FOOD SYSTEM

FOR

SPACE SHUTTLE PROGRAM

APRIL 30, 1971

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INTRODUCTION

Man's greatest period of space exploration was the 1960's. Man walked on the moon and satellites probed the solar system and conducted surveillance of this planet. While the concentration in the past has been largely a development activity, one of the major goals of the 1970's will be to improve mission economy and to leave the experimental stage of space flight and enter a truly operational phase. The space program costs must reach an economical operational level which will allow private industry, universities and other nations to rent time in space for their needs and purposes. By developing this capability the national emphasis will shift from the astronaut and the flying of his ship to applicable public benefits.

Potential benefits to be gained from advance space programs are incalculable. Benefits extend among such things as air and sea traffic control, navigation, and rescue operations, weather observations and forecasts, assay of natural resources, advanced communications, and new discoveries attributed to the vacuum state and zero gravity.

Two programs are necessary to achieve space flight economy and to increase public benefit - a low cost transportation system and a constant use earth orbit platform. To this end, the NASA has moved forward in the development of a space shuttle and space station with the space shuttle serving as the advanced logistics transportation system. The space station will become a unique national laboratory; a research station in orbit. Engineers, scientists

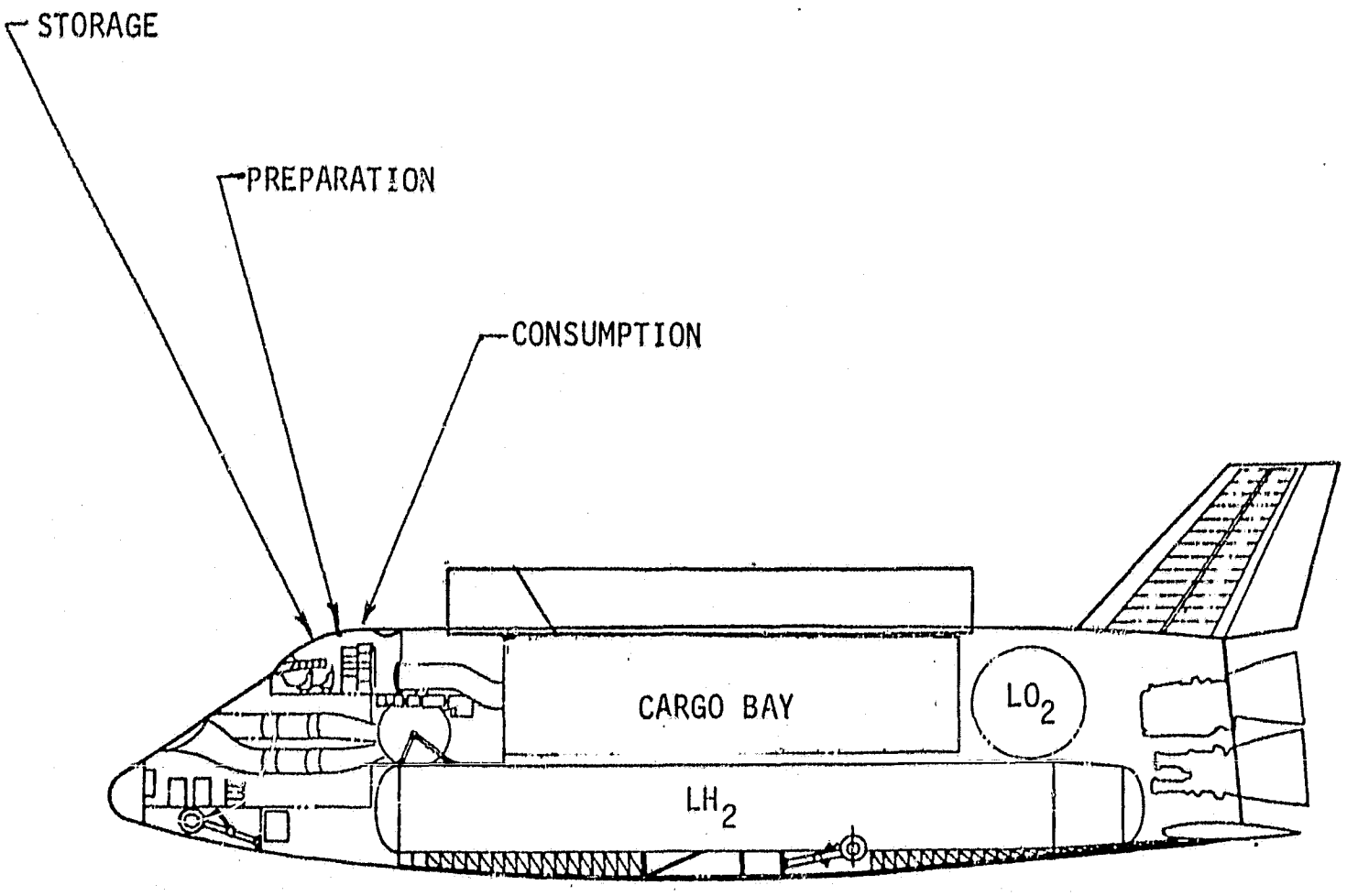
and astronomers will spend several months in orbit just as they now spend time as visiting researchers at laboratories and observatories on earth. With the tremendous potential of space, the problem of eating must be dealt with. The food system has a vital role and it must be conceived, analyzed and designed as a functioning element of the overall space vehicle. This study has been the prelude to follow-on activities to design the space shuttle food system.

SPACE SHUTTLE

Space Shuttle Program requirements have outlined a reusable two-stage vehicle with a gross lift-off weight of 3.5 million pounds. The food system for the space shuttle will interface with the crew compartment as illustrated by Figure 1. While the design reference mission is logistic resupply for space station or space base with personnel and cargo transfer operations normally accomplished in a single inter-vehicular operation, the space shuttle has many vital roles before the space station has a viable, operational capability. The space shuttle will be used for purpose oriented dedicated payloads such as carry experiment modules into orbit, conduct experiments and return to earth in what is known as the Shuttle sortie concept and accomplish a multitude of other tasks such as delivery of unmanned spacecraft and retrieval of cooperative and noncooperative satellites.

A mission duration of at least 7 days of self-sustaining lifetime shall be provided and for missions in excess of 7 days, the weight of the expendables shall be charged against the payload. The booster and orbiter crew and the orbiter passengers environment shall be shirtsleeve. Launch rates will vary from a minimum of 25 to a maximum of 75 per year. The intended combined storage and operational service life of this system is 10 years after initial operational capability and a booster/orbiter life of 100 missions with a cost effective level of refurbishment and maintenance.

FOOD SYSTEM



SPACE SHUTTLE ORBITER

Figure 1

The total space shuttle turnaround time from landing to launch readiness should be less than 2 weeks with a removal and replacement time minimized with on-board checkout and module accessibility. Solid waste products will be stored onboard for return to earth.

Space shuttle launch sites may be located at KSC or an inland site. Each element of the space shuttle shall have a two-man flight crew and shall be flyable under emergency conditions by a single crewman. The orbiter crew compartment shall provide for a two-man flight crew and a maximum of 2 passengers. For the design reference mission, rescue operations (including personnel transfer) must be completed within 48 hours after notification. The program shall be based on building 7 orbiter and 4 booster vehicles to be flight tested in 1976 and first manned orbital flight the second quarter 1978

SPACE SHUTTLE

CREW COMPARTMENT

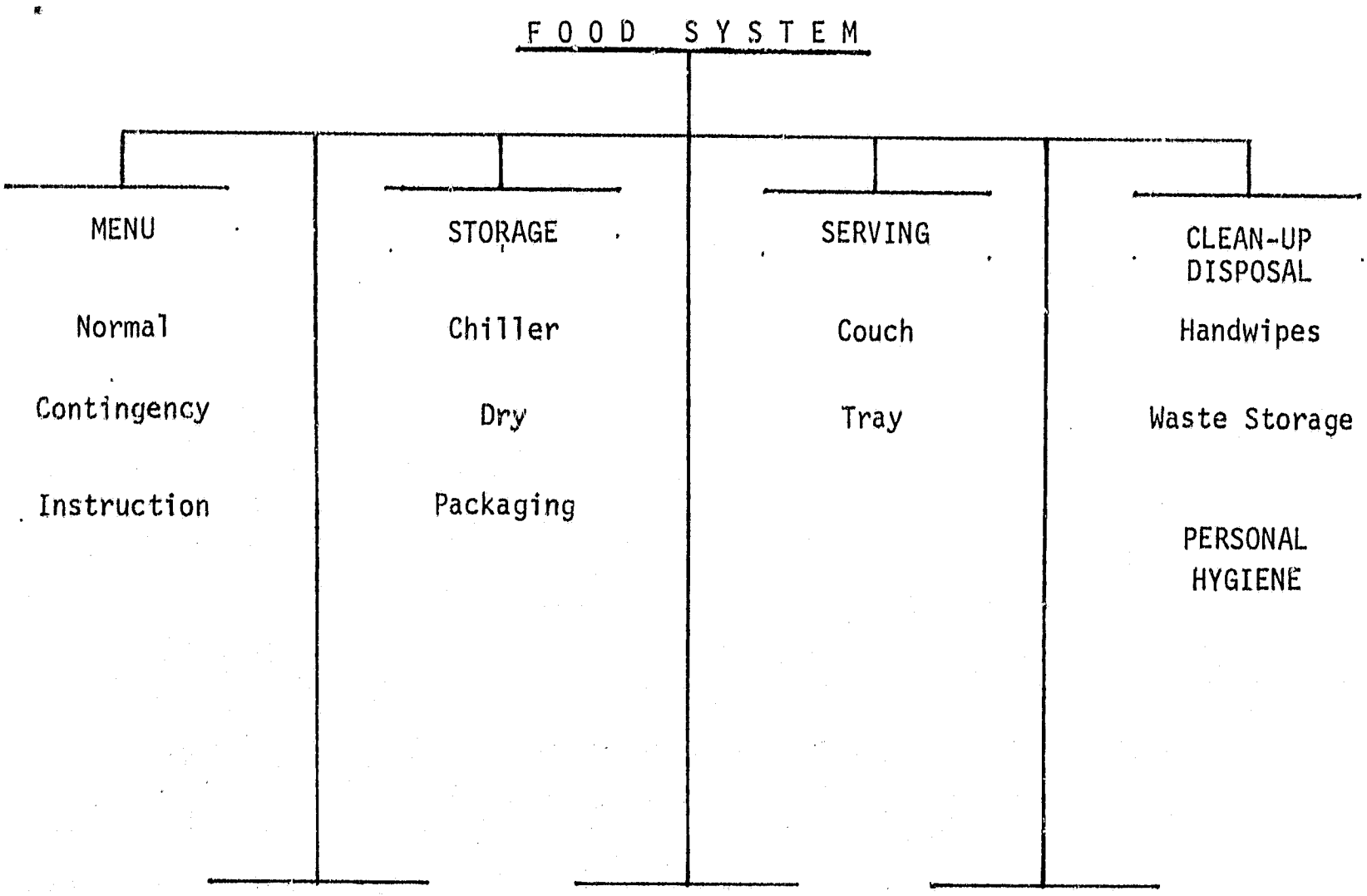
The general approach to the crew compartment development for the tandum shuttle vehicle is to have the orbiter crew compartment drive the design of the booster cockpit. The orbiter crew station will be developed first with an optimized design. This crew station will then be used for the booster with changes as required for differences in systems or operations. The crew compartment encompasses all crew accommodations; its arrangement, compartment furnishings, mobility aids and restraints, stowage lockers, and loose crew equipment of two categories - pilot operational equipment (POE) such as cameras, and pilot personal equipment (PPE) such as wearing apparel.

The food system of the crew compartment will encompass the menu, measurement, storage, preparation, serving, consumption, and clean-up/disposal subsystems. Each subsystem will have a unique role and vital interfaces to accomplish the overall goals of the food system.

FOOD SYSTEM

The food system will be modified for the shuttle role against a standard or baseline configurat'on. Trade-off to optimize the baseline configuration against the shuttle roles was not a study requirement but necessary before the food system specifications are written. The Space Shuttle Crew Compartment Food System must establish an optimal balance between the food technology and the spacecraft engineering design. This system will strive for maximum performance and minimum costs. The food system program concepts are: design for an airline type operation, and insure provision for a 48-hour insuit rescue system.

The space shuttle food system characteristics are: optimal ground service, such as containerized handling and storage; nutritionally balanced meals such as nutritional modularity in the menu; using dehydrated, intermediate moisture and fresh food types; simplicity of design such as hydraulic temperature control and hydraulic food serving tray; minimum weight and volume; and a central food depot at MSC. These system characteristics will be amplified and detailed in each subsystem and component write-up. The overall system as illustrated in the Figure 2 family tree shows the various subsystems and components and the respective interfaces.



Family Tree

Figure 2

This family tree, Figure 2, encompasses both software and hardware to insure performance of the overall system. As shown by Figure 2, the food system has been divided into seven distinct and unique subsystems to ease the definition, to establish the performance and outline the design criteria. This division provides a simple and effective identification of each component making up the food system and facilitates the readily identifiable hardware software interfaces.

Menu Subsystem

Definition: The menu is defined as the identification of those individual food items which meet the crewman's nutritional requirements.

Performance: The menu must have the capability to provide each man with a 3200 Kcal per day maximum nutritional level to assure the necessary energy. The food items selected for the menu must be psychologically and physiologically compatible with each crewman. A preflight and rescue alert feeding program must be established to provide the crewmen with safe and nutritional food items. This program shall interface with the normal flight menu and provide a smooth transition from prelaunch to orbital activity.

Design Criteria:

1. The normal menu shall be designed from the 72 approved spaceflight food items.
2. Each food item shall meet or exceed the current approved space food specifications.
3. The normal menu shall consist of dehydrated, intermediate moisture and fresh food types.
4. A modified menu shall be established for flights of one and two day duration for the flight crew and passengers.
5. A menu shall have a 7-day cycle and provide maximum pantry selection for mission extending beyond 7 days.
6. A rescue alert and a 72-hour preflight crew feeding control shall be provided.

Measurement Subsystem

Definition: The measurement subsystem consists of those software elements, i.e., weight, volume, and inventory, which control the storage, consumption, depot processing and disposition of the food items selected for the menu.

Performance: The subsystem must account for all elements of the food system including the nutritional analysis of the foods, the logistic control of the food items, and the weight/volume of the food items as stored on the space vehicle.

Design Criteria:

1. An automated accounting and control system shall be established to track, record and monitor the nutritional ingredients of the menu selected food items.
2. A system shall be established to provide the space vehicle operational personnel with current and specific weight/volume of the food items for each mission.
3. An inventory control system shall be established for recording and reporting the food item location and quantity to assure the logistic needs are met.

Storage Subsystem

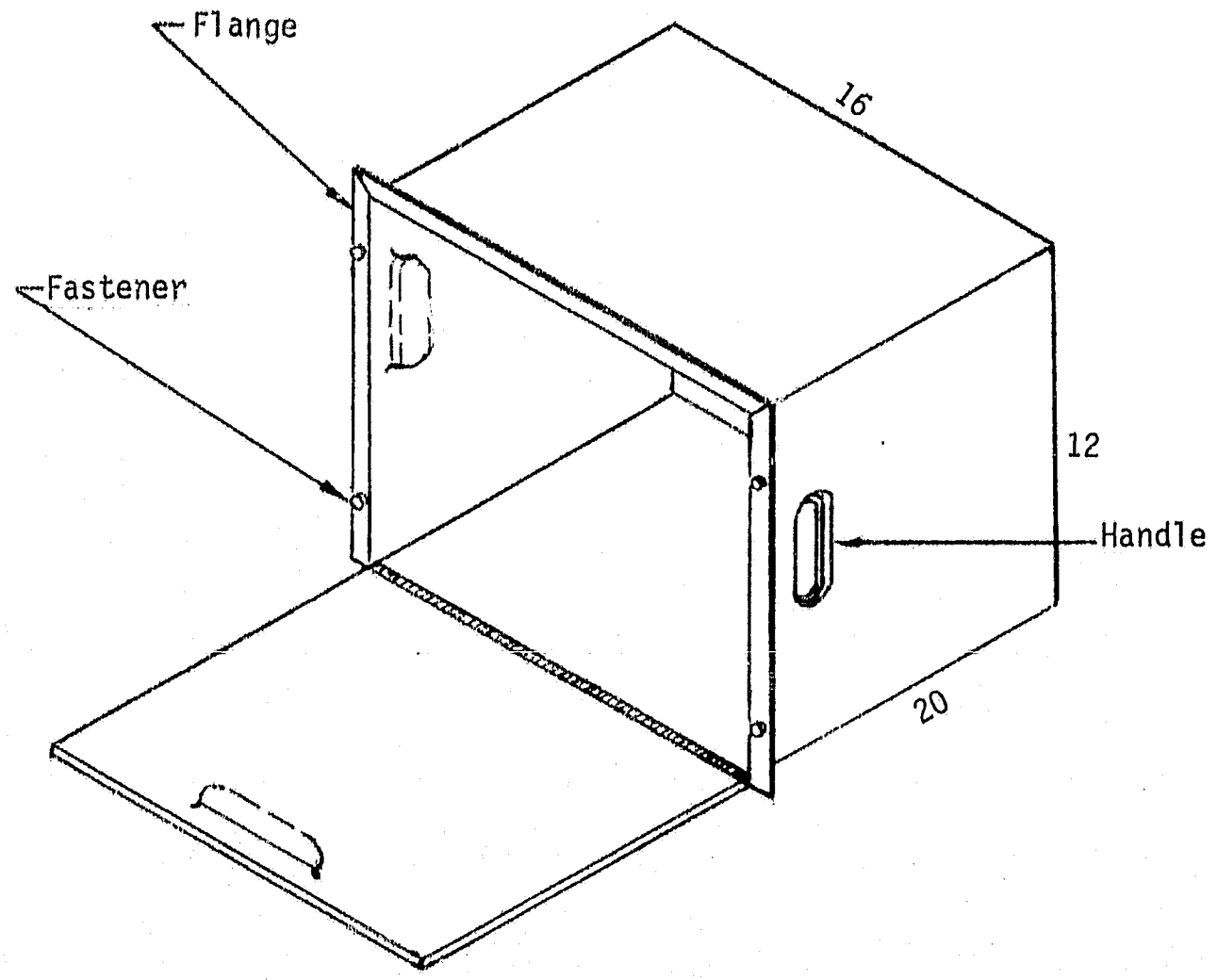
Definition: The storage subsystem is the hardware components required to handle the food items from time of initial packaging until consumption by the crewman.

Performance: This subsystem shall be responsible for the environmental control of the three types of food items, i.e., dehydrated, intermediate moisture and fresh. The storage of food items shall include the transfer of the food items from the manufacturing point until consumption such as initial packaging, ground handling, launch environment and flight environment. A chiller shall be provided to maintain fresh vegetables and fruits in an edible condition during the various shuttle missions.

Design Criteria:

1. A modular dry ground storage locker (refer to Figures 3 and 4 for conceptual examples) shall be designed to handle the dehydrated and intermediate moisture food items. It shall become an integral part of the airframe for flight storage.
2. The dry storage locker shall maintain a constant internal temperature for 30 minutes when exposed to 100 degrees Fahrenheit ambient temperature.
3. A chiller ground/flight storage locker (Figure 4 is conceptual example) shall be designed to maintain an internal temperature between 33 and 39 degrees Fahrenheit at external temperatures up to 120 degrees Fahrenheit. The cooling mechanism shall follow the liquid nitrogen aircraft galley refrigeration principle.

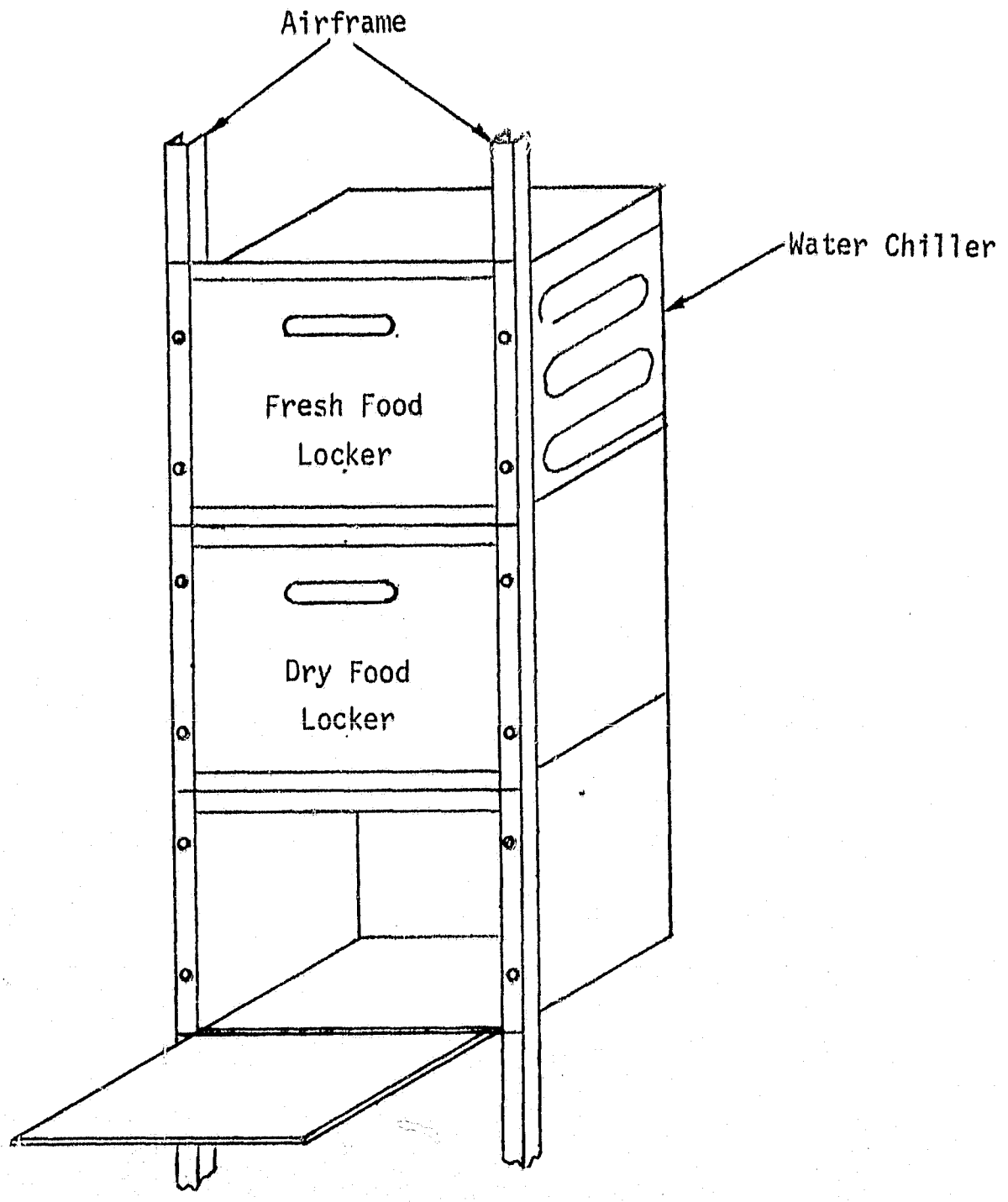
STORAGE GROUND



Ground Handling and Storage Locker

Figure 3

STORAGE FLIGHT



Crew Compartment Storage

Figure 4

4. The dry and chiller storage locker shall withstand the environmental structure loads for launch and flight of the space shuttle orbiter.

5. Ground handling procedures shall be established to insure that the dry storage locker will remain within the ambient temperature limits of $40^{o}F.$ and $100^{o}F.$

6. Food items shall be packaged in 401 and 211 by 105 can size which is compatible with the food storage locker and serving tray. Visible and descriptive labeling shall be provided on each food container.

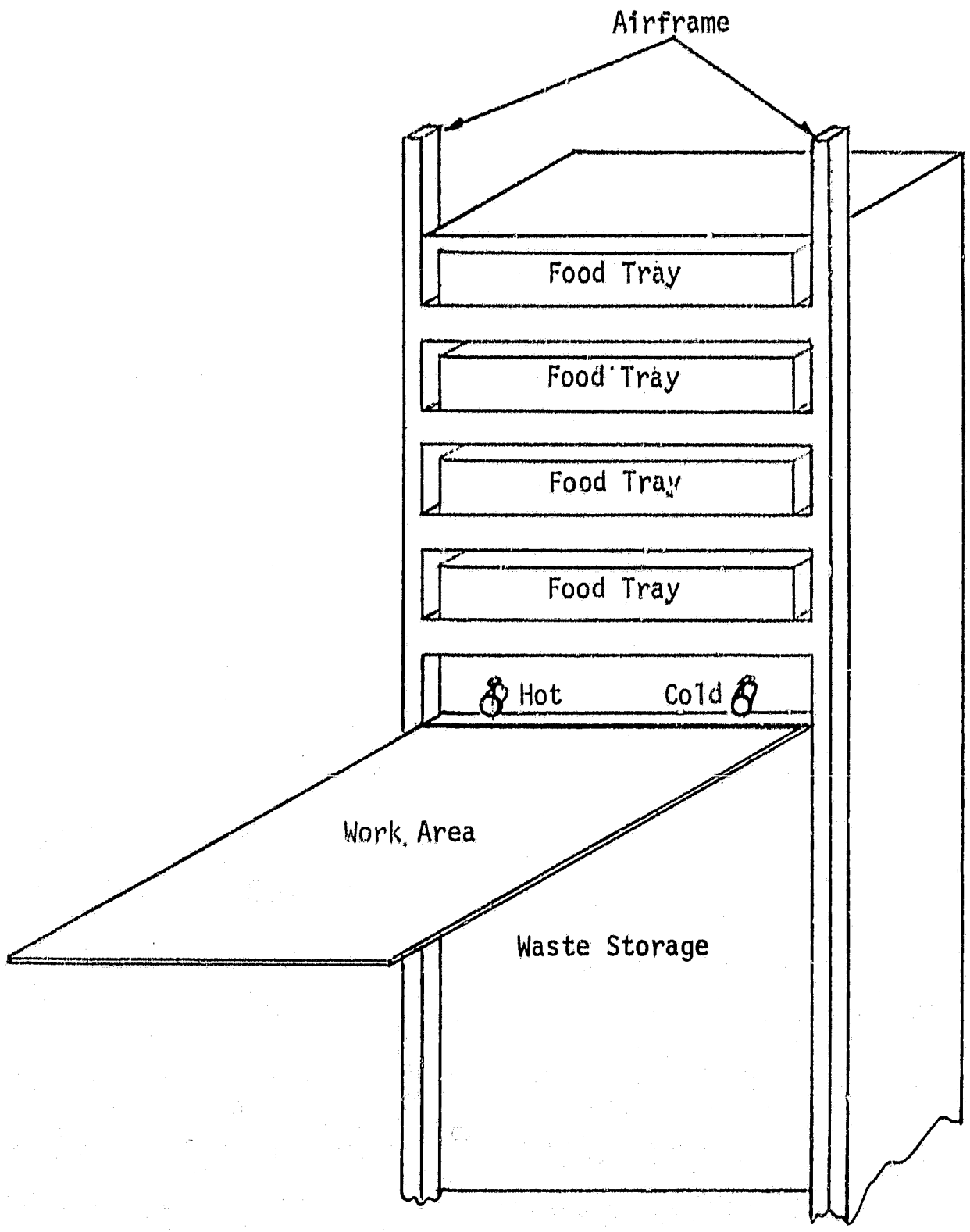
Preparation Subsystem

Definition: The preparation subsystem is defined as those hardware and software elements required to convert the menu food items from a storage state to a serving state.

Performance: This subsystem shall minimize the preparation time and insure safe handling techniques. It shall function within a zero gravity and shirtsleeve environment. The meal assembly and rehydration procedures shall be simple and easily followed.

Design Criteria:

1. Storage racks (refer to Figure 5) shall be provided for the food serving tray and it shall provide circulated water such that respective food shall be maintained at 105 ± 5°F. and 40 ± 5°F. stored on the food serving tray
2. Hot and cold potable water at 155 ± 5°F. and 35 ± 5°F. respectively shall be provided for food rehydration. A water gun, similar to the Apollo hardware, shall be provided for each water temperature.
3. A work area shall be provided to hold the serving tray for meal assembly and rehydration.
4. Procedures shall be provided for meal assembly and the rehydration process.



Tray Heating and Storage

Figure 5

Serving Subsystem

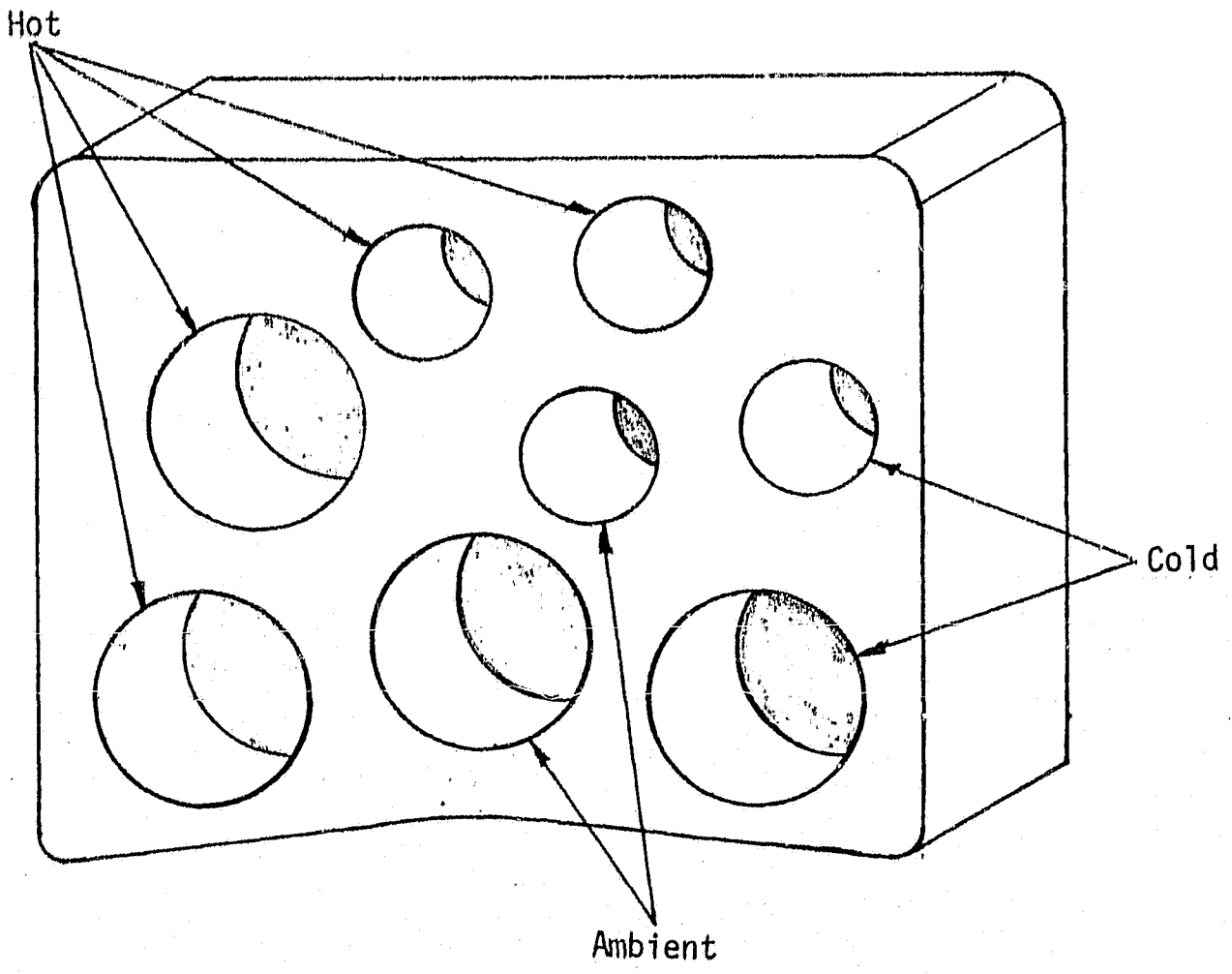
Definition: The food serving subsystem is defined as a tray to handle the assembled meals during either storage or consumption periods.

Performance: The serving tray shall be similar in external configuration to the Skylab serving tray. It shall contain receptacles for the food items and maintain the designated temperatures. It shall have hydraulic (water) temperature control on a noninterference basis with other vehicle vital supplies to conserve electrical power and not to perturbate the living environment. It shall provide for receptacles for hot, cold, and ambient food items.

Design Criteria:

1. The food serving tray shall have two 401 and two 211 size receptacles for heating, one 401 and one 211 size receptacles for chilling and one 401 and one 211 size for ambient.
2. The receptacles will provide thermal conditioning such that food items shall be maintained at the following temperatures: hot 105 ± 5^{o}F. and cold 40 ± 5^{o}F.
3. The food serving tray shall have the same surface layout as the Skylab food tray (Figure 6).
4. The food serving tray shall use spacecraft water during storage only for maintaining the desirable temperatures.
5. The food serving tray shall be compatible with the tray storage rack and the crew seat/couch where it can be mounted in an airline style configuration.

SERVING



Food Serving Tray

Figure 6

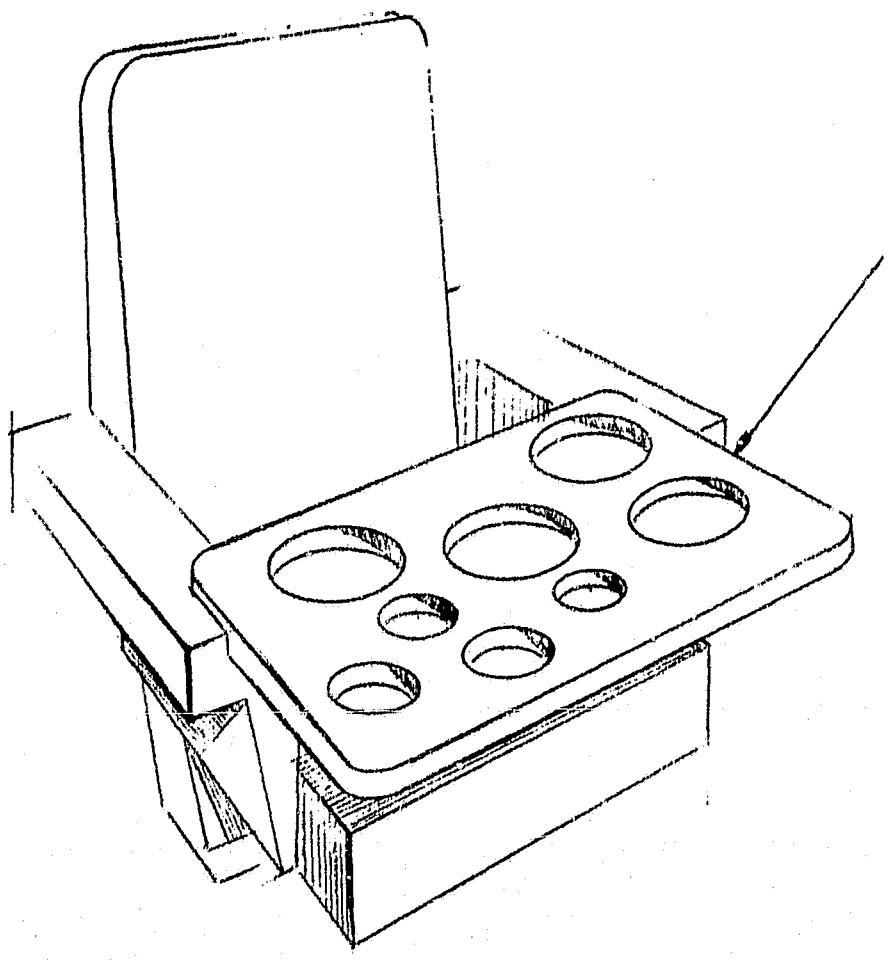
Consumption Subsystem

Definition: The consumption subsystem is defined as those hardware components used during eating of the food items.

Performance: The subsystem shall provide a comfortable and natural position during the time of meal consumption (Figure 7 is a conceptual example). It shall insure that the food items are maintained at an edible temperature during the consumption period and it shall provide the necessary utensils, i.e., spoon, fork, knife, and scissors.

Design Criteria:

1. The food serving tray shall interface with the crewman's couch and be restrained during zero gravity environment.
2. A knife, fork, spoon, and scissors shall be provided which are similar to the Skylab utensils.
3. Storage shall be provided for the eating utensils which is readily accessible to the crewman during food consumption.



Food Tray and Couch

Figure 7

Clean-up/Disposal Subsystem

Definition: The clean-up/disposal subsystem consists of the hardware components necessary for bacteria control, personal hygiene, and waste storage for return to earth.

Performance: This subsystem shall insure that the food items not consumed will not adversely affect the crewmen and all items such as the eating utensils, tray, etc., will not produce a toxic condition.

Design Criteria:

1. A waste disposal locker shall be provided as an integral part of the food preparation subsystem.
2. The waste disposal locker shall be free of bacteria and any other toxic condition during the mission and refurbishment.
3. Hand wipes shall be provided to clean the utensils and insure personal hygiene.
4. There shall be provision for germicidal agents for waste stabilization to be added to uneaten food items.

DEVELOPMENT PLAN

Introduction

This document contains the development plan for the Food System to be used with the Space Shuttle Crew Station. The food system plan defines the studies, evaluations, analyses, and other activities that are required in order to arrive at a satisfactory design of the food system which is compatible with the shuttle missions and the crew station. This plan will encompass the food system subsystems, respective interfaces, and controlling environments.

General development criteria shall be based on MSC document NAS 9-10960, Study Control Document, Space Shuttle System, Program Definition (Phase B).

Development Criteria

Food system shall be considered GFE to the prime contractor.

The space shuttle crew station shall have provisions for 2 flight crewmen and 2 passengers.

Each man will be provided a maximum of 3200 Kcal/day.

Menu design shall be nutritionally modular on a 7-day cycle with a pantry.

Orbital duration for a shuttle mission shall not exceed 7 days. Food shall be provided to account for the 7-day duration, launch and landing.

A contingency food supply for a 48-hour period shall be provided. This supply shall be compatible to a suited crewman in a pressurized garment.

The weight of expandables for missions beyond 7 days shall be charged against the payload.

The crew station shall provide the following food storage environments:

Dehydrated and thermostabilized	
Temperature	70 to 85°F.
Pressure	0 to 26 PSIA
Chilled Food	
Temperature	33 to 39°F.
Pressure	0 to 26 PSIA

A tray similar to the Skylab food serving tray will be used for food preparation and consumption.

Food preparation and serving shall be within the timeline constraints of the space shuttle design reference mission.

Food items shall be psychologically acceptable to the crewmen in terms of taste, aroma, appearance, color, texture, etc.

Food items shall be physiologically compatible with each crewman. It shall not produce excessive gastro-intestinal gas and shall produce normal fecal mass and consistency.

Development Task

A requirements review to consolidate and verify ground rules, constraints, and desired system characteristics.

A definition effort to define the configuration system baseline, alterations, operational characteristics, and major interfaces.

A preliminary design effort to develop details and specifications down to component level for the space shuttle food system and to identify all appropriate interfaces between the food system, the crew station, and anticipated medical experiments.

Trade-off evaluation studies to determine the most useful, most economical and minimal development cost for all subsystems of the food system.

A documentation effort consisting of final reports for the study phase and the formulation of test, development and program plans for the follow-on effort.

Conduct a resource and cost analysis to obtain reliable estimates of the total program cost including estimates of operational costs.

Throughout the duration of the study, continuously report cost and schedule status.

Perform an interface effort under MR&OD direction with the Space Shuttle Program Office and the Spacecraft Design Office.

Development Schedule

The attached schedule defines the milestones and tasks phasing for the activities defined by the task section. The timing of this development plan is compatible with the Space Shuttle Crew Station development plan.

SPACE SHUTTLE CREW STATION
CREW ACCOMMODATION

DEVELOPMENT PLAN

FEBRUARY 4, 1971

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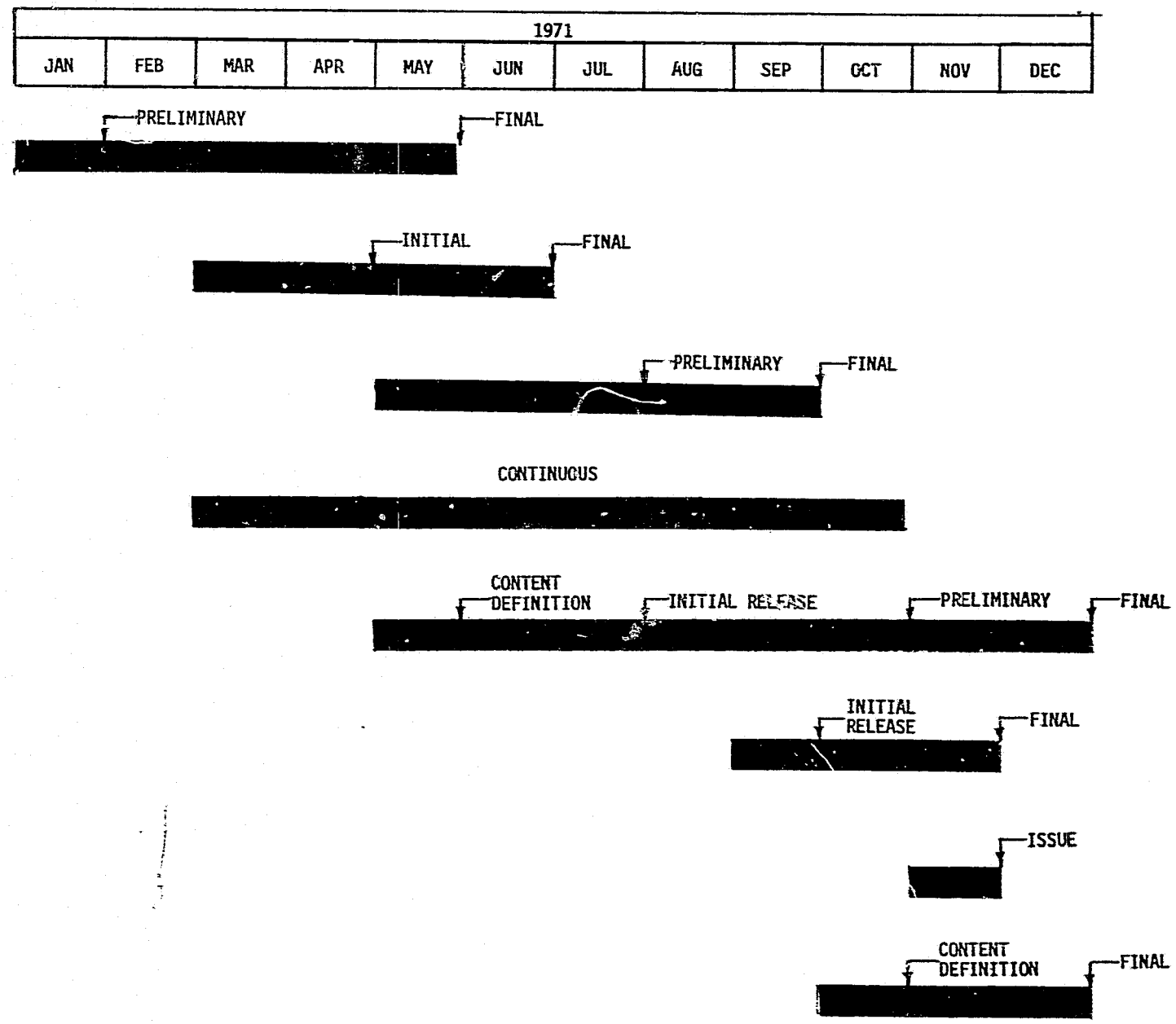


STATEMENT OF WORK

INTRODUCTION

A space shuttle system that can transport persons and cargo to low earth orbit and return the crew, passengers, and cargo safely to earth at greatly reduced costs over present systems is the single most important goal of the national space transportation system.

Purpose - The purpose of this Statement of Work is to define the tasks necessary to perform the Phase B study for the Space Shuttle Food System.

Scope - This work statement delineates the effort required to conduct the necessary analyses, synthesis and trade studies for development of the Space Shuttle Food System Specification.

Program Objectives - The objective of the space shuttle food system program is to provide a low-cost, economical feeding system for the crew and the passengers. This requires that the development costs, as well as the operational costs, be minimized. It is emphasized that low operational costs alone will not meet program objectives. In order to achieve this goal of a low-cost system and other objectives, the following characteristics are identified:

a. An operational mode which will reduce costs an order of magnitude below present operating costs.

b. A flexible capability to support a variety of payloads and missions.

c. An airline-type operation for passengers and cargo transport.

d. A reusable system with a high launch rate capability and short turnaround and reaction times compatible with rescue missions.

Study Objectives and Approach - The fundamental objectives of the study are as follows:

a. To define the space shuttle food system design.

b. To accomplish preliminary designs of the space shuttle food system optimized for:

Minimum crew preparation time
Maximize the nutritional value
Minimum storage volume and weight
Maximum crew/passenger acceptability

c. To obtain an understanding of the scope, schedule, and cost of the food system.

d. To obtain an understanding of the supporting research and technology which must be accomplished.

The primary end product of the Phase B study activities will be the food concept, preliminary food system design, and the accompanying system specifications.

The development program shall carry out an in-depth, nine-month design study of the food system and supported by critical areas by trade studies to verify the results of analysis.

The general approach to the food system development for the two space shuttle vehicles is to have the orbiter equipment and software drive the design of the booster system. The orbiter will be developed first with an optimized design and it will then be used for the booster with changes as required to account for differences in systems or operations.

The food system will be divided into seven (7) subsystems to facilitate the analysis and synthesis. The subsystems are identified as follows: menu, measurement, storage, preparation, serving, consumption, and clean-up/disposal. In the definition and preliminary design phase, the contractor shall strive to establish configurational and operational concepts which promise the safest, most useful and most economic system.

APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form a part of this statement of work to the extent specified herein. In the event of conflict between the requirements of the documents listed below and this document, the requirements of this document shall govern.

Number	Title	Date
Publication No. 1694	Recommended Dietary Allowance, 7th Edition, National Academy of Science, Washington, D.C.	1968

GENERAL REQUIREMENTS

Program Requirements - The program concept and guidelines shall be as defined by the "Study Control Document Space Shuttle System Program Definition (Phase B) June 1970, NAS 9-10960."

Technical Requirements - Upon the issuance of the following documents by the Space Shuttle Program they shall be used as guidance and control of the Phase B study:

Flight Hardware Environmental Design Requirements
Ancillary Hardware General Requirements
Cluster Requirements Specification

TASKS

Program/System Analysis - This analysis shall identify the most cost conscious approaches. The analysis shall be performed with respect to the overall missions of the space shuttle, the operational characteristics, system and mission requirements and the human engineering as outlined by the applicable program documentation. The analytical results shall guide the development of specifications for the most economical and efficient functional system.

Preliminary Design Study - The functional requirements established by the program/system analysis shall be carried through to preliminary system hardware definition. The system shall be defined in terms of each subsystem in the food system configuration. This definition of the food system subsystems will include description, performance characteristic, interface requirements, weights and volumes. Trade-off studies will be conducted, as necessary, to optimize subsystem definition and to assure compatibility with mission requirements and system characteristics.

Menu - A prototype menu shall be established for the orbiter crew and passengers. A trade-study shall be conducted to optimize the normal menu type between crew preference, pantry, or preplanned. A contingency menu shall be established to provide the nutritional requirements for the crew and passengers for a 48-hour period.

Measurement - The method and criteria shall be established for system performance measurement. This includes a weight and volume standard for storage based upon man-day measurement.

Storage - The size, volume and type of food storage to be used on the orbiter shall be established. A trade-study shall be conducted to define the optimum food packaging.

Preparation - The method of food preparation shall be defined which minimizes the time consumed by the crewman.

Serving - The most efficient method shall be determined for food serving and define the method selected.

Consumption - The optimum utensils, table/chair, personal hygiene and restraint to be used during food consumption shall be established.

Clean-up/Disposal - The requirements and interfaces for the clean-up/disposal subsystem shall be defined. The guideline of no solid waste will be dumped to the space environment shall be followed.

Supporting Research and Technology - During the course of the Phase B study work, the contractor shall identify and define the technology which would further enhance the design, or decrease development risk. The contractor shall submit to NASA the need for technological data and indicate the specific range of data requirements needed to support the food system design effort. The phase B study work in supporting research and technology shall include identification and definition of the food system interface requirements such as water and waste management and personal hygiene.

END PRODUCTS

The delivery of one final study milestone document, "A Food System Specification for the Orbiter Space Shuttle Crew Station," shall be the end product. Pursuant to the final milestones, intermediate milestones will be completed, documented, and delivered to the Technical Monitor. These reports shall be delivered to the technical monitor at the milestone dates on the accompanying schedule.

Program/System Requirements - The program/system requirements document will consist of those applicable guidelines and constraints governing the design of the food system.

Functional Requirements - This report shall be a functional requirements specification describing the design and characteristics in the establishment of the food system.

Subsystem Requirements Specification - These documents will be the performance allocation assigned to each subsystem of the food system. Each document shall contain a general description, component description, specific performance, design criteria, interfaces and qualification requirements.

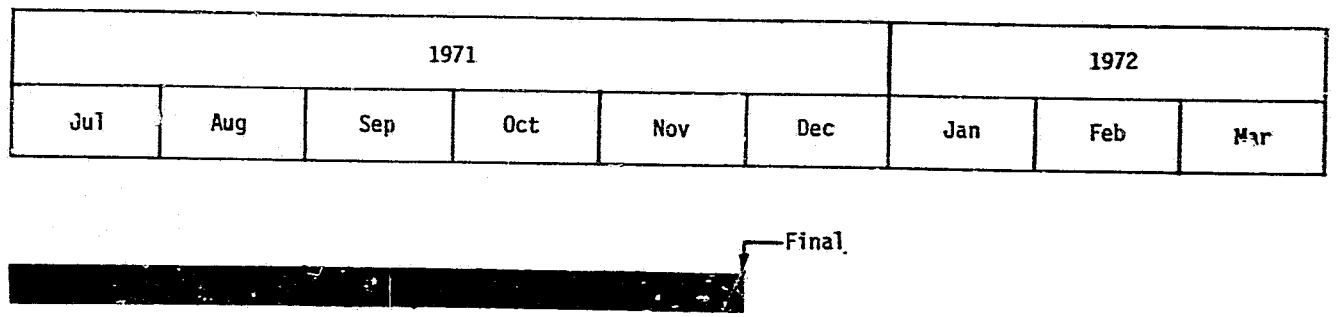
Trade-Off Studies - Each trade-off study performed during the contract period will be issued as a technical report and submitted to the technical monitor. These studies will be as justification for subsystem design and they will become a part of the Food System Specification as appendices.

A Food System Specification - The contractor shall develop and document a preliminary specification for the food system to be used for the Orbiter Space Shuttle Crew Station. This will consist of a CEI Part I specification for the food system concept defined by the preliminary design studies.

STATEMENT OF WORK

April 12, 1971

Food System
Space Shuttle Crew Station



OVERALL PROGRAM SCHEDULE

The overall scheduling of the milestones for the food system space shuttle shows an integrated program with control and timing of all elements. This schedule is compatible with th. Space Shuttle Program schedule.

FOOD SYSTEM PROGRAM SCHEDULE