NASA CR-134374

FINAL REPORT
SPACE SHUTTLE/ FOOD SYSTEM STUDY
VOLUME I
SYSTEM DESIGN REPORT

prepared for

NATIONAL AERONAUTICS and SPACE ADMINISTRATION
Johnson Spacecraft Center
Houston, Texas 77058

(NASA-CR-134374) SPACE SHUTTLE FOOD SYSTEM STUDY. VOLUME 1: SYSTEM DESIGN REPORT Final Report (Pillsbury Mills, Inc.) 104 p HC $8.25 CSCL 06H
N74-32548
Unclas
G3/05 46371

Contract NAS9-13138

Prepared by

THE PILLSBURY CO.

1974

FINAL REPORT
SPACE SHUTTLE/ FOOD SYSTEM STUDY
VOLUME I
SYSTEM DESIGN REPORT

prepared for

NATIONAL AERONAUTICS and SPACE ADMINISTRATION
Johnson Spacecraft Center
Houston, Texas 77058

Contract NAS9-13138

Prepared by

THE PILLSBURY CO.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

ABSTRACT

The Pillsbury Company (TPC) Advanced Foods and Support Systems Group, and the Fairchild Republic Division (FRD) of Fairchild Industries performed a 14 month study under Contract Number NAS 9-13138 Entitled "Space Shuttle Food System Study" for the National Aeronautics and Space Administration, Johnson Spacecraft Center. The study was conducted so as to identify and define the optimum Food System to support the Space Shuttle Program, to provide sufficient Engineering Data to support the necessary RFP's, and to assemble these data into a final report to be delivered along with a Galley Mockup to NASA, JSC.

The final report summarizes the results of this study, and has been prepared in two volumes and one Data Summary.

Final Report - Volume I - System Design

This volume contains the study approach used in performance of the contract; technical data and sketches for each functional area; Logistic support analysis; System assurance; and recommendations and conclusions based on the study results.

Final Report - Volume II - Detailed Analysis and Supporting Data

This volume contains the various analyses performed in support of the study effort, presented in the form of free standing reports. The sections of each report supporting each contract end item are identified.

Shuttle Food System Data Abstract

This item contains, under Separate cover, selected Tables of summary data abstracted from Volume I and Volume II of the Final Report, for the purpose of insuring compatible interfaces with the remainder of the shuttle systems.

The contract effort was performed under the direction of Col. Norman Heidelbaugh, U.S.A.F., Ph. D., Food and Nutrition Branch of the Johnson Spacecraft Center.

1.0 INTRODUCTION

The Space Shuttle will be a space transportation system designed to carry out various missions in Earth orbit at a fraction of the cost of present systems. It will consist of two stages, a booster for launch from Earth, and an airplane-like manned reusable orbiter. The Shuttle will be launched vertically. The orbiter will separate from its booster and go into orbit under its own power. When it accomplishes its mission, its pilots will fire its rockets to slow it down. fly it through the atmosphere, and land it like an airplane on a jet size airstrip.

The delta-winged manned orbiter will be about the size of a DC-9 airplane. The cargo compartment, which can accommodate experiments and passengers, will be about 4 1/2 meters (15 feet) in diameter and up to 18 meters (60 feet) long. The orbiter will be able to carry cargo and/or passengers weighing in total as much as 29,500 kilograms (65,000 pounds).

The Shuttle will be able to send most unmanned applications spacecraft into orbit - this includes spacecraft for communications, weather, navigation, Earth resources, and military operations. It will also launch scientific spacecraft for study of space near and far. With the Shuttle, men will supervise the launch and placement of the satellites and will be able to service and repair them as needed. Thus, launch vehicle and satellite failures, which require the construction of a whole new satellite, will become things of the past.

1.0 con't

The Space Shuttle will extend man's ability to do useful work in space while contributing to economy of space operations. The Space Shuttle will make launching of payloads into Earth orbit a virtually routine event. The Shuttle will encourage far greater participation in space flight. With the Shuttle's easy and routine access to space, scientists, engineers and astronauts will be able to go into orbit to supervise and check on their space experiments. You won't have to be an astronaut to ride the Space Shuttle. Healthy individuals will be able to withstand the mild forces of acceleration and deceleration experienced when the Shuttle is launched and reenters the atmosphere. In addition, the Shuttle will be built and pressurized so that passengers such as scientists, engineers and others will be able to ride in ordinary clothing, as in an airliner. Also, by lowering the cost of space operations the Shuttle will encourage more nations to participate in space activities.

These operations and crews required the design of a unique food system. This food system includes: food, food packages, groundbased logistics subsystem, food packages, and a Shuttle orbiter food galley. This galley will be an integral part of the orbiter located in the crew compartment. The rationale for the definition of the design of this galley was based upon assignment of priorities to each functional element of the total food system. Principle priority categories were assigned in the following order: food quality, nutrition, food packaging, menu acceptance, meal preparation efficiency, total system weight, total system volume, and total power requirements. Hence, the galley was designed using an "inside-out" approach which first considered the food and related biological functions and subsequently proceeded "outward" from the food to encompass supporting hardware. The resulting galley is an optimal design incorporating appropriate priorities for trade-offs between biological and engineering constraints.

The Space Shuttle Program represents the start of a new era in the exploitation of space. Space flights are now routine and conducted in an environment of close scrutiny and high concern for cost effectiveness. This condition is reflected in the changing character of space food systems.

In man's early suborbital missions, space feeding systems provided dry, bite-sized foods plus only a limited selection of rehydratable food items. These rations, although nutritionally adequate, were generally unsatisfactory from the standpoint of crew acceptability.

The performance of Space food systems was steadily improved throughout the Mercury, Gemini and Apollo programs culminating in the Skylab food system, which represented the upper limit within current state-of-the-art. This increased acceptability was purchased in part by penalties to the vehicles in terms of power, weight and volume associated with freezers, coolers and heating devices, and frozen and thermal processed foods.

A number of characteristics of the shuttle program, not shared by previous programs, prevents a simple extension of past food systems from yielding an optimum shuttle food system.

These included: a) frequent, short missions, b) routine ground support, c) weight and volume penalty-critical vehicle, d) high hedonic acceptability of food system required to support a variety of crew members, e) availability of excess potable water from fuel cells.

In selecting an optimum food system for the Shuttle Program, this study emphasized the following: a) Maximum gain in hedonic acceptability for each incremental increase in vehicle penalties, b) such ground support considerations as modular components, inventory management, manufacture and supply, and alert-crew support, c) The role of R & D in improving the variety and hedonic acceptability of the food items and the procedures and components associated with preparation and consumption, d) a well-designed central galley. The study was conducted in such a manner as to minimize pre-judgment of system components, and to analyze as broad a range of Candidate food systems as possible.

1.0 cont'd

Volume I of this final report details the study approach and the study results supporting the selected system. The detailed analyses and supporting technical data are presented in Volume II.

2.0 Study Approach

2.1 Objectives and Scope

The primary objective of this Space Shuttle Food System Study is the identification of the optimum Flight and Ground support-systems to support the Shuttle Program. This includes the optimum food items, primary packaging, associated hardware components, and ground support elements of a highly acceptable, maximum cost effective Space Shuttle Food System.

A second study objective is to assess the detailed results of the study and incorporate the system definition and design data into the design and fabrication of a semi-functional shuttle food system mockup deliverable as a contract end item.

Finally, the study identifies areas where realizable state-of-the-art advances in food technology and engineering may be utilized in developing immediate and near-future Space Shuttle Food System Components.

2.2 Mission Model Guidelines

2.2.1 Mission Parameters

The baseline mission and focus of major emphasis in the study, is the 6 man/7day mission. All sizing of galley hardware and food stowage facilities were made to accomodate the 6 man/7 day mission. An additional requirement for contingency food to support 4 men for 4 days was included in the analysis.

The Environmental Conditions are described as "shirtsleeve", that is:

Atmosphere	14.7 PSIA
PN_2	11.6 PSIA

2.2.1 Cont'd

PO_2	3.1 PSIA		
Temperature	65^o-85^o F.		
No decompression requirements			
Gravity	0 g or 1 g operation		
Loads	entry	3 g	30 minutes
	maneuver	+2.5 g to -1.0 g	
	crash	+9.0 g	
	Launch		

2.2.2 General System Requirements

The general system requirements for the Space Shuttle Food System are as follows:

a) Provide for the identification and definition of optimum food items and types and supporting components of the food system.

b) The food system will normally function in an atmosphere of 14.7 psia with an oxygen partial pressure of 3.1 psia and a nitrogen diluent, and will operate at plus-one and zero gravity. Cabin temperature range will be 65^o - 80^oF.

c) The food system will support Shuttle operations over a minimum of 10 years, with each Orbiter capable of low cost refurbishment and maintenance for as many as 500 reuses.

2.2.2 Cont'd

d) The food system will be compatible with a Shuttle turnaround time from landing/return to the launch facility to launch readiness of less than 160 working hours over 14 calendar days.

e) The food system will be capable of sustaining entry trajectory load factors of 3 g's.

f) The food system will not preclude the Orbiter from being launched within 24 hours of notification in order to fulfill its space rescue role

2.2.3 General Vehicle Requirements

The general vehicle requirements as they input the food system design, are as follows:

a) The food system will be provisioned for support of a 49 man-day mission, including expendables storage, with no system changes.

b) Additional supplies will be on-loaded without being charged to the basic design, to permit orbital stay times of up to 30 days.

c) The food system will support the ferry requirements of the Shuttle, including transcontinental non-stop flights utilizing aerial refueling.

d) During atmospheric flight, limit positive maneuvering loads will be 2.5 g's, and limit negative maneuvering load factor will be 1.0 g.

2.2.3 Cont'd

e) The orbiter will have the capability of supporting the crew for 96 hours after an in-orbit contingency, assuming a powered-down configuration.

h) The galley will be a permanent facility in the Orbiter and utilized for all Shuttle missions. The galley will be packaged as a modular unit for complete overhaul.

2.2.4 Functional Requirements

The functional requirements for the Shuttle Food System are as follows:

a) The Shuttle Food System will support flight personnel and ground alert crews.

b) The inflight food system will be sized for supplies and galley hardware to support the baseline mission of 6 men/7 days with contingency support of 4 men/4 days in a powered-down condition.

c) As applicable and practical, all functions of the ground based facility will be automated or made routine to minimize crew time and handling.

d) No single malfunction or credible combination of malfunctions and/or accidents will result in injury to personnel using the food system and/or its components.

2.2.4 Cont'd

e) The mission menus shall meet the following nutritional requirements:

3000 KCalories per Man/Day

100 grams Protein per Man/Day

Less than 35% of Calories from fat

Vitamins and minerals meet RDA Standards

Control of specific nutrients as identified by physiological studies on Skylab.

2.3 Methodology

2.3.1 Study Tasks

The task flow diagram, shown in Fig. 2.3.1, outlines the sequence of tasks performed during the study. Descriptions of the approach to each task effort are summarized below.

Task 1 - Select Food Items.

From a large survey of food items common to earth feeding patterns, food items were selected which were compatible with the requirements of the Shuttle Program. These items were assigned to an array of 16 unique food groups. Various combinations of food groups formed alternate mission food stowage possibilities.

Task 2 - Select methods to Heat.

The various candidate methods for accomplishing in-flight food-heating were presented in a parametric basis so as to display the relationship of each method to the food items and the system impact on the vehicle. Several viable candidates from this display were selected as options and subjected to a detailed Thermodynamic analysis. The impact of each option was incorporated into alternate galley possibilities.

Task 3 - Select Methods to Refrigerate

The various candidate methods for accomplishing in-flight chilling, refrigerating or freezing of foods were treated in the same manner as the heating methods of task 2.

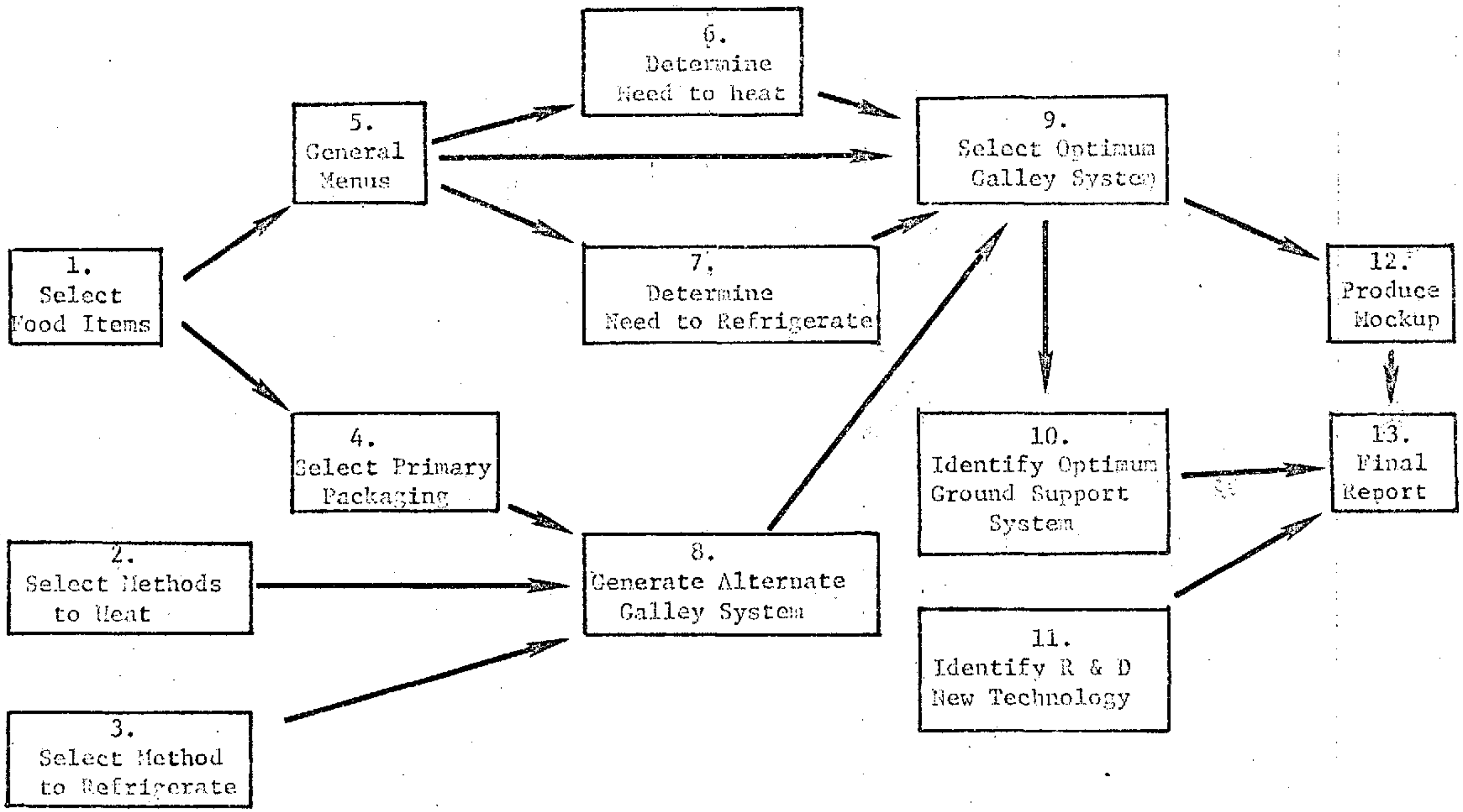


FIGURE 2.3.1 TASK FLOW DIAGRAM

2.3.1 Cont'd

Task 4 - Select Primary Packaging.

Candidate Primary packaging was screened for compliance with various packaging requirements. The surviving concepts were subjected to a comprehensive trade-off analysis of performance criteria, and the selected candidates were incorporated into the alternate Golby system concepts. A rehydration system for rehydratable foods was analyzed and recommended.

Task 5 - Generate Menus

An analysis of typical earth feeding patterns determined the numbers of each type of food item to be provided per man/day. Portion sizes were set by nutritional requirements. Mission menus were generated for four and six crewmen, on a repeat cycle of 3, 4, 5, 6 and 7 days.

Task 6 - Determine Need to Heat.

The need to provide facilities for serving hot food was determined by assessing the impact on acceptability of not providing that capability.

Task 7 - Determine Need to Refrigerate.

The need to provide facilities for the refrigeration of food items was determined by assessing the impact on acceptability of deleting refrigerated foods from the menus.

Task 8 - Generate Alternate Galley Systems

A comprehensive analysis of alternate stowage configurations, timelines, and crew choice was conducted. From the results of this analysis, and the available alternate combinations of food groups, methods to heat and methods to refrigerate, five alternate shuttle galley systems were generated.

Task 9 - Select Optimum Galley System.

A detailed analysis of each alternate galley system was performed to determine the vehicle and mission penalties associated with each. The optimum galley systems was selected on the basis of criteria providing the maximum acceptance for the penalties incurred.

Task 10 - Identify Optimum Ground Support System.

The elements required to fulfill the functions of the ground support system were identified and analyzed in terms of capabilities and facilities required.

Task 11 - Identify R & D New Technology.

During the conduct of the other study task , those areas which are most amenable to research and development efforts that can result in Shuttle Food System performance improvements were identified.

2.3.1 Cont'd

Task 12 - Produce Mockup

A full-size, semi-functional mockup of the Orbiter galley was designed and fabricated of wood and metal.

Task 13 - Final Report

This document represents the final report on the results of the Shuttle Food System Study.

This structure in the task sequence allowed maximum use of the "inside-out" approach, in which the optimum foods were chosen for the Space Shuttle Program, and the necessary ancillary galley hardware was designed to optimally support the food.

2.3.2 Correlation of Contract End Items to Study Tasks.

Each of the study tasks of section 2.3.1 is directly related to one or more of the identifiable NASA end items assigned to the Space Shuttle Food System Study. A matrix showing the relationship of study task to end item is presented as Table 2.3.2.

2.3.3 Correlation of Food System Functions to Study Tasks.

The basic functions of the Food System can be identified as follows:

Provide Food

Provide Stowage

2.3.3 (continued)

Provide for Preparation

Provide for Serving

Provide for Consumption

Provide for Clean-Up

Provide for Logistic Support

Each of the study tasks of section 2.3.1 is directly related to one or more of the Food System Functions listed above. A matrix showing the relationship of study task to food system function is presented as Table 2.3.3.

2.3.4 Correlation of End Items to Food System Functions

A matrix showing the relationship of Food System Functions to Contract end items is presented as Table 2.3.4.

2.3.5 Correlation of End Items to Volume II Appendices

The detailed analyses supporting this study were conducted as discrete, self-consistent efforts, which are reported as appendices in Volume II of the Final Report. A matrix showing the relationship of Contract End Items to these appendices is shown in Table 2.3.5.

TABLE 2.3.2

Study Organization

End Item Numbers by Study Tasks

STUDY TASK

END ITEM NUMBERS	1 Select Food Items	2 Select Methods to Heat	3 Select Methods to Refrigerate	4 Select Primary Packaging	5 Generate Menus	6 Determine Need to Heat	7 Determine Need to Refrigerate	8 Generate Alternate Galley Systems	9 Select Optimum Galley System	10 Identify Optimum Ground Support System	11 Identify R & D New Technology	12 Produce Mockup	13 Final Report
3.1 Food Items Mix and Processing Modes	X										X		X
3.2 New R & D Technology											X		X
3.3 Menu Selection					X								X
3.4 Need to Heat						X							X
3.5 Method to Heat		X									X		X
3.6 Need to Refrigerate							X						X
3.7 Method to Refrigerate			X								X		X
3.8 Ground Based Support System										X			X
3.9 Primary Packaging				X							X		X
3.10 Logistics Support										X			X
3.11 Galley Mockup								X	X			X	X

TABLE 2.3.3

STUDY ORGANIZATION

FOOD SYSTEM FUNCTIONS BY STUDY TASKS

Study Task

SYSTEM FUNCTION	1. Select Food Items	2. Select Methods to Heat	3. Select Methods to Refrigerate	4. Select Primary Packaging	5. Generate Menus	6. Determine Need to Heat	7. Determine Need to Refrigerate	8. Generate Alternate Galley System	9. Select Optimum Galley System	10. Identify Optimum Ground Support System	11. Identify R & D New Technology	12. Produce Mockup	13. Final Report
Provide Food	X				X						X		X
Provide Stowage			X	X			X	X	X	X		X	X
Provide for Preparation		X						X	X		X	X	X
Provide for Serving				X				X	X		X	X	X
Provide for Consumption				X							X		X
Provide for Clean-up												X	X
Provide for Logistic Support										X	X		X

TABLE 2.3.4

STUDY ORGANIZATION

END ITEM NUMBERS BY FOOD SYSTEM FUNCTIONS

SYSTEM FUNCTION

END ITEM NUMBERS	Provide Food	Provide Stowage	Provide for Preparation	Provide for Serving	Provide for Consumption	Provide for Clean-up	Provide for Logistic Support
3.1 Food Items Mix and Processing Modes	X						
3.2 New R & D Technology	X		X	X	X		X
3.3 Menu Selection	X						
3.4 Need to Heat			X				
3.5 Method to Heat			X				
3.6 Need to Refrigerate		X					
3.7 Method to Refrigerate		X					
3.8 Ground Based Support System							X
3.9 Primary Packaging		X		X	X		
3.10 Logistics Support		X					X
3.11 Galley Mockup		X	X	X		X	

Table 2.3.5

Correlation of End Items
to Volume II Appendices

APPENDIX

End Item Numbers	Appendix A	Appendix B	Appendix C	Appendix D	Appendix E	Appendix F	Appendix G	Appendix H
3.1 Food Items Mix and Processing Modes						X		
3.2 New R&D Technology		Volume I, section 5.0						
3.3 Menu Selection						X		
3.4 Need to Heat						X		
3.5 Method to Heat	X	X						
3.6 Need to Refrigerate						X		
3.7 Method to Refrigerate			X					
3.8 Ground Based Support System							X	
3.9 Primary Packaging						X		
3.10 Logistics Support							X	
3.11 Galley Mockup				X	X			X

3.0 Study Results

3.1 Introduction

This section of Vol. I of the Final Report of the Space Shuttle Food System Study presents the major results of the study in a summary form. The purpose of this section is to provide the summary data output of the study, and an understanding of the inputs and logic supporting that data. The detailed analyses can be found in Vol. II of this report.

The shuttle food system necessarily requires engineering and food technology support. The application of these disciplines was consistent with an "inside-out" approach to Food System design. The food to be delivered by the system was analyzed, and the necessary hardware to support that food was then designed.

The primary analytical tools employed in the study were tradeoff analyses and systems analysis: the ancillary galley hardware, stowage techniques, primary packaging and preparation techniques were determined by tradeoff studies. The food mix and overall system design was selected by systems analysis of the resulting flight galley.

The study was organized into major sections represented by the appendices of Vol. II of this report. The results presented in this section of Vol. I are organized according to the major functions of the Shuttle Food System:

Provide for Food	Provide for Storage
Provide for Preparation	Provide for Serving
Provide for Consumption	Provide for Clean-up
Provide for Logistic Support	

3.2 System Selection Criteria

The system selection criteria can be expressed in one statement: The system must provide maximum food acceptability at minimum system penalties, while satisfying the requirements and guidelines in section 2.0 of Vol. I of this report. Since food acceptability and vehicle penalties are not independent functions, the selection criteria implies a tradeoff analysis to optimize the selection of the food system.

Food acceptability is a product of four major criteria: Nutrition, safety, reliability ("stability") and hedonic acceptability. There is no allowable tradeoff on nutrition, safety or reliability. High standards must be met before any item can be considered acceptable. There is an allowable tradeoff on hedonic acceptability. The hedonic acceptability associated with the food mix of each alternate food system constitutes one variable of the optimization curves.

The major system penalties constituting the other variable to the optimization curves were weight and volume. Many other penalties were analyzed in the course of the study, but none of the other penalties carried the weight to drive the system selection against the indications of the weight and volume penalties.

The selection methodology consisted of constructing plots of hedonic acceptability versus weight and volume penalties for each of five alternate food systems, and examining the plots for the point of diminishing returns.

3.3 System Selection

3.3.1 Alternate Systems Descriptions

The five alternate systems subjected to systems analysis differed in the mix of food items supplied by the system, and in the galley hardware necessary to support each food mix. Table 3.3.1a summarizes the average composition of each alternate food mix.

Table 3.3.1a

AVERAGE NUMBER OF FOOD ITEMS PER MAN/DAY BY FOOD TYPE

Mix	Beverage	RTE	Rehydratable	Refrigerated	Frozen	Thermo stabilized
1	6	0	0	0	0	0
2	8	6	0	0	0	0
3	8	4	7	0	0	0
4	8	4	6	1	0	0
5	8	4	4	1	1	1

Condiments, spices, spreads assumed to be 2 packages per man meal.

Each mix is constructed in such a way as to meet the pre-imposed nutrition, safety and reliability standards.

A listing of the particular food items consistent with each mix definition is presented in section 3.2.3.3 of Appendix F of Vol. II of this report.

The hedonic acceptability of each alternate mix, represented by the score each receives on the hedonic scale, is shown in Figure 3.3.1b . The bell-shaped curve represents the distribution of common food items on the hedonic scale, and is included to place the alternate mixes in context.

3.3.1 Cont'd

Tables 3.3.1c through 3.3.1g present the various hardware components of the galleys supporting each alternate food mix, and the weight and volume penalties. Table 3.3.1L presents a summary of the penalties.

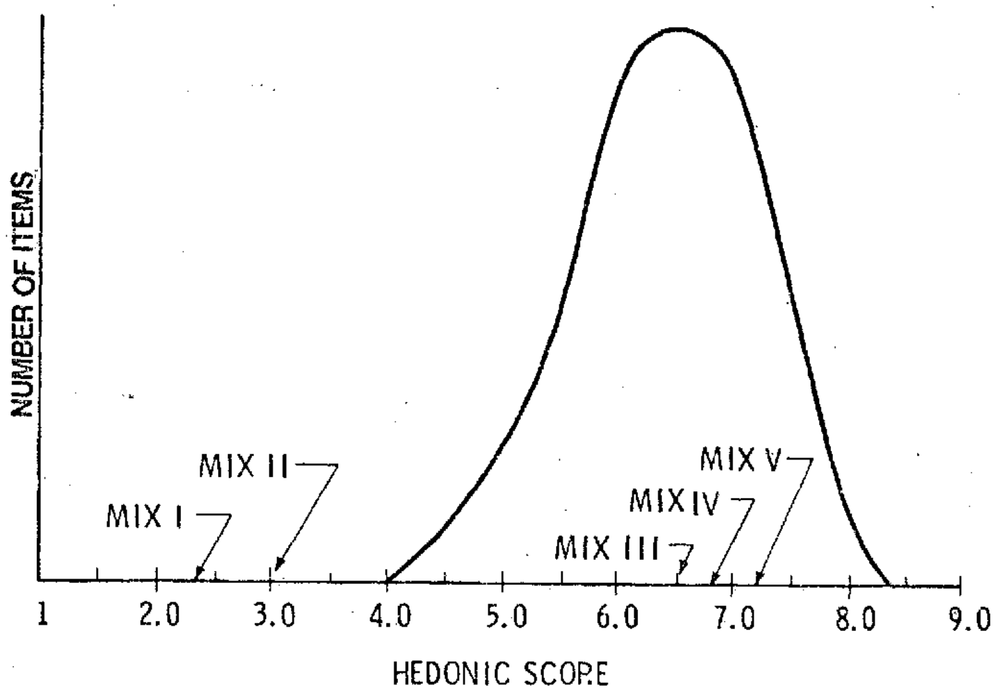


Figure 3.3.1b Hedonic Acceptability of Alternate Food Mix

3.3.1 Cont'd

Table 3.3.1c

SYSTEM I GALLEY DATA

	LB.	FT^3
Food and Primary Package	83.38	2.68
Logistics Liner	12.8	2.81
Water System	1.00	0.13
Wipes and Dispensers	4.29	0.27
Equipment Totals	18.1	3.21
Food Lockers	5.85	1.62
Equipment Installation	0.91	0.25
Miscellaneous Hardware	0.26	0.06
Trash (1/1 of Food and Pkg Volume)	9.62	2.68
Installation Totals	16.6	4.61
Total System (less food)	34.7	7.82

Table 3.3.1d

SYSTEM II GALLEY DATA

	LB.	FT^3
Food and Primary Package	100.56	2.35
Logistics Liners (Beverage Liner) (RTE Liner)	21.7	2.54
Water System (ambient)	1.00	0.13
Wipes and Dispensers	4.29	0.27
Equipment Totals	27.0	2.94
Food Lockers (Beverage & RTE)	7.20	1.99
Equipment Installation	0.91	0.25
Miscellaneous Hardware	0.26	0.06
Trash-Bev 1/1 Vol. Ratio RTE .25/1 Vol. Ratio	6.24	1.74
Installation Totals	14.6	4.04
Total System (less food)	41.6	6.98

3.3.1 Cont'd

Table 3.3.1e

SYSTEM III GALLEY DATA

	LB.	FT^3
Food and Primary Package	144.0	7.24
Logistics Liners	31.1	7.60
Water System - Hot & Cold	19.2	0.78
Wipes and Dispensers	9.75	0.30
Utensils - 6 Sets	1.70	0.14
Trays	11.6	1.17
Semi-active Oven	15.6	1.65
Equipment Totals	88.9	11.7
Food Lockers	14.2	3.97
Equipment Installation Structure	6.73	1.80
Utensil Stowage	0.39	(trays)
Tray Stowage	2.08	0.39
Trash Stowage	20.9	5.85
Work Surface	2.73	0.78
Miscellaneous Hardware	0.52	0.13
Galley Installation	47.6	12.9
Total Galley (less food)	136.5	24.6

3.3.1 Cont'd

Table 3.3.1f
SYSTEM IV GALLEY DATA

	LB.	FT^3
Food and Primary Package	181.33	7.68
Case 1 - No Meal Choice Logistics Liners	28.6	7.41
Case 2 - 1 Meal Choice Cabinets w/drawers and refrig. liner	59.7	12.7
Water systems - hot and cold	19.2	0.78
Wipes and Dispensers	9.75	0.30
Utensils - 6 sets	1.82	0.16
Trays (hot insert type) -6	9.82	1.10
Semi-active Oven	15.6	1.65
Refrigerator	35.4	1.72
Equipment Totals Case 1	122.	13.2
Case 2	153.	18.5
Case 1 - Food Lockers	15.1	4.17
Case 2 - Cabinet w/drawers	*(59.7)	*(12.7)
Equipment Installation Structure	10.0	2.77
Utensil Stowage	0.39	0.09
Trays Stowage	1.87	0.52
Work Surface	2.34	0.66
Miscellaneous Hardware	0.52	0.16
Galley Installation Case 1	61.7	17.1
Case 2	46.6	12.9
Total Galley (less food) Case 1	**184.	30.3
Case 2	200	3.15

* Not Additive

** Case 1 chosen for study purposes.

3.3.1 Cont'd

Table 3.3.1g

SYSTEM V GALLEY DATA

	LB.	FT^3
Food and Primary Package	223.4	7.76
Case 1 - No Meal Choice	29.2	6.76
Logistics Liners		
Case 2 - 1 Meal Choice	62.8	12.7
Cabinet w/drawers & refrig liner & frozen liner		
Case 3 - Full Meal Choice	108.	14.0
Cabinet w/drawers & refrig liner & frozen liner		
Water System - Hot and Cold	19.2	0.78
Wipes and Dispensers	9.75	0.30
Utensils - 6 sets and preparation utensils	1.95	0.17
Trays (hot insert type) 6	11.6	1.26
Hot Air Convection Oven	53.7	1.90
Refrigerator	35.4	1.72
Freezer 0 F	45.8	1.72
Trash Compactor	19.5	0.38
Equipment Totals		
Case 1	226.	15.0
Case 2	260.	21.0
Case 3	305.	22.4

3.3.1 Cont'd

Table 3.3.1g (Cont'd)
SYSTEM V GALLEY DATA

	LB.	FT^3
Case 1 Food Lockers	12.9	3.59
Case 2 Cabinet w/drawers	*(62.8)	*(12.7)
Case 3 Cabinet w/drawers	*(108.)	*(14.0)
Equipment Installation Structure	15.1	4.20
Utensil Stowage	0.39	0.09
Trays Stowage	1.87	0.52
Trash Stowage	31.9	8.85
Work Surface	2.34	0.66
Miscellaneous Hardware	0.58	0.17
Galley Installation Case 1	65.1	18.1
Case 2	52.2	14.5
Case 3	52.2	14.5
Total Galley (less food)		
Case 1	**291.	33.1
Case 2	3.12	35.4
Case 3	357.	36.7

* Not Additive

** Case 1 chosen for study purposes

3.3.1 Cont'd

Table 3.3.1h

SUMMARY TABLE GALLEY DATA

	I		II		III		IV		V	
	LB.	FT^3	LB.	$FT.^3$	LB	FT^3	LB	FT^3	LB.	FT^3
Food & Primary Packaging	83.38	2.68	100.56	2.35	144.0	7.24	181.33	7.68	223.4	7.76
Equipment Total	18.1	3.21	27.0	2.94	88.9	11.7	120.	12.8	224.	14.6
Galley Installation	16.6	4.61	14.6	4.0	47.6	12.9	61.8	17.2	65.1	18.1
Total Galley (less food)	34.7	7.8	41.6	7.0	136.5	24.6	182.	30.0	289.	32.7

3.3.2 System Selection

Figure 3.3.2 presents plots of the hedonic acceptance ratings versus the weight and volume penalties for each alternate food system. Both curves reach the point of diminishing returns at System III. System III was selected for the Space Shuttle Food System. The remainder of Section 3.0 of this report is a detailed description and summary data presentation of System III.

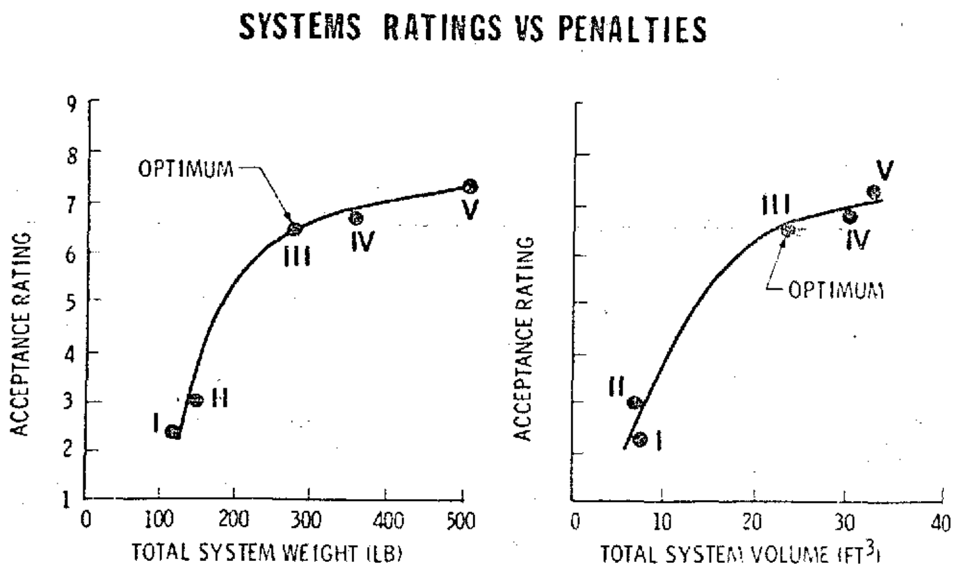


Figure 3.3.2 Plots of Hedonic Acceptance Ratings versus weight and volume penalties for the alternate food systems.

3.4 Provide for Food

3.4.1 Food Items

The food items selected for the Space Shuttle Food System are presented in Table 3.4.1 . These items were selected from lists of food items included in previous space missions, and from surveys of restaurant and institutional menus. They represent a wide variety of commonly accepted food items.

The item list has been screened to ensure compatibility with the allowable processing modes of the recommended food system, which are those modes which produce dry Ready - to - Eat (RTE) or dry rehydratable food items.

The list includes items which are not currently flight qualified, and so represents an opportunity to increase the variety and acceptability of current flight menus while incurring no added vehicle penalties.

TABLE 3.4.1

CANDIDATE FOOD ITEMS FOR

SPACE SHUTTLE FOOD SYSTEM

applesauce
strawberries
raspberries
cherries
blueberries
peach ambrosia
apricots
pineapple
shrimp cocktail
fruit cocktail
German potato salad
cole slaw
egg salad
apple juice
orange juice
pineapple juice
milk
lemonade
grape drink
cherry drink
nutritionally complete
    milk shake
grits
mashed potatoes
mashed sweet potatoes
pea soup
Chili with meat
chop suey
pork & scalloped potatoes
veal and BBQ sauce
pot roast
roast breast of chicken
scrambled eggs
Canadian bacon & applesauce
sausage patties
beef hash
macaroni/cheese
chicken a la king
turkey a la king
spaghetti/meat sauce
chicken stew
beef and gravy
chicken and rice
lobster bisque
diced beef
beef and rice
beef with vegetables
chicken and gravy
chicken and vegetables
noodles au gratin
Boston clam chowder
asparagus
green beans
wax beans
cauliflower
creamed peas
cream style corn
macaroni/beef
pudding
spiced fruit cereal
cornflakes
Rice Krispies
toasted oat cereal
spiced oat cereal
Grape Nuts
shredded wheat
raisin bran
raisin custard
chicken salad spread
tuna salad spread
salmon salad spread
instant breakfast
grapefruit drink
strawberry drink
tomato juice
fruit nectar
vegetable cocktail
cranberry/apple juice
cream of wheat
oatmeal
cream of rice
tomato soup
baked fish fillet
lobster tail
meat loaf
BBQ chicken
breaded porkchop
hamburger pattie
roast beef/mushrooms
Manhattan meat roll
veal loaf
roast veal
beef roll-em-ups
ham loaf
omelet/chicken or ham
ham slice
cheese omelet
hot beef sandwiches
hot turkey sandwiches
turkey supreme
sea food au gratin
chicken rosemary
baked chicken Maryland
corned beef
creamed chicken on toast
turkey roll/mushrooms
vegetable with rice
cream of mushroom
cream of asparagus
cream of chicken
cream of celery
chicken gumbo/rice
vegetable beef barley
peas and carrots
beets
brussel sprouts

yams
squash
broccoli
spinach
chicken cacciatore
frankfurters
ham/scalloped potatoes
corned beef/noodles
BBQ meat loaf
beef ragout/noodles
Shrimp Louie
meatballs/sauce
corned beef hash
veal scallopini
shrimp chow mein
veal stew/noodles
chicken chow mein
egg foo yung
cream of potato
pea soup
turkey rice
corn chowder
Romaine
chicken and rice
beef stew
chop suey/rice
beef stroganoff
chicken tetrazzini
dried apples

beef bouillon
chicken bouillon
tea
biscuits
cheddar cheese crackers
figurines
cereal bars
cookies
brownies
fudge
beef jerky
dried pears
cocoa
coffee
gingerbread
fruit cake
nut bread
crackers
muffin
bacon bars
nuts
dried peaches
toast
salt
pepper
other spices
mustard, catsup
horseradish
dried pears

3.4.2 Menus and Dietary

Menus were constructed from the food item list of section 3.4.1 in such a way as to reflect the item frequency commonly found in earth type eating patterns, that is, eight beverages, four RTE Items and seven rehydratables per day. This leads to fewer packages and slightly greater portion sizes than in previous missions. The menus were constructed to represent the range of crew size, mission duration and menu cycle length shown in Table 3.4.2 .

Table 3.4.2 Shuttle Menu Parameters

Mission Alternate	Crew Size	Mission Duration	Menu Cycle Length
1	4 Men	10.5 Days	3 Days
2	4	10.5	4
3	4	10.5	5
4	4	10.5	6
5	4	10.5	7
6	6	7	3
7	6	7	4
8	6	7	5
9	6	7	6
10	6	7	7

3.4.2 Cont'd

The average portion sizes required to provide 3000 Kcalories per man/day with the number of items per man/day represented in the menus was calculated using average nutritional data for each item of the menus. The calculated averages are:

Beverage Powder	35 grams
Ready-to-Eat Items	47 grams
Entree's	211 grams

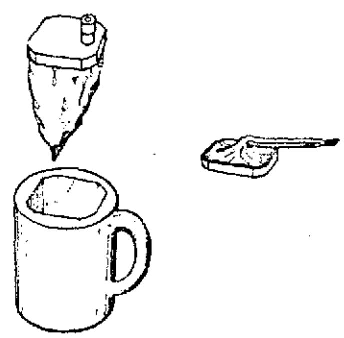
The rehydratables average 1.94 ounces dry weight and require an average of 5.46 ounces of water for reconstitution.

Several sources of variation can be recognized at this point. An individual may elect a menu of a different caloric density from the average, and hence a different food weight per man/day. He may elect rehydratables requiring an amount of reconstitution water other than the avarage 5.46 ounces. This will alter the water requirements on the system. For nutritional or other reasons individual items will vary from the average weight. It is not possible to deal at this point with these variances in an exact way. It was shown in the body of the study that the averages provided above are nutritionally adequate. For the average menu it is the task of the dietetics branch of the ground support system to ensure that each crewman's specific menu is both nutritionally adequate and falls within the physical stowage constraints of the galley.

3.4.3 Primary Packaging

There are four basic containers required for the stowage and preparation of food items in the Shuttle Food system: Beverage container, dry RTE container, Rehydratable container, and condiment container. The dry RTE container will also serve the contingency food items.

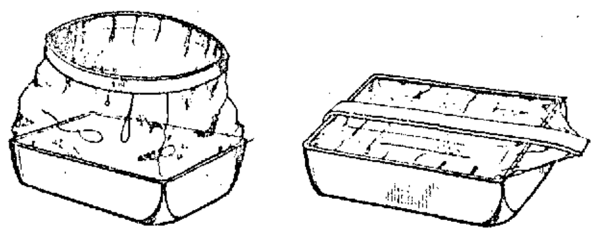
3.4.3.1 Beverage Container



The basic structure is a laminate pouch similar to the Apollo beverage container. There are two principle changes. The mechanical valve is substituted by a needle and septum rehydration system, and the pouch is designed to be retained within a reuseable insulating jacket. The pouch is vacuum packed and folded for compact stowage. The septum system requires a compatible demand-type valve to operate as the "straw" for withdrawal of liquid from the container. The insulating sleeve facilitates handling of hot beverages.

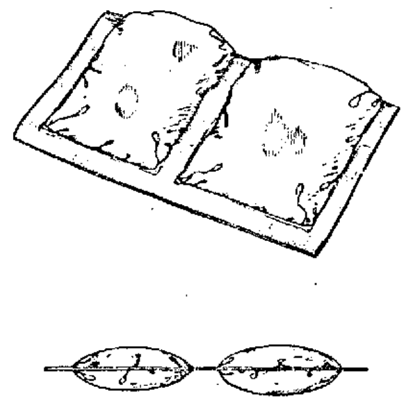
An alternative container would be the Apollo type pouch with the needle-and-septum type rehydration valve, but without the reuseable insulated jacket. The stowage hardware was sized for the proven Apollo type flexible pouch.

3.4.3.2 Rehydratable Container



The rehydratable container is a shallow bowl of rigid laminate, with an upper portion of flexible laminate. The top edge of the flexible film is sealed to two stiff polyethylene strips, which

3.4.3.4 Condiment Container



The condiment container is a square fin-sealed pouch of flexible laminate, with an additional seal through the center to form two separate servings of liquid condiment.

3.4.3.5 Rehydration System

The recommended rehydration system for the beverage and rehydratable containers is a system of the needle-and-septum design. This design better meets the performance criteria than valves of a mechanical design. The design is cheaper, easier to attach to the package, more reliable, more hygienic, and presents a greater barrier to passage of air and food matter.

3.4.4 Mission Impact

The data and tables of this section present the data necessary to assess the mission impact of the food and primary packaging in terms of weight, volume and water requirements.

3.4.4.1 Food and Primary Packaging.

Table 3.4.4.1
Item Weight and Stowage Dimensions

Item	Weight (Food & Package)	Stowage Dimensions
Beverage	1.73 oz.	3.0" x 4.5" x 0.28"
Dry RTE	1.90 oz.	2.0 x 4.0 x .56
Rehydratable	2.44 oz.	4.0 x 4.0 x 1.03
Condiment	1.55 oz.	3.5 x 1.5 x .25
Contingency	2.90 oz.	2.0 x 4.0 x 0.94

Food Consumed Per Man/Day (as stowed, dry weight)

Maximum - 2.38 lbs.

Nominal - 1.88 lbs.

Minimum - 1.55 lbs.

Average Mission Stowage

144 lbs. per mission (Food & Primary Packaging)

11.6 lbs. per mission (Contingency Items)

7.24 cu. ft. per mission (Food & Primary Packaging)

480 cu. in. per mission (Contingency Items)

3.4.4.2 Water Requirements

Table 3.4.4.2a

Water Requirements Per Man/Day

	Hot (149°F)	Cold (50°F)
Maximum 7.98 lbs.	4.47 lbs.	3.51 lbs.
Nominal 4.95 lbs.	2.72 lbs.	2.23 lbs.
Minimum 2.82 lbs.	1.13 lbs.	1.69 lbs.

Table 3.4.4.2b

Water Requirements, Total Real-time

	Hot (149°F)	Cold (50°F)
Maximum 15.41 lbs.	8.63 lbs.	6.78 lbs.
Nominal 9.52 lbs.	5.24 lbs.	4.28 lbs.
Minimum 5.75 lbs.	3.45 lbs.	2.30 lbs.

3.5 Stowage

Results of stowage analysis of on board versus on-ground menu choice show that a system providing for on-ground preselected and packaged menus will impose the least weight and volume penalties on the mission. A detailed analysis supporting this statement is presented as Appendix D of volume II of this report.

This section will discuss the systems engineering criteria and decisions leading to the definition and sizing of the system III stowage equipment. Detailed analysis supporting the summary data for system III is presented as Appendix H of volume II of this report.

3.5.1 Food Type and Quantity Requirements

The beverage (Bev), rehydratable (Rhyd), and ready-to-eat (RTE) foods chosen for system III must be supplied in minimum required quantity plus overage of approximately 5%. This overage approximation allows for extra food items per day on an ad-lib basis and the use of otherwise unutilized volume when the required food quantities would not stack evenly. Resulting quantities are Bev(357), RTE (217), and Rhyd (308).

3.5.2 Location

It was decided early in the analysis to provide the most compact and efficient galley design. This requires food stowage either immediately adjacent to or within the galley module. Complete analysis of dimensional volume requirements and installation penalties for the complete food system showed that sufficient volume was available for the six man seven day food supply contained in four food logistics liners.

3.5.3 Configuration Management

The trade-off between on board versus on-ground menus choice having been decided in favor of pre-flight menu choice, left the choice of crew meal versus individual meal pack configuration. The efficiency of packaging six man meals together in one overwrap over packaging six overwrapped meals is quite apparent. It was soon realized that a greater efficiency could be achieved by packaging food according to type in six man meal quantities as breakfast, lunch, and dinner overwraps.

Further dimensional analysis revealed that additional efficiencies could be obtained stacking the Bev and RTE foods together as a unit while stacking the Rhyd foods as a separate unit. This established the basis for development of Bev/RTE liners and Rhyd food liners which are prepackaged on the ground and carried aboard the vehicle for stowage within the galley structure. Typical stacking and crew meal configuration arrangements are shown in Figures 3.5.3a,b

Figure 3.5.3 c,d show the typical Rhyd and Bev/RTE 1 Day overwraps respectively.

3.5.4 Stowage Equipment

The typical liner detail shown in Figure 3.5.4 is applicable to the two Bev/RTE liners and two Rhyd liners. Only the relative height will change as the result of being designed as a three or four day liner. The liner support and guide detail depict typical galley structure capable of accepting and securing the food stowage and logistics liner.

REHYDRATABLES (ONE DAY SUPPLY)

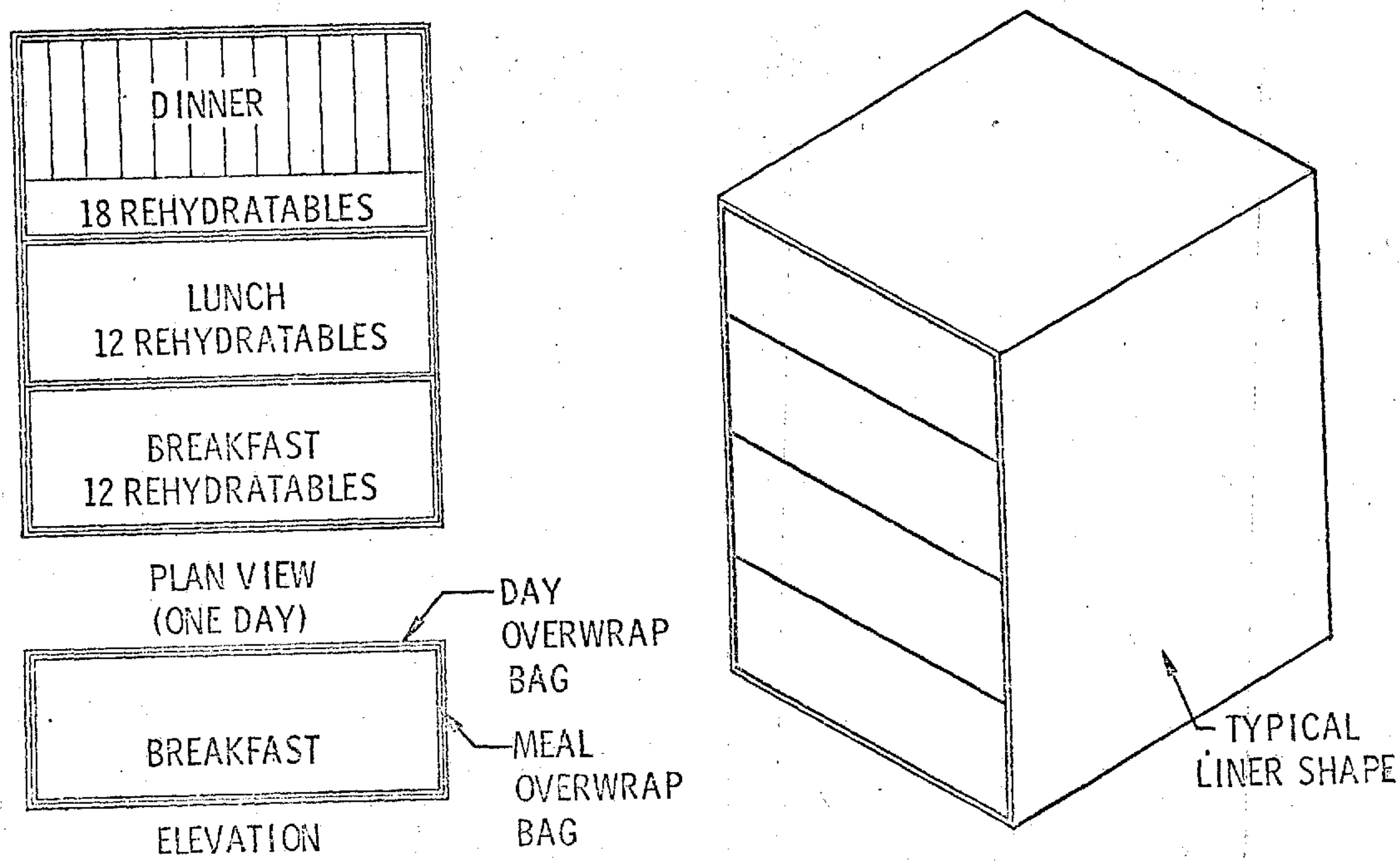


Figure 3.5.3a
Crew Meal Packaging Plan, Rehydratables (one day supply)

BEV & RTE ONE DAY SUPPLY

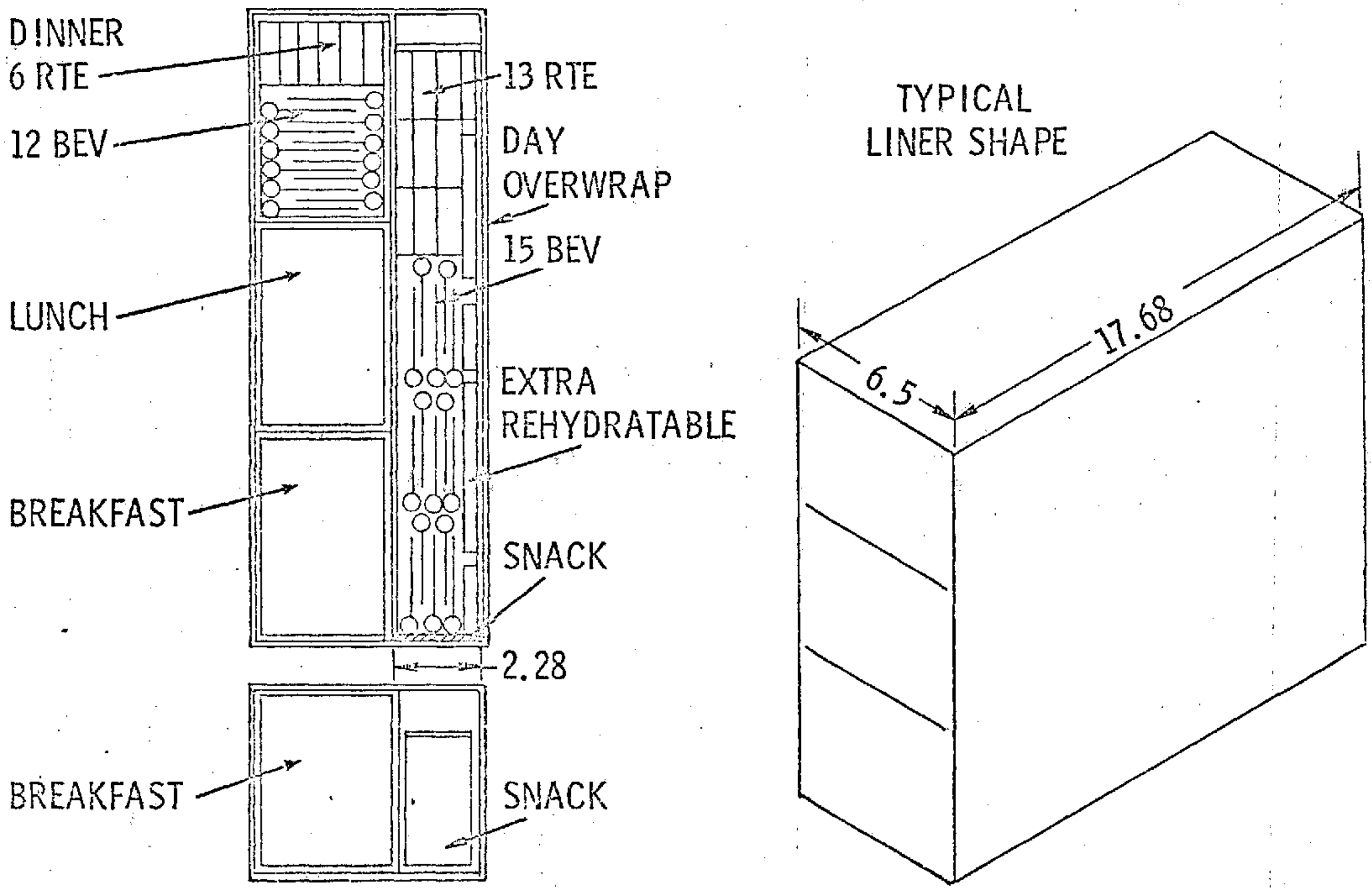


Figure 3.5.3b
Crew Meal Packaging Plan, Beverage and RTE Items (one day supply)

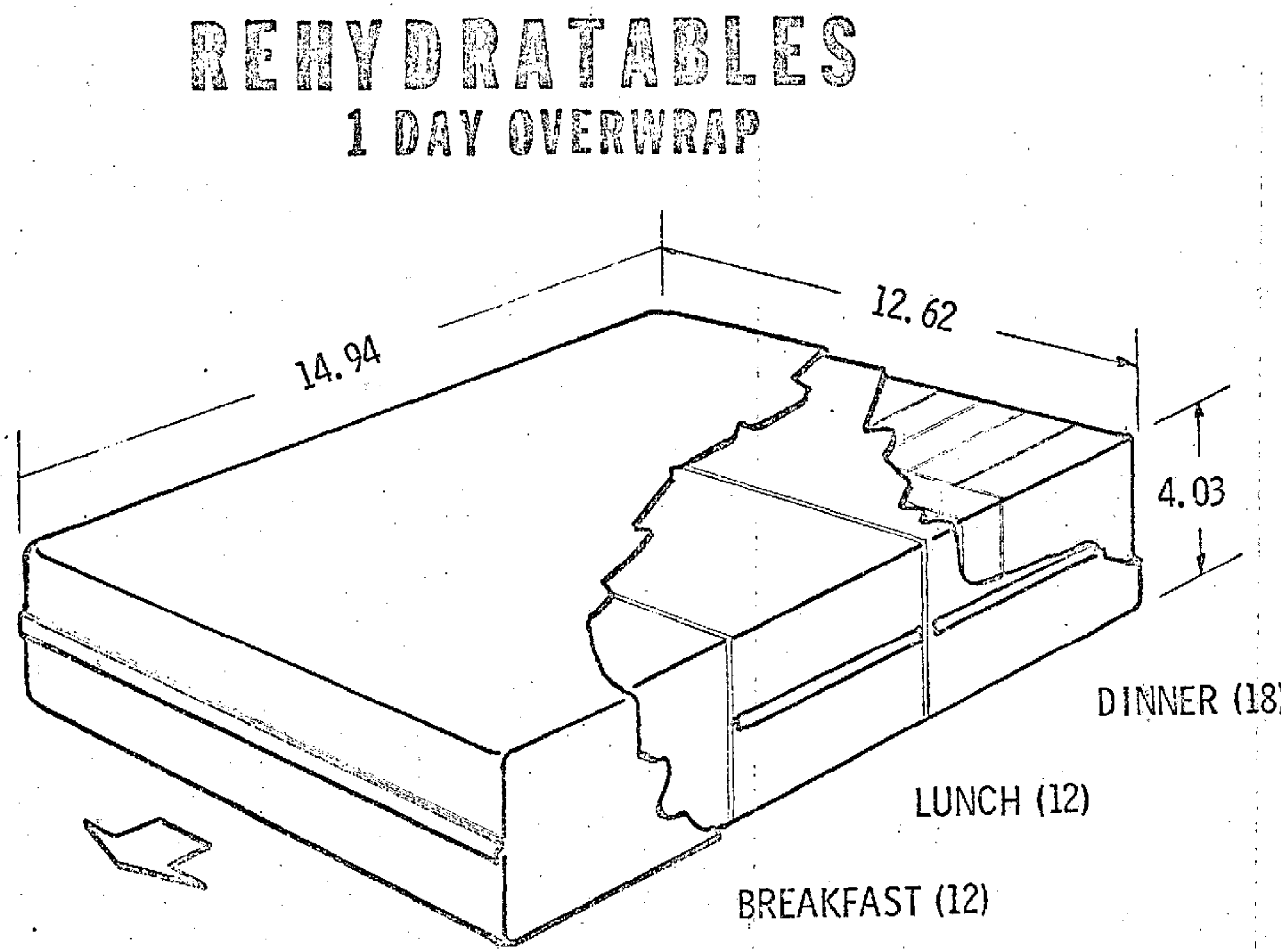


Figure 3.5.3c

Rehydratables, one day overwrap

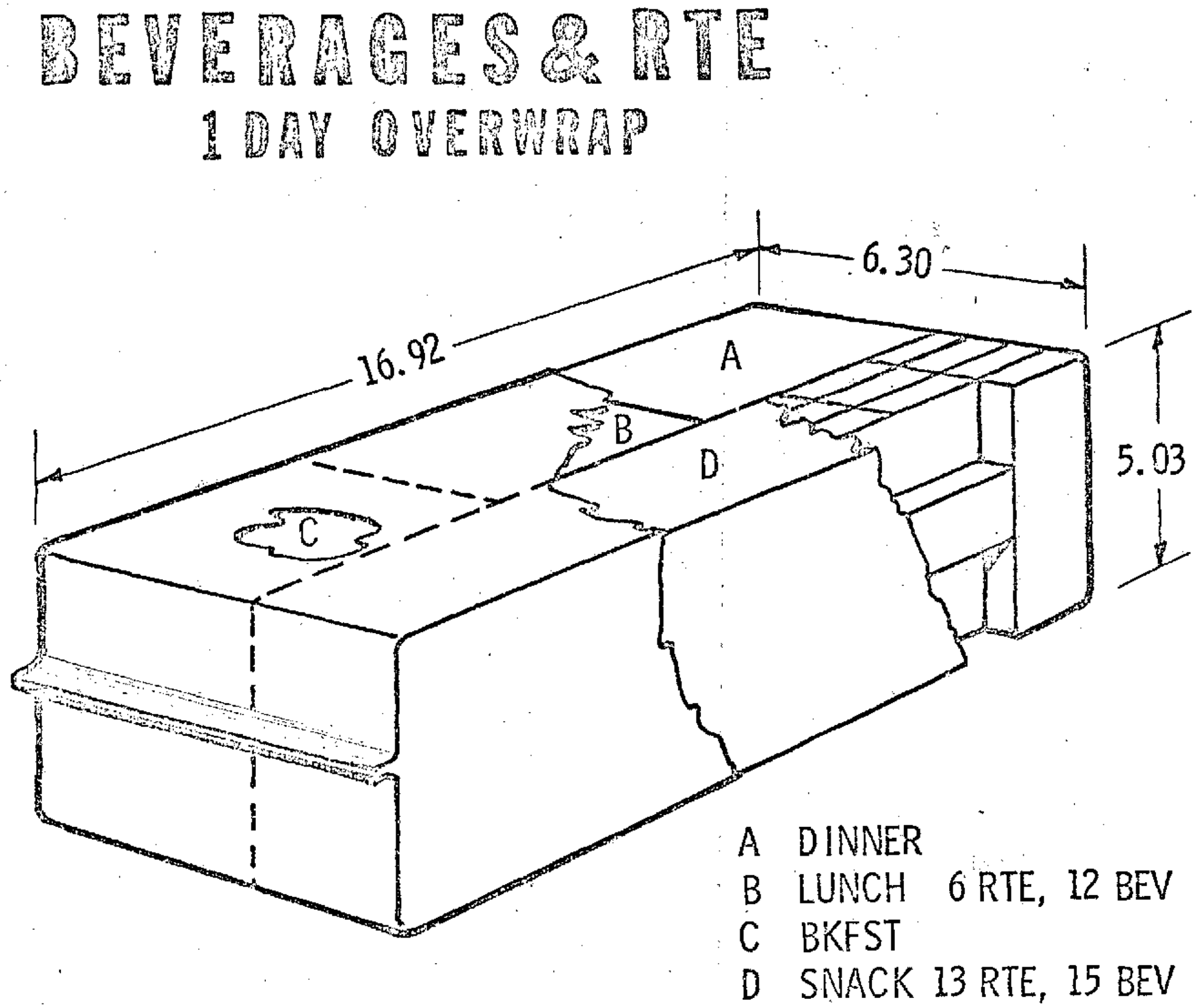


Figure 3.5.3d
Beverages and RTE, one day overwrap

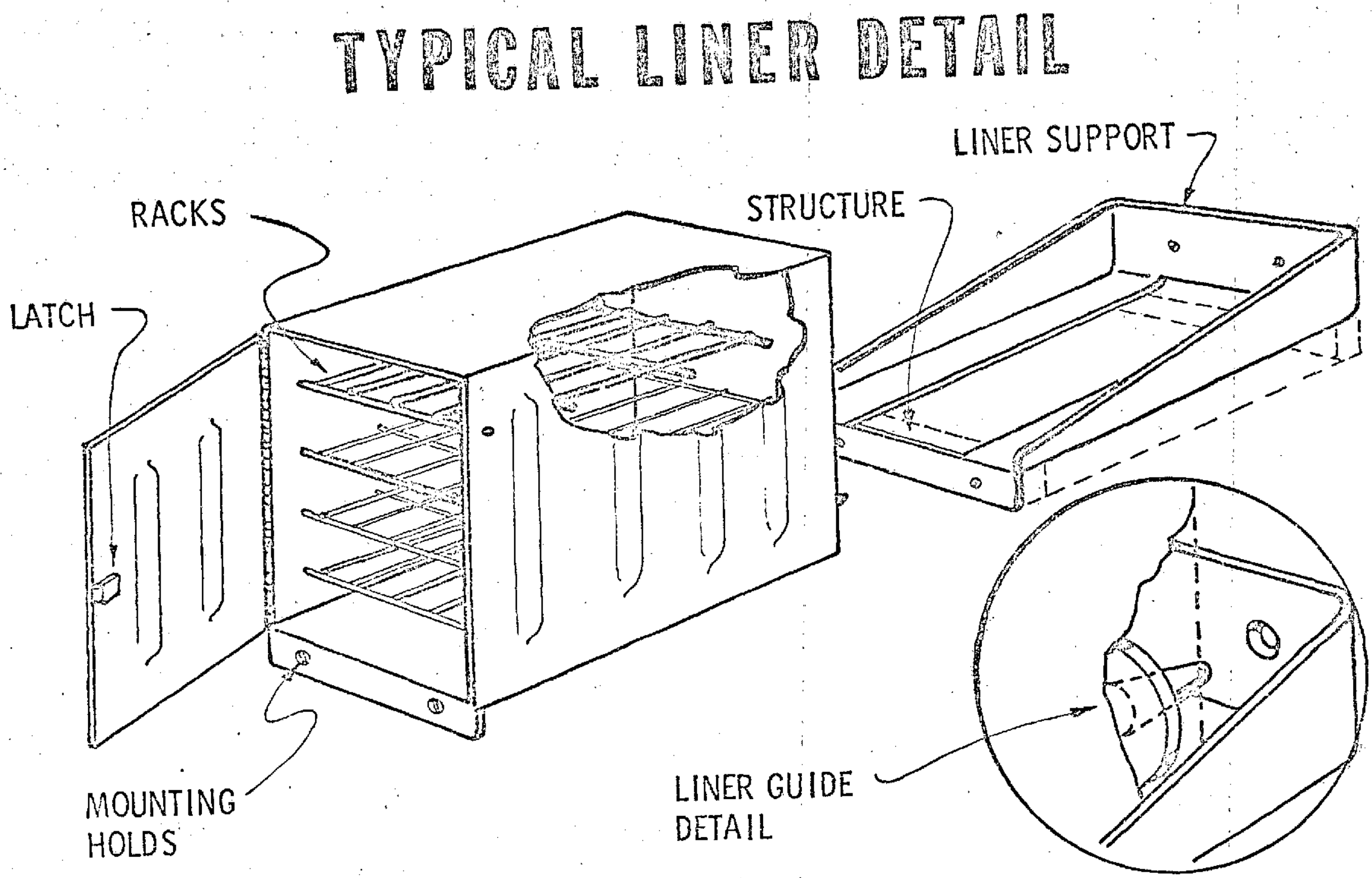


Figure 3.5.4

Typical Liner Detail

3.6 PREPARATION

Preparation of meals for six men is accomplished by one crew member who performs all the functions of preparing a crew meal. These are removal of food from storage, rehydration and meal assembly in preparation for serving. These functions are accomplished most efficiently with the aid of a work area for unpackaging and menu components assembly, a rehydration station providing required quantities of hot and cold water at $\dot{\omega}$ = 60 lbs/hr., a semi-active holding oven providing a constant temperature of 149°F, and hot insert trays for retention of hot food items in the oven and on the serving trays. See Table 3.6a

The efficiency of preparation is determined by minimum crew time, food safety, minimum system penalties, and food acceptance. The analysis of three heating techniques summarized in Table b below shows the passive system to set the minimum crew time and system weight, volume and power. It does not, however, provide for holding food at microbiologically safe temperatures which is felt to be an important consideration worth making in accepting a higher weight, volume, and power penalty associated with the semi-active holding oven.

TABLE 3.6a

ONE MAN PREPARATION SUMMARY

Task	Description (Quantity)	Requirements	Equipment
Unstow Crew Meal	Rehyd Overwrap (1) Bev/RTE Overwrap (1)		Bag retention on work surface
Rehydrate	Entrees and Side Dishes (1-3/man meal)	$\dot{\omega}$ = 60 lb/hr., 160°F	Hot water system
	Beverages (2/man meal)	$\dot{\omega}$ = 60 lb/hr., 45°F/160°F	Cold water system
Assemble	Entrees and Side Dishes (1-3/man meal)	Assemble as man meal - Hold at 149°F	Hot insert tray Work surface interface Holding oven
	Beverages (2/man meal)	Assemble as man meal	Work surface interface Serving tray interface

TABLE 3.6b

HEATING TECHNIQUES SUMMARY

Technique	System	Meal Timeline	System Weight	System Volume	Power
Passive	Ins. Jacket	93.6 Min.	17.0#	2.5 Ft^3	.248 KW
	Ins. Tray	86.2 Min.	15.7#	2.0 Ft^3	.256 KW
Semi Active	Oven	82.2 Min.	37.4#	3.2 Ft^3	.301 KW
Active	Hot Air Oven	102.7 Min.	75.5#	3.5 Ft^3	1.63 KW
	Microwave Oven	-	152.1#	3.5 Ft^3	1.8 KW

Includes Supporting Equipment and Penalties

3.6.1 Need to Heat

- Mission requiring six crew men to eat at same time
- Microbiological safe food temperature
- Enhance rehydration time
- To permit food to be eaten at accustomed temperature by all crew members at the same time. This will establish maximum acceptance of crew meals.

3.6.2 Method to Heat

The semi-active oven was one of three heating techniques studied. Results of that study are summarized in Table 1 above. Complete analysis of the passive, semi-active, and active heating systems can be found in Appendix B of Volume II of this report.

3.6.3 Preparation Procedure

- Obtain food packages and assemble heatables in hot insert sections of tray and balance in serving sections
- Open packages and unpack valves
- Add hot water to all packages in one insert
- Knead packages and restow in insert
- Place insert in oven
- Repeat for subsequent inserts

3.6.3.1 Rehydration Sequence

- In the order of rehydration times:

  Entree; Side Dishes; Soups/Desserts; Beverages
- Entree at Lowest temperature is most critical

TABLE

SEMI-ACTIVE SYSTEM - HOLDING OVEN

INDIVIDUAL MEAL PREPARATION TIME

$\dot{\omega}$ = 60 lbs/hr. = 16 oz/min.

TASK	Operation Time	Cumulative Time	Cululative Time + Rehydration Time
Obtain, Assemble, Open 3 Food Pkgs/Insert	.75 min.	.75	–
Add Water to Entree	.28	1.03	21.03
Add Water to Side Dish	.38	1.41	16.41
Add Water to Side Dish	.38	1.79	16.79
Knead Contents	1.50	3.29	–

3.6.3.2 Thermal Analysis

- Entree' cools to cabin during water addition, kneading and preparation of subsequent packages in an insert

3.6.3.3 Preparation Time Line

The complete system time line for one man preparation and clean up and six man dining is presented in Figure 3.6a This is based upon hot and cold water flow of 60 lbs/hr. and operations as shown in Table 3.6.3.1

3.6.4 Preparation Equipment

Preparation equipment system penalties summarized in Table 4 below are based upon analysis of the System III food system. Complete detailed analysis of Systems I through V can be found in Appendix B of Volume II of this report.

TABLE 3.6.4

PREPARATION EQUIPMENT

SYSTEM PENALTIES SUMMARY

	WT	VOL
Water Systems-Hot and Cold	*19.2 lb	0.78 FT^3
Trays - Complete	11.6 lb	1.17 Ft^3
Semi-Active Oven	15.6 lb	1.65 Ft^3
Work Surface	2.7 lb	0.78 Ft^3
TOTAL	49.1 LB	4.38 Ft^3

*Weights and volume 130% of calculated to allow for growth and contingency

3.7 Serving

Prior to the time for serving, the meal preparer has removed the serving trays from storage within the galley, magnetically coupled them onto the vertical work surface galley doors, and assembled the meal components and hot insert from the oven onto the tray. The most effective method of serving is to have each crew member come to the galley, remove his color coded meal tray from the vertical work surface door, and return to his dining station.

3.7.1 Serving Tray

The meal assembly and serving tray provides for assembly of a complete meal plus wipes, condiments, utensils, and a waste stabilizer packet (WASTAT). Dimensional data for the tray is presented in Table 3.7.1a

TABLE 3.7.1a

SERVING TRAY SUMMARY

	Dimensions (In.) W	x D	x H	Area (In^2)	Volume (In^3)
Overall	11.5	14.3	1.62	164.4	266
Insert Tray	5.2	12.9	1.2	67.1	80.5
Drawer	5.0	7.6	1.0	38.0	38.0
Utensil Surface	4.7	7.0		32.9	-

3.7.1.1 Hot Insert Tray

The hot insert tray shown in Figure 1 is a detachable rectangular unit sized to contain one to three rehydratable food package types. Its design and construction permit interface with the serving tray, galley work surface drawer, and the holding oven.

3.7 Cont'd

3.7.1.1 Cont'd

The hot insert tray is normally stored as part of the serving tray. During preparation it is removed from the serving tray and attached to the galley work surface drawer. During rehydration, one to three individual rehydrated food packages are assembled into the insert tray. The tray is then inserted via track guide into the holding oven to allow for food reconstitution and temperature maintenance. On demand, the hot insert tray can be removed from the oven, attached to the otherwise assembled serving tray and passed on to the crewman.

3.7.1.2 Utensil Drawer

The utensil drawer is a permanent part of the serving tray, taking advantage of an otherwise unused volume. It is 1.0 in. deep with a 5.0 x 7.6 in. magnetic floor surface sufficient to securely stow a conventional spoon, fork, and tape scissor. The drawer is normally closed.

3.7.1.3 Utensil Surface

A magnetic surface area of 32.9 in.^{2} (4.7 x 7.0) is provided for positive retention of utensils during tray transport and dining.

3.8 CONSUMPTION

To provide for consumption in the zero gravity environment we consider the food types and its packaging and how best to provide for the transfer of food from its package to the consumer. It has been well established that the individual can utilize the standard spoon and fork for transfer of solid cohesive foods in the zero-g environment. For liquid transfer, the squeeze package has thus far been proven most successful.

3.8.1 Food Types

The three types of food selected for the Shuttle Orbiter System III are Beverage, Ready to Eat, and Rehydratable. The Beverage and RTE impose no requirement for eating utensil but do require a scissor for opening the package. The Rehydratable food reconstituted in the 4 x 4 rectilinear package cannot be removed from the package except by utensil.

3.8.1.1 Beverage

After reconstitution and valve cutoff, the beverage package itself provides the vehicle and implement for consumption. The stemmed bag is rectangular in cross section and collapsible permitting hand held positive pressure delivery of contents through the steim to the consumer. The only requirement for utensil here is the scissor with which to separate valve from the steim. Beverage package surfaces will not exceed touch temperature.

3.8.1.2 Ready to Eat (RTE)

The RTE foods are rectangular, single layer packaged, sized to be hand opened and hand held while consuming in small bites. No utensils are required for RTE foods.

3.8.1.3 Rehydratable

The crew man encounters the rehydrated food positioned in the hot insert portion of the tray. The package surface is folded over such that the crew man lifts a tab on the top surface, pulls the material up into a tent shaped configuration with each end folded in. When the top of the tent shaped package is cut off the package opens to a full rectilinear column exposing the entire surface of the rehydrated food for access with a spoon and/or fork.

3.8.2 Utensil Stowage

The standard fork and spoon plus a small tape scissor are stowed on a magnetic surface in the utensil stowage drawer in the serving tray. (See Section 3.7.1.2). Utensil and stowage drawer dimensions are presented in Table 3.8.2.

3.8.2 Cont'd.

TABLE 3.8.2

UTENSIL DIMENSIONS* (In.)

	W	L	H
Fork	1.00	7.25	0.75
Spoon	1.30	6.00	0.75
Scissor	1.95	6.30	0.25
Drawer	5.0	7.6	1.0

*Maximum dimension

3.9 TRASH CONTROL

The Shuttle Orbiter galley is self contained for clean up and trash control. Personal and galley wipes are provided for personal hygiene and cleaning of trays, utensils, and surfaces. Waste stabilizer packets (WASTATS) are provided for chemical stabilization of food wastes. Trash volume containment is provided for by a one-day trash liner and reuse of otherwise unoccupied food stowage volume on mission days succeeding the first.

3.9.1 Trash Generation

Trash types generated as result of the Shuttle Orbiter Feeding System functions are summarized in Table 3.9.1

3.9.1 Cont'd

TABLE 3.9.1

TRASH GENERATION

Function	Trash Type
Stowage	-
Preparation	• Water Spills • Empty Food Stowage Bags
Serving	-
Consumption	• Beverage Packages • Ready-to-Eat Packages • Rehydratable Packages • Dry Food Spills • Wet Food Spills • Personal Wipes and Packets • Condiment Packets
Clean Up	• WASTATS • Galley Wipes and Packets

3.9.2 Trash Quantity and Volume Efficiency Ratios

Table 2 presents the trash quantities generated over the total mission. Adjacent to the trash quantity in parentheses is a fraction. This fraction is the ratio of trash stowage volume to initial launch stowage volume. The (1/1) ratios for the leverage package and rehydratable food package are very generous and thus permit flexibility in the overall analysis, i.e., putting WASTATS and condiment packets in the rehydratable packages. The (.25/1) ratio for the RTE package more than allows for stowage of all wipes and their associated packages in the RTE Launch Volume.

3.9.2 Cont'd

TABLE 3.9.2

MISSION TRASH QUANTITIES

Trash Type	Quantity
Empty Food Stowage Bags	42 (1/1)
Beverage-Packages	357 (1/1)
Ready-to-Eat - Packages	217 (.25/1)
Rehydratable-Packages	308 (1/1)
Wipes	210 (.25/1)
Packets (Wipes, Condiments, WASTATS)	473 (.25/1)

3.9.3 Trash Collection

The bulk of the trash will be generated during consumption as shown in Table 1 above. This trash is readily contained on the serving tray and is transferred back to the galley on the tray upon completion of consumption. Trash generated during preparation consists of wipes to clean spills and empty food stowage bags. Those empty bags will act as receptacles for the used wipes until after consumption when the serving trays are returned to the galley.

3.9.4 Clean Up

One individual crew member can most efficiently perform the clean up tasks of the Shuttle Orbiter food system galley. These tasks are detailed below:

1) Remove food packages from trays and place them into food stowage bags from which they came, i.e., beverage pack to Bev/RTE bag.

2) Remove wipes and accessories packets from tray and place them in food stowage bags ad lib.

3.9.4 Cont'd

3) Obtain galley wipes (1 per tray) and

- Clean utensils and place in utensil drawer
- Wipe tray surface
- Place wipe and packet in food stowage bag
- Repeat process for remainder of trays

4) Seal food stowage bags by removing protective tape and pressing flaps together.

5) Stow these bags according to following schedule

Day one - 2/meal trash filled food stowage bags are placed in trash liner drawer

Days two thru seven - 2/meal trash filled food stowage bags are placed according to type in day overwrap bags emptied on the previous day.

6) Seal filled day overwrap bags.

Clean Up Equipment

A summary of clean up equipment required to support the shuttle orbiter food system galley is presented in Table 3.9.4.

3.9.4 Cont'd

TABLE 3.9.4

CLEAN UP EQUIPMENT SUMMARY

Item Description	Quantity	Support Hardware
Packages		
Beverage - Flexible top	357	Bev/RTE Logistics Liners
RTE-Rectangular 4 x 4 in. base Foil Wrap	217	Bve/RTE Logistics Liners
Rehydratable - Flex 3 x 5 in	308	RHYD Logistics Liner
Condiments-Foil Packed	352	Dispenser 7 in x 12 in x 2 in
WASTATS-Foil Packed	126	Dispenser 7 in x 12 in x 2 in
Wipes		
Personal (4.5 x 6) in	168	Dispenser 5 in x 5 in x 12 in
Wet Wipes Foil Packed Galley (12 x 12) in	42	Dispenser 6 in x 3 in x 7 in
Zephiran R Wet Wipes Foil Packed		

3.10 GALLEY MOCKUP

The galley mockup is a metal and wood framed semi-functional unit representative in size and function of the on-board shuttle orbiter food system facility. The six-man seven-day galley summarized in Table 1 is a completely self contained facility for food stowage, meal preparation, serving, cleanup, and trash containment. Its overall dimensions are:

Width:	23 in.
Height:	78 in.
Depth:	22 in. Ceiling
	27 in. Midsection
	16 in. Floor

TABLE 3.10

SYSTEM III GALLEY SUMMARY

	Lb.	Ft^3
Food and Primary Package	144.0	7.24
Logistics Liners	31.1	7.60
Water System - Hot and Cold	19.2	0.78
Wipes and Dispensers	9.75	0.30
Utensils - 6 Sets	1.70	0.14
Trays	11.6	1.17
Semi-Active Oven	15.6	1.65
Equipment Totals	88.9	11.7
Food Lockers	14.2	3.97
Equipment Installation Structure	6.73	1.80
Utensil Stowage	0.39	(Trays)
Tray Stowage	2.08	0.39
Trash Stowage	20.9	5.85
Work Surface	2.73	0.78
Miscellaneous Hardware	0.52	0.13
Galley Installation	47.6	12.9
Total Galley (Less Food)	136.5	24.6

3.10.1 Food Stowage/Logistics Liners

- Two Rehydratable food liners
- Two Beverage/Ready-to-Eat (RTE) food liners

3.10.1.1 Stowage Configuration

- Four day liners, upper section of galley
- Three day liners, lower section of galley

3.10.1.2 Packaging Configuration

- Overwrap bag (4 or 3 per liner) contains crew breakfast, lunch, and dinner overwrap bags (crew day overwrap)
- Individual color coded menus are prepackaged in breakfast, lunch, and dinner overwrap bags (crew meal overwrap)

3.10.2 Trays - Stowage and Use

- Tray stowage compartment sized for six complete trays
- Magnetic coupling of trays to zero "g" work surface doors

Tray Features

- Utensil stowage drawer
- Detachable hot insert tray
- Magnetic utensil surface area
- Retention slots for RTE and Beverage Meal components
- Retention slots for wipes and WASTATS

3.10.3 Meal Preparation and Assembly

- Hot insert tray interfaces with serving tray work surface and holding oven
- Menu components and accessory items are assembled directly on to hot insert or serving tray
- Empty meal bags remain attached to work surface to become trash bags

3.10.3.1 Pull Out Work Surface Features

- Retention for six hot insert trays
- Beverage and RTE and meal accessory retention slots
- Attachment for crew meal bags

3.10.3.2 Holding Oven

- Sized to hold six hot insert trays
- Maintains food at safe temperature 149°F ± 6°F which enhances food flavor and reduces rehydration time

3.10.3.3 High Use Items Clustered at Hand Level

- Pull out work surface drawer
- Hot and cold water dispensers 160°F and 45°F, $\dot{\omega}$ = 60 lb/hr
- Semi-active holding oven
- Galley and personal wipes dispensers
- Condiments and WASTATS dispensers

3.10.4 Cleanup and Trash Control

- Trays returned to vertical work surface
- Empty packages transferred to empty meal bags
- Trays, utensils, and surface wiped clean
- Wipes transferred to empty meal bags
- Meal bags sealed

3.10.4.1 First Day Trash Control

- Six sealed meal overwrap bags, 2/meal transferred to pull out trash receptacle

3.10.4.2 Volume Recycling (Days Two thru Seven)

- Sealed meal overwrap/trash bags placed in previous day's stowage volume within the day overwrap bag within the logistics liner.
- Day overwrap bag is sealed when filled with three sealed meal overwrap/trash bags

3.10.5 Logistics

3.10.5.1 Liners

- Carry on food
- Carry off trash

3.10.5.2 Expendables

- Galley wipes, personal wipes, WASTATS, and condiments are packaged in dispensers accessible from front face of galley

3.10.5.3 Reusables

- Trays
- Utensils
- Handling equipment

3.11 Provide for Logistic Support

The Ground Support System serves the dual function of pre-flight feeding of flight personnel and the supply and control of the flight food system. Twelve major functional elements contribute to the efficient functioning of the Ground Support System: Administration, Dietetics, Analytical Labs, Flight Food Warehouse, Stowage Module Assembly Area, Launch-Site Module, Storage Area, Crew Galleys, Ground Food Warehouse, Manufacturing Facilities, Transport, and Computer Support. The functions, capabilities and facilities of each of these elements under baseline conditions were studied.

The following assumptions and requirements have been incorporated into the analysis.

1) Baseline Mission: 6 Men - 7 Days
2) 60 flights per year.
3) Ground System Sizing - 40 consumers maximum
10 -1 consumers minimum
4) Complete Nutritional Control
5) Real time, a la Carte choice from a large variety of food items.
6) 24 hour availability at all dining facilities
7) Support of Flight Food System
8) Training Facility for Flight Food System operation
9) Accommodate Foreign Nationals
10) High quality, restaurant-like dining with table service at main dining facility.
11) Minimum meal preparation time.
12) Support alert crew at any location.

The majority of the operations will be at JSC, Texas. There will be permanent facilities at each launch site and major landing site. In addition, there will be mobile facilities as needed to support the crew when removed from any of the permanent facilities.

The ground feeding system is designed around pre-cooked, frozen food items, formulated and packaged to be compatible with the boil-in-bag method of preparation. Additionally, such uncooked, refrigerated items as salads, desserts, breads and beverages will be made available. It is recommended that added versatility in preparation methods be provided by developing food items which can be reconstituted in a microwave oven as well as in boiling water.

Sufficient support facilities and personnel will be provided to perform the following identified activities:

* Management and Program Interface
* Nutritional Control and Menu Planning
* Stowage Module Assembly and Storage
* Record keeping
* Acceptance Testing
* Warehouse Inventory Management
* Transportation and Shipping
* Alert-crew Feeding
* Crew Training
* Manufacturing
* Computer Support

4.0 System Assurance

4.1 Safety

The food and Primary Packaging manufacturing specifications will be written for the maximum consideration of crew safety. All packaging will be required to be vacuum sealed, in order to prevent the growth of microorganisms during storage and provide an effect indicator of package integrity, as well as to facilitate stowage and rehydration efficiency. All food items will be of sufficiently low moisture content to prevent the growth of spoilage or pathogenic microorganisms during stowage. No food items will be included in the stowage which require maintenance of refrigerated temperatures to control microbial growth.

Hardware items shall be designed for maximum human interface level consistent so with safe operation and utilization. Particular attention shall be paid to surfaces, closures, and restraints and sub systems. Finishes shall be smooth to provide for ease of cleaning and protection against trauma. Doors, drawers, latches, and interfaces shall be designed for ease of use consistent with safe handling. Restraint systems shall be consistent with accepted crew systems technology. Heating techniques shall insure temperature rise consistent with microbiological safety.

4.2 Reliability

Food items are highly reliable. Food items will be manufactured according to specifications in order to insure that the items will meet or exceed standards of nutrition and hedonic acceptability. Reliable performance of the food items is contingent on the reliable performance of the primary packaging.

The primary packaging will be designed and manufactured so as to prevent package material failure or separation of the package seals as a result of storage, preparation, consumption, or manipulation activities.

All non-expendable galley and food system component and subsystem shall be subjected to failure mode and effect analysis to insure reliability beyond the shuttle maximum requirements. Expendable components will meet or exceed mission reliability requirements.

4.3 Quality Assurance

A quality assurance inspection program will be instituted to routinely inspect food and primary packaging items received at the ground support system warehouse. A system of testing procedures will be developed to support acceptance decisions on received expendables. The Q. A. Program will routinely test representative samples of each lot through the time of warehouse storage, and a visual 100% inspection will be made at the time of stowage module assembly. All testing procedures will be included in the manufacturing specifications for food and primary packaging items.

4.3 Cont'd

For galley hardware components, general requirements for continuous quality assurance provisions through concept, preliminary design, fabrication, and delivery phases are set forth in the following chart.

Phase	Q A Activities
Concept Phase	• Assure adequate screening • Review concepts as requirements change.
Preliminary Design	• Track preliminary design sketches and drawings through engineering release system. • Parallel tracking of interface requirements. • Scheduled reviews of preliminary designs, problems, and solutions. • Coordinate with vendors for supply, inspection, and tracking procedures.
Design & Fabrication	• Inspection of purchased and processed parts for conformance with specifications, drawing, and tracking. • Establish logistics and spares requirements.

4.2 Cont'd

Phase	Q A Activities
Pre delivery	• Inspection for conformity with assembly drawings, interface, tracking, and spares requirements.
Delivery	• Installation and checkout

5.0 Conclusions and Recommendations

The Food System detailed in this report meets all of the Food System requirements currently identified for the Space Shuttle Program.

The system will deliver a highly acceptable, varied menu from a permanent control galley aboard the vehicle. This is a cost effective system with minimum penalties to the weight-and volume-critical shuttle orbiter.

The system accomplishes this through the anticipated completion of several recommended development programs. These programs are described below.

A. Food System - Galley Mockup

Objective

Design and fabricate a semi-functional verification mockup that provides a galley arrangement based on the present Shuttle Orbiter mission definition of six men for seven days, updated RI/SD configuration constraints and Orbiter requirements, and determination of final primary food package sizing and definition studies.

Purpose

To provide a Shuttle-compatible working mockup of the recommended galley system which will demonstrate its basic operational, functional, and installation feasibility in the Shuttle Orbiter for the baseline mission requirements.

A. Food System - Galley Mockup Cont'd

Description

The primary functions of the verification mockup are to provide a realistic galley system configured to represent actual volumetric requirements within the Shuttle and to be utilized as an engineering tool in establishing preparation procedures, crew timelines, equipment servicing, ground handling interfaces and food stowage options. In addition, the mockup will be constructed so as to permit demonstration of the functional aspects of the system with respect to modular packaging, trash handling, equipment stowage and usage, and work surface access. The mockup will also be the demonstration vehicle for the complete Galley system and will provide a visual method for anticipating the impact of potential or recommended changes to the Galley.

B. Preliminary Interface Control Documents

Objective

Develop and prepare preliminary Interface Control Documents (ICD's) for the Shuttle galley system.

Purpose

To provide preliminary data defining required interfaces of physical and functional connections between the galley and Orbiter, so as to establish baseline requirements.

5.0 Cont'd

B. Preliminary Interface Control Documents Cont'd

Description

The preliminary ICD's are required at an early date to establish the galley impact and constraints with the Shuttle Orbiter. The interfaces to be defined include water, electrical and structural, and will be determined after a preliminary design effort.

The water system ICD will establish the vehicle water delivery requirements at the interface in terms of quantity and flow per unit time, temperatures and physical connection. A preliminary location of the inlet fittings will be determined based on minimum run lengths to preclude excessive temperature variations.

The electrical ICD will establish the type and amount of energy required to power the semi-active oven in the galley as well as any heaters within the hot water system. The size of electrical connector will be specified and the voltage, amperage, phase and cycles defined for the interface. A convenient preliminary location will be established based on location of the electrical equipment.

The structural ICD will establish the galley, attach points to the Orbiter structure, and define required loadings to be transferred to the Orbiter structure based on launch, reentry and landing conditions. Preliminary weights will be estimated for the galley and food for these conditions. The attach points will be selected based on optimum locations consistent with the galley design and compatible with the Orbiter installation of similarly constructed equipment.

C. Detailed Requirements Document

Objective

Develop and prepare a preliminary requirements document (end Item Specification) for the Shuttle galley system.

Purpose

To provide a preliminary galley specification defining the end item design requirements with respect to performance and physical parameters.

Description

The preliminary specification document defines the details of the galley system to a level and depth that would normally establish design, fabrication and testing requirements. The document will be a procurement type specification in format and arrangement and will outline all required data, including interface descriptions.

The specification will be based on the design effort described in the Work Statement for preparation of preliminary ICD's. Galley description, diagrams, major components identification, preliminary performance and physical characteristics, and a preliminary quality assurance approach for development, acceptance, assessment and certification, can be outlined. Specifics of design and construction, with respect to materials, parts and processes, traceability, maintainability, reliability, safety, and delivery requirements for example, will be left as TBD.

5.0 Cont'd

E. Food Specifications

Objective

Develop manufacturing specifications for each food item of the Space Shuttle Food System.

Purpose

To provide manufacturing specifications defining the food items with respect to performance and physical parameters.

Description

The manufacturing specifications define the ingredients and ingredients specifications, manufacturing process procedures and conditions, and the testing procedures required to insure the performance of each food item. This will entail verification of the manufacturing specifications of all currently flight-qualified items on the Space Shuttle food item list, and the development of Formulation, Process and Testing Procedures for all items on the food item list which are not currently flight qualified.

F. Food Rehydration Study

Objective

Study food rehydration as it relates to vacuum, flavor development, texture development, temperature, water flow characteristics.

Purpose

To provide data to support the design of the rehydration system and rehydratable package to minimize consumer-perceived defects.

D. Primary Food Package Definition

Objective

Design and develop improved rehydratable and beverage packages for the Space Shuttle food system.

Purpose

To establish the feasibility and subsequent development of functional rehydratable and beverage packages that provide complete rehydration with minimum stowage penalty, and to define the manufacturing requirements and specifications for such packages.

Description

Current rehydration packages are, by design, hand assembled and tailored to specific applications. For the Space Shuttle, where larger quantities of packages will be consumed and where onboard space is at a premium, a highly efficient machine manufacturable rehydration package is a clear requirement. Current data indicates that the design and proper operation of the rehydratable food package can influence the rate and degree of rehydration of the food.

The Apollo and Skylab programs have revealed several opportunities for improving the operation of beverage container, notably in the areas of insulation value, weight and reliability.

F. Food Rehy. Study Cont'd

Description

Current systems do not provide a vacuum-tight package during rehydration, nor do they provide gas free water to the rehydratables. Preliminary laboratory tests have indicated that if water fills all the voids in the package and through the rehydratable items, total rehydration may take place very rapidly. A research study is needed to determine rehydration time lines in an optimum system and to determine the relationship between rehydration time and flavor/texture development. A successful rehydration method will allow new and unique rehydratable foods to be introduced to the food system. Such desirable entree items as steak and lobster tail would then become feasible candidates in a rehydratable menu. The inclusion of large chunk foods in a rehydratable menu will greatly enhance the hedonic acceptability of the feeding system.

G. Semi-active Oven System Design

Objective

Develop a prototype semi-active oven system consisting of an oven and serving tray assembly for Space Shuttle application.

Purpose

To provide a Shuttle compatible low power/weight/volume oven system that will maintain reconstituted food items at a palatable and safe level during the preparation and serving cycle.

G. Cont'd

Description

The primary function of the semi-active oven is to prevent further cooling of food after rehydration with hot water and during normal handling operations that occur in the reconstitution/preparation cycle. The semi-active oven system consists of an insulated oven whose inner wall is maintained at a selected serving temperature by means of resistance heaters; and serving trays with oven inserts to prevent food from cooling below 105°F at the end of a 20-minute dining period.

H. Sortie Lab Study

Objective

Evaluate the impact of the Sortie Lab mission on the Orbiter galley installation.

Purpose

The Sortie Lab provides a manned module in which selected personnel will perform experiments and investigations in a shirt-sleeve environment. The personnel will be supported by the Orbiter galley system and will require food, water, utensils, trays and supporting accessories, such as wipes and disinfectant packages. The baseline galley will therefore be required to service six (6) passengers in addition to the original four (4) crew members. The purpose of the proposed study is to perform the necessary analysis and trade studies required to define the various options and associated penalties in support of this mission.

H. Sortie Lab Cont'd

Description

The Sortie Lab manned module located in the Orbiter payload or cargo bay provides a workshop for both U.S. and non-U.S. scientists and investigators to perform experiments of various types, but does not provide the basic habitability functions of feeding, waste management, housekeeping and personal hygiene. Present concepts envision use of the Orbiter vehicle to fulfill these functions. With respect to the Galley system, requirements must be generated that represent optimum solutions in support of these additional personnel. These solutions may entail additional modules of equipment and food liners at discrete locations either in the Orbiter or in the Sortie Lab. Dining and preparation may be allocated in shifts in order to reduce the amount of facilities and individual equipment required. An additional galley may be required or the baseline galley may be reconfigured to adopt various sized food liners or new equipments (refrigerator and/or freezer) that would be more appropriate for a larger crew size or longer missions with revised menus. The considerations must be weighted and trade studies conducted so that system recommendations can be optimized.

I. Computer Support Study

Definition of elements of the computer support function of the Shuttle Food System.

Purpose

To define the requirements, functions, components, and operations of the computer systems supporting the Shuttle Food System.

5.0 Cont'd

J. Cont'd.

Description

The baseline flight feeding system has been designed to be optimum for a flight crew of six men and a mission duration of seven days. This consists of a specific mix of food types and supporting hardware which are optimum for the baseline definition. Missions can be defined which differ from baseline in the number of flight personnel, mission duration, ethnic food items, and individualized nutritional items. Each non-baseline condition could result in a unique optimum food mix and supporting hardware. The flight system must have the versatility necessary to support any nonbaseline mission at minimum penalties of weight, volume and crew time.

I. Computer Support Study Cont'd

Description

The Shuttle Food System will support a program of great variety, in terms of missions, personnel, and timetable. The preparation time for each flight, and the frequency of the flights, indicates that the food system will be simultaneously supporting several flights in various phases of progress. In addition, the support of each flight will be a complex interaction of menu generation, nutrition, warehousing, manufacturing, maintenance, in-flight monitoring, stowage assembly, alert crew feeding and administration. The efficiency of the food system will be greatly enhanced by computer support.

J. Non-baseline Missions Study.

Objective

To define the flight feeding system necessary to support non-baseline missions.

Purpose

To determine whether the baseline system has sufficient versatility, and to define the required modifications, to support missions shorter or longer than baseline, and to support individualized feeding resulting from ethnic eating habits or special nutritional requirements.

6.0 Glossary of Terms

Acceptance:	Willingness to use or adopt. Implies meeting of criteria or standards.
Active Oven:	An oven designed to raise the temperature of the contents.
Ambient:	Refers to normal environmental conditions, usually temperature.
Bar:	Coherent dry food of regular dimensions, e.g., Fudge implies more than one mouthful.
Beverage:	Hot or cold liquids reconstituted from powdered form.
Bites:	Dry food items in bite-size form.
Calorie:	(Correctly Kcalorie). In this context refers to the energy content of food material which is matabolically available to an organism. 1 Kcal = 4186 joules = 3.97 BTU
Condiment:	Food seasonings or relishes, usually as sauces, e.g., Mustard.
Consumable:	Items which are used up in use, e.g., food
Consumer:	Crew or passengers utilizing the food system.
Consumer Acceptance:	Willingness of consumer to use or adopt. Implies meeting of consumer criterion or standards.
Contingency:	Refers to any unforeseen occurrences.

Contingency Food:	Emergency food to be used in the event of galley failure.
Diet:	Daily fare. Implies consideration of both menu and nutrition.
Dietary:	A system or regimen of diet.
Expendables:	Items with an expected service life of one or a few missions only, e.g., packaging.
Expendable Ammonia System:	The evaporation and dumping of liquid ammonia at a controlled pressure to produce and maintain a cold temperature.
Food Item:	Anything which is eaten and provides nourishment.
Food System:	The food and primary packaging, all supporting hardware to stow, prepare, serve, consume, clean-up the food, and all logistic support.
Forced Hot Air Convection Oven:	An oven which transfers heat by forced circulation of hot air over the contents.
Fortified:	Enriched with nutrients.
Freezer:	A device which maintains food in a frozen state.
Frozen Item:	Food item stored in the frozen state.
Galley:	The on-board hardware of the food system.
Gastro-enterology:	Study of the digestive system.
Hedonics:	Branch of psychology dealing with feelings of pleasure, here with pleasure from food.

C-2

Hydration:	To combine with water. Usually refers to processes at the molecular level.
Liner:	Transport and stowage container for the food packages.
Locker:	The on-board vehicle structure which accepts the liner:
Intermediate Moisture:	Foods at a moisture level which will not support microbial growth.
Menu:	A list of foods in the diet and the sequence of consumption.
Microwave Oven:	An oven designed to raise the temperature of the contents by the use of electromagnetic energy in the microwave frequencies.
Mix (Food):	Types of food and proportion of each type in stowage.
Module:	A vehicle mounted stowage structure which could be designed to provide any specific degree of access to the stowed packages.
Nutrient:	Substances in food necessary to life and growth.
Nutrition:	Refers to study of nutrient requirements.
Optimum:	Maximum acceptance at minimum penalties.

Oven:	A device for raising or controlling temperature of contents at above-ambient temperatures. Implies air space between heating elements and food items.
Oven, Hot Air Convection:	An oven which circulates heated air past food items for the purpose of heating the items.
Oven, Semi-Active Holding:	An oven which maintains a surface temperature of 140°F on the interior walls for the purpose of preventing the cooling of hot food items.
Overage:	A surplus provided to allow for choice or failure.
Overwrap:	Bag or pouch used to contain and organize individual packages.
Package:	Combination of packaging and item(s) contained.
Packaging:	Material comprising the primary packaging.
Primary Packaging:	The packaging immediately containing the individual food item.
Passive Heating Technique:	Utilization of insulation around the food item to retard the loss of heat energy.
Phase Change Heat Sink System:	A cooling technique that utilizes a reusable material which changes phase from a solid to a liquid at a constant temperature.

6.0 Cont'd

RDA:	Recommended dietary allowance established by 1968 National Research Council.
Ready-to-Eat (RTE) Item:	Foods requiring no preparation. Here dry or intermediate moisture bars, bites, wafers.
Refrigerated Item	Food item stowed in a refrigerator.
Rehydratable Item:	Commonly refers to freeze-dried items intended to be reconstituted with water.
Rehydration:	Commonly refers to adding water to a rehydratable item.
Rehydration System:	The dispensing portion of the water system, utilized to add water to dry foods.
Rehydration Valve:	One-way device through which water is added to package contents.
Retortable:	Items thermostabilized by steam retorting, e.g., wet pack beef stew.
Semi-active Oven:	An oven to which sufficient heat is added to maintain the temperature of the contents.
Spices:	Substances used to season foods. Usually dry materials, e.g., pepper.
Spreads:	A soft substance spread on bread items,e.g.,jam.
Thermo-electric System:	A cooling technique that utilizes the reverse thermocouple effect to transfer heat between two junctions of dissimilar metals by application of applied voltage.

Thermo-stabilized:	Heat sterilization of food item.
Trash:	Waste plus additional used expendables.
Vapor Cycle System:	A cooling technique which utilizes the successive evaporation and condensation of a coolant to absorb heat.
Waste:	Leftover consumables.
Waste Stabilizer:	Chemical added to waste food to in-activate spoilage organisms.
Water System:	The total equipments required to accept, store, change temperature and deliver water to the galley.
Wet Pack:	Thermostabilized items.

7.0 BIBLIOGRAPHY

MOL Quarterly Progress Report and FSPC Agenda
June, July and August, 1969
Date Item (U) C-500, Sequence A))L
Contract F04701-68-0079

System Analysis of MOL Feeding System
MOL Contract F04701-68-C-0079

Space Shuttle Food System Design Study
NAS 9-12307

Development of a 90 Day Aerospace Feeding System
Phase I Technical Report
Contract No. F41609-69-C-0059

U. S. Army Natick Laboratories
Space Food Prototype Production Guides
for the
Manned Orbiting Laboratory (MOL)
Feeding System Assembly
RFP-F04695-67-R-0076

Evaluation of Packaging Samples for Manned
Orbiting Laboratory
RFP-F04695-67-R-0076

Flexible Packaging of Foods A.L. Brady
Critical Reviews in Food Technology, 1(1); 71 (1970)

Modern Plastics Encyclopedia, 1972-1973,
p. 142-164, 295-297, 336-339, 342-346, 456-458, 648-656

Modern Packaging Encyclopedia, 1971

R. L. Flentge, A.C. Grim, F.F. Doppelt, and J. E. VanderVeen,
How Conventional Eating Methods were Found Feasible for
Spacecraft, Food Tech., 25 (51):51 (1971)

PRECEDING PAGE BLANK NOT FILMED

I. Epstein, Self-Heating Container
U.S. Patent 3,527,201 (1970)

M.S. Cohen, Self-Cooking Package
U.S. Patent 3,619,214 (1971)

L.L. Katan, Present and Future of Thermoplastics
Food Manufacture, p. 50 (September, 1970)

J. H. Briston, Plastics in Packaging
The Flavour Industry, p. 55 (Jan. 1970), p. 107 (Feb. 1970)

J. H. Briston, Plastics for Food Packaging
Food Manufacture, p. 59 (May 1971), p. 71 (Mar.-Apr. 1971)

R. E. Reinke and C.F. Reinhardt
Fires, Toxicity and Plastics
Modern Plastics, p. 94 (Feb. 1973)

Food Technology Problems Relating to Space Feeding
H.A. Hollender and Mary V. Klicka
U.S. Army Natick Laboratories, Natick, Mass., U.S.A.
and M.C. Smith, NASA, Houston, Texas U.S.A.

Microbiological Testing of Skylab Foods
N.D. Heidelbaugh, D.B. Rowley, E.M. Powers, C.T. Bourland,
and J.L. McQueen; Applied Microbiology 25 (1):55 (1972)

N.D. Heidelbaugh, Space Flight Feeding Systems,
Characteristics, Concepts for Improvement, and Public
Health Implications, J.A.V.M.A. 149 (12): 1662 (1966)

C.J. King, Recent Developments in Food Dehydration Technology,
Critical Reviews in Food Technology

T. P. Labuza, Nutrient Losses During Drying and Storage
of Dehydrated Foods,
Critical Reviews in Food Technology, p. 217 (Sept. 1972)

J. M. Tuomy, Freeze Drying of Foods for the Armed Services
U.S. Army Natick Labs. Tech. Report 72-28-FL

7.0 Cont'd

J. M. Tuomy, Development of Reversibly Compressed Freeze-Dried Foods for Use in Individual Ration Packets
U.S. Army Natick Labs. Tech. Report 72-4-FL

M. M. Hamdy, Compression of Dehydrated Foods,
Review of Literature
U.S. Army Natick Labs. Library Bulletin No. 5

E.F. Eckstein, Models for Control of the Nutritive Content of Menus Planned by Computer
Food Technology 25; 600 (1971)

N.D. Heidelbaugh, D.C. Rambaut, M.C. Smith
Incorporation of Nutritional Therapy in Space Food Systems
NASA Document, Houston, Texas 77058

M.C. Smith, C.S. Huber, N.D. Heidelbaugh
Apollo 14 Food System, Aerospace Medicine 42 (11): 1185 (1971)

Aerospace Food Technology
NASA SP-202

Research and Development in the Development of the AAP Food System Assembly
Contract NAS 9-9958 1970-Whirlpool

Design Review - Food Heating Trays
Contract NAS 8-24000 1970-Martin Marietta

Skylab CDR - Habitability Subsystem
MDAC documents 0/W-4712, 3508 1970

North American Specification FS-083-Food Management
Dec. 1971

Orbiter Environmental Control-Life Support System
North American document 100SV 490 8A 3/8/72

7.0 Cont'd

Space Station/Base Food System Study
Contract NAS 9-11139 1970-Fairchild Republic

Food System for Space Shuttle Program
NASA Management Report April 30, 1971

Method of Heating Foods During Aerospace Flight
Contract AF33 (657)-7922 GATC Report MR11 87-60 1963

Feeding System Design for Advanced Orbital Facilities
Contract NAS 9-9780 Whirlpool

N.D. Heidelbaugh, J.E. VanderVeen, and H.G. Iger,
Development and Evaluation of a Simplified Formula Food
for Aerospace Feeding, Aerospace Medicine p.38-43, Jan. 1968

C.R. Stadler, D.P.Sanford, J.M. Reid, N.D. Heidelbaugh
Skylab Menu Development, Journal of the American
Dietetic Association, 62; 390-393 (1973)

"The Skylab Program", Activities Report No.1, Vol. 25, 1973,
Research and Development Associates for Military Food
and Packaging Systems, Inc.