

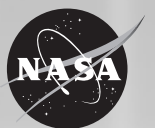
Introduction

From John Glenn's mission to orbit Earth to the International Space Station program, space food research has met the challenge of providing food that tastes good and travels well in space. To better understand this process, we can look back through history. Explorers have always had to face the problem of how to carry enough food for their journeys. Whether those explorers are onboard a sailing ship or on the Space Shuttle, adequate storage space has been a problem. Food needs to remain edible throughout the voyage, and it also needs to provide all the nutrients required to avoid vitamin-deficiency diseases such as scurvy.

Early in history, humans discovered that food would remain edible longer if it were dried and stored in a cool dry place until it was time to be consumed. Early food dehydration was achieved by cutting meat, fish, and certain fruits into thin strips and drying them in sunlight. Rubbing food with salt or soaking it in salt water, an early

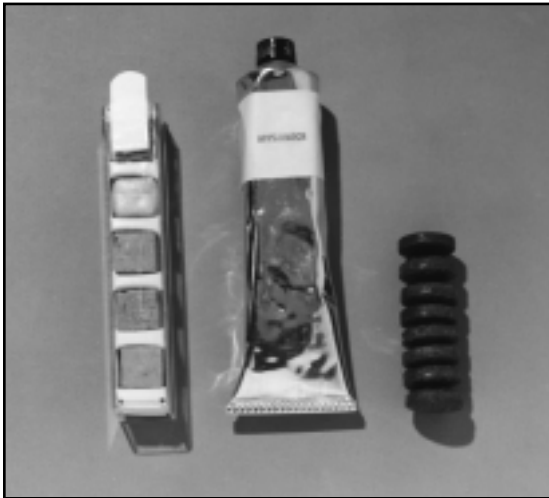
form of curing food, also helped preserve it. Later techniques were developed for cooking, processing, preserving, and storing food in sealed containers. With the developments of pasteurization and canning, a much larger variety of foods could be stored and carried on long journeys. More recently, refrigeration and quick-freezing have been used to help preserve food flavor and nutrients and prevent spoilage.

While these forms of packaged food products are fine for travel on Earth, they are not always suitable for use on space flights. There are limitations to weight and volume when traveling and the microgravity conditions experienced in space also affect the food packaging. Currently, there is limited storage space and no refrigeration. To meet these challenges, special procedures for the preparation, packaging, and storing of food for space flight were developed.



Mercury

In the early days of the space program, known as Project Mercury, space flights lasted from a few minutes to a full day. Because of the short duration, complete meals were not needed. The major meal was consumed prior to the flight. However, the Mercury astronauts did contribute to the development of space food. They tested the physiology of chewing, drinking, and swallowing solid and liquid foods in a microgravity environment. These first astronauts found themselves eating bite-sized cubes, freeze-dried foods, and semi-liquids in aluminum toothpaste-type tubes. The food was

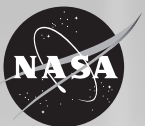


Early Project Mercury flight food: food tube and dry bite-sized snacks with a gelatin coating, which was necessary to control crumbling.

unappetizing, and there were problems when they tried to rehydrate the freeze-dried foods.

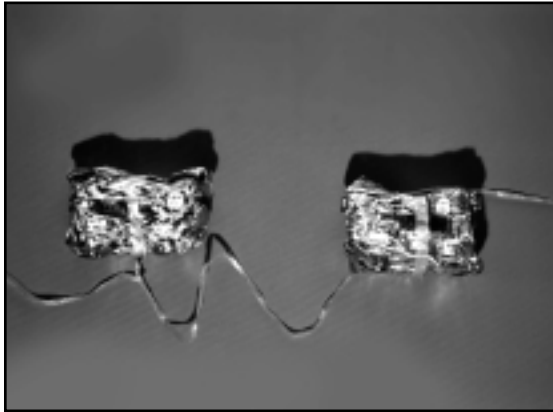
The tube foods offered many challenges to food development. First, a method of removing the food from the tube was needed. A small straw was placed into the opening. This allowed the astronauts to squeeze the contents from the tube directly into their mouths. This is similar to drinking your favorite soda from a straw, except that the food was a thicker substance. Special materials were developed to coat the inner surface of the aluminum tubes to prevent the formation of hydrogen gas as a result of contact between metal and the acids contained in some foods, such as applesauce. This aluminum tube packaging often weighed more than the food it contained. Because of this, a lightweight plastic container was developed for future flights.

During the later Mercury test flights, bite-sized foods were developed and tested. These were solid foods processed in the form of compressed, dehydrated bite-sized cubes. The cubes could be rehydrated by saliva secreted in the mouth as food was chewed. Foods floating about in a microgravity environment could damage equipment or be inhaled; therefore, the cubes were coated with an edible gelatin to reduce crumbling. These foods were vacuum-packed into individual serving-sized containers of clear, four-ply, laminated plastic film for storage. This packaging also provided protection against moisture, loss of flavor, and spoilage.



Gemini

The major advancements in food items during the Gemini period were more variety and improved packaging. The dehydration process provided foods that were similar in appearance including color, taste, shape, and texture to freshly prepared food products. Some examples of the food flown on Gemini missions included grape and orange drinks, cinnamon toasted bread cubes, fruit cocktail, chocolate cubes, turkey bites, applesauce, cream of chicken soup, shrimp cocktail, beef stew, chicken and rice, and turkey and gravy.



Gemini meal wrap.



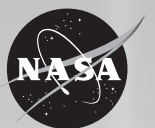
Sample types of food that have been dehydrated and packaged in cellophane for use by Gemini astronauts.

Dehydration occurs naturally in warm climates, and in cold climates, it is called freeze drying. Freeze-drying techniques in the space program consist of slicing, dicing, or liquefying prepared food to reduce preparation time. After the food has been cooked or processed, it is quick-frozen, then placed on drying trays and put into a vacuum chamber where the air pressure is reduced. Heat is then applied through heating plates. Under these conditions of reduced pressure and increased temperature, the ice crystals in the frozen food boil off, and the water vapor that is left is condensed back to ice on cold plates in the vacuum chamber. Because water is the only thing removed in this process, the freeze-dried food has all the essential oils and flavors. The texture is porous and can be easily rehydrated with water for eating.

To rehydrate food, water was injected into the package through the nozzle of a water gun. The other end of the package had an opening in which the food could be squeezed out of the package into the astronaut's mouth. Because of the size of the opening, food particle size was limited. After the meal had been completed, germicidal tablets were placed inside the empty package to inhibit microbial growth on any leftovers.

The advantages of freeze-dried foods were paramount in their development. The food is lightweight because the water has been removed. The food has a longer shelf life and can be stored at room temperature. The food also has flavors and textures more closely resembling that of the original fresh food items.

Adequate nutrient intake became a health concern with extended space flights in the Gemini program. Each crew member was supplied with 0.58 kilograms of food per day. These included dehydrated juices, freeze-dried and dehydrated foods, and compressed, noncrumbling, bite-sized foods. These made up the three meals a day that the astronauts ate. Meals were planned in advance, and the menu was repeated every 4 days.



Skylab



This Skylab food tray had individual recessed compartments into which the canned food item was placed for heating. At meal time, the crew member selected the meal and placed the items to be warmed in the food tray.



Skylab Astronaut Owen K. Garriott eating in the Skylab dining area.

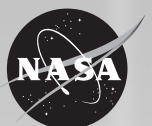
The dining experience on Skylab was unlike any other space flight. The Skylab laboratory had a freezer, refrigerator, warming trays, and a table. Eating a meal on Skylab was more like eating a meal at home. The major difference was the microgravity environment.

The supply of food onboard was sufficient to feed three astronauts for approximately 112 days. The menu was designed to meet each individual astronaut's daily nutritional requirements based on age, body weight, and anticipated activity. Each astronaut's caloric intake was 2,800 calories a day. These nutritional requirements were part of the life science experiments conducted on Skylab.

Skylab foods were packaged in specialized containers. The rehydratable beverages were packaged in a collapsible accordion-like beverage dispenser. All other foods were packaged in aluminum cans of various sizes or rehydratable packages.

To prepare meals, the Skylab crew placed desired food packages into the food warmer tray. This was the first device capable of heating foods (by means of conduction) during space flight. Foods consisted of products such as ham, chili, mashed potatoes, ice cream, steak, and asparagus.

Visit <http://spacelink.nasa.gov/space.food> to see and download the Skylab Food List.

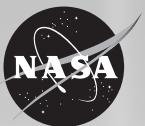


Apollo-Soyuz Test Project

American astronauts on the Apollo-Soyuz Test Project were provided meals similar to those consumed on Apollo and Skylab flights. Russian meals were composed of foods packaged in metal cans and aluminum tubes. Their spacecraft had a small heating unit onboard, and individual menus were selected for each cosmonaut. In general, a meal consisted of meat or meat paste, bread, cheese, soup, dried fruit and nuts, coffee, and cake.

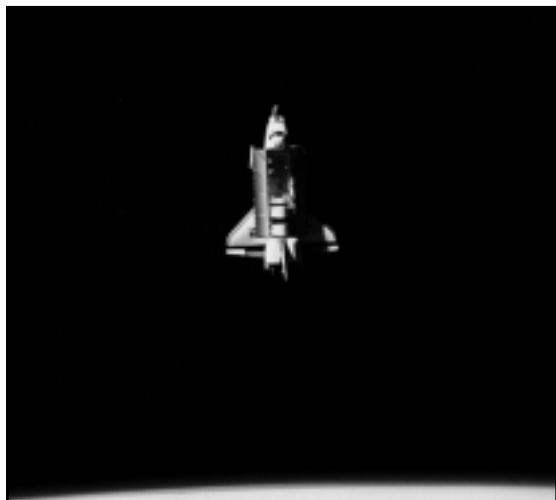


Russian space food.



Space Shuttle

For the Space Shuttle program, a more Earth-like feeding approach was designed by updating previous food package designs and hardware items. Food variety expanded to 74 different kinds of food and 20 kinds of beverages. The changes were driven by the relatively large crews and regularly scheduled space flights. A standard Shuttle menu is designed around a typical 7-day Shuttle mission. Astronauts may substitute items from the approved food list to accommodate their own tastes or even design their own menus, but these astronaut-designed menus are checked by dietitians to ensure that they provide a balanced supply of nutrients.



STS-7 SPAS view of Challenger

On the Shuttle, food is prepared at a galley installed in the orbiter's middeck. This modular unit contains a water dispenser and an oven. The water dispenser which can dispense hot, chilled, or ambient water is used for rehydrating foods, and the galley oven is used to warm foods to the proper serving temperature. The oven is a forced-air convection oven and heats food in containers different in size, shape, and material. A full meal for a crew of four can be set up in about 5 minutes. Reconstituting and heating the food takes an additional 20–30 minutes. A meal tray is used as a dinner plate. The tray attaches to the astronaut's lap by a strap or can be attached to the wall. Eating utensils consist of a knife, a fork, a spoon, and a pair of scissors to open food packages. Many astronauts will tell you that one of the most important things they carry in their pockets is a pair of scissors. They could not eat without them!

Weight and volume issues have always driven the design of any hardware to be taken into space. Food and beverage packaging is no exception. As Shuttle mission length increased, certain food and beverage packages required



Prepared foods on Shuttle food trays Velcroed to middeck stowage lockers.

modification. Rigid square rehydratable packages were being used but proved cumbersome and problematic on longer missions. Packages made of a lighter flexible material were developed and first tested on STS-44 (1991). These Extended Duration Orbiter (EDO) packages are made of flexible plastic and have a valve for inserting water. These eventually replaced the rigid square rehydratable packages on a permanent basis. In addition, a trash compactor was developed to reduce the volume of the trash, and the new packages were designed to be compatible with the compactor.

Visit <http://spacelink.nasa.gov/space.food> to see and download the Space Shuttle Food List and Shuttle Standard Menu.



STS-91 onboard view: Astronaut Dominic Gorie prepares a meal on the middeck of the Space Shuttle Discovery. Gorie prepares to use the nearby galley to add water to one of the rehydratable packages.



International Space Station

The International Space Station (ISS) will become operational on a full-time basis with a crew of three. Later, the crew size will grow to a maximum of seven people. The crew will reside in the Habitation Module (HAB). Food and other supplies will be resupplied every 90 days by the Multi-Purpose Logistics Module (MPLM). The MPLM is a pressurized module carried in the Space Shuttle payload bay that is used to transport materials and supplies. The food system described here is for the completed ISS and will be considerably different from the Space Shuttle food system. But until 2004 when the HAB module is launched, ISS residents will utilize a joint U.S.-Russian food (Shuttle-Mir) system.

The fuel cells, which provide electrical power for the Space Shuttle, produce water as a byproduct, which is then used for food preparation and drinking. However, on the ISS, the electrical power will be produced by solar arrays. This power system does not produce water. Water will be recycled from a variety of sources, but that will not be enough for use in the food system. Therefore, most of the food planned for the ISS will be frozen, refrigerated, or thermostabilized (heat processed, canned, and stored at room temperature) and will not require the addition of water before consumption. Although many of the beverages will be in the dehydrated form, concentrated fruit juices will be added to the beverages offered and will be stored in the onboard refrigerator.

Similar to the Space Shuttle, the ISS beverage package is made from a foil and plastic laminate to provide for a longer product shelf life. An adapter located on the package will connect with the galley, or kitchen area, so that water may be dispensed into the package. This water will mix with the drink powder already in the package. The adapter used to add water also holds the drinking straw for the astronauts. The food package is made from a microwaveable material. The top of the package is cut off with a pair of scissors, and the contents are eaten with a fork or spoon.

Visit <http://spacelink.nasa.gov/space.food> to see and download the ISS Food List.



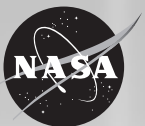
Empty International Space Station food tray.



International Space Station food tray (frozen food)



International Space Station frozen food storage: Food will be stowed in pullout drawers, which allow complete viewing of drawer contents. Lipped edges on the food package interface with the storage container, oven, and serving tray.



Food Systems Engineering Facility

The kinds of food the astronauts eat are not mysterious concoctions but foods prepared here on Earth, with many commercially available on grocery store shelves. Diets are designed to supply each crew member with all the recommended dietary allowances of vitamins and minerals necessary to perform in the environment of space.

Foods flown in space are researched and developed in the Foods Systems Engineering Facility at NASA Johnson Space Center in Houston, Texas. Foods are tested for nutritional value, how well they freeze dry, the storage and packaging process, and of course taste. Astronauts are asked to taste test food items. They use a simple form to rate the products on such things as appearance, color, odor, flavor, and texture. These components are rated using a numbering system. The Food Systems Engineering Facility uses the astronauts ratings to help design better space food.

Astronauts select their menu about 5 months before they fly. For the ISS, they will choose 30-day flight menus. Crew members will store the food in the galley onboard the Station.

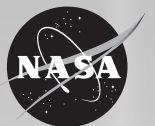
The astronauts will use a special tray on the ISS to hold their food during preparation and eating. Because everything drifts in a microgravity environment, utensils and food containers need to be held in place. Food trays will be designed on the basis of the food packages that will be used on the ISS. These trays will be different from those used on the Space Shuttle because the ISS will have a



Four individuals participate in a cantaloupe “sensory evaluation” at the Food Systems Engineering Facility. This facility consists of several areas: Kitchen (shown), Freeze Drying Room, Packaging Room, Analytical Laboratory, and Packaging, Fabrication, and Tasting Area.

table available; the Space Shuttle does not. The ISS tray will attach to the table.

From the beginning of human space travel, food has been an important feature that has involved astronauts, technicians, and engineers. Because food is an important part of life, it is imperative that the space food system is the best it can be. Astronauts on the ISS cannot get into a car and go down to the local grocery store if they do not like what is for dinner. The supply of food must be nourishing and tasty so astronauts maintain their health during their important stays in space.



Types of Space Food

There are eight categories of space food:

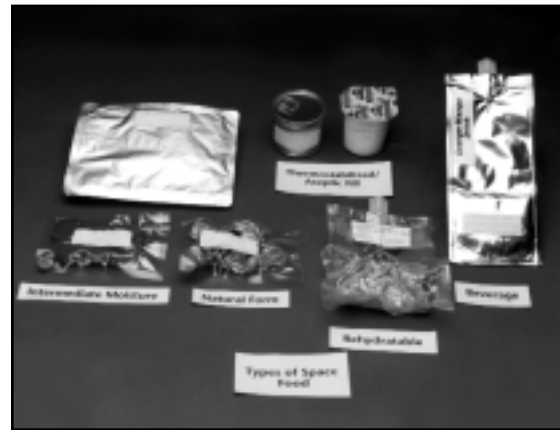
Rehydratable Food: The water is removed from rehydratable foods to make them easier to store. This process of dehydration (also known as freeze drying) is described in the earlier Gemini section. Water is replaced in the foods before they are eaten. Rehydratable items include beverages as well as food items. Hot cereal such as oatmeal is a rehydratable food.

Thermostabilized Food: Thermostabilized foods are heat processed so they can be stored at room temperature. Most of the fruits and fish (tuna fish) are thermostabilized in cans. The cans open with easy-open pull tabs similar to fruit cups that can be purchased in the local grocery store. Puddings are packaged in plastic cups.

Intermediate Moisture Food: Intermediate moisture foods are preserved by taking some water out of the product while leaving enough in to maintain the soft texture. This way, it can be eaten without any preparation. These foods include dried peaches, pears, apricots, and beef jerky.

Natural Form Food: These foods are ready to eat and are packaged in flexible pouches. Examples include nuts, granola bars, and cookies.

Irradiated Food: Beef steak and smoked turkey are the only irradiated products being used at this time. These products are cooked and packaged in flexible foil pouches and sterilized by ionizing radiation so they can be kept



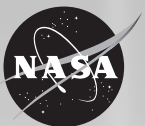
Food on the Space Shuttle comes in several categories. Represented here are: thermostabilized, intermediate moisture, rehydratable, natural form, and beverage.

at room temperature. Other irradiated products are being developed for the ISS.

Frozen Food: These foods are quick frozen to prevent a buildup of large ice crystals. This maintains the original texture of the food and helps it taste fresh. Examples include quiches, casseroles, and chicken pot pie.

Fresh Food: These foods are neither processed nor artificially preserved. Examples include apples and bananas.

Refrigerated Food: These foods require cold or cool temperatures to prevent spoilage. Examples include cream cheese and sour cream.



Microgravity

Food and how it is eaten and packaged have been greatly affected by the unique microgravity environment of space. A microgravity environment is one in which gravity's effects are greatly reduced. Microgravity occurs when a spacecraft orbits Earth. The spacecraft and all its contents are in a state of free-fall. This is why a handful of candy seems to float through the Space Shuttle when it is released. The candy does not drop to the floor of the Shuttle because the floor is falling, too.

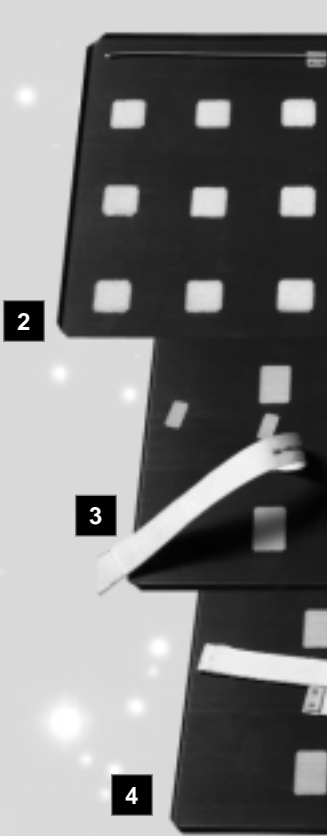
Because of this phenomenon, foods are packaged and served to prevent food from moving about the Space Shuttle or ISS. Crumbs and liquids could damage equipment or be inhaled. Many of the foods are packaged with liquids. Liquids hold foods together and, freed from containers, cling to themselves in large drops because of cohesion. It is similar to a drop of water on a piece of wax paper. The only difference is that this drop of water is moving about the microgravity environment of the Space Shuttle. Special straws are used for drinking the liquids. They have clamps that can be closed to prevent the liquids from creeping out by the processes of capillary action and surface tension when not being consumed.

Microgravity also causes the utensils used for dining to float away. The knife, fork, spoon, and scissors are secured to magnets on the food tray when they are not being used. The effects of microgravity have had an enormous impact on the development of space food packaging, food selection, and related food system requirements.



Astronaut Loren J. Shriver aboard STS-46 pursues several floating chocolate candies on the flight deck. Shriver is wearing a headset for communication with ground controllers.





- | | |
|---|---|
| <ol style="list-style-type: none"> 1. Shuttle galley. 2. Shuttle food tray top view. 3. Shuttle food tray bottom view, strap closed. 4. Shuttle food tray bottom view, strap open. 5. Shuttle rehydratable container components. 6. Shuttle stowage tray. Space Shuttle food is stowed in labeled pullout drawers in the middeck. Drawer contents are covered with a mesh, which allows top viewing of the drawer contents. | <ol style="list-style-type: none"> 7. Shuttle galley. The Shuttle food galley consists of two parts: forced air convection oven and a rehydration station where hot, cold, or ambient temperature water can be dispensed. 8. Shuttle beverage packaging components. 9. Shuttle rehydratable food package. Top and bottom view of broccoli au gratin. Label shows name, preparation, and batch number. Bottom has Velcro for attachment to the Shuttle food tray. 10. Shuttle beverage containers. 11. Astronaut Dr. Franklin R. Chang-Diaz prepares a tortilla at the Shuttle food galley. |
|---|---|

