight stowage of used food packages.

Only cold water (21.1 to 21.2°C) was available to rehydrate dry products. The water was a by-product of electrical power generation in the spacecraft fuel cells. The Apollo spacecraft used a similar method to produce water.

APOLLO

The initial Apollo food system was basically the same as the one developed for the Gemini program. As a result of the spacecraft fire in January 1967, each spacecraft system, subsystem and component received thorough re-evaluation and analysis to identify and reduce the hazards of flammable materials. Since it is impossible to produce non-flammable foods, packaging materials that would not support combustion in a pure oxygen environment were selected and developed. Commencing with Apollo 7, meal units were over-wrapped in a non-flammable fluorohydrocarbon.

Several significant developments occurred during the Apollo program. First, hot water (65.5°C) was available to rehydrate dry food. Second, commencing with the Apollo 8 mission a spoon was used to consume many food items. Keplerian trajectory aircraft flights verified that a spoon could be used in null gravity.

Based on results of laboratory research and null-gravity studies of foods during Keplerian trajectory flights in C-135 aircraft, candidate foods and packages that appeared to have the desired characteristics for use during space flight were selected and used on subsequent Apollo flights. As a result, a wide variety of foods and dispensing techniques were added to the Apollo food system. Six types of foods were used in the later Apollo missions: dehydrated, intermediate moisture, irradiated, rehydratable beverage, rehydratable solid/semi-solid and thermostabilized. Several food items in the dehydrated and rehydratable solid/semi-solid categories were freeze-dried.

In addition, the first meal after launch in Apollo flights consisted of a frozen sandwich, which was prepared and packaged under Apollo system quality control and stowed for easy access in a pocket of each crew member's flight suit. Bread and wine were included on some later Apollo flights.

The average weight and storage volume per man per day for later Apollo missions were 1125.9 grams and 3083 cm^3, respectively.

Dehydrated and intermediate moisture foods were consumed directly from the package without rehydration. These foods were protected by a sealed four-ply laminated plastic package, which was opened with scissors.

Irradiated food on the Apollo missions was bread processed from flour pasteurized by exposure to 5×10^5 rads of cobalt 60 gamma radiation.

Rehydratable solid and semi-solid Apollo foods were packaged in a pouch that allowed convenient preparation and eating with a spoon in null-gravity. Water was inserted from the spacecraft water dispenser into the pouch through a one-way, spring-loaded valve. After the food was completely rehydrated (5 to 10 minutes), the astronaut opened the pouch and consumed the contents. Rehydratable beverages were packaged in a similar container fitted with a drink spout instead of an opening to allow a spoon to enter. Thermostabilized beverages were packaged in drawn aluminum cans fitted with a drink spout. Thermostabilized foods were packaged in drawn aluminum cans fitted with full-panel, pull-out lids or in flexible laminated aluminum foil plastic pouches opened with scissors. Thermostabilized foods were consumed with a spoon.

The last Apollo flight was the Apollo/Soyuz docking mission in 1975. Menus included approximately 80 different food items including bread and cheese. To facilitate preparation and eating, a food tray was provided. Food packages were restrained with springs and Velcro, and were secured to the crew member's leg during meal time.

SKYLAB

The unmanned Skylab spacecraft was launched into earth orbit in May 1973. This unmanned vehicle contained most of the foods for life support of the nine astronauts who later rendezvoused with it and lived in it for 500 man-days during the next 10 months. The Skylab food supply had to have long-term stability and safety, and yet accurately and adequately provide nutrition for the astronauts during their epic expeditionary voyages.

All the Skylab foods, other than beverages, were packed in drawn-aluminum cans fitted with full-panel, pull-out lids. At meal time, cans were assembled into meals and inserted into a food warmer/serving tray. In this way, the astronauts warmed their food and consumed it (using conventional tableware) directly from the opened cans that were held in the warmer/serving tray. This tray provided the first capability to heat foods during a U.S. space flight. The heaters were electrical resistance wires designed to heat to a maximum of 69.4°C. Higher temperatures had to be avoided to prevent food from boiling and expelling particles in null-gravity. Boiling would have occurred near 72.2°C in the Skylab, which was approximately one-third atmosphere total pressure.

In the Skylab program, one of the basic objectives was to learn more about human physiology in null-gravity. Before longer journeys into space were attempted, it was necessary to determine the long-term effects of extended periods of weightlessness. To study the effects of the space environment on human physiology, a metabolic balance study was conducted in-flight.

The nutritional constraints for the metabolic balance study are presented in Table 1. The menus also complied with the Recommended Dietary Allowance and met the expected in-flight energy demands of each individual.

TABLE 1

NUTRITIONAL CONSTRAINTS FOR SKYLAB METABOLIC BALANCE STUDY

Nutrient	Constraint (mg)
Protein	90-125 ± 10
Calcium	750-850 ± 16
Phosphorus	1,500-1,700 ± 120
Sodium	3,000-6,000 ± 500
Magnesium	300-400 ± 100
Potassium	2,740 minimum, no maximum, no range

The scope of the Skylab food system is revealed by the list presented in Table 2. This was the first time frozen foods were used in the U.S. space program. Refrigerators were also available for chilling food after rehydration.

SPACE SHUTTLE

The Space Shuttle is equipped with a modular galley which features hot and cold water dispensers, a pantry, an oven and food serving trays. Food requiring heating is placed in a forced air convection oven. The maximum temperature of the oven is 82°C and can maintain food temperatures at 65°C. The oven is compatible with containers of different sizes and shapes.

The Space Shuttle menu features more than 70 food items and 20 beverages.

A new concept has been introduced in the Space Shuttle food system. A fresh fruit and vegetable tray (apples, bananas, carrots and celery) has been provided for the initial days of the flight.

TABLE 2

SKYLAB BASELINE FOOD LIST

Ham sandwich spread (T)
Butterscotch pudding (T)
Tuna sandwich spread (T)
Lemon pudding (T)
Dry roasted peanuts (W)
Vanilla ice cream (F)
Dried apricots (W)
Orange crystals (B)
Sugar cookie wafers (W)
Grapefruit crystals (B)
Cheddar cheese crackers (W)
Mints (W)
Sausage patties (R)
Ham and cheese crackers (W)
Sugar-coated cornflakes (R)
Scrambled eggs (R)
Bacon wafers (W)
Mustard (T)
White bread (F) or (I)
Catsup (T)
Filet mignon (F)
Asparagus (R)
Lemonade (B)
Pre-buttered rolls (F)
Salmon salad (R)
Pork loin with dressing and gravy (F)
Strawberries (R)
Vanilla wafers (commercial cookie) (W)
Ham (T)
Canadian bacon and applesauce (R)
Coffee cake (F)
Mashed potato (R)
Peanut butter (T)
Chili with meat (T)
Cream of tomato soup (R)
Fruit jam (T)
Pea soup (R)
Pineapple (T)
Lobster newberg (F)
Turkey and gravy (T)
Hard candy (W)
Grape drink (B)
Applesauce (T)
Hot dogs (T)
Potato salad (R)
Peaches (T)
Pears (T)
Biscuits (W)
German potato salad (R)
Cocoa-flavored instant breakfast (B)
Shrimp cocktail (R)
Cheddar cheese sandwich spread (T)
Turkey rice sour (R)
Rice krispies (R)
Chicken and rice (R)
Creamed peas (R)
Chicken and gravy (R)
Cocoa (B)
Pork and scalloped potatoes (R)
Orange drink (B)
Mashed sweet potatoes (R)
Black coffee (B)
Beef hash (R)
Stewed tomatoes (T)
Cream style corn (R)
Tea with lemon and sugar (B)
Sliced dried beef (W)
Prime rib of beef (F)
Peach ambrosia with pecans (R)
Fruit beverage (B)
Veal and barbecue sauce (R)
Spaghetti and meat sauce (R)

(T) = Thermostabilized; (W) = Wafer or bite-sized or natural state; (F) = Frozen; (R) = Rehydratable; (B) = Beverage; and (I) = Irradiated

SPACE STATION

As we look towards the future and the Space Station food system, several items could be considered.

Irradiation

Irradiation can be used to extend the shelf life of fresh fruits and vegetables. Application of appropriate packaging techniques coupled with an irradiation treatment and refrigeration could extend the shelf life of many fruits and vegetables for the projected Space Station mission length. The Proposed Rules for "Irradiation in the Production Processing and Handling of Food" were published in the Federal Register dated 14 February 1984.

Controlled Atmosphere

The shelf life of many fruits and vegetables could be extended with controlled atmospheres (bulk or unit packages).

Bulk Packaging of Food

Bulk packaging and serving of food needs to be investigated as a means of improving packaging efficiency.

Microwave Heating

Microwave heating needs to be investigated as a combination/alternative method of heating and baking. Appropriate microwave-compatible packages and restraints need to be developed.

Prepared Bread Doughs

The use of prepared bread dough (ambient, refrigerated or frozen), which is available commercially, needs to be investigated for the Space Station food system. Frozen baked bread was a popular item on Skylab. Minimal preparation involvement, such as baking bread, may offer some relaxation and a break in a work schedule.

Ice Cream

Ice cream could be provided in the hardened form as it was on Skylab. An alternative method would be the preparation of an ice cream on board with a dry mix - water - ice combination in a blender. Preparation time, however, should be minimal.

Plant Growth Experiments

Sprouting seeds as a potential "fresh" food source was investigated on the Space Shuttle and should be explored further. NASA has several contracts with scientists through the CELSS program involving plant growth experiments. Experiments with lettuce (performed by Dr. Mitchell of Purdue University) need to be evaluated in the Space Shuttle program and could be thoroughly evaluated on the Space Station.

Cleaning and Sanitizing of Utensils and Equipment

This is a definite food safety issue; appropriate methods need to be developed to effectively clean utensils and containers.

Summary

There are some significant challenges to be met in designing a food system for the Space Station. The food system will undoubtedly be an extension of the sequential development that occurred during Mercury, Gemini, Apollo, Skylab and the Space Shuttle programs, yet it should allow the introduction of some new and exciting technological advances. The end result will be a system providing crew members with appetizing, safe, nutritious and convenient food which is compatible with the mission.

ALTERNATIVE FOOD PRESERVATION TECHNIQUES, NEW TECHNOLOGY IN FOOD PREPARATION AND APPROPRIATENESS OF FOOD SUPPLY FOR THE PERMANENTLY MANNED SPACE STATION

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Alternative food preservation techniques are defined as unique processes and combinations of currently used processes for food preservation. Basically, food preservation is the extension of the useful shelf-life of normally perishable foods (from harvest to final consumption) by controlling micro-organisms, enzymes, chemical changes, changes in sensory characteristics and the prevention of subsequent recontamination. The resulting products must comply with all applicable good manufacturing practice regulations and be safe.

Most of the foods currently used in both space and military feeding are stabilized either by dehydration or the use of a terminal sterilization process. Other available options would be formulation to reduce water activity, the refrigeration and freezing of perishable foods, chemical addition, and physical treatment (ionizing or non-ionizing radiation or mechanical action). Additionally, in the commercial sector significant use is made of controlled atmosphere storage for extending the shelf-life of bulk commodities and, more recently, in unit packages at the retail level. Many alternative processes and/or combinations of processes offer promise for feeding in a permanently manned space station, where resupply estimates currently range from 14 days to 6 weeks. Additionally, due to the small number of people in a permanently manned space station (at least in the near-term) some processes which might not receive regulatory approval for broad public usage may be acceptable for use in space feeding (i.e., broad range irradiation sterilized foods).

Alternative food preservation techniques, as we mentioned earlier, can either involve the use of one process or the synergistic effects of combinations of these processes. Table 1 lists some of these typical processes. Some processes which depend on fumigants, chemical bleaching or stabilizing agents are now considered endangered processes (i.e., sulfiting and fumigation with EDB and ETO). Safer physical treatments, such as using the Entoliter for disinfestation of flour or using ionizing radiation disinfestation or pasteurization of grain, citrus fruits and spices, are envisioned as replacements.

Recently it was reported that the shelf-life of both cook-chill entrees and packaged fruits and vegetables was extended up to three months by careful pre-preparation (sanitization or pasteurization), appropriate packaging in selectively permeable casings and subsequent refrigeration (28 to 30°F) under carefully controlled conditions. Small quantities of entrees, and fresh fruits and vegetables could reasonably be made available in the menu cycle at various times through a three-month space station assignment, depending on the amount of space available for storing refrigerated perishable foods.

Other food preservation/preparation technologies are evolving. Partial pre-preparation (searing of meat, partial blanching of vegetables and the nearly finished par-frying of potatoes) prior to freezing in a cooking container enables microwave thawing and finish cooking in a few minutes. The initial processing can be altered to allow for different degrees of doneness, etc.

Products also could be frozen in ovenable sleeves for rethermalization in any of a number of cooking appliances ranging from microwave ovens to radiant heating devices. This is just one of a number of "unique" package/process combinations which may go a long way toward providing at least occasional meals equivalent to home/scratch cooked.

For any of the food preparation modes, other than warming or adding hot water to a closed system, great care must be taken to minimize the impact on the space station's internal environment. Even the use of electric convection or microwave ovens results in quantities of water, odors and other cooking effluent products being given off during the cooking operation. Thus, consideration of food service systems for a space station should include a complete evaluation of the potential environmental impacts of the cooking process and of any effluents from cleaning and sanitization which might result from the use of reusable eating utensils.

We have discussed a number of food preservation and preparation techniques which are either commercially available or may be practical in the foreseeable future. Now we will discuss the application of these foods to space station feeding. Currently, the foods used in the shuttle are mostly dehydrated or thermostabilized. While there is nothing inherently wrong with these classic foods, longer-term missions may well reveal shortcomings of this limited variety. They tend to lack some of the textural contrast of a standard five to six week cycle menu normally used in institutional or military garrison feeding. Also, at the R&DA meeting last week in Chicago, there was some concern because of long-term consumption of the military operational ration (the Meals Ready-to-Eat, MRE) has resulted in weight losses in some studies. It is not understood exactly what caused this; however, because of the similarity of the MRE and current shuttle foods, the integration of supplemental types of either fresh or more nearly like fresh foods into the food system should be considered. Of course, any new foods or food preservation techniques must assure equivalent food safety and should not cost significantly more on initial purchase, storage or preparation.

The overall charge to the space station food system is to provide appropriate, nutritious, and safe beverages, snacks and meals to the crews. This is certainly a challenge. The food system's impact on the space station environment and the overall mission must be assessed before any changes could be made. The degree of closure of the environmental control system could have a significant impact on the types of food available as well as the cost of providing water and nutrients. Additionally, it is possible water recycling will become necessary in longer-term space station missions. If a closed or partially closed ecological life support system is envisioned, the possible generation of foods by sprouting seeds and/or hydroponic culture of simple vegetables) may reduce food storage requirements. Additionally, due to the current problems with waste handling related to the single-service packaging of thermostabilized and dehydrated foods, it may become desirable to move toward the use of reusable/cleanable dishes and eating utensils to reduce packaging waste and permit bulk packaging of certain food items.

Table 1

SYNERGISTIC PRESERVATION TECHNIQUES

- Blanching and Freezing
- pH Adjustment and Water Activity Adjustment
- pH Adjustment and Spices and Herbs with Natural Inhibitors
- Dehydration and Controlled Atmosphere (Bulk or In-Package)
- Sanitization, Clean Room Packing and Controlled Atmosphere Packaging
- Thermal Pasteurization and 28-30°F Chill

  (Extended Refrigeration Shelf Life $\leq$ 3 Months)
- Irradiation Pasteurization and Refrigeration
- Thermal Process and Irradiation (Shelf Stable)
- Thermal Process Food/Irradiation Process Packaging

USE OF IRRADIATED FOODS

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Recently there has been growing recognition of the safety of irradiated foods. In the Fall of 1980 the joint FAO/IAEA/WHO Expert Committee on the Wholesomeness of Irradiated Food met at the World Health Organization Headquarters in Geneva, Switzerland to consider the wholesomeness of food processed by irradiation. The Committee reviewed the toxicological, microbiological and nutritional data collected by a great many laboratories around the world and concluded that irradiation of any food commodity up to an overall average dose of 1 Megarad presents no toxicological hazard so toxicological testing of foods so treated was no longer required. The Committee further concluded that irradiation up to an overall average dose of 1 Megarad introduces no special nutritional or microbiological problems.

Since then, studies on the effect of sterilizing doses (2 to 7 Megarads) in the United States and abroad have corroborated the conclusion that food treated with sterilizing doses is safe.

This recognition is gradually leading to appropriate guidelines and regulations for processing irradiated foods. The highly respected Codex Alimentarius Commission has developed "General Standard for Irradiated Foods" in international trade. This General Standard and a corresponding "Code of Practice for the Operation of Radiation Facilities Used for Treatment of Foods" applies to foods treated with doses up to an overall average of 1 Megarad. Presently, the U.S. Food and Drug Administration (FDA) is preparing regulations for foods irradiated up to 0.1 Megarad. I believe that in this decade, the FDA will approve foods treated with sterilizing doses.

The wholesomeness question is very important. I will reflect, therefore, on some of the changes in food when it is irradiated. First, no radiation remains in the food, nor is any induced activity produced, because the energy of the radiation used is below the threshold energies required to induce activity. The wholesomeness question, therefore, primarily concerns the possible toxicity of radiolytic products formed in the food when it is irradiated.

Scientists in this field recognized early that while animal feeding studies are highly relevant they are not very sensitive for testing or measuring possible toxicity, although most of what we know about wholesomeness of other food processes is based on animal feeding studies. Therefore, the scientist in charge of these studies sought to supplement the animal feeding studies with analyses to identify the radiolytic products formed in the food when it is irradiated. These studies consisted of:

1. Theoretically analyzing formation of radiolytic products from the different components of foods,

2. Extracting the many categories of radiolytic products using extraction techniques appropriate for each category of products,

3. Analyzing and identifying these products with the help of gas chromatographs, high pressure liquid chromatographs, electrophoretic methods, mass spectrometric methods and other methods,

4. Studying radiolytic product formation in the food and in model systems using electron spin resonance (in continuous and pulsed irradiation),

5. Studying model systems using pulse radiolysis methods,

6. Studying the product formation as a function of temperature, dose rates and concentrations of many environmental components, and

7. Checking and rechecking the theoretical estimates to establish a consistent reaction mechanism. The results of these chemical analyses were then turned over to qualified toxicologists who evaluated the toxicological significance of the radiolytic products.

In summary, we learned that the radiolytic products consist mostly of oxidation, hydrolyses and decomposition products commonly found in fresh and processed foods. The amount of decomposition products is generally much less than that produced by cooking and by heat sterilizing the food. The amount of energy needed to irradiation sterilize food (4 Megarads) corresponds to an energy absorption of about 10 calories per gram or to the heat absorbed when we heat food 10 to 12°C.

To kill the microorganisms we must always produce chemical changes. Any method that kills or inactivates the microorganisms in the food must necessarily produce some chemical changes in the food.

Radiation is dangerous to all life forms, including microorganisms, parasites and insects. We can, therefore, destroy these pests in the food without causing many chemical changes or much damage to the food. This may be best understood in light of the "target theory". The DNA molecule in the bacteria may have an atomic weight on the order of 10^6 (or even 10^8). To inactivated bacterium we must hit its DNA about 10 times. That is about one "hit" per molecule with the molecular weight of 100,000. An amino acid, carbohydrate unit or fatty acid unit has an atomic weight on the order of 150 to 300. While killing the bacterium we would decompose or change less than one molecule per every 300 molecules (or 0.3 percent) of amino acid, carbohydrate, or fatty acid. This is much less than the decomposition caused by heat sterilization, where on the order of 1 out of every 10 molecules would decompose or be significantly altered.

Further, to preserve the quality of food much more is needed than just to free it from harmful microorganisms and parasites. We also must prevent oxidations or rancidity and we must inhibit or halt enzymatic breakdown (self-digestion) of the food. In the early days of food irradiation the microbial problem was usually the main concern. Other factors, such as oxidation and enzymatic decomposition, were often ignored, often leading to misunderstandings. For example, some of the off flavors produced by oxidation or self-digestion were thought to be produced by irradiation.

Today when we irradiate meat, the meat is first enzyme inactivated by mild cooking, at about 71°C (=160°F), then it is vacuum packed in cans or in plastic aluminum laminated foils that serve as oxygen barriers and prevent recontamination after irradiation. Processed this way the meat and fish items are shelf stable at room temperature for several years. Several items prepared this way were found highly acceptable by the astronauts who have used them in some of the space flights.

Low irradiation doses (less than 0.1 Megarad) can be used to delay ripening of fruits such as bananas, and to prevent sprouting of potatoes and onions. However, fresh fruits and the potatoes treated this way are alive, breathing, and susceptible to microbial attack. Therefore, they still require good storage conditions.

Food irradiation processing is not a panacea for all problems in food preservation, but properly used, usually in combination with other treatment, it may serve us well.

EQUIPMENT FOR HOT-TO-SERVE FOODS

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Textures, odors and flavors of foods change with temperature, making serving temperature very important to appreciation. However, serving temperature alone will not provide the delightful but fugitive taste, texture, and odor of freshly browned meat or the crisp crust over the tender moist interior of freshly baked, grilled or fried foods.

So-called "microwave" penetrating radiation can heat foods quickly. It illustrates that serving many foods at proper temperature enhances appreciation, but it also illustrates that both primary and reheating of steaks, hamburgers, breads, crisp-crust pizzas and many other foods requires something more.

This requirement led to development of a family of relatively new patented surface heating devices with a much faster air-to-solid heat transfer rate than previous air ovens.

The Food Finisher oven prototype was made from a microwave oven modified to apply jets of recirculating air to both top and bottom surfaces of a product.

Figure 1 illustrates separately controlled center heating by microwave and rapid surface heating by Jet Sweep® impingement air. The oversize, tasteless biscuits were baked with only microwave. Rapid Jet Sweep® surface heating alone bakes a thin, tasty crust, but the center is still cold. When the microwave and the jets of hot air are combined, the biscuits were baked in two minutes instead of the usual eight to ten minutes.

The accelerated surface heating can brown, sear or crisp much more rapidly than in conventional ovens so that partially prepared foods can be finished quickly and tastefully immediately before serving. The crisp, freshly browned surfaces result from the faster heat transfer which does not dry out the food.

Recirculating air in convection ovens is widely applied to give clean, easily controlled heat transfer and the new developments extend this usefulness. As shown in Figure 2, updraft natural convection air moves around the edges of a flat product with air prockets on the windward and leeward sides. Forced convection, usually more parallel to the surface, reduces air pockets and moves the air faster. However, the less dense, lower viscosity hot air moves around the colder boundary layer close to the colder product.

As shown in the lower diagram of Figure 2, localized jets of hot air directed perpendicularly to the surface disperse the insulating boundary layer and give much faster heat transfer.

The effects of the Jet Sweep® impingement air-to-solid heat transfer can be illustrated by photographs of pizza crusts. Figure 3 shows how a flat object is heated most around the edges if air is blown directly at the surface. This condition occurs as air rises around a product in a natural convection oven.

The pizza shell shown in Figure 4 shows the intense localized heating effect of multiple air jets. Figure 5 shows the even heating obtained when the multiple air jets are caused to sweep separately over a surface.

An Untended Meal Server (Figure 6), built for U.S. Army Natick Research and Development Laboratory stores containers of frozen foods in stacks. When a meal is desired, an entree, a vegetable and a starch can be selected (Figure 7). Each portion is retrieved from the freezer and placed into one of the three Food Finisher compartments. It is thawed by microwave at a low power level, then the microwave can heat it rapidly. If browning and crisping is desired, the hot air jets automatically open the shrink film overwrap and project into the box to crisp and brown the portion. With proper partial food pre-preparation and program selection foods, this unit can supply very fine meals from frozen portions.

The Jet Sweep® impingement principle uses lower temperatures and still bakes much faster than most ovens. This tolerance of operation finds application in self-timing, conveyorized pizza ovens for restaurants.

The jet air principle is also applied to give very uniform and faster commercial baking (Figure 8). In contrast, the small counter top Impinger oven (Figure 9) starts commercial distribution this month. The smaller conveyorized ovens facilitate rapid heating for food preparation or finish heating before serving.

The Progressive Food Finisher® (Figure 10) heats chilled foods to serving temperatures for distribution in insulated trays to hospital patients. It applies individually programmed heating in ten successive microwave component units to give each meal its proper finishing. This unit has run about two million meals in about four years in the United Hospitals in St. Paul, Minnesota. Each meal is manually programmed so that a full meal or a side order is properly heated.

A later model Food Finisher (Figure 11) was installed less than six months ago at University Hospitals of Cleveland. This unit receives a meal which is plated according to a patient's menu request. It heats the plate with jet impingement air so that it does not take heat from the food. The food is heated by pulses of microwave as it moves through the 10 compartments. An infra-red, non-contacting sensor "looks" at the plate in alternate cavities and sets the proper heating cycle. This sensing and heating is automatically repeated until the food reaches the desired temperature.

In use, the platers fill the plates with chilled food which is held in refrigerated compartments. The meals travel through the Finisher and the heated finished meal is placed on the tray for delivery to the patient (Figure 12).

These Enersyst Progressive Food Finishers® illustrate proven concepts which can be adapted for rapid repetitive food preparation and for finishing partially prepared foods for excellent serving quality.

® REGISTERED TRADEMARK

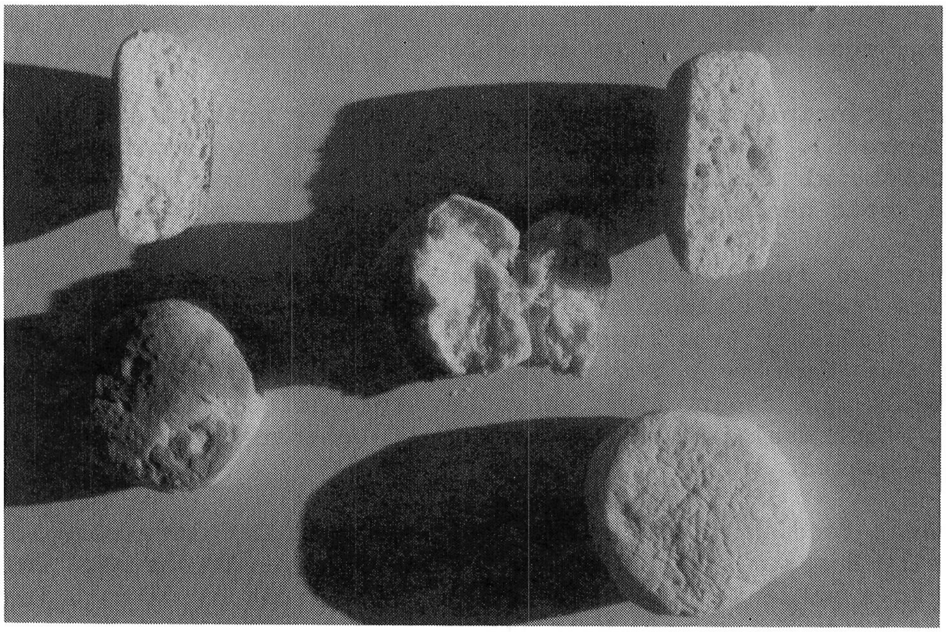

Figure 1. - Biscuits center heated by microwave and rapidly surface heated by impingement air.

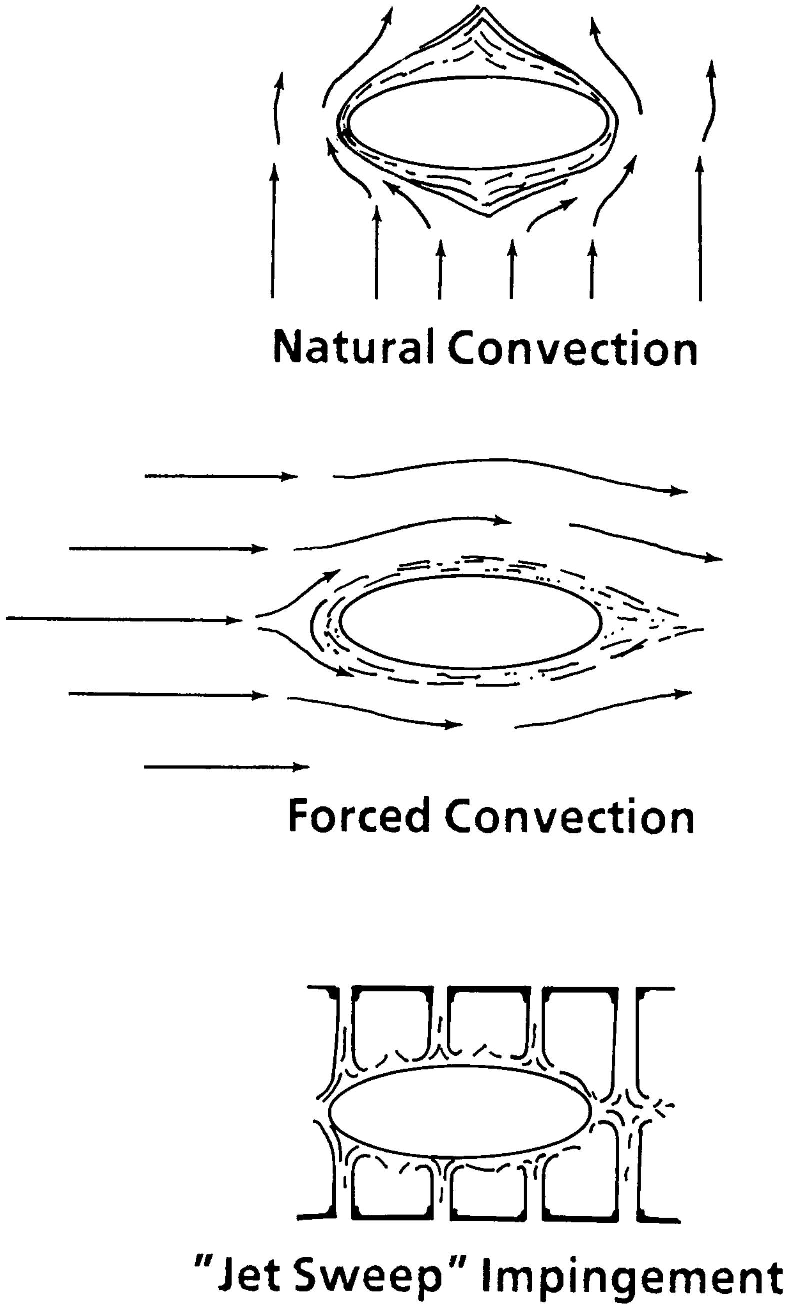

Figure 2. - Comparison of air movement by natural and forced convection and Jet Sweep impingement.

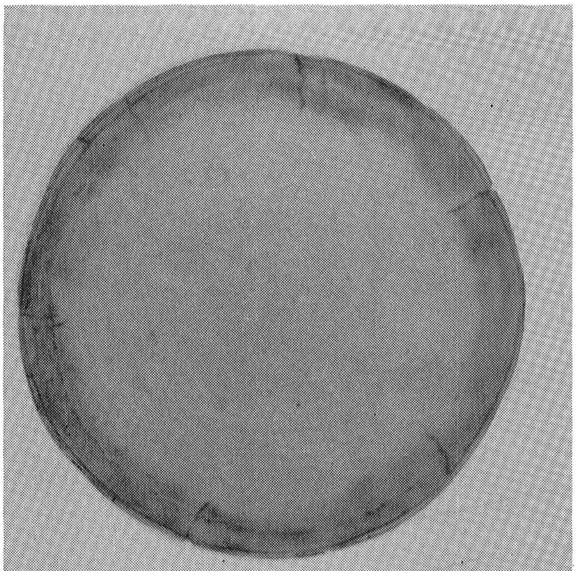

Figure 3. - Natural convection oven heating of flat object.

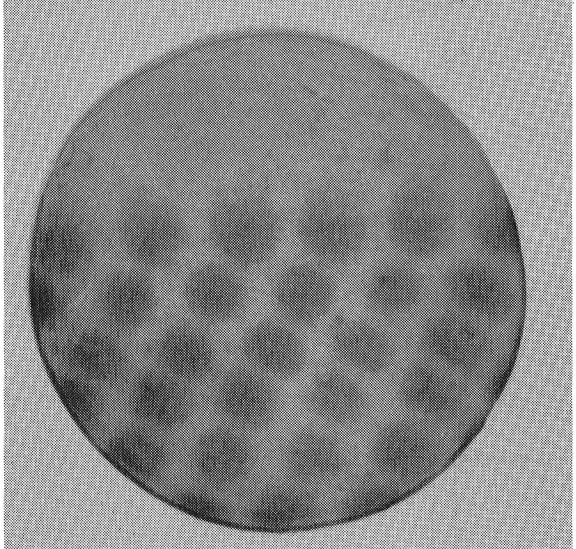

Figure 4. - Localized heating effect of multiple air jets.

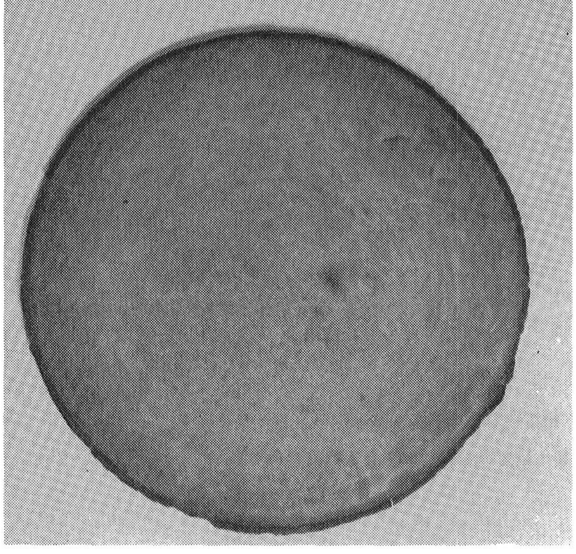

Figure 5. - Even heating of multiple air jets sweeping separately over a surface.

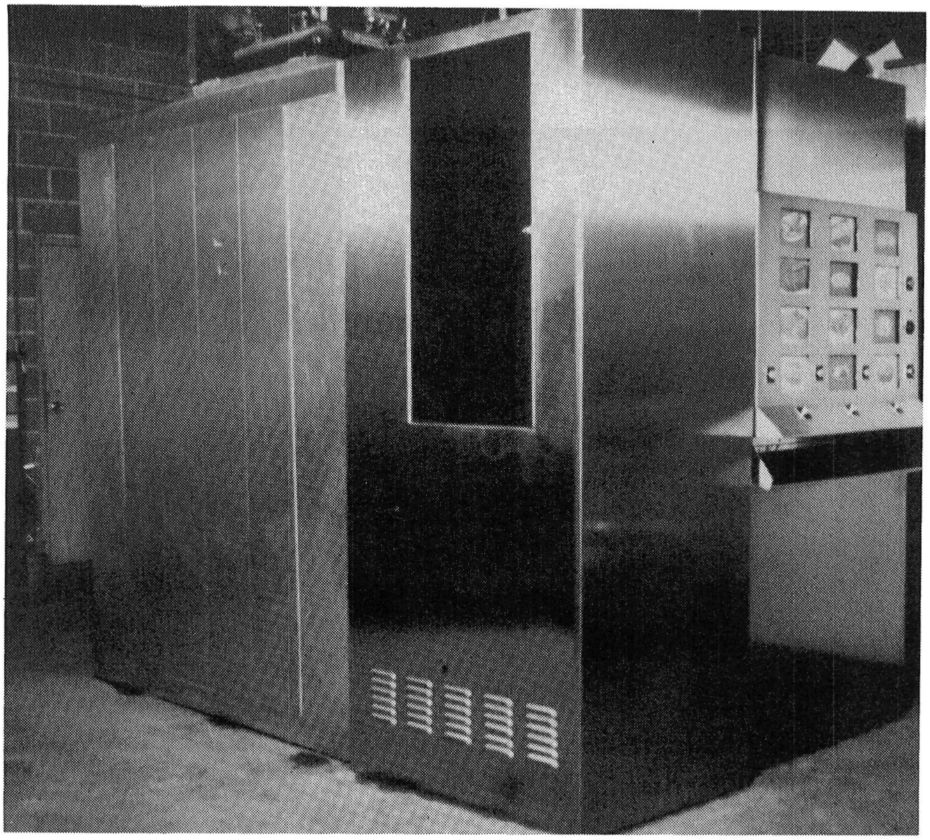

Figure 6. - Meal server.

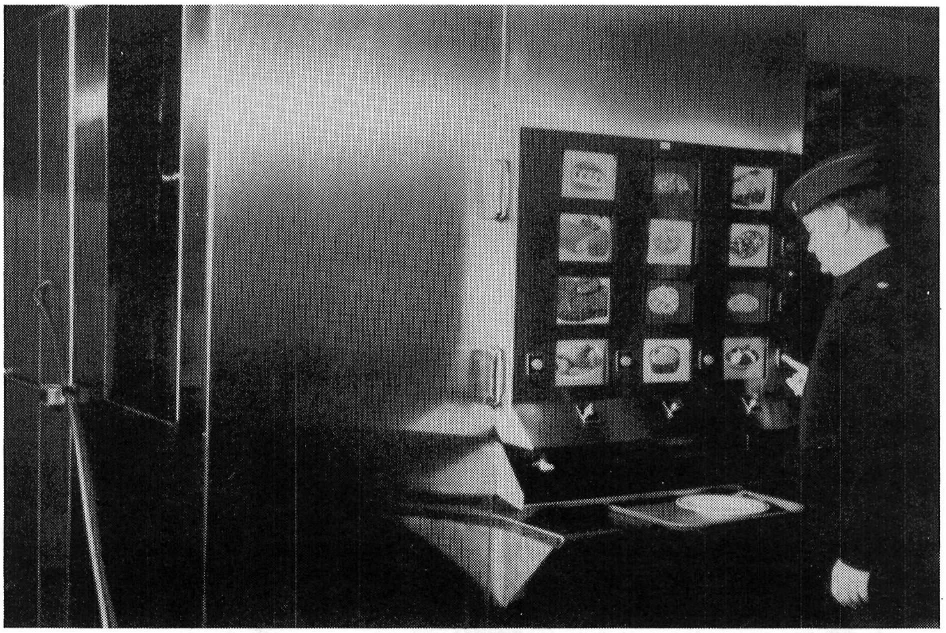

Figure 7. - Selection of an entree, vegetable, and starch from a meal server.

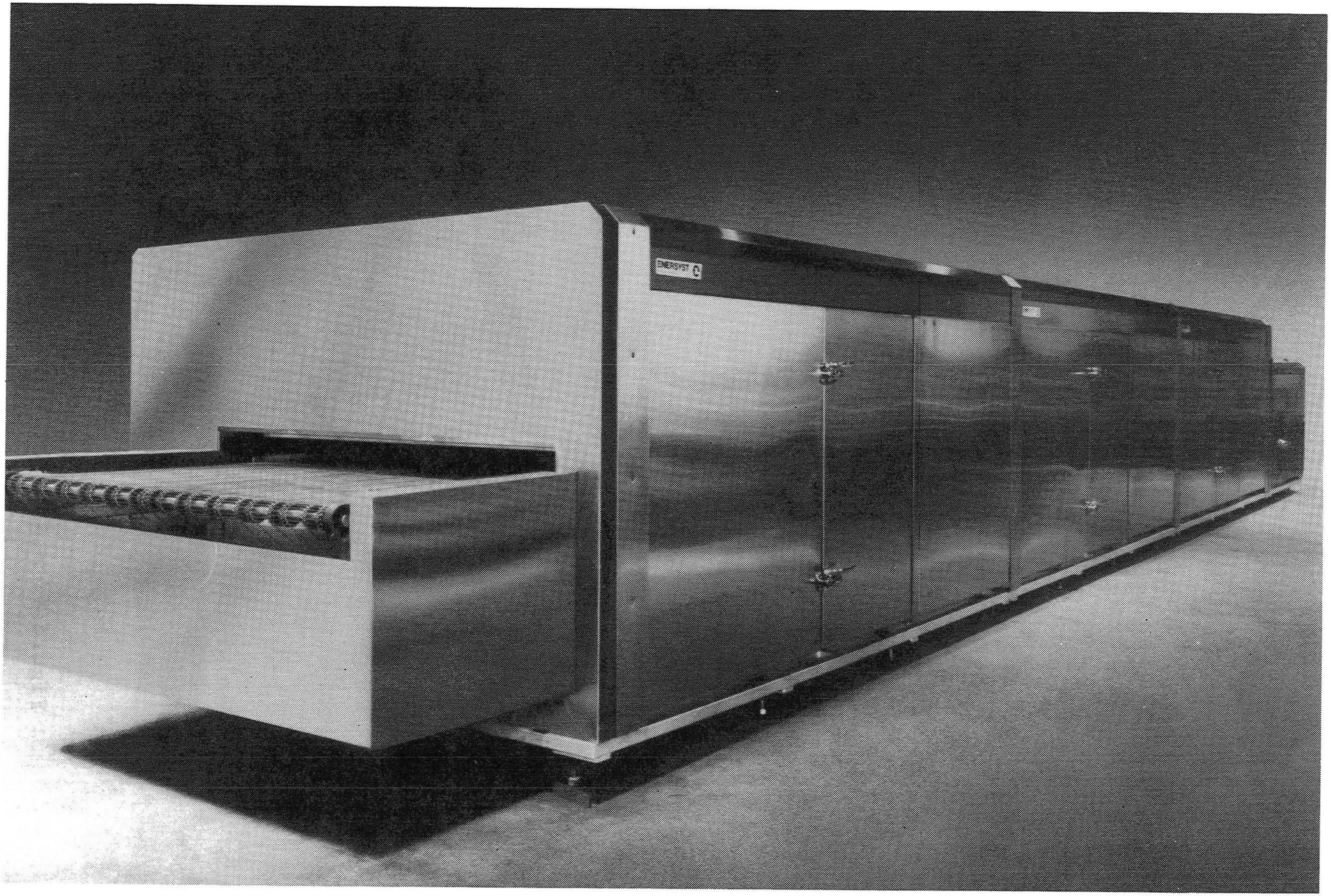

Figure 8. - Commercial baker which uses jet air principle.

Figure 9. - Counter top impinger oven.

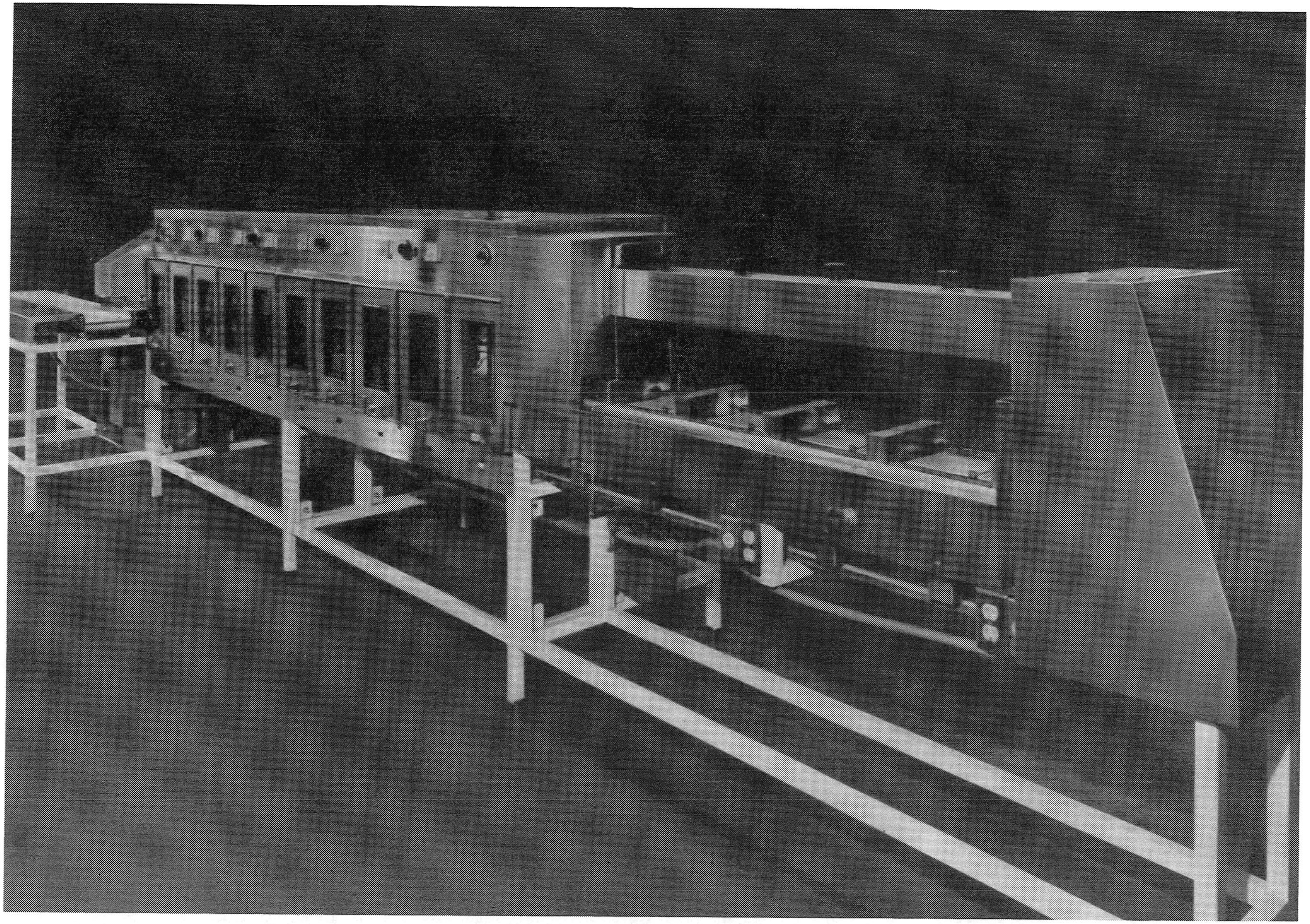

Figure 10. - Progressive Food Finisher, Model PFF-1.

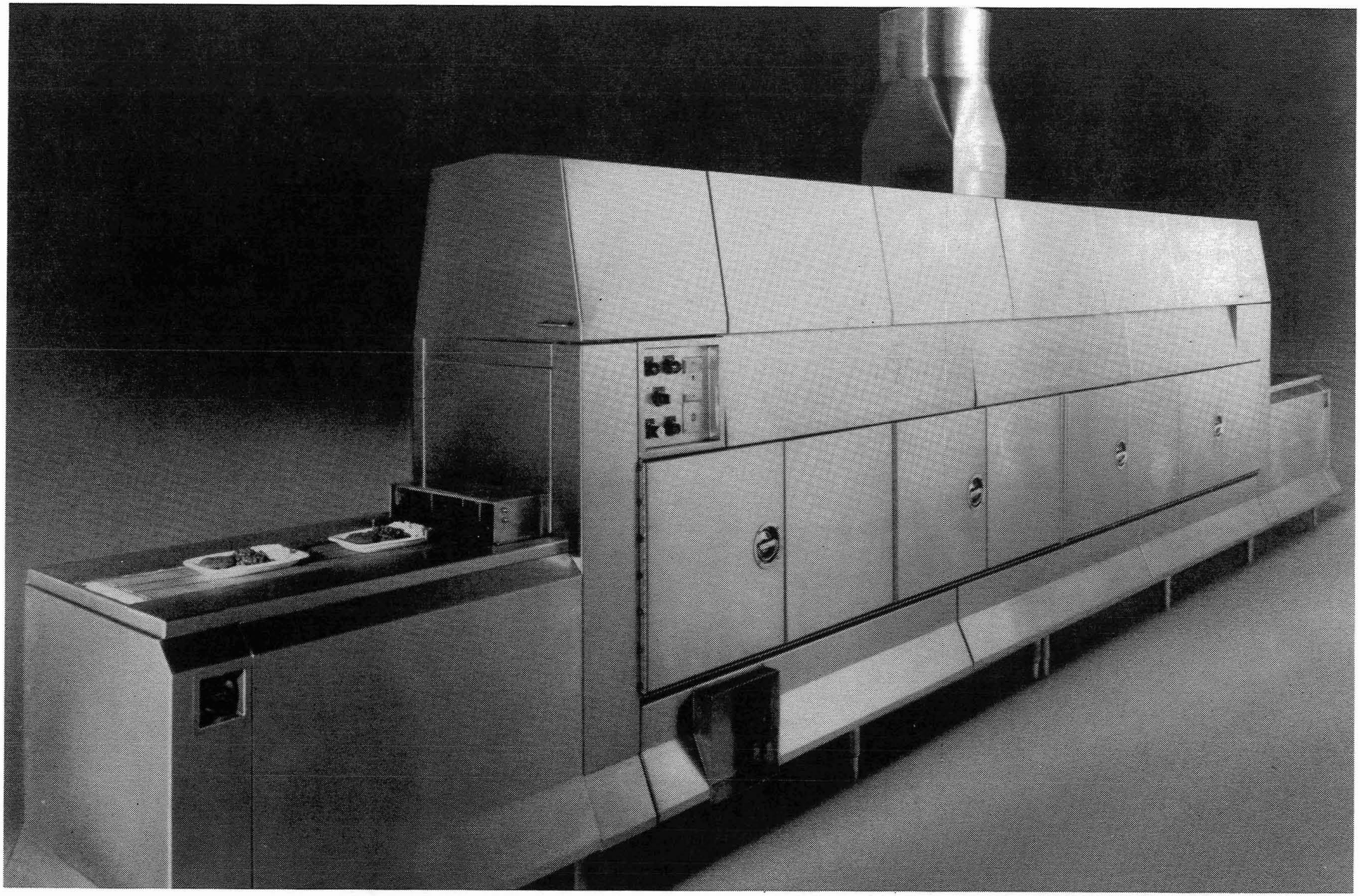

Figure 11. - Progressive Food Finisher, Model PFF-2.

NUTRITIONAL CRITERIA FOR MILITARY RATIONS AND EFFECTS OF PROLONGED FEEDING ON ACCEPTABILITY

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In the Department of Defense, The Office of the Surgeon General (OTSG) of the Army is responsible for establishing nutritional allowances and standards for male and female personnel of the Army, Air Force, Navy, and Marines. These allowances and standards are based upon the familiar Recommended Dietary Allowances (RDA's) of the Food and Nutrition Board of the National Research Council. As noted in Table 1, the military recommended allowances are adjusted to reflect the differences in nutrient demands of moderately active male and female personnel in the age group 17-50 years. The recommended allowances are used by menu planners to develop and evaluate the menus served in military dining halls. In contrast, the nutritional standards are criteria used in the development and procurement of our operational rations such as the individual packaged combat ration, the Meal, Ready-to-Eat (MRE).

The OTSG has also established broad nutritional policies for operational rations which are designed to insure that the nutritional content of the rations served to our troops will sustain their combat effectiveness. These policies include the following:

- Rations must satisfy OTSG nutritional standards at time of consumption.
- Ration developers must compensate for projected nutrient losses during food processing, expected storage conditions, and food preparation.
- If fortification is necessary, the required nutrients are to be formulated into menu components and are not to be provided in the form of vitamin/mineral pills.
- Operational rations must be tested under conditions of intended use to determine if troops will consume sufficient quantities to prevent unacceptable body weight loss.

It has been long standing Army policy that individual combat rations (such as the "C" ration) should not be fed as the sole source of subsistence for more than ten consecutive days. There was concern that these rations, although nutritionally complete, would become monotonous because of limited variety causing nutrient intakes to decrease and body weight losses to occur with possible adverse effects on morale and combat effectiveness. Whenever possible, troops are now fed one or two hot meals per day containing fresh foods and a much greater variety of foods than are available in packaged rations.

Recently, the Army has been looking at opportunities to reduce the logistical burden needed to support troops which must be capable of rapid deployment to hot spots around the world. One consideration was to have troops subsist solely on packaged rations for periods of up to 90 days without the support of field kitchens and associated cook personnel. Accordingly, the US Army Natick Research and Development Center recently conducted a laboratory and a field test to evaluate the effects of prolonged feeding of the MRE ration. The laboratory test was conducted with student volunteers and it was found that students eating MRE's three times per day for 45 consecutive days were able to maintain body weight.

A 34-day test was conducted at an isolated training area on the Island of Hawaii. One company of troops was fed three MRE's per day and a control company was fed one MRE and two hot "A" field rations per day. The preliminary data reported to date indicate that the company eating three MRE's per day lost an average of about 10 lbs., whereas, the control company lost an average of 4-lbs. over the 34-day period. It would appear that the MRE company ate only about two-thirds of the calories provided. These factors include: (a) lack of defined "meal time" when hot meals are not served; (b) hassles with menu component packaging systems; (c) time required to rehydrate selected items; (d) insufficient variety of drinks; and (e) too many calories in the form of desserts.

The Army's recent experience with prolonged feeding of MRE's may be very applicable to those planning food service for the Space Station missions of up to 90 days in duration. Acceptability of food items in space may depend as much upon the degree of ease of preparing and eating the food as on the taste, texture, and aroma of the food. it will be very important to determine which foods are highly acceptable throughout a 90-day mission and which foods, although acceptable, are tolerated only infrequently. Every effort should be made to validate in space any Earth-bound preference and acceptance methodologies. The Army's recent studies have suggested that preference and hedonic ratings of food items may not always satisfactorily predict actual food consumption in the field.

NUTRITION IN SPACE FLIGHT: SOME THOUGHTS

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We know that going into space will cause physiological changes related to microgravity and on which nutrition has a bearing. Some examples are: muscle atrophy-protein; bone atrophy-calcium, phosphorus, vitamin D; space sickness-fat; cardiovascular deconditioning-sodium, water, potassium. In the following discussion, I will touch on these and some others which relate to living in space.

Any trip into space, whether for two days or a week, will result in a 2% body weight loss even with an isocaloric diet and adequate water-salt intake. During longer missions, an increase in caloric intake greater than eaten on Earth can decrease this weight loss. The U.S.S.R. has increased the caloric intake of its crews during long-term flights. The U.S. did it in Skylab IV (84 days). What happens, however, is not very desirable for an athletic astronaut. He continues to lose muscle mass as is usual for space flight but replaces it with fat as a result of the extra calories. What is a surprise about living in the microgravity of space is the amount of calories required. NASA originally believed that a lower number of calories would suffice in space flight just as it had learned that bed rested subjects fed an isocaloric diet gain weight during the bed rest period. Experience in space flight operations proved that this was not the case and that to maintain a normal weight, it is necessary to feed the crewman about the same number of calories in orbit as he eats before the flight.

Skeletal atrophy is the biggest medical problem NASA will face in space station crews. Our knowledge about the skeletal changes of microgravity is based on Skylab data which is now over 10 years old. Since that era, the U.S.S.R. has had longer missions but no metabolic balance study has been performed, and therefore, the U.S.S.R. studies do not tell us whether or not their crewmembers are losing calcium at the same rate as found in Skylab crews.

You may recall in Skylab, there were three missions with three people each. The first mission lasted 28 days. The second mission lasted approximately two months, and the third, three months. The numbers represent only nine individuals at the beginning and only three at the end of three months. Thus, the entire world data on the subject are very scanty. If these data turn out to be representative of the general population, then Skylab will have been a great contributor to the knowledge base of what happens to the bones when you live in a microgravity environment. The Skylab results indicate that after the first week or so, each crewman lost about 0.5 of his skeletal calcium each month. In some areas, like the weight-bearing skeleton, the loss may have been as high as 5% per month. All crewmembers lost calcium and this loss continued through the mission.

NASA studies have shown that if a subject is placed at bed rest, some of the physiological responses simulate space flight because gravity effects on the length of the supporting skeleton are removed. Bed rest will produce bone atrophy similar to that found in Skylab crews. After returning to normal living conditions, the subject's calcium balance returns to near normal. But the subject's skeleton contains less calcium than it would have if the subject had not been placed at bed rest.

The calcium loss of space flights poses no problem if you are a gung-ho astronaut who goes up once, gets the Congressional Medal, meets the President, and then resigns to go into industry. It will be different in the space station era when a worker is trained to work in space, goes up for 90 days, comes back for 90 days, goes back, and so on for many trips. Would the worker retire at the end of his life's work in serious jeopardy as far as his skeleton goes? In a way, he is somewhat like the worker exposed to radiation. What is the allowable lifetime loss of calcium before NASA as an employer should call a halt?

There is not much known about calcium and the skeletal changes over a lifetime. There have been several studies, but they are flawed because the researchers have not followed a single individual over several decades. What they do is rely on measuring a group of 50-year olds, a group of 40-year olds, etc. When this is done, the average calcium of a person at 50 is less than in a 40-year old which in turn is less than in a 30-year old and it is less than in a 20-year old. Skeletal calcium is maximal around 20 to 25 years of age in a male and female, and from then on calcium decreases gradually at a rate of about 5%/decade. There is a certain skeletal density below which a person will become very prone to stress or traumatic fractures. A woman starts out at a maximum skeletal calcium at age 20, but this is somewhat less calcium than a male because her skeletal size is smaller. During the reproductive years, her calcium loss is at the same rate as a man, although losses might increase some during pregnancies and breast feeding. When she goes through menopause at age 50 to 55, the calcium loss is equivalent to about three decades of loss prior to that. Thus, by the time she goes through menopause, her calcium loss is equivalent to a man 30 years older. Thus, starting with less calcium and losing it faster, women have more trouble at ages 70, 80, and 90 with fractures than males of the same age. We can predict then, if a man spent a lifetime occupation in space flight losing calcium at 0.5% per year, he would probably have a problem with his skeleton at age 70 or 80 like some women, and a woman astronaut would have trouble earlier. The big unknown at this time is how to stop the crew's calcium loss.

Various ideas come to mind on how to stop the calcium loss: One, we could increase the calcium in diet. If we ingested more calcium, would it preserve calcium in the bone, would the calcium loss level off sooner? The answer tested in bed rest studies says yes it does, but the effect lasts only for about 12 weeks. Other things have been tried. High phosphorus in diet may help decrease urinary calcium. Certain nutrients have been tried as pharmaceuticals. Fluoride will probably be of some benefit. Phosphanates which are a detergent-like compounds will stop calcium loss. A high protein diet increases the rate of calcium loss. Should the diet be low in protein?

The bones in a human are trabecular or cortical. Trabecular areas are constantly being remade and torn down and remade--constantly remodeled. Bones trabeculae are changed in thickness and number depending on physiological need. In space flight, we believe but have not yet proven, that the remodeling, even if it proceeds under the influence of a therapy, would probably be in the wrong spots. For example, as I stand here, I stress my femur which is a bone that responds to remodeling. As I move around, I am stressing it and it may take up more calcium. Jogging and hitting the heel on the pavement may induce stress fractures. When it does, the body may increase the calcium supplied to that area. In space there is no gravity, there is no pull; therefore, any calcium added to the skeleton might be distributed indiscriminately. For example, calcium might be added to the skull near openings where nerves come out. These openings could be made smaller resulting in pressure on the nerves. In space flight it is important not only to prevent the loss, but if bone remodeling is going to go on, to find a way to make the remodeling meet the body's requirements for living on Earth.

The urinary calcium increases immediately after exposure to weightlessness since the body starts to unload calcium in the first few days. This means the kidney has to increase calcium excretion up to a maximum of about 500 milligrams. With further loss of bone calcium, less food calcium is absorbed by the intestines. Increased urinary calcium could result in renal stones. Would dietary modification decrease this health hazard? Would increasing the dietary phosphorus decrease this? Would an acid-producing diet help?

There are many studies that have been done to try to determine what causes the calcium loss. Today we really do not have a good understanding of its cause. Hormones do not seem to change a lot, the level of phosphate and calcium in the blood goes up, and protein stays about the same. There is not much we can say about it other than that lack of stress and strain on the bone causes the bone to lose calcium. NASA hopes that by the time the space station is developed that it will have found a therapeutic measure. Perhaps it will be a food additive. There are some interesting sidelights in NASA data. For example, just because a person is a jogger during adult life does not necessarily mean that he or she has more calcium in the skeleton. Studies have shown that runners can have low calcium or high calcium skeletons depending on factors other than exercise stress.

When an astronaut is exposed to weightlessness, unpleasant symptoms develop. The most unpleasant is space sickness. Space sickness is somewhat similar to car sickness or air sickness. Nutritionists might help astronauts by finding foods which tend to decrease the symptoms of space sickness. Shortening gastric emptying might help. Fatty foods slow stomach emptying. Therefore, should NASA reduce fat in the diet during the first few mission days? Vomiting in space is not a retching type of vomiting often associated with food poisoning. It is more like, "Oh my golly, it happened," type of situation. One of the most useful drugs to combat space sickness is a combination of a centrally acting anticholinergic and a stimulant to overcome the soporific effects of the anticholinergic drug. Anticholinergic drugs dry the mouth and the stimulant decreases appetite; both undesirable effects for a crewmember. Even if they have had no problem in airplane spinning and on merry-go-rounds it does not mean that an individual will not be sick in space. Terrestrial motion sickness does not correlate with space sickness.

We know there is a fluid shift on entering space, and maybe the fluid shift is one of the causes of space sickness. If the individual's extracellular water is high, or if there is edema of the legs it might help to reduce it before launch by eating less salt and drinking less water. Some astronauts try to dehydrate themselves before they go up to decrease the rate of urine formation during launch and to postpone urination in early orbit. It is not much fun to have to urinate while waiting on the launch pad.

The astronauts sometimes do not want to drink the water offered while in orbit. The water often comes out of the spicket containing excess gas because it is a by-product of the fuel cells and can contain uncombined oxygen and hydrogen. The gas bothers them, and they prefer to avoid drinking gas-filled water. However, on reentry, if the body's fluid content is too small, there is a tendency to faint, to have a lower blood pressure, and to excrete more adrenalin. If the crewman increases his salt-water intake just before he comes back, he feels better. They do that by taking a liter of isotonic saline solution. This is made up in the stomach by eating 8 salt tablets and drinking 1 liter of water.

There is an old wives tale that the astronauts used to believe that Gatorade had significant amounts of salt in it. For a while they took Gatorade instead of the salt tablets because people remember getting sick after taking salt tablets on Earth. It took a while before the flight surgeons convinced crews that Gatorade is mostly sugar and almost no salt, and that they could drink it as a personal preference beverage but could not use it for the countermeasure.

Muscle mass in the calves, thighs, and back needs to be maintained during orbital living. Protein intake may have to be increased to do this during long missions, along with administration of anabolic steroids. Red cell loss of 10% occurs in space flight. We do not know how to prevent it. After return to Earth, the individual will need a little more iron and definitely need more folic acid to regenerate the lost red cells. It may also be desirable to decrease cholesterol and carbohydrates in the diet since on return, high density lipoproteins (HDL) are decreased for a period of time predisposing the individual to increased cholesterol deposition in the blood vessels.

The toilet facilities on the spacecraft are not a lot of fun. During long missions, we might want to increase the fiber content of the diet to aid evacuation. A higher fiber diet might help reduce intestinal gas pains which are unpleasant.

We will have to guard against vitamin deficiency. The processed food for a space diet may be five or more years old, and therefore, may lack some vitamins and nutrients. We should by all means plan to use fresh foods whenever possible. The caloric intake should be planned to be as on Earth and should not be decreased even though it appears that astronauts floating around in space would not be working so hard. During extravehicular activities (EVA) very high metabolic rates have been recorded. Most of this occurs because the astronaut does not have experience with this type of activity, so in a sense, he is clumsy. He does not know how to pull on a bolt without flying off in the opposite direction, and trying to hold on, he uses more energy than is needed. By the time the space station is built, astronauts will be trained to work effectively in space suits. Their caloric use or metabolic rate when they are working in EVA should not be any greater than it would be on Earth except that if the space suit is not functional and pleasant to wear, calories will be used to move around in the suit and to endure the discomfort. In present space suits, using the hands causes pain from the glove. With a better suit and especially better gloves, training, and experience, working in space should be like any other job.

FOOD SERVICE AND NUTRITIONAL NEEDS

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I really did not come here to pontificate on the food system, although being a former member of the crew I will wind up doing so no doubt. Some of the people here know how the food system has developed and how it got to where it is now. It struck me that on the very first few flights in the manned space program the food system presented no problem whatsoever because there did not have to be one when Alan Shepard was up for 15 minutes and Gus Grissom after him, and even John Glenn, when he flew for 5 hours. It really was not a big deal, but from then on, as we began to fly for 8 hours and then 24 hours and then 32 hours and then 8 days or bust on Gemini, it began to be a big deal. The name of the game has been nutrition and packaging all the way along. Although nutrition was the unknown area, packaging has been a big problem. We have had our nutritional problems and from the Skylab point of view I can reminisce about some of those. The original Skylab food plan was to give all the astronauts 2400 calories a day whether they wanted it or not. This resulted in Deke Slayton writing his famous memo saying that his crews were not goose livers and he would not stand to see them stuffed. From there we got into the plan where each of us ate test meals for two six-day periods, as I recall, and every scrap that we ate and every scrap that we left was measured. They figured out what our caloric requirements were on the ground, subtracted 300 calories from that and then gave us that package for Skylab. It was that or nothing. The potassium, calcium, sodium, magnesium and a number of other things were all rigidly specified. We had pills to eat each day should we fail to consume some of our food, which we often did if it was asparagus, peas, or some of those favorite things. The next day we would report to the ground, "I didn't eat my peas." "Tomorrow you take two white pills and one brown pill and you'll be all right."

On Apollo we had the famous potassium flap. I believe it was Apollo 15 with Dave Scott, Al Worden, and Jim Erwin. They came back from a very vigorous pair of excursions on the surface of the Moon substantially dehydrated, and they had some cardiac arrythmia during the return flight to Earth, which scared everybody a bit. They had their body potassium estimated after they got back and it was like a 15 percent loss on a 10- or 11-day flight. Potassium was the buzz word for awhile. John Young complains to this day that the cause of his diarrhea and stomach upset on Apollo 16 was all the potassium that was put in the orange juice. I guess bananas were not ready yet.

So there have been things like that as we went from tubes to bags to cans and dealt with crumbs and spills and all the packaging constraints, and now on the Shuttle we have a system that works. The food is nicely packaged and there is a good selection. The crew is still edging toward a bit more individual selection, rather than a standard menu, but on a 7-day flight you can pretty well eat what is available in the cafeteria and it works very well.

The difficulty is that as we go into the Space Station world, the cost, effort, hardware, food trash, and food waste that the food service system will generate (which is quite tolerable on a 7-day mission), probably will be intolerable on a 90-day Space Station mission. The challenge for Space Station, and this is strictly a personal guess, will not be the nutrition. There are certainly some nuances; we are in a closed system, the food you bring is what you get, and we are going to have to be careful not to forget any trace elements, vitamins, and the nutritional things that we need. However, by and large, we understand that the needs of the human being in weightlessness are at least qualitatively much the same as they are on the ground.

The challenge in the food service supply is not so much packaging but systems engineering. It is a very interesting system but the big constraints are in the supply pipeline. The average owner of a four-star restaurant can go out and get supplies from wherever he gets them any time he wants; he can use all the water he wants in his food preparation and his cleanup. He is not constrained, except for cost constraints, of course. The Space Station will be extremely limited in the weight and the volume of supply that is allowed to be brought up to it because each launch will cost $100 million and one space Shuttle worth of cargo, which may approach 60,000 pounds, has to resupply everything including new crewmen. We are going to have to be very, very careful. For example, in the clothing system it has been estimated that if we do not get smart and figure out some way to wash the clothes or clean them and reuse them in flight, there will be a 3,000-pound weight bogey when the Shuttle comes up to resupply every 90 days. That is very, very expensive clothing, no matter where you get it. The same analogy applies to the food system. That is why we have to think about bulk packaging and cooking in a meal style rather than individual packaging.

These constraints impose a very interesting new set of tradeoffs. For one thing we have been able to control individual nutrition rather accurately in a system that packages each food item individually and gives a crewman a combination of those items which meet his nutritional requirements. This system is available today. Of course, Deke Slayton was right; you do not have to eat the food. Some of it has come back uneaten, but, again, during seven days that is not a big deal. One of the things we want to figure out is how big a deal it is in 90 days. However, if we go to group meals we will have less control because we will not have control over the portion size. It will be more like at home where you are presented with good nourishing food and a well-balanced diet but you do not have to eat it if you do not want to.

From an efficiency standpoint, will there be less waste if we bring up the food in bulk and cook it and allow the crew to waste 20 percent of it as plate waste? Should we go back to individual packaging, or is there some combination of the two, such as bulk cooking and serving into individual packages in measured amounts? If there is such a combination, which is certainly feasible in principle, what is the capital cost, weight of the equipment, power drainage, and all the other factors that have to be considered in a tradeoff study so that we can figure out what to do?

I suppose palatability would be affected by these choices. It certainly would be affected by the choice of eating what is on a menu or selecting individual items. At this point, I want to mention our experience with the German potato salad. The way we did it at Skylab was to have rigidly specified diets. We were allowed individual choice during the menu selection phase but the individual items were then balanced to produce set meals. We ate the same breakfast every sixth day. We had a six-day cycle, so the food was very well set, but there was a pantry--a big locker downstairs--in which excess food was stored to provide for contingencies such as spoilage. There was a little candy that we could eat if we wanted to, there was extra coffee and there was some German potato salad. The German potato salad was quite spicy, and on the ground most of us did not select it very often so it did not occur in our meals. When we got up there we found that the very best thing in the world was German potato salad, and I must shamefully confess that by the end of Skylab 1, our flight, there was no German potato salad left in the pantry. The second and third crews just had to make do with what they selected. Of course, they could not change their minds because the food items were launched in Skylab and they were up there waiting for them--the asparagus, the green peas and the irradiated bread. Even with peanut butter it was pretty bad stuff. I am not knocking the food system, a lot of the food was very good. Once the missions proceeded, we began to exercise more and finally had a little bit of a breakthrough from the medical experimenters who agreed that yes, if the crew was hungry and they did not want to eat just candy, they could eat extra nourishment, extra protein, extra carbohydrate and extra fat. The upshot of this was that the third crew, which was up three times as long as the first crew came back with only about one-third the weight loss, stronger in the lower extremities, and with less muscle loss. Their caloric intake per day had increased.

Bill Thornton had a wonderful chart which showed the weight loss as a function of time related to the nutritional input in calories per pound. It is a straight line across the three missions, with the last one being very close to baseline. This is why I say that the nutritional environment in weightlessness is not quite as strange as we thought it was when we embarked on the space program.

It is a new ball game, a very interesting ball game and a very challenging systems engineering job. Creative contributions will be required. We need to solve the tradeoffs and give the crew a sense of control over their destiny in terms of being able to modify their diet, even if it is only adding condiments or changing the day's menu a little bit. I know, from having been up there, that one way to keep the crew off your back is to dump the problem on their shoulders. They will be much more cooperative and will have a better time.

PSYCHOBIOLOGY AND FOOD PERCEPTION

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Psychobiology is a scientific discipline which encompasses the phenomena known to be important as regards nutrition and food consumption in space. Specifically, it includes those areas of biology which are clearly related to behavior, human subjective experience and problems of coping and adapting to stress.

TASTE AND ODOR PERCEPTION

All five senses of taste are important. These are the sensations perceived on the tongue and smell, which are those sensations perceived in the olfactory center behind the bridge of the nose. Also important are the sense of sight which perceives color and shapes of foodstuffs and lends identification and expectation; the sense of hearing, which helps in distinguishing fresh or crisp from stale and soggy, and the sense* of feel, which perceives textural differences.

Flavor is a term generally used to encompass the interaction of the perceptions of the senses of taste, smell, and mouth and nose feel. These perceptions are caused by chemical stimuli. The tongue has four groups of taste buds that react to water soluble chemicals to produce sweet, sour, salty and bitter sensations. Generally, there are more sweet taste buds on the tip of the tongue and more salty and sour taste buds on the sides toward the back. Most bitter taste buds are on the rear of the tongue.

Volatile chemicals from foods are warmed in the nose and mouth and impinge on the olfactory center, either through sniffing or through chewing and swallowing. Any congestion in the nose will reduce the number and intensity of the aromatics perceived, thus leading to distorted or suppressed "flavor". If the sight, shape and textural quality is correct, the senses of sight, sound and hearing will frequently compensate for loss of smell, thereby making foods appear to taste more normal.

PROBLEMS ASSOCIATED WITH TASTE AND ODOR PERCEPTION

There are indications that changes in both taste and odor perception occur during missions reported by U.S. and USSR astronauts. Evidence for these changes is mostly in the form of anecdotes. There is no concrete evidence of the types and degrees of change. The greater the change, however, the more likely the possibility that consumption will decrease and that cravings for spicier or "different" foods will increase. This has implications for provision of sufficient variety to maintain interest and proper nutrition.

There is more positive documentation of the buildup of background odors during missions. Astronauts probably become "fatigued" or adapted to these odors, but the odors probably contribute subliminally to decreased appetite and consumption, and can promote changes in acceptance and active dislike of specific foods.

PERCEPTION - KNOWLEDGE GAPS

There needs to be a much greater understanding of the degree of changes in taste and odor perception, if indeed these occur, and then an increased understanding of the causes. In addition, a study should be made of consumption patterns in past missions to correlate acceptance with perception and perceptual change. As perceptual change may be, or may become, a function of duration, flight correlations should be made with this factor as well.

PERCEPTION - NEEDS

A means for training astronauts to recognize the four specific tastes, and a group of 20 to 50 aromatics and their intensities should be developed. Several excellent training mechanisms are available, the most noted being the Flavor Profile Method developed by Arthur D. Little, Inc., which is used worldwide. Astronauts would be trained on earth, calibrated with a professional panel and then asked to perform similar experiments in space. It is of utmost importance that adequate reference standards be used so that there is no confusion as to the descriptions and scaling of the perceptions. Establishing this common vocabulary and rating scale will take approximately 16 hours, but it is essential to the success of the experiment.

Once correlation as to perceptions in space versus those on Earth has been established by the astronauts using appropriate statistical techniques, it will be possible to use a professional (non-astronaut) panel to predict the sensory effects of future menus.

FOOD PREFERENCE AND MENU SELECTION

The problems that have been observed with past mission menu selections include satiety; lack of flavor variety; lack of fresh fruit, meat and vegetables; boredom; and a build-up of dislike. It is important that food research groups address these and other problems to ensure the effectiveness of the space station missions. One objective is to select those foods that create the sensation of being well fed without leading to a "stuffed" feeling. In trying to extend flavor variety it might be possible to create protein or carbohydrate substrates with many different flavors for snacking or quick nourishment. By changing shapes, textures, sizes and fiber content it is possible to vary entrees, pasta, desserts, etc. without affecting nutritional content but decreasing possibility of boredom. Lastly, a group of acceptance curves should be developed for meats, vegetables, desserts and beverages served on missions in order to determine "wear out" or onset of dislike.

OTHER POINTS

In addressing problems of choosing the most acceptable diets it should be remembered that about one-third of the crew will be discriminating and will react more strongly positively or negatively. Another one-third will probably not pay much attention to the food except when it is really inconvenient or unpleasant. The remaining third will fluctuate. It is important to define a means for isolating and then testing the more discriminating two-thirds for preference/acceptance ratings of potential menu items.

There is a great need for flexibility in the diets. This can be added by using spices so some entrees will be "hot" and some mild.

When measuring like/dislike and preference, it is important to measure consumption in flight and not to rely on replies to questionnaires.

Use of colors, shapes, garnishes, and portion control to present meals is extremely important to a pleasurable eating experience and should be considered. Also, the color of the packaging, the shape and weight of the utensils, and visual display of the trays should be considered and tested for most acceptance.

Lastly, time and energy should be expended on creative approaches rather than "force fitting" concepts and ideas that appear not to work.

PACKAGING'S CONTRIBUTION FOR THE EFFECTIVENESS OF THE SPACE STATION'S FOOD SERVICE OPERATION

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It is obvious that storage limitations will have a major effect on space station food service. For example:

- o Foods with low bulk density such as ice cream, bread, cake, standard-type potato chips and other low density snacks, flaked cereals, etc. will exacerbate the problem of space limitations.
- o Package containers are inherently volume-consuming and refuse-creating.
- o Refuse and waste need to be accommodated.

The useful observation of Joe Stillwell of Arthur D. Little that the optimum package is no package at all leads to the tentative conclusion that the least amount of packaging per unit of food, consistent with storage, aesthetics, preservation, cleanliness, cost and disposal criteria, is the most practical food package for the space station.

This conclusion suggests that a series of trade-offs may have to be made to arrive at the most appropriate package design for a particular type of food taking all the criteria into account. Some of these trade-offs are:

o SINGLE SERVE VS. BULK

COMPARISON OF SINGLE SERVE VS. BULK FOOD SERVICE SYSTEMS

Single Serving	Bulk
ADVANTAGES:	ADVANTAGES:
- Simple preparation equipment. - More flexible preparation: Conventional oven or microwave depending on package design	- Higher bulk density. - Better aesthetics if kitchenware is used.
DISADVANTAGES:	DISADVANTAGES:
- Greater total volume/unit of food. - More packaging material to be disposed of.	- Less personal choice. - Special dispensing systems needed. - If kitchenware is used, a cleanup system is required.

It is of course possible to supply both types of systems. Work will have to be done to determine which mode provides the highest level of benefits for each specific food item or type.

o CONVENTIONAL OVEN VS. MICROWAVE OVEN

The use of packages that permit hot food preparation in two major ways: by heating in a microwave oven or a conventional oven.

COMPARISON OF MICROWAVE VS. CONVENTIONAL OVEN PREPARATION

Conventional Oven

ADVANTAGES:

- Some prefer oven flavor.
- Can cook several different items at once.

DISADVANTAGES:

- Lower energy efficiency.
- Longer preparation time.

Microwave Oven

ADVANTAGES:

- Short preparation time.
- Simplicity of use; can be programmed for best conditions.

DISADVANTAGES:

- Flavor not always preferred.
- Cooking may be uneven.

New container systems now available commercially will permit the prepared food package to be heated in either a microwave or conventional oven. These packages must be stored in a freezer or refrigerator and have shelf-life limitations.

o NONMETALLIC ASEPTICALLY- VS. NON-ASEPTICALLY PACKAGED FOODS

It is now possible to package microwavable and ovenable foods in specially-made containers that have relatively short or relatively long shelf-lives. The options available are:

- o The use of standard packing techniques with plastic or aluminum trays and aluminum foil lids. Refrigeration (limited shelf-life) or freezer storage (extended shelf-life) are required.
- o The use of special multi-layer barrier plastic containers and lids with standard filling techniques and retorting of the plastic package at about 250°F for 15-45 minutes to achieve relatively unlimited shelf-life without freezing or refrigeration.
- o The use of special multi-layer barrier plastic containers together with aseptic filling techniques now being perfected to achieve relatively unlimited shelf-life without freezing or refrigeration. The less drastic aseptic treatment used in this case should result in better food quality.

COMPARISON OF ASEPTIC VS. NONASEPTIC FOOD PACKAGES

	ADVANTAGES	DISADVANTAGES
Metal Nonaseptic	- Ease of production. - Technologies well known - Containers available.	- Refrigeration or freezer storage needed. - Limited shelf-life one month to four months. - Not microwavable without transfer to nonmetal.
Plastic Nonaseptic	- Relatively easy to produce. - Containers recently available. - Microwavable or ovenable. - Lower cost. - Better aesthetics for package if made in tray form.	- Refrigeration or freezer storage needed. - If pouch, difficult to handle.
Metal Aseptic	- Well-known technology. - Tastes are well-established. - Can be stored under ambient conditions.	- Cylindrical shape wastes space. - Costly. - Bulk of food is over-cooked during retorting. - Hard to dispose of. - "Fresh" taste is lacking.
Plastic Asepticized by Retorting	- Better taste than metal aseptic. - Containers can be shaped as required. - Package technology close to commercialization. - Can be stored under ambient conditions. - Microwavable or ovenable. - Food can be eaten directly out of dish- or tray-shaped package.	- Packages not yet widely available. - Not as "home made" tasting as nonretorted plastic package.
Plastic Asepticized Without Retorting	- Best taste of all options; closest to "home-made". - Containers can be shaped as required. - Can be stored under ambient conditions - Microwavable or ovenable. - Food can be eaten directly out of dish- or tray-shaped package.	- Packages not yet widely available. - Technology for filling needs to be further developed.

In order to capitalize on the latest technological innovations in the packaging, preparation, and storage of food, some of the evaluations that need to be made include:

- o Refrigerator and freezer storage volume to be available on the station.
- o The effect of conditions in space on food products that have been packed in microwavable/ovenable packages and then retorted for preservation.
- o The effect of conditions in space on food products that have been packed in microwavable/ovenable packages under aseptic conditions.
- o The formulation of foods that will be palatable under the packaging conditions described above.
- o The effect of conditions in space on the type of plastic packaging materials chosen for use in retorted or aseptic food preservation systems. There are numerous types of multi-layer systems available whose suitability needs to be verified for space station use.
- o The selection of foods that, considering all the circumstances, should be supplied in bulk and those where single servings made the most sense.

PACKAGING FOR FOOD SERVICE

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For package design purposes, the principle concerns of food packaging for the space station can be considered the same as traditional concerns of food packaging for more conventional environments. These are containment, preservation, cleanliness, storage, delivery, presentation, and disposal. The differences lie in the ranking of these concerns. Major concerns would seem to be disposal and presentation. On the minor end of the spectrum would be preservation. The rest fall in between. Preservation is of less concern because shelf life requirements are relatively short when compared to most food packaging.

PREMISE--OPTIMUM PACKAGE IS NO PACKAGE

When considering the mechanics of storage and disposal in space, the cost of delivery, and the cost of low volume preparation of foods for delivery, it becomes apparent that the least packaging is the best packaging. Thus the task of the workshop was to seek out the materials and techniques that will allow us to achieve traditional packaging functions while approaching the "optimum package" as closely as possible.

The format for discussion of packaging for representative food types was:

- o Categorize foods by:
  - form.
  - essential preservation requirements.
  - mechanics of production.
- o Describe preferred preparation mechanics.
- o Describe delivery systems.
- o Describe preferred presentation.
- o Describe achievable disposal systems.
- o Identify alternative package approaches.
- o Identify available materials and technology.
- o Identify technology or materials voids.

Three food forms were discussed: fresh foods, liquids and whole processed or semiprocessed foods. The following summarizes significant points brought out in discussion.

FRESH FOOD FORMS

Astronauts with past experience aboard orbital flights expressed a strong desire for fresh fruits and vegetables. It was illustrated by photo and discussion that fresh fruits and vegetables can be consumed in space vehicles, although some require more dexterity and concentration than others. It was determined that:

- o Applicable spectrum of preservation techniques could include refrigeration, gas flush and surface treatments such as irradiation, coatings and edible films.
- o Efforts should be made to acquire produce as close to harvest as possible in order to maximize shelf life.
- o Fresh produce was considered bulk food in terms of packaging and

delivery--cube being the principle restraint.

- o Psychology of presentation was considered important with fresh fruit. The perceived quality of a fruit would be enhanced if it was presented in conventional or familiar form.
- o Certain produce could be semi-prepared to reduce the amount of discard and thereby reduce impact on the space station disposal system.

It was concluded that packaging of fresh food should be minimized to eliminate packaging where possible. System design efforts should be directed toward bulk delivery and storage, i.e., tray designs, storage for trays, easy accessibility, inventory control, identification and encapsulation to accommodate controlled atmosphere preservation, if this technique is to be employed.

LIQUID FOOD FORMS

The beverages discussed included fruit juices, soups and milk; carbonated beverages and alcoholic beverages were not considered. Two forms of presentation were discussed as part of a meal and as a single serving drawn out anytime as a snack. The bag-in-box for bulk liquids was discussed briefly. It was determined that:

- o The principal elements to be preserved were essential oils, vitamins, etc. in juices, and flavor in milk.
- o The favored method of production was dehydration or freeze drying for later reconstitution aboard the space station. Concentrates and whole liquid food forms also were discussed.
- o Reconstitution of powdered drinks is an acceptable way of consuming liquids in today's society. Presenting drinks from a dehydrated form through a multi-use dispenser could provide a broad selection of hot or cold beverages.
- o Concentrates would require greater microbial control than powder--different critical preservation techniques. However, the engineering of a dispensing system to dispense concentrates would be simpler than dispensing powders in space.
- o In the reconstitution process a container would have to be supplied in the form of a cup or some other device to accommodate consumption. This would increase waste disposal requirements unless it was a washable container for reuse.

The dehydrated or freeze dried concept for later reconstitution aboard the space shuttle seemed to be the preferred approach throughout the discussion. However, the use of concentrates or bulk liquid food forms was not discarded. The final selection of package forms will depend greatly on the preferred presentation and the selected preparation mechanics, as well as the selection of foods to be presented. Proven packaging approaches currently exist for all of the alternatives discussed.

WHOLE PROCESSED OR SEMIPROCESSED FOODS

This form includes the widest spectrum of foods and the widest spectrum of presentations--from prepared entrees through vegetables and breads to desserts and snacks. Certain of these food forms will require a high degree of preservation to be supplied by the package in terms of barriers to gas, moisture and microbial attack.

Due to the wide spectrum of foods in this category, packaging selection will depend greatly on the preferred preparation mechanics. The perceived desire for "home cooking" was discussed. It was resolved that all methods of preparation could be available. However, great care would need to be exercised in controlling the cooking effluent, which could contaminate the atmosphere in the living compartments. The vending machine concept was also discussed. It would provide pre-portioned foods for consumption in a modular fashion from a tray, allowing selection by preference to form a meal. It was heavily stressed that quality should not be sacrificed for this convenience. The presentation of bulk foods for portioning and rethermalizing in a reuseable container (i.e., dinnerware instead of package) also was discussed. This would require a mechanism for washing and reusing utensils and dinnerware. Freezer storage seemed to be the preferred method of preservation aboard the spacecraft. Maintaining foods at low temperature extends shelf life and reduces the barrier demands placed on the package.

It was concluded that the selection of packaging approaches must be coupled closely with the selection of preparation mechanics and preferred presentation aboard the space station. Packaging materials currently exist to achieve all the requirements discussed. However, there will likely be innovative design required in creating package forms that will meet design requirements imposed by the selected feeding system. In the course of package development, the need to interface with the mechanics of production should not be overlooked.

GENERAL CONSIDERATIONS

Several of the points discussed were universal to all food forms:

1. The space station, unlike the space shuttle, will not generate water as a by-product of its power generation system; therefore, water must be supplied.

2. The group perceived that the astronauts desire for fresh or conventional food forms was really the desire for acceptable food forms. Where a freeze dried food such as hash brown potatoes or dehydrated orange drink is an acceptable form in today's society, it also would be quite acceptable aboard the space station.

3. A market survey among astronauts with experience in space, as well as others currently considered for the program, should be conducted to determine acceptable foods and preferred methods of presentation.

4. It was suggested that during the space shuttle flights and other orbital flights the astronauts maintain "camp-out" thinking concerning housekeeping, principally because of the limited duration of the flights. Since the space station will be in flight for about ten years, with crews changing every 90 days and replenishment space shuttles arriving every 30 days; it was determined that housekeeping should be a major concern in food selection and packaging.

5. Packaging will have a great impact upon the waste disposal system selected. The systems discussed were compactors and wet oxidation--both coupled with shredding. Flame oxidation techniques are not allowed.

6. Sanitation and cross-contamination were also points of discussion. Concern was expressed for the degree to which a disposal system could be isolated from the rest of the living compartments. Past experience with orbital flights could provide direction in food selection based on its performance in disposal environments.

7. If freezer space is available for the preservation of foods, then as food is drawn out of the freezer, waste could be packaged and placed in that freezer space for return to earth on the replenishment shuttle. This would require close control to avoid cross-contamination.

GENERAL CONCLUSIONS

This discussion covered most of the key areas of concern in packaging the three principle food forms for the space station. It can be generally concluded from this discussion that there are no significant voids in packaging materials availability or in current packaging technology. However, it must also be concluded that the process by which we make packaging decisions for the space station feeding program will be very synergistic. Packaging selection will depend heavily on the preparation mechanics, the preferred presentation and the achievable disposal systems. It will be important that packaging be considered as an integral part of each decision as these systems are developed.

SHUTTLE OPERATIONAL TEST AND SCIENTIFIC INVESTIGATIONS

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One of my jobs is to be the interface between the Life Sciences Organization and the Shuttle Program Office. If there's something we in the scientific world want to do on board the shuttle I help usher the paperwork through the system and try to keep things in order and make sure we meet all the right schedules.

What I would like to talk about is something that you have been talking about -- the Detailed Test Objectives (DTOs) and Detailed Supplementary Objectives (DSOs). What are they and how do we meet them with on-board experiments?

Each shuttle mission has a primary objective, such as delivering satellites into orbit or taking a large scientific package up for Earth or planetary observations. Along with this primary objective there usually are a collection of secondary objectives. One type of secondary objective are experiments which may be performed either in the cargo bay or in the orbiter cabin. Other types of investigation which are not as formal, rigorous, or as complex as scientific experiments, are classified as DTOs and DSOs.

The DTO originated as a test or measurement made to verify the function of a vehicle system for certification of a vehicle system (Figure 1). At the start of the shuttle program about seven or eight orbital test flights were planned, but a schedule acceleration cut that number to four. As a result of a reduced flight test program, some system testing and verification continued into the operational flight phase. These tests are DTOs. Other examples of DTOs are tests of the thermal protective system, avionics, landing gear and vehicle aerodynamics.

The DSO is a demonstration or test that has a lower priority than a DTO. It is not a mandatory task and is usually a scientific or medical measurement or observation (Figure 2). A DSO also may be a test of prototype flight hardware or checkout of an operational procedure. Examples of DSOs include the microbial sampling performed on several flights, especially flights on which animals were flown, and is the prototype plant growth chamber, which was tested prior to actual use in support of a full scientific experiment. Often, from the results of prototype testing, we can save money and time in the design of the actual flight hardware.

The major DSO emphasis presently is on investigations related to space motion sickness. They are our highest priority DSOs, so if they are submitted in a timely manner they are routinely approved, provided stowage space and planned in the crew time line. To date all DSOs have been performed in the orbiter or in the cabin. A review system establishes DSO priorities, by category, if there is not enough time to perform all of them on any given flight.

A handbook should be available shortly describing the required procedures for submitting a DSO proposal, the formats, the reviews and available assistance.

Figure 3 indicates the approval criteria that internal NASA review boards use in judging a DSO proposal. Is there some procedure, technique or measurement to be performed that can contribute significantly to upcoming flights? The space motion sickness related DSOs are in the operational urgency category and therefore are readily approved. Most of these DSOs also directly relate to solving a known problem.

DSOs involving tests of prototype equipment should be designed to gain technical information that cannot be obtained during tests in a one-g earth environment. The DTO and DSO proposals can be very competitive -- often from a scientific viewpoint, certainly from an equipment stowage volume and crew time viewpoint. Therefore, it is important that the expected results are worthwhile and not in a "nice to know" category. A DSO sponsor can expect the review boards to ask many questions and he should be prepared to "sell" his proposal.

Let me walk you through a DSO proposal. A brief overview of the review cycle is shown in Figure 4. The first step is to prepare the proposal and present it to the Science Management Review Board (SMRB) as a concept. The SMRB is chaired by Dr. Joseph Kerwin, Director of Space and Life Sciences. Members of the board are personnel from Dr. Kerwin's organization. The SMRB will review the proposal and decide whether more work is required or whether, in their judgment, the proposal is ready for flight. Usually suggestions are offered that will improve the concept or assist in the preparations for flight. The lead time for concept proposals can be from one or two years prior to a desired flight. The type of information to be submitted is listed in the figure and will be amplified in the handbook previously mentioned. Typical information required is equipment weight and volume, supporting studies, ground based tests, which space tests will supplement existing information and the description of the hardware. Questions include: Where is the hardware coming from? Is it off-the-shelf? Is it to be modified? Is it to be designed from scratch? Where are you in the design procedure?

Provide some scope of the procedures to be used in space. Will the procedure take 15 minutes or more or less time? Does it involve one or two crew members, or all of them? This information is very important because we will take it and coordinate it with the crew and the mission planners that must approve the DSO. We must get support from several organizations; therefore, we want to understand the concept before NASA resources are committed to a project. It is of considerable help in these projects to find someone in NASA who can be a co-sponsor or associate to help you through the system, to understand the terminology, to understand the procedures and to understand the documentation requirements.

When a proposal is determined to be ready for flight and a specific flight can be targeted, the proposal is reviewed again by the SMRB, this time to hear an update on the planning and to determine its overall readiness to fly. Following this SMRB review we can go to one of the Space Transportation System's control boards and ask that this DSO be included in the planning for an upcoming flight. If we have done our job correctly internally we would have completed our coordination with the mission planners, the crew representatives, stowage planners, safety office and organizations in the program office.

Let me tie the proposal process to a schedule. As mentioned, the concept milestone should be at least a year or two before flight and will depend a great deal on the DSO complexity and the amount of preparation required for flight. The flight proposal should occur from six months to a year before flight time in order to meet the program office crew activity "freeze point" of launch minus five months (L-5). The crews are in their final phases of flight training by that time and must be familiar with all the procedures required in the DSOs.

The primary emphasis is to start your activity with NASA early. Get people thinking about your ideas; seek help in preparing your proposal.

Proposing an experiment is a bit more formal, but because it is more formal it also has some guarantees. An experiment is considered to be more complex than a DSO and to have more shuttle interfaces. The DSO might be considered a mini-experiment or some portion of an experiment. The experiment must be proposed through NASA Headquarters on a standard NASA Form 100 and will receive an internal NASA review as well as an outside peer review. If the experiment proposal is approved by Headquarters it will be scheduled for a specific flight. Once scheduled, a "manifested" experiment carries a higher priority than a DTO or a DSO. The formality for experiment approval is a little more rigid, but once approved it is guaranteed to be flown.

Flight Planning

Development Test Objective (DTO) - A test or measurement made to verify the function or capability of a vehicle system or subsystem.

- Designed to complete STS verification and for continued development
- Examples
  - Ascent performance data collection
  - Thermal protective system evaluation
  - Crosswind landing performance
  - EMU/EVA evaluation
- STS-5 - 47 DTO's and DSO's scheduled

Figure 1

Flight Planning

Detailed Supplementary Objective (DSO) - Tests, demonstrations, or investigations that are not mandatory to achieve mission objectives or systems verification.

- Includes scientific medical tests/investigations, hardware prototype tests, television and photo documentation

- Examples
  - Microbial sampling
  - Plant growth chamber
  - Space motion sickness investigations

- Performed in the orbiter

- Priorities established - A - B - C

Figure 2

Detailed Supplementary Objective

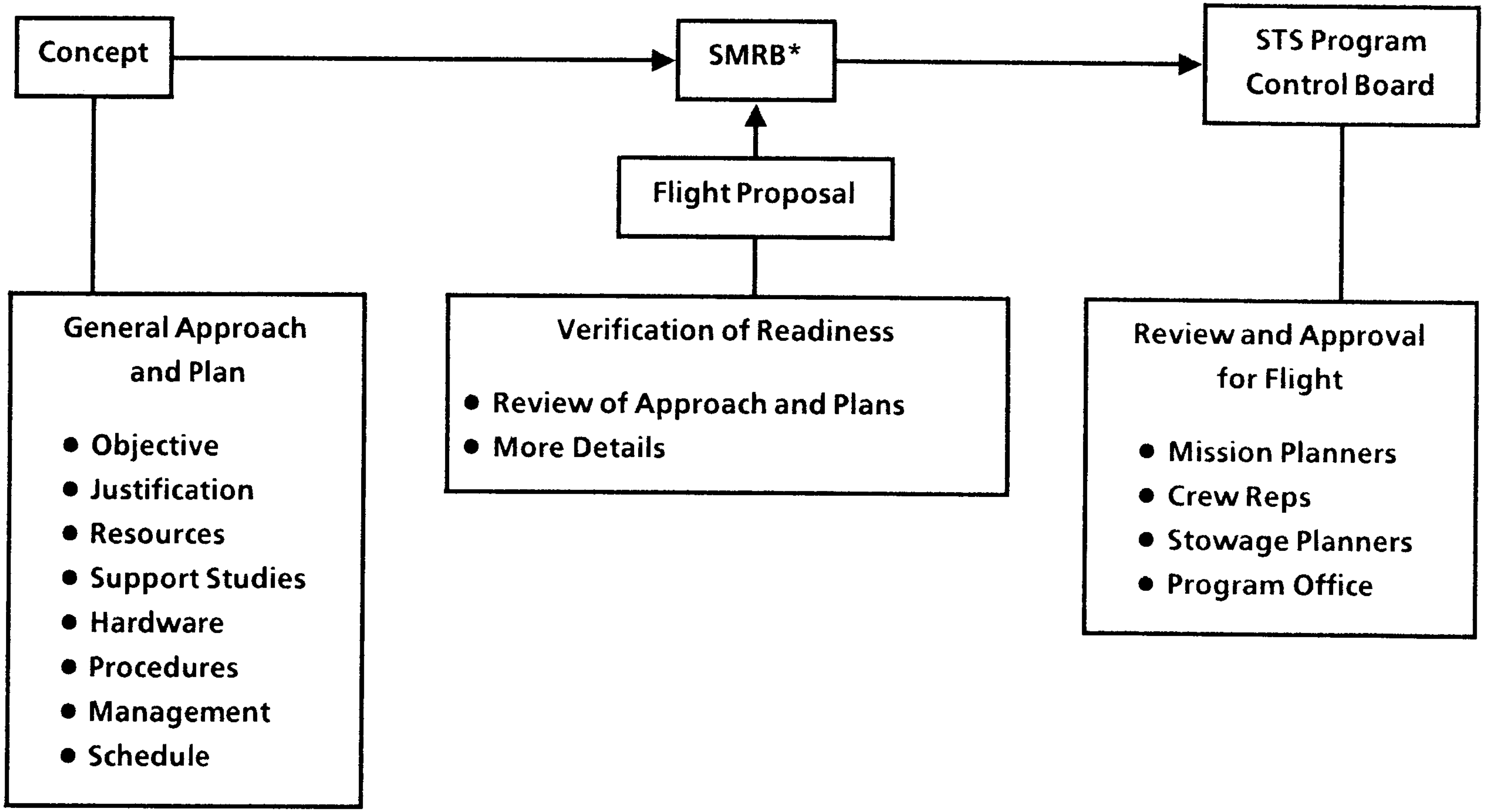
Approval Criteria -

- Operational urgency
- Solve a known problem
- Gain equipment/technical information (design/procedural information - "can't be done on the ground")
- Man/system safety/operation
- Not - "nice to know"

Figure 3

Detailed Supplementary Objective

Proposal Process



*Science Management Review Board
Chairman - Director of Space and Life Sciences

Figure 4

SUMMARY OF DISCUSSIONS ON DETAILED SUPPLEMENTAL OBJECTIVES FOR FUTURE SPACE SHUTTLE EXPERIMENTS

by

Workshop Participants

DETAILED SUPPLEMENTAL OBJECTIVES (DSO) FOR SPACE SHUTTLE EXPERIMENTS

An important objective of the Workshop was to discuss and formulate DSOs which would provide information to guide the development of food service systems and nutrition for a space station. The subjects presented in the informal talks, as summarized in the these Proceedings, were designed to provide information to the Workshop participants as a foundation for discussions of the DSOs.

The DSOs cover the following major areas and represent the creative inputs of the participants:

1. Food Acceptance

2. Integrated Food Preparation, Presentation and Consumption Systems

3. Multipurpose (Re)Thermalization Appliance

4. Food Preservation

5. Waste Disposal and Sanitation

6. Environmental Control

The participants recognized that each DSO deserves further study and elaboration so that meaningful space shuttle experiments could be devised. The DSOs are indicative of the knowledge gaps which will need to be addressed at an early stage of the space station development program. Meeting the DSOs by conducting appropriate space experiments, will not only provide results applicable to space station activities, but also will benefit terrestrial activities, pertaining to food service systems and nutrition.

Food Acceptance

I. Rationale

Maintain adequate nutrition, morale and performance by providing appropriate meals, snacks and beverages for the crew.

II. Knowledge Gaps

The following knowledge gaps will need further investigations:

1. Is there altered taste and flavor perception in the space station environment and if so, does it result from micro-gravity effects and/or long-term fatigue?

2. What are existing menu patterns and how acceptable are they to the current astronaut population?

3. How would these patterns have to change to be acceptable during extended space station missions?

4. What degree of menu individualization is possible to meet individual crew preferences during extended missions, and how should this be accomplished?

5. What are preferred methods for preparing protein matrices?

III. STS Experiments

The following are STS experiments which could assist in closing the existing knowledge gaps:

1. Perform experiments designed to train a space station crew to identify sensory effects and use them to determine whether perceptual changes take place.

2. Correlate food acceptance with odor and flavor characteristics of foods using trained personnel. Determine how changes in perception (if they occur) affect acceptance.

3. Undertake market research with past, present and future STS crew members to correlate sociological, physiological and psychological responses with acceptance of food items consumed during STS missions.

4. Develop and test approaches to monitor consumption (rather than like or dislike) as a basis for establishing food acceptance and nutritional delivery.

5. Obtain feedback from crew members on use of condiments to individualize basic menu items.

IV. Expected Results

The following are expected results of STS experiments:

1. A data base on food acceptance and perception which correlates micro-gravity with Earth-normal perceptions. This data base could be used to guide food system development in an Earth-normal environment including menu selection, food item preparation, flavor development and secondary effects of waste disposal.

2. The data base could be the basis for specifying menu items, food service systems and preparation methods acceptable to crew members in a space station.

3. Information on acceptability of protein matrices.

Integrated Food Preparation, Presentation and Consumption Systems

I. Rationale

Improve habitability through functional food service systems, meet aesthetic criteria for food presentation and achieve health and safety requirement.

Create desirable living conditions to maintain morale, assure that food preparation will be convenient and meet time-line constraints, provide a congregate atmosphere for food consumption which will be appreciated as a recreational period, and enhance enjoyment associated with all aspects of food service systems.

II. Knowledge Gaps

What are the most effective approaches to pre- and post-preparation of food items to achieve desirable living conditions and how should these conditions be defined?

1. What will be the acceptance of:

   - Bulk vs. individual servings
   - Dispensing and mixing
   - Participation in food preparation tasks

2. How can food production and food preparation be accomplished effectively?

3. How can aesthetic appeal of food items be improved through presentation including:

   - Methods of packaging and serving
   - Serving temperatures
   - Flavor, texture and color
   - Variety of food attributes
   - Physical environment (color, noise, lighting)?

4. How can functionality of food consumption be improved through:

   - Design of dinnerware and utensils by choosing most appropriate configurations for ease of manipulation and reuse, e.g., chopsticks, scoops, drink cages and straws.
   - Design of eating facility to provide pleasant surroundings and congregate atmosphere?

III. STS Experiments

The following are suggested STS experiments:

1. Develop and test how foods (liquids, wet solids and powders in suspension) in bulk or individual servings should be portioned, dispensed and mixed.

2. Develop and test different designs for dinnerware and utensils to handle solids, wet foods, liquids and food preparation.

3. Evaluate desirable levels of participation in food production and preparation tasks.

4. Develop and design approaches for a dedicated eating facility and test selected components.

5. Develop, test and survey acceptance of food production and presentation methods.

IV. Expected Results

The following are expected results of STS experiments:

1. Selection of configurations for dinnerware and utensils.

2. Data leading to the design of a congregate eating facility.

3. Improved methods of food presentation to achieve aesthetic appeal.

4. Methods for and degree of participation in production and preparation of food items.

Multipurpose (Re)Thermalization Appliance

I. Rationale

Increase food acceptability and variety and broaden food system options by using more effective and versatile methods for reheating and/or cooking.

II. Knowledge Gaps

1. What heating methods can be used in the space station environment consistent with criteria for crew safety, energy conservation, mission compatibility and human factors?

2. How might specific heating methods influence food acceptance?

3. How should food items be packaged to be compatible with preferred reheating and/or cooking methods?

III. STS Experiments

The following are steps towards STS experiments:

1. Conceptualize, design and test prototype methods to heat or cook pre-prepared or partially pre-prepared foods including: baking, jet pulse heating, broiling and fluid immersion techniques, in the Earth-normal environment for adaptation to space flight use.

2. Select the most effective/preferred heating method(s) and design and construct a multipurpose appliance.

3. Evaluate multipurpose appliance performance in Earth-normal and in STS mission environment use.

4. Evaluate effectiveness and compatibility of selected food packaging methods and materials.

IV. Expected Results

The following are the expected results of STS experiments:

1. Definition of a preferred multipurpose (re)thermalization appliance.

2. Specifications of parameters for reheating and/or cooking of foods.

3. Specification of preferred food packaging methods and materials.

Food Preservation

I. Rationale

Assure food acceptability, crew health and safety, and optimize food shelf-life.

II. Knowledge Gaps

1. How can controlled atmosphere storage be used for maintaining fruit and vegetable freshness and control ripening process?

2. How much refrigeration will be required to maintain food items at required conditions?

3. What are the tradeoffs between controlled atmosphere and refrigerated storage?

4. How can "fresh baked" product quality be provided?

5. How will the different food preservation techniques enhance food acceptance criteria?

6. How can deterioration of stored foods be detected?

III. STS Experiments

Perform STS experiments to provide data on the preferred method for food preservation:

1. Develop and test methods which could ensure fresh-baked product quality.

2. Select and test flavor, color and texture additives if required to improve food acceptance after preservation for extended periods.

3. Develop and test food preservation techniques in the space environment based on food refrigeration, irradiation, controlled atmospheric storage and aseptic packaging.

IV. Expected Results

The expected results of STS experiments are:

1. Definition of food preservation techniques and equipment to assure food acceptance consistent with mission constraints.

2. Selection of food additives to improve food preservation and acceptance.

3. Selection of packaging materials to reduce requirements for active food preservation techniques.

Waste Disposal and Sanitation

I. Rationale

Reduce waste generation and disposal and enhance sanitation to meet health and safety requirements.

II. Knowledge Gaps

The following are current knowledge gaps:

1. What methods could be used to dispose of waste?

2. How could waste generation be minimized?

3. How could sanitary conditions be maintained?

III. STS Experiments

STS experiments could be designed to achieve the following:

1. Develop and test systems to determine waste disposal requirements based on processes such as:

   --Shredding
   --Heating (including treatment of off-gases)
   --Wet Oxidation
   --Dry Oxidation (including treatment of off-gases)
   --Compacting

2. Develop and test alternative materials for:

   --Edible and digestible packaging
   --Bulk service of food items
   --Alternative packaging methods
   --Reusable food preparation and service equipment dinnerware and utensils

3. Develop methods and test their effectiveness to:

   --Sweep particulates and aerosols with controlled airflow
   --Decontaminate food equipment to meet sanitary requirements
   --Dispose of used sanitizers and cleaners

IV. Expected Results

STS experiments could provide information on:

1. Definition of waste disposal methods.

2. Definition of waste avoidance materials and methods.

3. Acceptable sanitizers and cleaners.

Environmental Control

I. Rationale

Assure crew health and safety, increase habitability and crew morale.

II. Knowledge Gaps

The following are specific knowledge gaps:

1. What is the existing level of environmental control pertaining to byproducts of food supply service systems and the crew reaction to it?

2. What contaminants will be generated during food production, preparation, service and disposal?

3. What are the background odors and their levels? What is the crew perception of these odors? How do they affect performance and/or well-being?

4. How could odors be eliminated or masked?

5. How could contaminants (e.g., particulates and aerosols) be controlled and/or removed from the environment?

III. Crew Training

Crew members could be trained to provide feedback on the effectiveness of environmental controls:

1. Train selected crew members to describe their sensory reactions based on odor, taste and flavor descriptors.

2. Design and develop dose/response sensory measurement system.

IV. STS Experiments

The following STS experiments could provide needed information:

1. Develop and test chemical or physical means to eliminate or reduce odors.

2. Develop and test materials to mask or ameliorate odors.

3. Develop and test methods to measure and define effectiveness of environmental controls.

V. Expected Results

The expected results of STS experiments are:

1. Definition of environmental control requirements.

2. Definition of materials and methods to achieve and maintain desirable control conditions.

AGENDA

WORKSHOP ON FOODSERVICE AND NUTRITION FOR THE SPACE STATION

sponsored by

National Aeronautics and Space Agency
at
Nassau Bay Hilton Hotel
Houston, Texas

Tuesday, April 10

9:00

- Introduction — Richard Sauer, *Program Manager, Food Systems*, *NASA, Johnson Space Center*
- Workshop Objectives — Peter E. Glaser, *Workshop Chairman*, *Vice President*, *Arthur D. Little, Inc.*
- NASA Plans for Space Station — Clark Covington, *Space Station Program Manager*, *NASA, Johnson Space Center*

Break

10:30 **Foodservice and Nutrition: Issues, Problems and Knowledge Gaps**

I. Foodservice

Discussion Leaders

- Food Service Management
  Summary Results of Previous Study; Issues in Organization of Food Service System — Clinton Rappole, *Associate Dean*, *Conrad N. Hilton College of Hotel and Restaurant Management*
- Food Acquisition
  Food Ingredients; Raw Materials, Supply — David W. Wheat, *Sr. Consultant, Agribusiness Unit*, *Arthur D. Little, Inc.*
- Preparation Methods:
  Past and Potential Methods of Food Preparation for Space; Portions; Safety Issues — Clayton S. Huber, *Professor, Food Science and Nutrition*, *Brigham Young University*
- Alternative Food Preservation Techniques:
  New Technology in Food Preparation; Appropriateness of Food Supply for Space Station — Richard H. Whelan, *Food Service Specialist*, *Arthur D. Little, Inc.*
- Food Systems Engineering:
  Food Preparation, Equipment and Techniques — Donald P. Smith, *Sr. Consultant, Food Engineering/Equipment*, *Enersyst, Inc.*

12:00	Lunch	
	• Experience with Food Preparation and Consumption in Space	Major Brewster Shaw, Jr. *STS-9 Astronaut*
1:00	Tour	
	• STS Food Facility	Richard Sauer *Program Manager, Food Systems* *NASA, Johnson Space Center*
3:00	II. Nutrition	
	• Menu Selection: Nutritional Requirements Under Stress; Long-Term Acceptability Conditions	David Schnakenberg *Nutritional Consultant* *H.Q. Department of Army*
	• Calcium Metabolism; Other Metabolic Problems; Nutrition in Space	Phillip Johnson, M.D. *Chief, Space Adaptation Syndrome Branch* *NASA, Johnson Space Center*
5:00	Adjournment	
6:00	Reception	Arthur D. Little, Inc.
7:00	Dinner	
	• Foodservice and Nutritional Needs	Joseph Kerwin, M.D. *Director, Space and Life Sciences Directorate* *NASA, Johnson Space Center*
9:00	Group Meeting	
	• Concepts for Detailed Test Objectives	Peter E. Glaser *Workshop Chairman* *Vice President* *Arthur D. Little, Inc.*

Wednesday, April 11

Breakfast	Reports on Results of Group Meeting	
8:30	III. Psychobiology and Food Perception	
	• Taste and Odor Perception: Changes in Taste and Odor Perception in Space	Anne Neilson *Sr. Consultant,* *Food & Sensory Science* *Arthur D. Little, Inc.*
	• Menu Selection: Food Preference and Menu Value Issues Resulting from Flavor Perception Changes	
9:30	IV. Packaging Technology	
	• Traditional Functions: Containment, Cleanliness, Presentation and Delivery	E. Joseph Stilwell *Sr. Consultant, Package Engineering* *Arthur D. Little, Inc.*
	• Design of Package Assuming Optimum is No Package	
10:30	Break	
10:45	**Detailed Test Objectives (DTOs)**	**Discussion Leader**
	• Development of Specific DTOs	Peter E. Glaser *Workshop Chairman* *Vice President* *Arthur D. Little, Inc.*
	• Priorities for Implementation	
12:00	Lunch	
1:30	**DTOs, Continued**	
	Workshop Results: Follow-up Activities, Action Items, Issues List, Specific Recommendations, Future Development Plans	Peter E. Glaser
4:00	Adjournment	

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Appendix C

WORKSHOP PARTICIPANTS' VIEWS

The views of the Workshop participants were obtained on a number of issues of importance to food service system and nutrition in a space station. Figure 1 shows the guidelines for rating knowledge gaps, Table 2, the ratings of existing knowledge and Table 3, the ratings of areas of interest.

These views indicate the broad range of interests of the participants and the assessment that there are considerable knowledge gaps which will have to be bridged before effective food service systems can be developed for use in a space station.

GUIDELINES FOR RATING KNOWLEDGE GAPS IN FOOD SERVICE AND NUTRITION FOR A SPACE STATION

SUBJECT:____________________ NAME:____________________

ORGANIZATION:____________________

A. EARTH KNOWLEDGE

How well understood is this subject in Earth conditions?

3. Poorly ☐
2. Somewhat ☐
1. Fairly well ☐
0. Extremely well ☐

? Don't know ☐

B. HOW WELL UNDERSTOOD IS THIS SUBJECT IN A SPACE STATION?

3. Poorly ☐
2. Somewhat ☐
1. Fairly well ☐
0. Extremely well ☐

? Don't know ☐

C. IMPORTANCE

How important is this subject to the success of the space station?

3. Extremely important ☐
2. Important ☐
1. Somewhat important ☐
0. Not important ☐

D. SPACE EXPERIMENT REQUIREMENTS

Are space experiments required to resolve knowledge gaps?

	Food Service	Nutrition
3. Essential	☐	☐
2. Desirable	☐	☐
1. Limited usefulness	☐	☐
0. Not required	☐	☐

E. PARTICIPATION IN SPACE EXPERIMENTS

	Food Service	Nutrition
3. Very interested	☐	☐
2. Interested	☐	☐
1. Mildly interested	☐	☐
0. Not interested	☐	☐

F. SPECIFIC AREAS OF INTEREST

List by DTOs according to level of interest

(3 highest - 1 lowest)

______________________________ ☐

______________________________ ☐

______________________________ ☐

______________________________ ☐

Date: ____________________

Table 2

WORKSHOP PARTICIPANTS' RATINGS OF EXISTING KNOWLEDGE

	MARKET RESEARCH	FOOD ACCEPTANCE	FOOD SERVICE SYSTEM	MARKET SURVEY	PRESERVATION (FRUIT & VEG.)	PERCEPTIONS	FOOD PRESERVATION	FOOD PREPARATION	MENU CYCLE	PLANT GROWTH	SANITATION	FOOD SERVICE SYSTEM	LOW DENSITY FOOD ITEMS	ASEPTIC PACKAGING	BULK LIQUID PACKAGING	PACKAGING MATERIALS
A. EARTH KNOWLEDGE	1	2	1	1	2	1	3	3	1	2	3	3	3	3	3	3
B. SPACE STATION KNOWLEDGE	0	1	1	1	0	0	1	0	0	0	1	2	0	0	1	1
C. IMPORTANCE	3	3	2	3	2	2	3	3	3	2	3	3	2	3	3	3
D. SPACE EXPERIMENT REQUIREMENTS	3	3	3	2	2	3	3	3	2	3	3	2	3	3	0	3
E. PARTICIPATION IN EXPERIMENT	3	2	2	3	2	3	3	3	2	3	2	1	1	2	0	2

NOTE: 0 ------- 3
Low High

Table 3

WORKSHOP PARTICIPANTS' RATINGS OF AREAS OF INTEREST

AREAS OF INTEREST	RATING HIGH 3	MEDIUM 2	LOW 1
Baking and Food Finishing	X		
Refrigerated Storage of Bulk Foods		X	
Variable Portion Dispensing		X	
Survey of Astronauts	X		
Storage of Irradiated Foods	X		
Food Acceptance		X	
Taste/Perception Changes	X		
Controlled Atmosphere Preservation	X		
Preservation of Ice Cream		X	
Irradiated Foods	X		
Microwave Oven	X		
Convection-Conduction Oven	X		
Ice Cream Freezer		X	
Coffee Machine		X	
Menu Cycles	X		
Market Research	X		
Materials Interaction/Compatibility	X		
Food Processing	X		
Sanitation		X	
New Packaging Techniques	X		
Aseptic Packaging	X		
Consumption Monitoring System	X		
Preservation of Fresh Foods		X	
Thermalization Equipment	X		

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Washington, DC 20546

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15. Supplementary Notes

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16. Abstract

This document contains the proceedings of the Workshop on Food Service and Nutrition for the Space Station which was held in Houston, Texas, on April 10 and 11, 1984. The workshop was attended by experts in food technology from industry, government, and academia. Following a general definition of unique space flight requirements, oral presentations were made on state-of-the-art food technology with the objective of using this technology to support the space flight requirements. Numerous areas are identified, which in the opinion of the conferees, would have space flight application. But additional effort, evaluation, or testing to include Shuttle inflight testing will be required for the technology to be applied to the Space Station.

17. Key Words (Suggested by Author(s))

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Nutrition
Preserving
Food processing
Dehydrated foods
Irradiation
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