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Final Report

December 1976

A Trade-off Study to Determine the Optimum Approach to a Wash/Rinse Capability to Support Future Space Flight

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DETERMINE THE OPTIMUM APPROACH TO A
WASH/RINSE CAPABILITY TO SUPPORT FUTURE
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FINAL REPORT

A Tradeoff Study to Determine
the Optimum Approach to a Wash/
Rinse Capability to Support
Future Space Flight

DECEMBER 1976

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FOREWORD

This document presents the results of work performed by the Martin Marietta Corporation's Denver Division for the National Aeronautics and Space Administration, Lyndon B. Johnson Space Center. This final report was prepared as fulfillment of Contract NAS9-15102, *A Tradeoff Study to Determine the Optimum Approach to a Wash/Rinse Capability to Support Future Space Flight*. The NASA Technical Manager was Mr. John B. Westover, Payloads Systems Support Branch.

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ABBREVIATIONS

ac	Alternating Current
BL	Baseline
BTU	British Thermal Unit
°C	Degree Centigrade
cm	Centimeter
dB	Decibel
dc	Direct Current
°F	Degree Fahrenheit
g	Gram
gpm	Gallons per Minute
Hg	Mercury
hp	horsepower
hr	Hour
HZ	Hertz
in	Inch
kg	Kilogram
kw	Kilowatt
lb	Pound
LGS	Liquid-Gas Separator
m	Meter
ml	Milliliter
mm	Millimeter
N	Newton
ppm	Parts Per Million
psi	Pounds Per Square Inch
psig	Pounds Per Square Inch - Gauge
sec	Second
SIL	Speech Interference Level
V	Volts
VL	Value

I. INTRODUCTION

A. SCOPE

The forthcoming manned space missions with their increased crew size, mission duration and vehicle volume are placing increased emphasis on overall crew comfort. Both crew motivation and comfort can significantly be enhanced by the ability to cleanse the body and hands after performing personal hygiene functions and biological testing.

Past space flights have readily demonstrated this requirement for inflight washing capability for personal hygiene functions. Space missions planned for the future, in particular Shuttle/Spacelab, have an extensive biological experiment involvement, and, like similar experiments on earth, could greatly benefit from some means of washing capability. An alternative to this method would be to provide disposable utensils/tools and gloves to the crewman performing the biological experiment, thus eliminating the need for a wash/rinse capability. The objective of this contract was to determine if there existed specific requirements for a wash/rinse capability to support Spacelab biological experimentation and to identify various concepts for achieving this capability. This included the examination of current state-of-the-art and emerging technology designs that would meet the wash/rinse requirements. Once several concepts were identified, including the disposable utensils, tools and gloves or other possible alternatives, a tradeoff analysis involving system cost, weight, volume utilization, functional performance, maintainability, reliability, power utilization, safety, complexity, etc, was performed so as to determine an optimum approach for achieving a wash/rinse capability to support future space flights. Missions of varying crew size and durations were considered in this analysis.

B. TECHNICAL APPROACH

This section presents the sequence of tasks and their objectives that were followed so as to ensure the successful completion of the tradeoff study to determine an optimum approach to a wash/rinse capability for future space flight programs.

1. *Task One - Identification of Specific Uses of a Wash/Rinse Capability* - The objective of task one was to identify typical biomedical experiments and any other Spacelab function that could utilize a wash/rinse capability. This involved the review of Spacelab experiments planned and performed for the Spacelab Mission Demonstrations (I, II, and III) from which usages were defined and categorized into functionally similar groups. The principal investigator of each experiment (see Appendix B) was contacted so as to further investigate specific needs of each experiment. From this, the various usages of a wash/rinse capability were defined with respect to the experiments. Also functional and performance requirements were established as general guidelines for concept definition.
2. *Task Two - Identification of Alternate Approaches to Achieving a Wash/Rinse Capability* - The objective of task two was to identify and review current state-of-the-art and emerging technology that could provide a means to achieve a wash/rinse capability or possible alternatives. During this task, those designs and approaches that would satisfy the experiment usages defined in Task One were determined. For each design approach, applicable documents pertaining to the design (see Appendix B) were reviewed so as to define the characteristics of the concept's subsystems. These characteristics included such items as cost, functional performance, maintainability, reliability, volume, weight, power, safety, time requirements, expendable requirements, training and cost. A matrix sheet was constructed which indicated the characteristic of each design concept for easy comparison against other concepts' characteristics. Any concept that could not meet a functional or performance requirement established in task one was modified with a subsystem that would allow the concept to meet the requirement. This allowed each concept to be compared on an equal capability basis with all other concepts.
3. *Task Three - Tradeoff Analysis* - The objective of this task was to provide a tradeoff analysis to determine the optimum approach for space flight missions of varying lengths to achieve a wash/rinse capability. This task was accomplished by determining the impact of each characteristic upon missions of varying lengths and then assessing the relative importance of each characteristic so the concepts could be compared on a competitive basis for final analysis.
4. *Task Four - Contract Outputs* - The objective of task four was to provide the necessary conference requirements, data management requirements, and documentation requirements. All items identified and described by the Data Requirements List (DRL) No. T-1302 were

prepared and submitted. The data items were prepared in accordance with the Data Requirements Description (DRD) referenced in the DRL for each line of data. All reports and documentation generated under this contract were expressed in SI (metric) units with conventional units given in parentheses. Conventional units were utilized for principal measurements and calculations with conversion factors being inserted in equations to convert the results to the international system of units (SI). The only data item required for submittal was a final report. In addition to the formal documentation submittal, telephone calls on a weekly basis were made to the NASA Technical Manager at his convenience to inform him of the progress, evaluations and results of the tradeoff study analysis.

II. REQUIREMENTS FOR WASH/RINSE CAPABILITY CONCEPTS

The investigated concepts are to provide an efficient technique for both cleansing and rinsing of crewman's hands and laboratory utensils/tools. The identification and selection of concepts to be considered for the desired wash/rinse capabilities or possible alternative to this capability must be based upon functional and performance requirements. These requirements were used as general guidelines during Task Two concept definition.

A. FUNCTIONAL REQUIREMENTS

- 1) The wash/rinse capability concepts or possible alternatives to this capability shall have the ability to operate in either a zero or a one-gravity environment.
- 2) The concepts shall accommodate a 5th/ to 95th/percentile male/female crew size based on anthropometric dimensions of the USAF population projected to 1980.
- 3) The concepts shall have a useful life of 10 years when exposed to the environments of IIB.
- 4) The concepts shall be fail-safe as a minimum.
- 5) Concepts shall require minimal inflight maintenance and repair throughout the mission.
- 6) The concepts shall be acceptable in some degree to all mission personnel.
- 7) The concepts shall not be uncomfortable to gain access to and use.
- 8) The concepts shall require little training in order for the crewmen to use them.
- 9) The concepts shall utilize minimum crewman waking time.
- 10) Bacteriological breeding areas with the concepts shall be avoided.

11) All concepts shall be of the size so as to not impede crew traffic patterns within the Spacelab.

12) All concepts shall have design features that will not affect the safety of the crew (electrical shock, lacerations from sharp edges, etc).

13) Waste disposal containers shall cause no back contamination to the cabin or support microbial breeding.

B. PERFORMANCE REQUIREMENTS

1. *Crew Sizing* - The system shall be based on the following:

- 4-man, 7-day Shuttle/Spacelab Mission;
- 7-man, 7-day Shuttle/Spacelab Mission;
- 7-man, 30-day Shuttle/Spacelab Mission;
- 7-man, 180-day Space Station Mission;
- 7-man, 30-day Shuttle/Spacelab Mission, Wash Water Recovery capability;
- 7-man, 180-day Space Station Mission, Wash Water Recovery capability.

2. *System Tasks* - The concepts shall be capable of supporting any one or more of the following functions:

- Washing hands and face;
- Sponge bathing;
- Shaving and cleaning razor;
- Brushing teeth;
- Washing or wetting of hair;
- Oral hygiene;
- Waste fluid disposal;

- Cleansing/disposal laboratory utensils/tools;
- Work area cleanup.

3. *Interface Requirements*

a. Cabin Environment

1) Cabin Atmosphere

a) The total oxygen/nitrogen pressure shall be maintained at $1.013 \times 10^5 \text{ N/m}^2 \pm 1.73 \times 10^3 \text{ N/m}^2$ (760 mmHg $\pm$ 13 mmHg).

b) The oxygen partial pressure shall be maintained at $2.2 \times 10^5 \text{ N/m}^2 \pm 1.73 \times 10^3 \text{ N/m}^2$ (165 mmHg $\pm$ 13 mmHg).

c) The carbon dioxide partial pressure shall be maintained at or below 400 N/m^2 (3 mmHg) during nominal operations. The carbon dioxide shall be maintained below $2 \times 10^3 \text{ N/m}^2$ (15 mmHg) during emergency operations.

d) The maximum allowable concentration of total organics (exclusive of fluorocarbons) will be 100 ppm n-pentane equivalents.

e) The maximum allowable total fluorocarbons will be 100 ppm.

f) The following chemicals shall not be used:

- Carbon tetrachloride;
- Chloroform;
- Methyl chloroform;
- Trichloroethylene;
- Mercury.

g) Airborne particles shall be less than 300 microns based on Spacelab airborne particle filtering capabilities.

2) Humidity

a) In an operating mode, the humidity shall be controlled within 25% to 70% and is not adjustable.

b) In a nonoperating mode, the humidity shall be controlled within 10% to 90%.

c) Atmosphere dewpoint temperature shall be at least 5.6°C (10°F) lower than the dry bulb temperature during operation.

3) Temperature

a) The temperature during operation shall be controlled within 18 to 27°C $\pm$ 1.1°C (65 to 80°F $\pm$ 2°F).

b) The temperature during nonoperation shall be controlled within 7 to 50°C (45 to 122°F).

c) During normal operation, the temperature of the Spacelab cabin wall shall not exceed 30°C (86°F). The maximum allowable shall be 45°C (113°F) for a cabin wall not usually in contact with mission personnel.

b. Power Interfaces - The power which will be available to the concepts will be 28V dc $\pm$ 4V dc and 115/200V ac $\pm$ 5%, 400 Hz $\pm$ 170 sine wave.

c. Fluid Interface

1) A single source of unheated water between 12.8°C and 48.9°C (55°F and 120°F) will be provided to the concepts.

2) A single return waste connection will be provided.

d. Air Interfaces

1) Air intake - cabin atmosphere as defined in III.3.a.1.

2) Discharge air - filtered and/or processed as required to remove contaminants or objectionable odors.

e. Acoustical Criteria - Continuous noise levels shall not exceed 50 dB re 0.002 dyne/cm² in speech interference level (SIL) range (600 to 4800 Hz), 70 dB at frequencies below SIL, nor 60 dB at frequencies above SIL.

f. Cabin Heat Load Cooling

	<u>Watts (Btu/hr)</u>
1) Maximum allowable latent heat load (at 23.9°C [75°F] dry bulb or 70% relative humidity)	477 (1500)
2) Maximum allowable sensible heat load (19.5°C [68°F])	1770 (6000)
(23.9°C [75°F])	2260 (7723)

g. Assumed Equivalent Weight Penalties

<u>Penalty Type</u>	<u>Equivalent Ratio</u>
1) Heat added directly into cabin which must be removed with cabin cooling circuit.	.198 kg/joule (.128 lb/Btu/hr)
2) Continuous dc power	268 kg/kw (591 lbs/kw)
3) Continuous ac power	322 kg/kw (710 lbs/kw)

h. Pressurant Gas Interface

- 1) Nitrogen - maximum pressure of $413.4 \times 10^3 \text{ N/m}^2$ (60 psig).

III. TASK ONE - IDENTIFICATION OF SPECIFIC USES OF A WASH/RINSE CAPABILITY

A. TASK OBJECTIVE

The objective of task one was to identify typical biomedical experiments and any other Spacelab function that could utilize a wash/rinse capability. This involved the review of Spacelab experiments planned and performed for the Spacelab Mission Demonstrations (I, II, and III) from which usages were defined and categorized into functionally similar groups. From this, the various usages of a wash/rinse capability were defined with respect to the experiments.

B. REVIEW EXPERIMENTS

At the time of this report, the experiments which will be flown aboard the Spacelab have not been finalized. In order to gain an insight into which types of biomedical experiments that could possibly utilize some means of a wash/rinse capability, those experiments which have already been performed or are in the planning stage for the Spacelab Mission Demonstrations were reviewed. These experiments represent typical experiments which will be flown on Spacelab and might possibly be flown themselves. During this subtask, experiments that had been performed on the SMD I tests were reviewed to determine if they could have made possible use of a wash/rinse capability during the performance of the experiment. Experiments performed on SMD II were also reviewed, not only for the above reason, but also to determine if any of them actually did utilize the personal hygiene station that was provided for an operation evaluation test. The documentation that was reviewed during this subtask includes the literature listed in Appendix B of this report and Spacelab Mission Demonstration III, Individual Experiment Proposals. Table III-1 shows a list of those experiments that were reviewed in detail for this subtask. The experiments reviewed involved monkeys, rats, frogs, bacteria, flies, mice, dogs and humans.

C. WASH/RINSE NECESSITY DEFINITION

Various principal investigators of the biomedical experiments were personally contacted (see Appendix B) to further determine any need for a wash/rinse capability that might not have been pronounced in

Table III-1 Experiments Reviewed for Possible Wash/Rinse Capabilities

SMD I:

- Clinical Diagnostic Center
- Renal Concentration Test
- Cardiovascular Physiology and Cellular Repair

SMD II:

- Central and Peripheral Hemodynamic Responses during Isometric Exercises
- Effect of Orbital Fluid Shifts on Cardiovascular Dynamics
- Effect of Zero-G Fluid Shifts on the Vectorcardiogram
- Echocardiography
- Hemopoietic Function of Bone Marrow
- Respiratory Physiology and Pulmonary Function
- The Effect of Zero-G on Thermoregulation
- Vestibular Function
- Acute Responses of Fluid and Electrolyte Metabolism in Space Flight
- Study of Skeletal Muscle Function in Space Flight
- Salivary Analysis

SMD III:

- Rat Collagen Turnover during Weightlessness
- Effect of Weightlessness on the Plasma Somatomedin Concentrations in the Rat
- In Vivo Studies of Muscle Protein Degradation Under Weightlessness Environments
- Mechanisms of Cardiovascular Adaptation and Distribution of Flow during Weightlessness
- Fine Structural Observations in the Vestibulo-Cerebellum, Vomiting Center, and Hypothalamic Pituitary Endocrine Axis on Mice Exposed to Weightlessness in Space
- Effect of Space Flight on Bone Resorption Rate in Monkeys

Table III-1 (Continued)

SMD III (Continued):

- Cellular Response to Antibiotics in Space Flight
- Insulin Resistance during Zero-G Exposure
- Basal and Light Activity Metabolism during Zero-G
- A Preventative Method and Countermeasure for the Zero-Gravity Sickness Syndrome: Learned Self-regulation of Multiple Autonomic Responses by Crew Members
- Effects of Weightlessness on Drosophila Development and Aging
- Space Flight Related Histopathologic Changes in Lymphoid Organs
- The Function of Brain and Renal Renin-Angiotensin Systems during Space Flight
- Habitual Changes in Static-Otolith Activity during Prolonged Weightlessness
- Effect of Weightlessness on Proteolytic Enzyme Concentrations in the Muscle of Rats
- Effect of Weightlessness on the Muscle Atrophy in the Rat as Measured by Urinary Excretion of 3-Methyl Histidine
- Zero-Gravity, Nucleate Pool Boiling Experiment
- Metabolism and Heat Balance in Zero-Gravity
- Pyrogenic Fever-Salicylate Interaction at Zero-Gravity
- Otolith Response Adaptation as a Function of CNS Output
- Time Course of Human Cardiovascular Alterations during Weightlessness
- Factors Affecting Motion Sickness in Space: Conflict on Reduced Vestibular Function
- Human Pulmonary Function in Weightlessness
- The Effects of Space Flight on the Cellular Immune Response of Man
- The Influence of Space Flight on Erythrokinetics in Man

OTHER:

- Orbiting Frog Otolith

their experiment proposal. The crew members did utilize the personal hygiene station on SMD-II during the performance of the experiment, *Respiratory Physiology and Pulmonary Function*, for cleaning the respiratory valves and mouthpiece and was determined to be quite adequate. Other SMD-II principal investigators contacted did not make mention of possible use of the personal hygiene station. Some of the comments made by the SMD-II and III principal investigators contacted concerning the necessity of a Spacelab wash/rinse capability included:

- Crew members will work with animal urine and feces and will require a means of removing them from their hands.
- Crew members will be sacrificing animals and collecting their blood and will need a means to remove the blood from themselves.
- Some experiment utensils, particularly surgical tools, will need to be cleaned.
- In one experiment, a crew member will hand separate food particles from the animals' feces. Wipes alone are not determined to be adequate for this task.
- Some chemicals are used in the experiments and any residues must be disposed of.
- Crew members will have to clean any electrode gell left on the animal after electrode removal due to the sticky, salty nature of the gell.
- Animal secretions of any type will have to be removed from the crewman's hands.
- Respiratory and saliva collection devices will need to be cleaned at least once per week. A good disinfectant for these devices is also recommended.

From these comments, it was determine that there was a need for some means of a wash/rinse capability to accentuate the life sciences experiments that will be flown aboard the Spacelab. The need for such a capability not only hinged upon the crew members' personal hygiene functions, but also upon the well-being of the animals involved in each experiment and the successful completion of each experiment. These needs include:

- Work area cleanup and crew members' personal hygiene functions following animal sacrifice.

- Animal cage maintenance.
- Crew personal hygiene following animal food handling.
- Crew personal hygiene following animal waste (urine and feces) handling.
- Work area cleanup and crew members' personal hygiene following blood collection techniques.
- Laboratory utensil/tool and dental/medical kit component cleansing following use.
- Animal cleansing following surgery.
- Crew personal hygiene during and following animal surgery.
- Animal cleansing after electrode removal to remove sticky, salty electrode gel.
- Crew removal of animal secretions (including saliva) from their hands.
- Respiratory valves and mouthpiece cleansing following repeated use.
- Electrode cleansing following use.
- Available water source.

Table III-2 shows these needs for a wash/rinse capability in relationship to each experiment that was reviewed. Table III-3 is a summary of the number of experiments which have identified each need for a wash/rinse capability.

Table III-2 Experiment Wash/Rinse Capability Necessities

USAGES EXPERIMENTS	SACRIFICING ANIMAL-WORK AREA CLEANUP AND CREWMAN PERSONAL HYGIENE	ANIMAL WASTE PRODUCTION COLLECTION CLEANUP	ANIMAL FECAL HANDLING CREWMAN CLEANUP	BLOOD COLLECTION-CREW PERSONAL HYGIENE	LABORATORY UTENSIL/TOOL CLEANUP	ANIMAL SURGERY CLEANUP-CREW AND ANIMAL	WASTE CHEMICAL DUMP AND CREW PERSONAL HYGIENE	ANIMAL SPOT CLEANING-AFTER REMOVING ELECTRODES	ANIMAL SECRETION REMOVAL- PERSONAL HYGIENE OF CREW	BACTERIALOGY EXPERIMENT CLEANUP	SALIVA CLEANUP	RESPIRATORY VALVES AND MOUTHPIECE CLEANUP	ANIMAL FOOD HANDLING-CAGE MAINTENANCE	WOP% AREA CLEANUP	ELECTRODE CLEANING	DENTAL AND/OR MEDICAL KIT CLEANUP	AVAILABLE WATER SOURCE
The Effect of Zero-G on Thermoregulation									X ^H								
Orbiting Frog Otolith		X	X		X				X					X			
Central and Peripheral Hemodynamic Responses During Isometric Exercise								X ^H							X		
Rat Collagen Turn- over During Weight- lessness	X	X	X	X	X	X	X	X	X	X				X	X		
Effect of Weightless- ness on the Plasma Somatomedin Concen- tration in the Rat	X			X	X								X				105ml H ₂ O/ Day
In Vivo Studies of Muscle Protein De- gradation Under Weightlessness Environment	X			X	X	X							X	X			28ml H ₂ O/ Day
Salivary Analyses						X	X				X					X	
Mechanisms of Cardio- vascular Adapta- tion and Distribu- tion of Flow During Weightlessness				X									X				
Effect of Orbital Fluid Shifts on Cardiovascular Dy- namics								X ^H							X		
Effect of Zero-G Fluid Shifts on the Vector Cardiogram								X ^H							X		
Echocardiography								X ^H							X		
Fine Structural Obser- vations in the Ves- tibular-Cerebellum, Vomiting Center, and Hypothalamic Pitui- tary Endocrine Axis in Mice Exposed to Weight- lessness in Space	X				X	X							X	X			490ml H ₂ O/ Day
Hemopoietic Function of Bone Marrow	X			X	X	X							X	X	X		

Table III-2 (Continued)

USAGES	SACRIFICING ANIMAL WORK AREA CLEANUP AND CREWMAN PERSONAL HYGIENE	ANIMAL WASTE PRODUCTION COLLECTION CLEANUP	ANIMAL FECAL HANDLING CREWMAN CLEANUP	BLOOD COLLECTION-CREW PERSONAL HYGIENE	LABORATORY UTENSIL/TOOL CLEANUP	ANIMAL SURGERY CLEANUP CREW AND ANIMAL	WASTE CHEMICAL DUMP AND CREW PERSONAL HYGIENE	ANIMAL SPOT CLEANING-AFTER REMOVING ELECTRODES	ANIMAL SECRETION REMOVAL- PERSONAL HYGIENE OF CREW	BACTERIALOGY EXPERIMENT CLEANUP	SALIVA CLEANUP	RESPIRATORY VALVES AND MOUTHPIECE CLEANUP	ANIMAL FOOD HANDLING-CAGE MAINTENANCE	WORK AREA CLEANUP	ELECTRODE CLEANING	DENTAL AND/OR MEDICAL KIT CLEANUP	AVAILABLE WATER SOURCE
EXPERIMENTS																	
Study of Skeletal Muscle Function in Space Flight								X ^H							X		
Acute Responses of Fluid and Electrolyte Metabo- lism in Space Flight		X		X	X									X			
The Initial Effects of Weightlessness on In- flight Hemolysis in Monkeys													X				
Respiratory Physiology and Pulmonary Function											X	X					
Clinical Diagnostic Center					X											X	
Renal Concentration Test																	
Cardiovascular Phys- iology and Cellular Repair																	
Effect of Space Flight on Bone Resorption Rate in Monkeys	X			X	X		X						X	X			1000 ml H ₂ O/ Day
Cellular Responses to Antibiotics in Space Flight									X ^H								
Vestibular Function															X		
Insulin Resistance Dur- ing Zero-g Exposure				X	X												
Basal and Light Activ- ity Metabolism During Zero-g							X				X	X					
A Preventative Method and Countermeasure for the Zero-g Sickness Syndrome: Learned Self-regulation of Multiple Autonomic Re- sponses by Crew Members							X	X							X		
Effects of Weightless- ness on Drosophila Development and Aging	X				X		X										

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Table III-2 (Continued)

USAGES EXPERIMENTS	SACRIFICING ANIMAL WORK AREA CLEANUP AND CREWMAN PERSONAL HYGIENE	ANIMAL WASTE PRODUCTION COLLECTION CLEANUP	ANIMAL FECAL HANDLING CREWMAN CLEANUP	BLOOD COLLECTION-CREW PERSONAL HYGIENE	LABORATORY UTENSIL/TOOL CLEANUP	ANIMAL SURGERY CLEANUP-CREW AND ANIMAL	WASTE CHEMICAL DUMP AND CREW PERSONAL HYGIENE	ANIMAL SPOT CLEANING-AFTER REMOVING ELECTRODES	ANIMAL SECRETION REMOVAL- PERSONAL HYGIENE OF CREW	BACTERIOLOGY EXPERIMENT CLEANUP	SALIVA CLEANUP	RESPIRATORY VALVES AND MOUTHPIECE CLEANUP	ANIMAL FOOD HANDLING-CAGE MAINTENANCE	WORK AREA CLEANUP	ELECTRODE CLEANING	DENTAL AND/OR MEDICAL KIT CLEANUP	AVAILABLE WATER SOURCE
Space Flight Related Histopathologic Changes in Lymphoid Organs	X				X	X	X						X	X			
The Function of Brain and Renal Renin-Angiotensin Systems During Space Flight	X	X		X	X	X	X		X				X	X			
Habitual Changes in Static-Otolith Activity During Prolonged Weightlessness													X		X		
Effect of Weightlessness on Proteolytic Enzyme Concentration in the Muscle of Rats	X			X	X	X							X	X			
Effect of Weightlessness on the Muscle Atrophy in the Rat as Measured by Urinary Excretion of 3-Methyl Histidine		X			X								X				
Zero-Gravity, Nucleate Pool Boiling Experiment							N/A										
Metabolism and Heat Balance in Zero-G													X				
Pyrogenic Fever-Salicylate Interaction at Zero-G					X		X						X				
Otolith Response Adaptation as a Function of CNS Output	X				X				X				X	X	X		
Time Course of Human Cardiovascular Alterations During Weightlessness								X			X	X			X		
Factors Affecting Motion Sickness in Space: Conflict on Reduced Vestibular Function								X ^H									
Human Pulmonary Function in Weightlessness											X	X					
The Effects of Space Flight on the Cellular Immune Response of Man				X	X												
The Influence of Space Flight on Erythokinetics in Man	X			X	X		X						X				

Table III-3 The Number of Experiments that have Identified Each Need for a Wash/Rinse Capability

NEED FOR WASH/RINSE CAPABILITY	NUMBER OF EXPERIMENT
• Laboratory Utensil/Tool Cleanup	19
• Animal Food Handling - Cage Maintenance	16
• Sacrificing Animal - Work Area Cleanup and Crewman Personal Hygiene	12
• Blood Collection - Crew Personal Hygiene	12
• Electrode Cleaning	12
• Work Area Cleanup	11
• Waste Chemical Dump and Crew Personal Hygiene	10
• Animal Spot Cleaning - After Removing Electrodes	9
• Animal Surgery Cleanup - Crew and Animal	8
• Animal Secretion Removal - Personal Hygiene of Crew	6
• Animal Waste Production Collection Cleanup	5
• Saliva Cleanup	5
• Respiratory Valves and Mouthpiece Cleanup	4
• Dental and/or Medical Kit Cleanup	2
• Animal Fecal Handling Crewman Cleanup	2

IV. TASK TWO - IDENTIFICATION OF ALTERNATE APPROACHES TO ACHIEVING A WASH/RINSE CAPABILITY

A. TASK OBJECTIVE

The objective of task two was to identify and review current state-of-the-art and emerging technologies that could prove a wash/rinse capability that would satisfy the needs of the Spacelab functions and biomedical experiments identified in Task One. For each concept, applicable documents (see Appendix B) were reviewed to define that concept's characteristics.

B. WASH/RINSE CAPABILITY CONCEPT DESCRIPTION

1. *Disposable Wet and Dry Wipes* - Premoistened disposable paper wipes can be used to cleanse the crewmembers' hands, administer a "sponge-type" body wash, clean the laboratory work area and clean utensils/tools that were used during the conduct of various biomedical experiments. Each premoistened wipe contains water, alcohol, propylene glycol, benzalkonium chloride, propylparaben and several other chemicals to add fragrance and enhance the cleansing action of the wipe.

Drying is accomplished by the use of a disposable paper dry wipe. Two wet wipes and one dry wipe are provided for each wash.

The premoistened wipes are individually packaged in a foil wrapper that measures 5.1 cm x 7.6 cm x .32 cm (2" x 3" x .125"). When unfolded, the wipe, itself, measures 14 cm x 20.3 cm (5.5" x 8"). Each wet wipe weighs 5.3 g packaged and 1.6 g when it has been unpackaged and completely left to dry. The dry wipe measures 10.2 cm x 28 cm (4" x 11") and weighs 5.3 g. For each type of wipe, a storage cabinet for the unused wipes is provided, as is a waste storage cabinet for the used wipes. Also a dispenser, which is spring-loaded to provide easy access to each wipe in zero-gravity, is provided for the wet and dry wipes and is replenished from the wipes in the unused wipe storage cabinet. After use, the premoistened wipes and the dry wipes (which will contain moisture from the body drying areas) will be discarded wet and stored in the waste storage area where they will dry.

Figure IV-1 shows an artist's concept of the wipe dispenser, storage and waste storage cabinets.

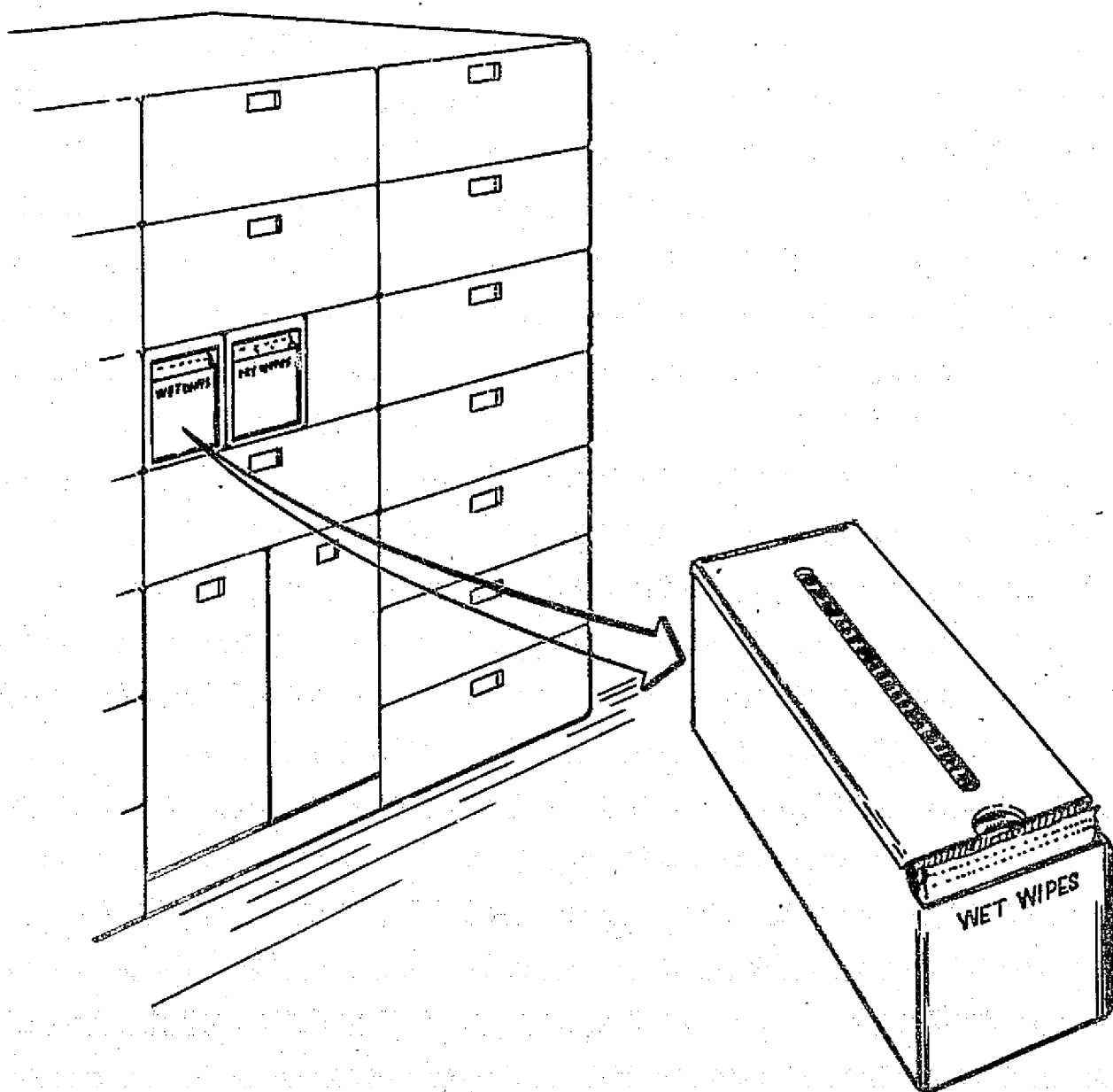


Figure IV-1 Disposable Wet and Dry Wipes

2. *Spacelab Utensil/Hand Cleansing Fixture* - The Spacelab utensil/hand cleansing fixture is a self-contained unit which can be installed into any standard water interface requirement. It provides a source of flowing water from which a crewmember cleanses his hands or various other tasks. The crewmember inserts his hands inside an enclosed dome through hand holes to obtain the water. The dome shape enclosure allows maximum washing area and ease of inside cleansing after use. Potable water enters the system through a disconnect at the coupling interface. The water is then heated to 320.4°K (117°F) which offers the maximum comfort to the crewmembers, in the hot water holding tank. When the foot water control switch is activated, the solenoid valve opens and water is delivered to the enclosure through the provided nozzle at 11 ml/sec (.17 gpm). A back contamination device is incorporated so that bacteria is prevented in going back through the water supply system from the enclosure.

Liquid soap (Palmetto hand soap) is stored in the soap bladder tank. Nitrogen gas is used to provide a pressure behind the soap which, when the solenoid valve is open, moves up into the soap nozzle and flows into the enclosure at .5 ml/sec (.008 gpm). Cleansing agents for other tasks such as shaving and brushing teeth are individually packaged and separate from the cleansing fixture. A liquid disinfectant is also provided to disinfect the enclosure on a weekly basis.

Water and soap mixed with air leaves the enclosure through an opening in its basin and travels to the liquid-gas separator. The air is removed from the LGS by a blower and is transferred to the cabin ambient. Both the air and any evolved gases from the chemical disposal into the cleansing fixture are filtered in the utensil/hand cleansing assembly before being released into the habitability area. The water collects in the sump of the LGS until it is full, at which time the water pump is activated and removes the water.

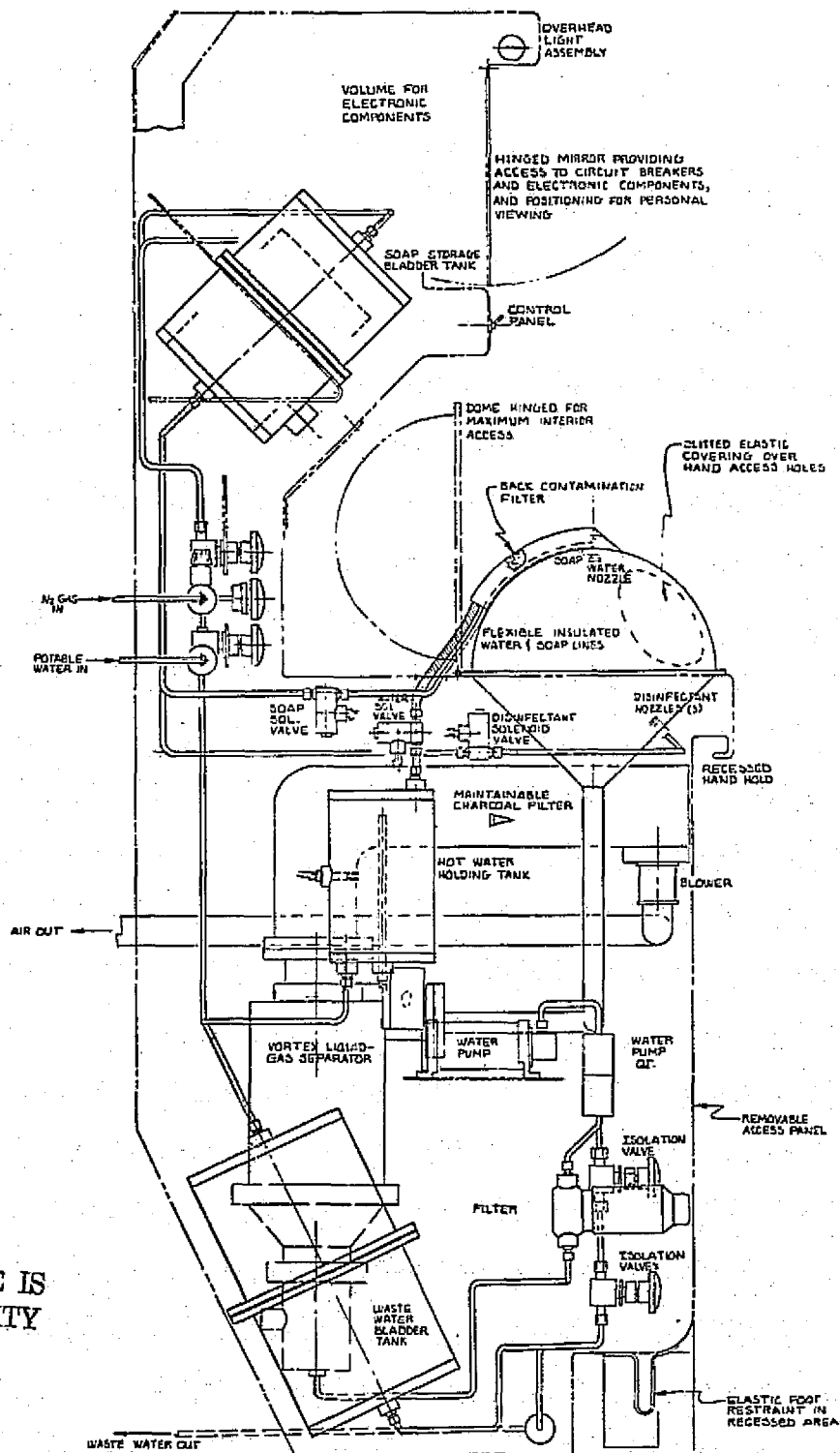
The unit fits a standard Spacelab rack and operates on Spacelab 28V DC and 115V AC, 400 Hz power. Maximum power usage is 26 watts continuous AC and 99 watts continuous DC. The location of the cleansing enclosure, controls and personal hygiene mirror are such so as to accommodate both a 5th percentile female and a 95th percentile male in a zero-gravity neutral body position. The cleansing fixture alone weighs 24.2 kg (53.4 lb) and has a volume of approximately .55 m³ (33,394 in³).

The functions that are capable of being performed in conjunction with the cleansing fixture include handwashing, shaving, laboratory utensil/tool cleansing, brushing teeth, hair wetting, "sponge-type" body

washing, work area cleanup, and a waste chemical and liquid waste (urine, blood, etc) disposal area. Dry wipes are provided for drying and as in the first concept, a storage and waste storage area is provided for the wipes. Also a dispenser, which is spring-loaded, is provided for the dry wipes and is replenished from the wipes in the unused wipe storage cabinet. One dry wipe is provided for each wash. The wipes are again discarded wet into the waste storage where they are left to dry. Figure IV-2 shows the structure and components for the Spacelab utensil/hand cleansing fixture.

3. *Disposable Drying Wipe Plus Cleansing Agent* - The dry wipe and its storage and waste storage provisions are identical to those detailed in concept one. No premoistened wipes are provided in this concept which are replaced by a liquid cleansing agent. With various cleansing agent compositions, handwashing, body washing ("sponge-type"), shaving, brushing teeth, hair washing, utensil cleansing and work area cleanup can be accomplished by the use of dry wipes. The cleansing agent is applied directly to the body area or work area and removed using a wipe. A second dry wipe is provided to finish the task. Each cleansing agent is housed in a nonrefillable small bladder-type container fitted with a continuous spray valve. A propellant is used to pressurize the internal bladder of each container. For hand cleansing, the cleansing agent contains kerosene, amerchol L-101, oleic acid, cetyl alcohol, chlorhexidine, triethanolamine, propylene glycol, cocoyl sarcosine and water. A body and hair cleansing agent contains amerchol L-101 and pHiso-hex, which contains 3% hexachlorophene. A general purpose cleansing agent that can be used to clean the work area and laboratory utensils/tools, contains Pola wax A-31, anhydrous ethanol, providone/iodine, propylene glycol, boric acid and water. Shaving and dental creme are of the standard commercial formulations. Storage and waste storage areas are provided for the cleansing agent containers. The diameter of each container is approximately 7.6 cm (3 in.) and is 15.2 cm (6 in.) long and can hold approximately 13.5 g of cleansing agent.

4. *Astro-Vac* - The Astro-Vac has water delivery and pickup lines leading to a hand-held head with a sponge at the water delivery point. A hot water holding tank heats the potable water to 320.4°K (117°F). A housing connected to a low pressure source surrounds the sponge and acts as a pickup for the water as it is deposited on the skin by the sponge. The hand-held unit is moved over the body for cleaning local areas. Liquid soap (Palmetto hand soap) is also dispensed through the hand-held head whose dispensing is controlled by the user. At the pickup end, a centrifugal separator is used to remove the used water for delivery to the water management system. An air



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Figure IV-2 Spacelab Utensil/Hand Cleansing Fixture

transport system returns the processed air into the cabin ambient. The sponge head is removable and can be cleaned. Sufficient sponge heads are provided to allow a clean sponge every 30 days. Drying is accomplished with the use of dry disposable wipes as in concept one. The Astro-Vac not only provides a means for hand and body wash, but also provides a means for laboratory work area cleanup.

The assembly itself weighs approximately 13.2 kg (29.2 lb) and has a volume of .042 m³ (2592 in³). Storage and waste storage areas are also provided for the disposable dry wipes and sponges. Maximum power usage is 90 watts continuous DC. The wipes are discarded wet into the waste storage where they will dry. Sponges are left to dry in the cabin ambient air.

Figure IV-3 shows an artist's rendition of the Astro-Vac concept.

5. *Orbiter Personal Hygiene Station* - This concept is very similar to the Spacelab utensil/hand cleansing fixture except that bar soap replaces the liquid soap and dispenser, and water flow is manually operated, not automated. In the Shuttle Orbiter, the personal hygiene station is located on the side of the food galley in the mid-deck. The blower, liquid-gas separator and other related items are shared with the adjacent waste management compartment. Use of the personal hygiene station as it exists in the Orbiter is totally impractical for Spacelab needs due to the inconvenient location and taken apart from the food galley and equipped with the necessary components, the personal hygiene station would all be but identical to the Spacelab utensil/hand cleansing fixture except for the previously mentioned items.

Since this concept does not incorporate a liquid soap dispensing unit, the weight of the personal hygiene station is somewhat lower than the Spacelab utensil/hand cleansing fixture. Total assembly weight is approximately 22.7 kg (50 lbs). Total volume is approximately equal to the Spacelab utensil/hand cleansing fixture, .55 m³ (33,394 in³).

The personal hygiene station, however, does not employ the use of a dome shaped enclosure. Instead, the access holes for the hands and the enclosure surface are flush with the retaining structure. A manual valve is provided for activation-deactivation of the water flow.

As with the Spacelab utensil/hand cleansing fixture, dry wipes are provided for drying after each wash. Appropriate storage and waste storage areas are provided for these wipes. The wipes are discarded wet and left to dry in the waste storage area.

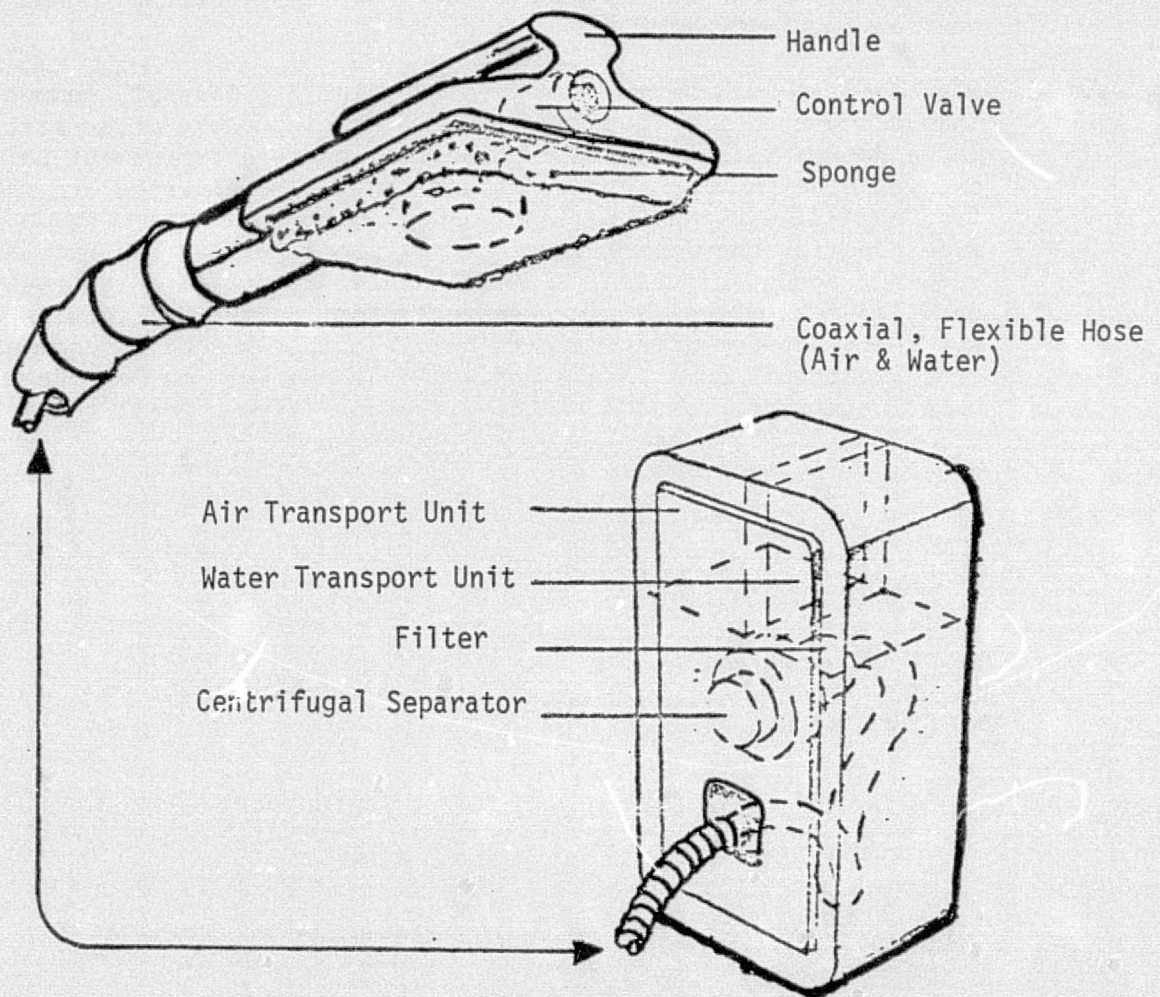


Figure IV-3 Astro-Vac

Maximum power usage during a wash cycle is 26 watts continuous AC and 99 watts continuous DC.

Figure IV-4 shows an artist's concept of the Orbiter personal hygiene station in the Orbiter food galley.

6. *Disposable Laboratory Utensils/Tools* - In this concept, commonly used laboratory utensils/tools are made to be disposable after each use. These do not include tools or utensils that are experiment unique and would be provided by each experiment. The pipettes are made from soda-lime glass, the syringes, scalpel handles and spatulas from plastic, the centrifuge from polypropylene and the hypodermic needles, forceps, scalpel blades and hemostats from a lightweight durable nickel-like metal. The following laboratory utensils/tools and their corresponding weights have been designated as common to most biomedical experiments and would be the best to be made disposable (weights correspond to the disposable type utensil/tool):

- 2.5 ml syringe: 5.71 g
- 10 ml syringe: 19.02 g
- hypodermic needles: 1.92 g
- 10 ml pipettes: .53 g
- 25 ml pipettes: .5 g
- forceps: 25.98 g
- spatula: 4.5 g
- centrifuge tubes: 20 g
- small sticks: .36 g
- scalpel: 10 g
- hemostat: 4.5 g

Assuming that approximately 12 biomedical experiments will be flown on Spacelab at any one time, the total number per day of each type utensil/tool is:

- 2.5 ml syringe: 24
- 10 ml syringe: 24

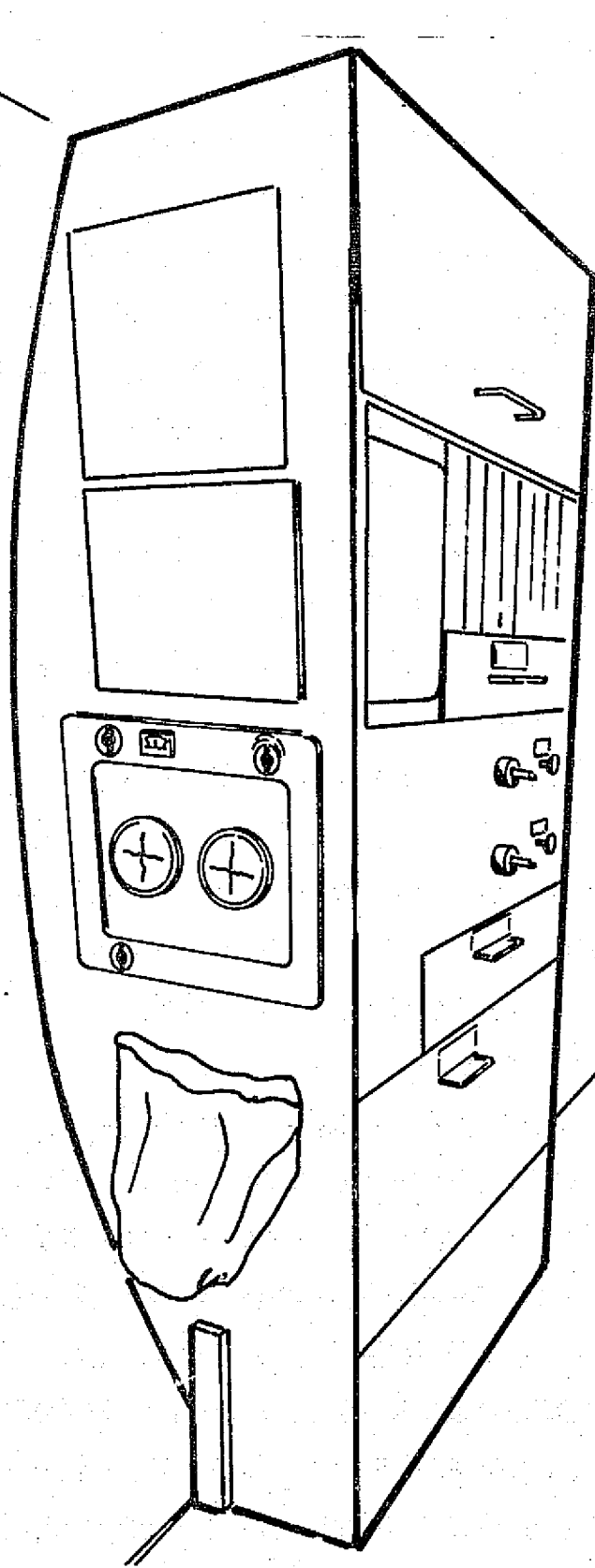


Figure IV-4 Orbiter Personal Hygiene Station

- hypodermic needles: 48
- 10 ml pipettes: 24
- 25 ml pipettes: 24
- forceps: 12
- spatula: 12
- centrifuge tubes: 24
- small sticks: 60
- scalpel: 12
- hemostat: 24

In addition to these items, disposable gloves (roll of 1000 gloves weighs approximately 1500 g) and disposable dry wipes (5.3 g each) are provided for crewmembers' hand protection and the work area clean-up.

Prior to use, each type of utensil/tool is stored in a separate compartment by the use of dividers and elastic restraints (see Figure IV-5). A common waste storage area is provided for all the utensils/tools. Both the wipes and gloves are discarded wet and left to dry in the waste storage area, as are the utensils/tools after each use.

7. *Hot Water Spray Washing - Centrifuge Drying System* - The laboratory utensils/tools are arranged in the compartment facing lengthwise radially. During the washing cycle, the drum is slowly rotated while the water spray bar sprays jets of water on the utensils. During the drying cycle, the drum is rotated at the relatively high speed to force drops off the utensil by the centrifugal forces overcoming the surface tension forces. A hot water heater is incorporated into the concept for hot wash water. The washer/dryer combination weighs 44.5 kg (98 lb) and has a volume of .694 m³ (42,336 in³). The electrical power for this concept is 150 watts continuous AC and 75 watts continuous DC.

The work cycle usage rate of water is 13.6 kg (30 lb) with 6.8 kg (.5 lb) each for both washing and rinsing. Residual water left on the laboratory utensils/tools after each washing cycle is .14 kg (.30 lb). The washer/dryer motor is 150 watts (.2 hp). The water pump is sized for a head of $55.2 \times 10^3 \text{ N/m}^2$ (8 psi) at 3.78×10^{-2}

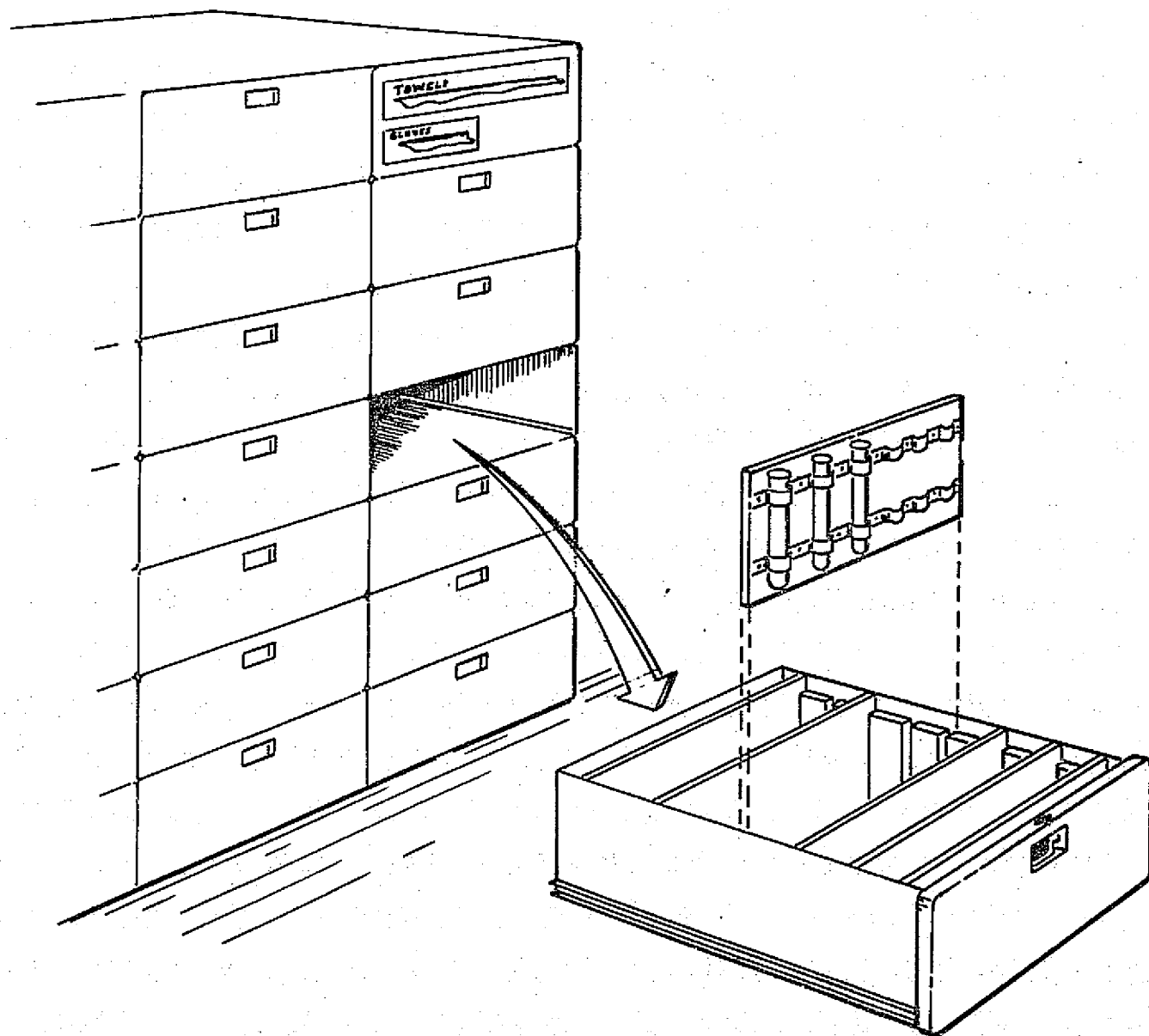


Figure IV-5 Disposable Laboratory Utensils/Tools Storage

kg/sec (300 lbs/hr). Figure IV-6 shows an artist's concept of the hot water spray washing-centrifuge drying system.

Disposable gloves are also provided with this concept to protect the crewmembers' hands from substances during the experiment performance. Also provided are dry wipes for work area cleanup and drying of crewmembers hands. Appropriate storage and waste storage are as provided for both the disposable gloves and wipes, which are discarded wet and left to dry in the waste storage.

8. *Reusable Wipes* - The wipes are 25.4 cm (10-in.) squares of dry terry cloth, which are wetted before used. A mechanical wipe wetting system with an access hand hole is used to wet the wipes. Bar soap is also provided. The wipe wetting system furnishes water and has provisions for controlling the excess water with an air sweep through the hand hole. A centrifugal separator is provided to separate the free water from the air stream. Water temperature is controlled to 320.4°K (117°F) by the hot water holding tank. Weight of the wetter unit is 16.83 kg (37.1 lb) with a volume of approximately $.099 \text{ m}^3$ (6048 in^3). Maximum power usage is 224 watts continuous DC. Figure IV-7 shows a typical wipe drying rack and restraint system. Figure IV-8 shows an artist's concept for the wipe wetting unit.

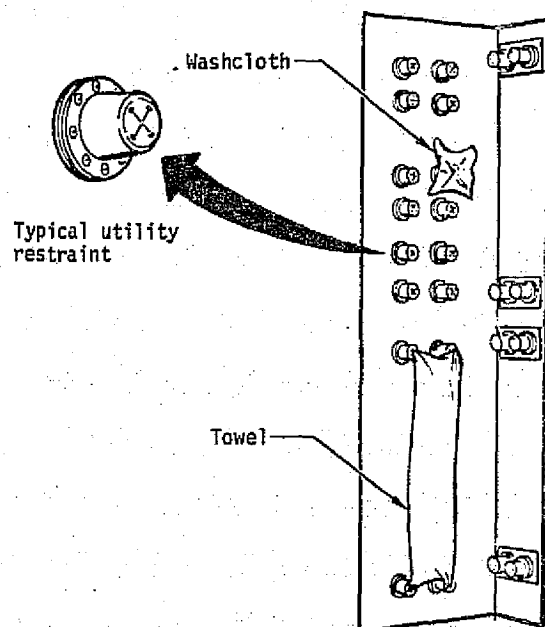


Figure IV-7 Wipe Drying Rack and Restraints

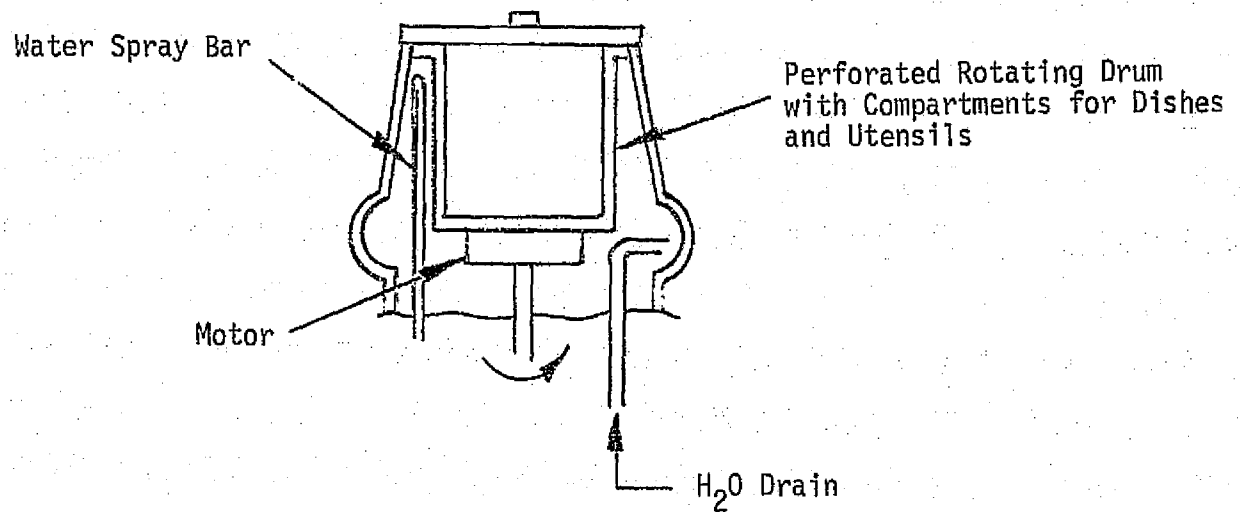


Figure IV-6 Hot Water Spray Washing - Centrifuge Drying System

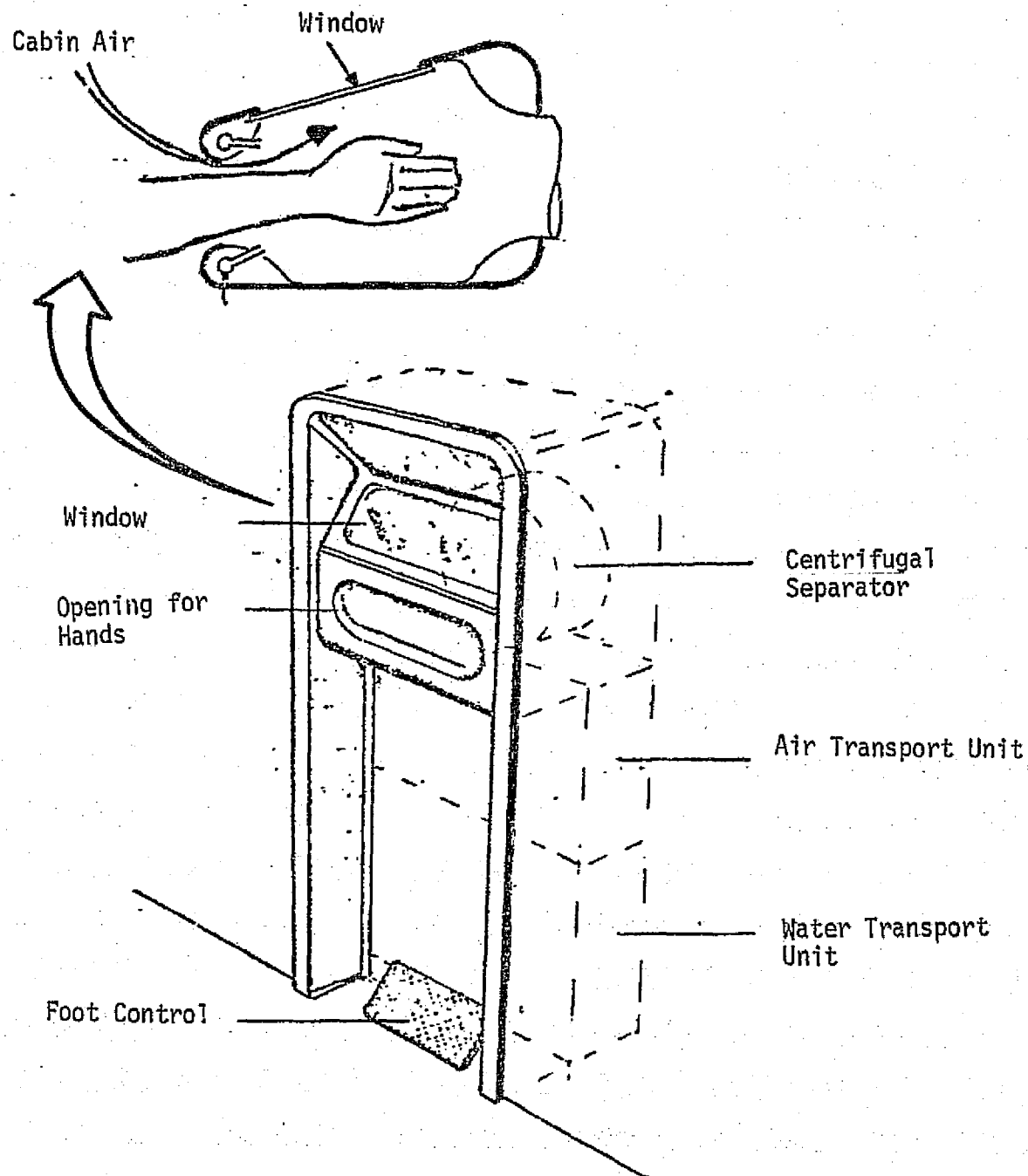


Figure IV-8 Wipe Wetting System

One wipe per wash per man is used, after which it is placed on a wipe drying rack and restraint assembly. Drying time for each wipe is approximately 28,800 sec (8 hrs), after which it is refolded and placed in the storage cabinet. After 60 washings, the wipe is discarded and replaced. Storage and waste storage areas for the wipes are provided.

In conjunction with the proper cleansing agents, handwashings, "sponge-type" body washings, shavings, dental brushing, utensil cleansing and work area cleaning can be performed with reusable wipes and the wipe wetting unit.

9. *Disposable Wipes with Wetter Unit* - Dry disposable wipes are used in conjunction with the wipe wetting unit described earlier for the Reusable Wipe Concept. Three dry wipes are provided for each wash. Each dry wipe measures 10.2 cm x 28 cm (4" x 11") and weighs 5.3 g. A storage cabinet for the unused wipes is provided, as is a waste storage cabinet for the used wipes. Also a dispenser, which is spring-loaded to provide easy access to each wipe in zero-gravity is provided for the dry wipes and is replenished from the wipes in the unused wipe storage cabinet. After use, the wipes will be discarded wet and left to dry in the waste storage area.

Cleansing agents similar to those in the disposable dry wipe plus cleansing agents concept are provided for each function. Storage and waste storage areas are provided for the cleansing agent containers.

C. SUPPORTING SYSTEMS TO THE WASH/RINSE CAPABILITY CONCEPTS

1. *Solid Waste Compactor* - The solid waste compactor reduces trash items to a volume which is approximately one-third of the original bulk volume. The compactor liner bag also serves as a temporary wet trash collector. Only one crewmember is required to accomplish the trash compaction and disposal. The compacted trash package is tied so that it will maintain its reduced volume shape when removed from the compactor. The compactor operates by simultaneous motions on the ratchet handles on the outside. The compactor measures 43.2 cm x 41.6 cm x 22.4 cm (17" x 16.4" x 8.8") and weighs approximately 30.84 kg (68 lbs). The compactor trash package measures 43.2 cm x 12.7 cm x 22.4 cm (17" x 5" x 8.8") and has a volume of (748 in³). The compactor itself has an overall volume of .004 m³ (2450 in³). Figure IV-9, IV-10 and IV-11 show the exterior view, component parts, and compactor bag operations, respectively, for the solid waste compactor.

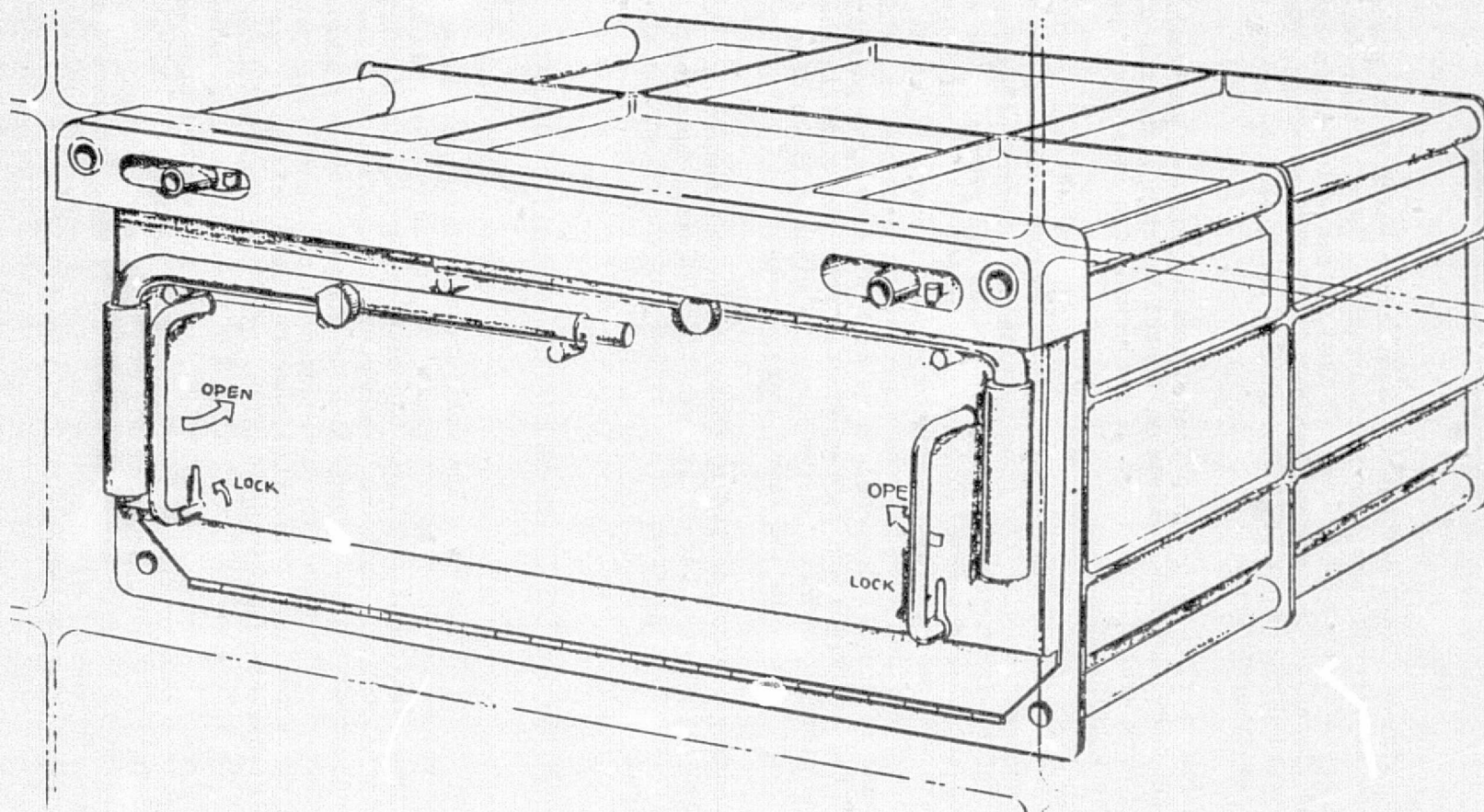


Figure IV-9 Solid Waste Compactor Exterior View

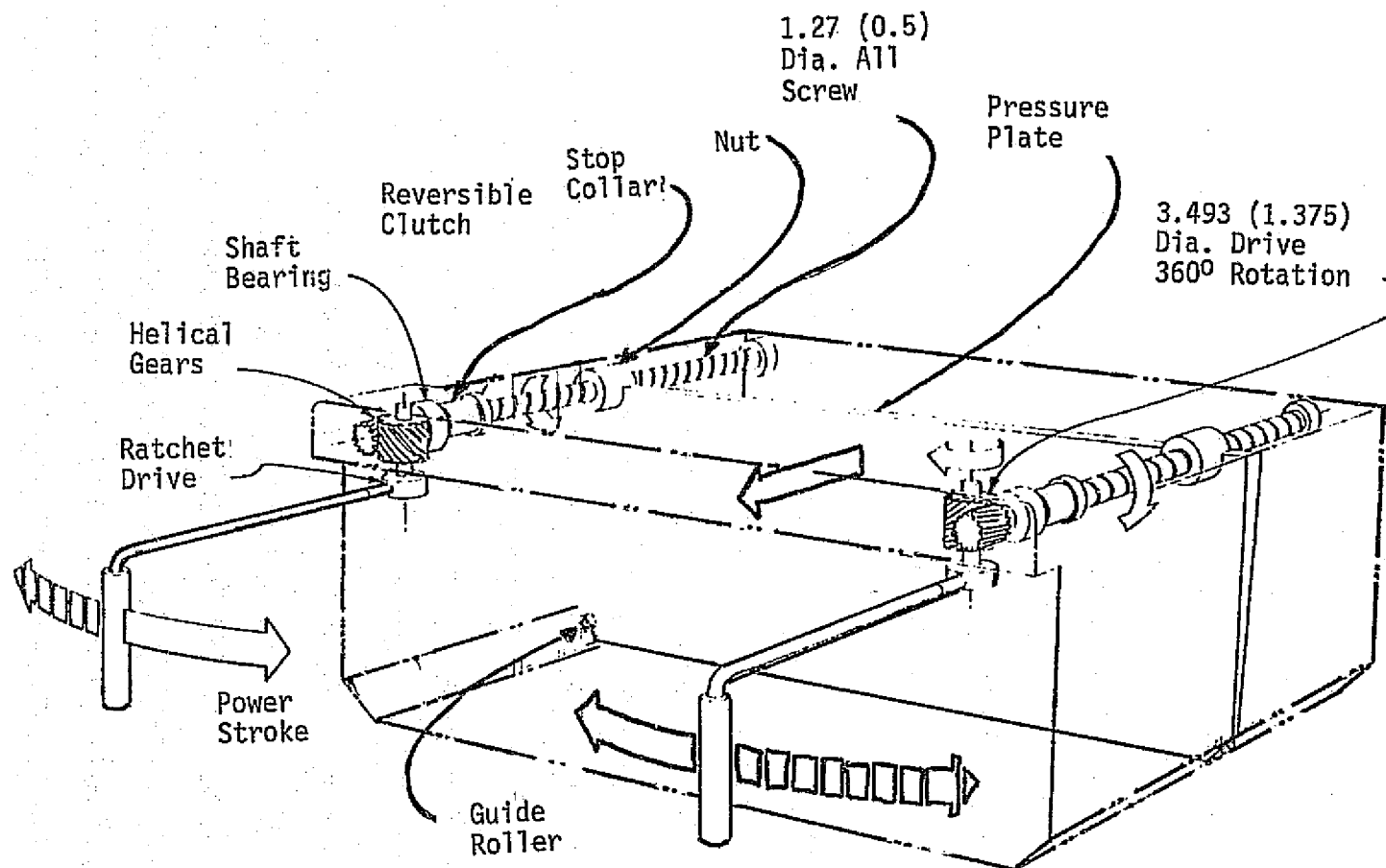


Figure IV-10 Solid Waste Compactor Component Parts

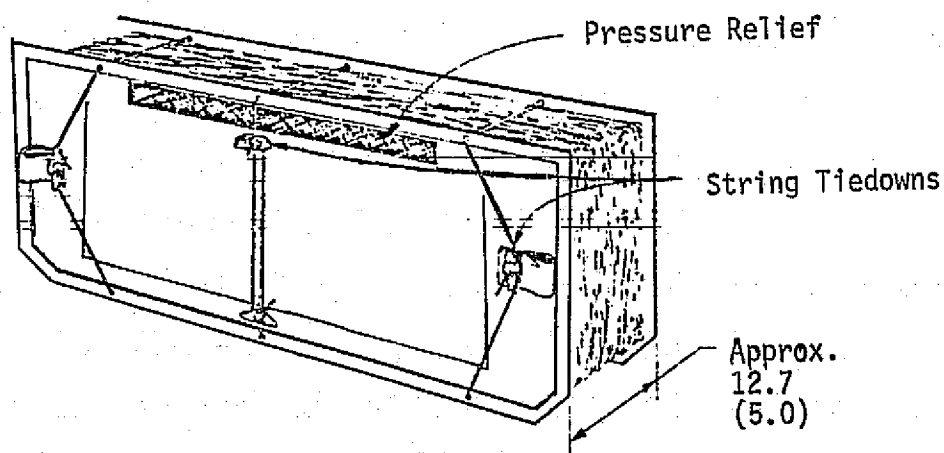
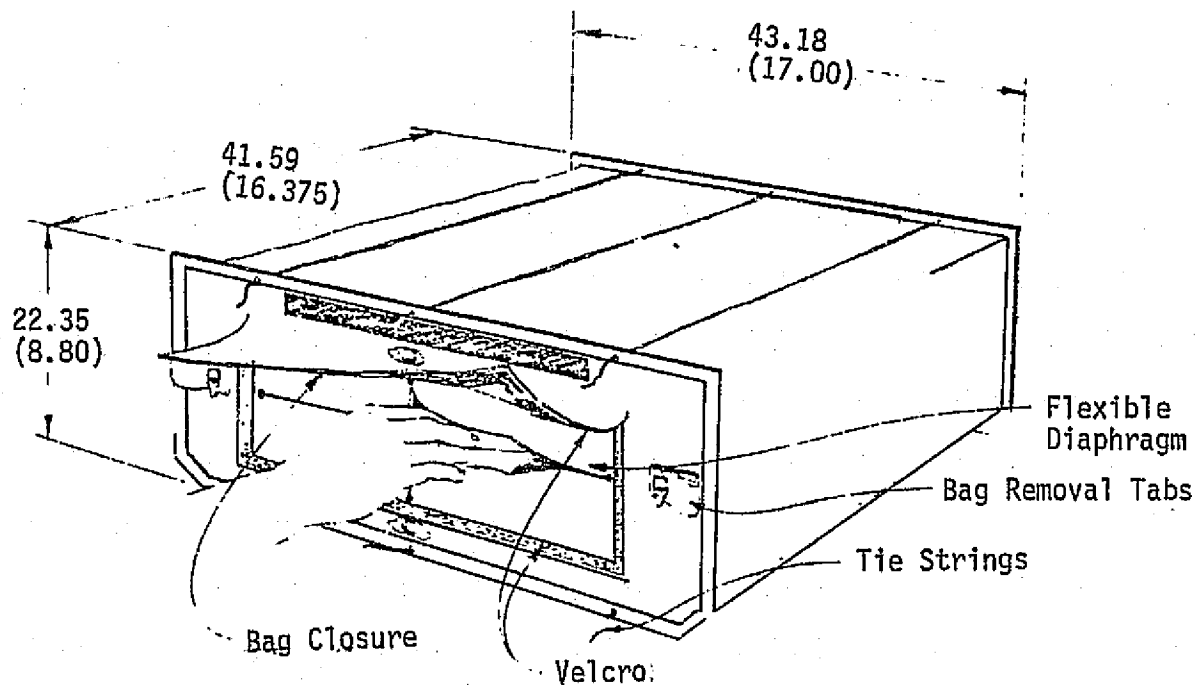


Figure IV-11 Solid Waste Compactor Bag Operation

2. *Wash Water Recovery System* - The wash water recovery system employs a hyperfiltration module to remove contaminants from the wash water. The processed water is delivered back to the hot water holding tank for reuse. The residue from the hyperfiltration unit is stored. The system has a capability to process 18.14 kg (40 lbs) of water per day with a recovery efficiency of 90%. The weight of the unit is approximately 84 kg (179 lbs) and has a total volume of .27 m³ (16,556 in³). The maximum power usage is 55 watts AC and 100 watts DC.

Table IV-1 shows the composition of typical wash water that will be reclaimed. The processed water from the system has the following characteristics:

- pH: 5 to 7.5
- total organic carbon: 200 mg/l
- specific conductivity: 2000 mho-cm-1
- ammonia: 5 mg/l
- turbidity: 10 ppm SiO₂
- color: 15 Pt-Co units
- total dissolved solids: 1500 mg/l
- urea: 50 mg/l
- lactic acid: 50 mg/l
- NaCl: 1100 mg/l
- microorganisms: 10 per ml

This composition is the same as the wash water specification established by the National Academy of Science.

Figure IV-12 shows a system schematic for the wash water recovery system.

Table IV-1 Composition of Water from Typical Wash Water

MATERIALS	lb/lbw x 10 ⁻⁶
• Calcium	.28
• Chloride	22.22
• Chromium	.05
• Copper	1.00
• Magnesium	.28
• Manganese	.05
• Nickel	.05
• Potassium	8.31
• Silver	.05
• Sodium	22.22
• Zinc	5.0
• Amino Acids	.94
• Creatinine	.55
• Glucose	1.38
• Lactic Acid	6.94
• Urea	9.72
• Uric Acid	.19
• Soap	1000.0
• Sebum	19.52
• Body Hair, Skin, Etc	89.96
TOTAL	1189.01

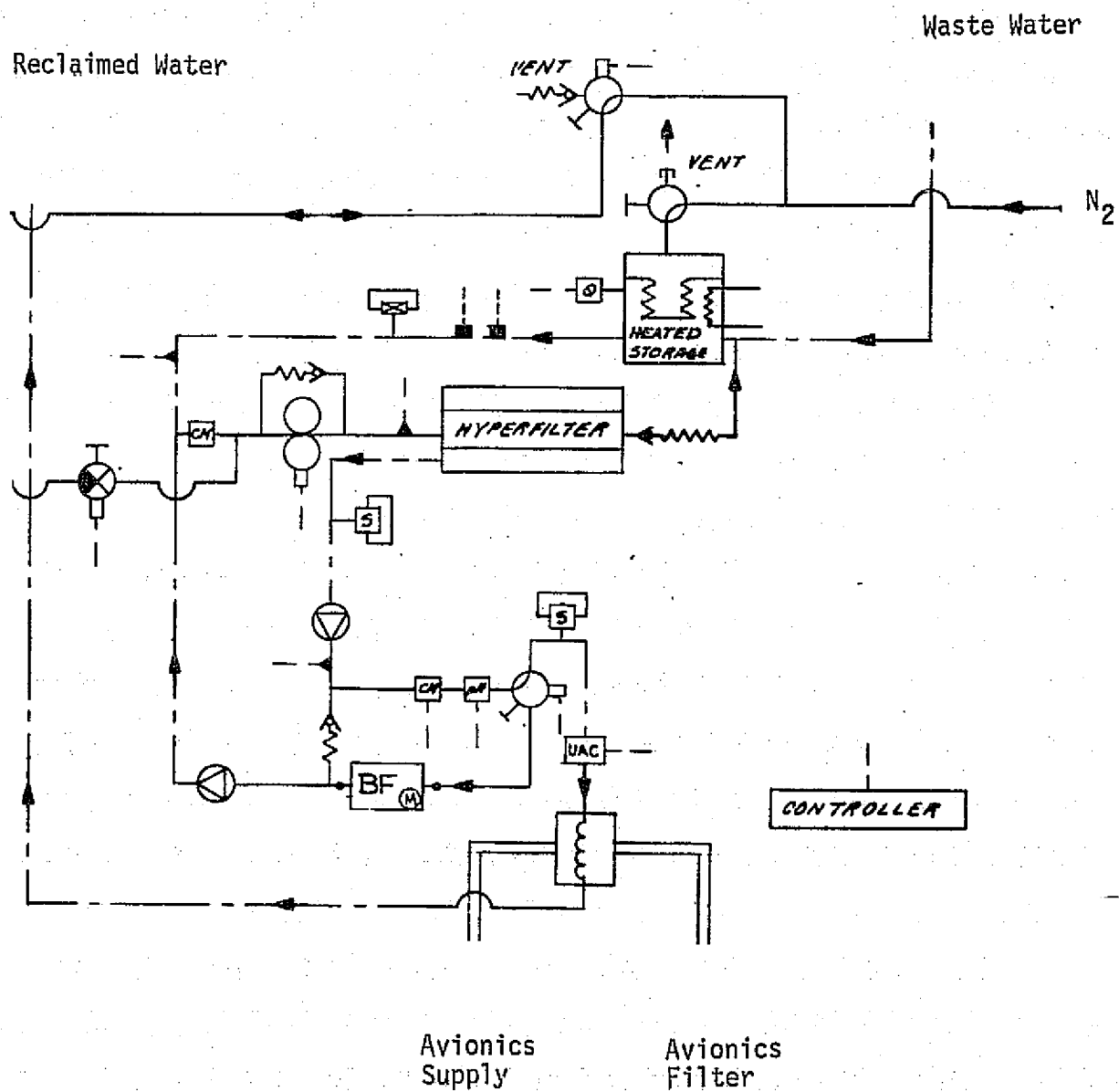


Figure IV-12 Wash Water Recovery System Schematic

D. BIOMEDICAL EXPERIMENT REQUIREMENTS WASH/RINSE CONCEPT UTILIZATION

The various concepts for achieving a wash/rinse capability were compared to the requirements of each biomedical experiment for a wash/rinse capability and the comments made by the experimentors. Table IV-2 shows which requirements each of the wash/rinse capability concept is able to meet.

The disposable wet and dry wipes did not meet any of the requirements that involved the crewmembers handling of animal waste products, secretions or blood due to the psychological effect of not feeling totally cleansed by using just a wipe. The use of a cleansing agent with the dry wipes aids in overcoming this effect but is not as satisfactory as the act of washing and rinsing the hands after such handlings as with the Spacelab utensil/hand cleansing fixture and the Orbiter personal hygiene station. A disposable wipe was expressed by several experimenters as being totally unsatisfactory for crew cleansing after animal fecal handling. Due to the sponge, the Astro-Vac was also felt to be unsatisfactory for these tasks. Disposable gloves in the hot water spray washing-centrifuge drying system and the disposable laboratory utensils/tools concepts protected the crewmembers' hands from unsatisfactory substances. The reusable wipe concept was also felt to be inadequate for these tasks since the wash cloth would easily become soiled and become totally unsatisfactory to the crewmembers, causing the reuse rate to decline.

Table IV-3 shows each experiment's utilization of the wash/rinse capability concepts. Due to their wide range of functions, the Spacelab utensil/hand cleansing fixture and the Orbiter personal hygiene station can easily be utilized by all the experiments. None of the other concepts can completely satisfy all of the experiment types which is depicted in Table IV-4.

Table IV-2 Experiment Requirements Concept Utilization

CONCEPT	REQUIREMENT
Disposable Wet and Dry Wipes	
Spacelab Utensil/Hand Cleansing Fixture	
Disposable Drying Wipe Plus Cleansing Agent	
Astro-Vac	
Orbiter Personal Hygiene Station	
Disposable Laboratory Utensils/Tools	
Hot Water Spray Washing Centrifuge Drying System	
Reusable Wipes	
Disposable Wipes with Wetter Unit	
Orbiter Personal Hygiene Station and Solid Waste Compactor	
Disposable Laboratory Utensils/Tools and Solid Waste Compactor	
Disposable Wet and Dry Wipes with Solid Waste Compactor	
Spacelab Utensil/Hand Cleansing Fixture with Solid Waste Compactor	

	SACRIFICING ANIMAL-WORK AREA CLEANUP AND CREWMAN PERSONAL HYGIENE	ANIMAL WASTE PRODUCTION COLLECTION CLEANUP	ANIMAL FECAL HANDLING CREWMAN CLEANUP	BLOOD COLLECTION-CREW PERSONAL HYGIENE	LABORATORY UTENSIL/TOOL CLEANUP	ANIMAL SURGERY CLEANUP- CREW AND ANIMAL	WASTE CHEMICAL DUMP AND CREW PERSONAL HYGIENE	ANIMAL SPOT CLEANING- AFTER REMOVING ELECTRODES	ANIMAL SECRETION REMOVAL- PERSONAL HYGIENE OF CREW	BACTERIALOLOGY EXPERIMENT	SALIVA CLEANUP	RESPIRATORY VALVES AND MOUTHPIECE CLEANUP	ANIMAL FOOD HANDLING-CAGE MAINTENANCE	WORK AREA CLEANUP	ELECTRODE CLEANING	DENTAL AND/OR MEDICAL KIT CLEANUP	AVAILABLE WATER SOURCE
				X	X			X					X	X	X	X	
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X		X	X	X		X	X	X	X	X	X	X	X		
						X		X	X	X	X			X			
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X								X	X			
					X	X		X	X	X	X	X	X	X	X		
				X	X	X		X	X	X	X	X	X	X	X	X	
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X								X	X			
				X	X			X					X	X	X	X	
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

IV-23
&
IV-24

FOLDOUT FRAME 2

Table IV-3 Biomedical Experiments Usages of Various Wash/Rinse Capability Co

CONCEPTS	
EXPERIMENTS	
The Effect of Zero-G on Thermoregulation	
Orbiting Frog Otolith	
Central and Peripheral Hemodynamic Responses During Isometric Exercise	
Rat Collagen Turnover During Weightlessness	
Effect of Weightlessness on the Plasma Somatomedin Concentrations in the Rat	
In Vivo Studies of Muscle Protein Degradation Under Weightlessness Environment	
Salivary Analysis	
Mechanisms of Cardiovascular Adaptation and Distribution of Flow During Weightlessness	
Effect of Orbital Fluid Shifts on Cardiovascular Dynamics	
Effect of Zero-G Fluid Shifts on the Vector Cardiogram	
Echocardiography	
Fine Structural Observations in the Vestibulo-Cerebellum, Vomiting Center, and Hypothalamic Pituitary Endocrine Axis on Mice Exposed to Weightlessness in Space	
Hemopoietic Function of Bone Marrow	
Study of Skeletal Muscle Function in Space Flight	
Acute Responses of Fluid and Electrolyte Metabolism in Space Flight	
The Initial Effects of Weightlessness on Inflight Hemolysis in Monkeys	
Respiratory Physiology and Pulmonary Function	
Clinical Diagnostic Center	
Renal Concentration Test	
Cardiovascular Physiology and Cellular Repair	
Effect of Space Flight on Bone Resorption Rate in Monkeys	
Cellular Response to Antibiotics in Space Flight	
Vestibular Function	

	DISPOSABLE WET AND DRY WIPES	SPACELAB UTENSIL/HAND CLEANSING FIXTURE	DISPOSABLE DRYING WIPE PLUS CLEANSING AGENT	ASTRO-VAC	ORBITER PERSONAL HYGIENE STATION	DISPOSABLE LABORATORY UTENSILS/TOOLS	HOT WATER SPRAY WASHING CENTRIFUGE DRYING SYSTEM	REUSABLE WIPES	DISPOSABLE WIPES WITH WETTER UNIT	ORBITER PERSONAL HYGIENE STATION AND SOLID WASTE COMPACTOR	DISPOSABLE LABORATORY UTENSILS/TOOLS AND SOLID WASTE COMPACTOR	DISPOSABLE WET AND DRY WIPES WITH SOLID WASTE COMPACTOR	SPACELAB UTENSIL/HAND CLEANSING FIXTURE WITH SOLID WASTE COMPACTOR
		X			X					X			X
		X	X		X	X	X			X	X		X
Exercise	X	X	X	X	X			X	X	X		X	X
		X			X	X	X			X	X		X
in the Rat		X			X	X	X			X	X		X
s Environments		X			X	X	X			X	X		X
		X			X	X	X			X	X		X
During	X	X	X	X	X			X	X	X		X	X
	X	X	X	X	X			X	X	X		X	X
	X	X	X	X	X			X	X	X		X	X
	X	X	X	X	X			X	X	X		X	X
g Center, and essness in Space		X			X	X	X			X	X		X
		X			X	X	X			X	X		X
	X	X	X	X	X			X	X	X		X	X
ght		X			X	X	X			X	X		X
onkeys		X	X		X					X			X
		X	X		X					X			X
	X	X	X		X			X	X	X		X	X
		X			X					X			X
	X	X	X		X			X	X	X		X	X
		X			X	X	X			X	X		X
		X			X					X			X
		X	X		X					X			X

Table IV-3 (Continued)

CONCEPTS EXPERIMENTS	DISPOSABLE WET AND DRY WIPES
Insulin Resistance During Zero-G Exposure	
Basal and Light Activity Metabolism During Zero-G	
A Preventative Method and Countermeasure for the Zero-Gravity Sickness Syndrome: Learned Self-Regulation of Multiple Autonomic Responses by Crew Members	X
Effects of Weightlessness on Drosophila Development and Aging	X
Space Flight Related Histopathologic Changes in Lymphoid Organs	
The Function of Brain and Renal Renin-Angiotensin Systems During Space Flight	
Habitual Changes in Static-Otolith Activity During Prolonged Weightlessness	X
Effect of Weightlessness on Proteolytic Enzyme Concentrations in the Muscle of Rats	
Effect of Weightlessness on the Muscle Atrophy in the Rat as Measured by Urinary Excretion of 3-Methyl Histidine	
Zero-Gravity, Nucleate Pool Boiling Experiment	X
Metabolism and Heat Balance in Zero-Gravity	X
Pyrogenic Fever-Salicylate Interaction at Zero-Gravity	
Otolith Response Adaptation as a Function of CNS Output	
Time Course of Human Cardiovascular Alterations During Weightlessness	
Factors Affecting Motion Sickness in Space: Conflict on Reduced Vestibular Function	
Human Pulmonary Function in Weightlessness	
The Effects of Space Flight on the Cellular Immune Response of Man	
The Influence of Space Flight on Erythrokinetics in Man	

	DISPOSABLE WET AND DRY WIPES	SPACELAB UTENSIL/HAND CLEANSING FIXTURE	DISPOSABLE DRY WIPES PLUS CLEANSING AGENT	ASTRO-VAC	ORBITER PERSONAL HYGIENE STATION	DISPOSABLE LABORATORY UTENSILS/TOOLS	HOT WATER SPRAY WASHING CENTRIFUGE DRYING SYSTEM	REUSABLE WIPES	DISPOSABLE WIPES WITH WETTER UNIT	ORBITER PERSONAL HYGIENE STATION AND SOLID WASTE COMPACTOR	DISPOSABLE LABORATOR** UTENSILS/TOOLS AND SOLID WASTE COMPACTOR	DISPOSABLE WET AND DRY WIPES WITH SOLID WASTE COMPACTOR	SPACELAB UTENSIL/HAND CLEANSING FIXTURE WITH SOLID WASTE COMPACTOR
		X	X		X	X	X	X		X	X		X
		X	X		X					X			X
ickness Syndrome: embers	X	X	X	X	X			X	X	X		X	X
	X	X			X	X	X	X	X	X	X	X	X
		X			X	X	X			X	X		X
Space Flight		X			X	X	X			X	X		X
stlessness	X	X	X	X	X			X	X	X		X	X
he Muscle of Rats		X			X	X	X			X	X		X
red by Urinary		X			X	X	X			X	X		X
	X	X	X	X	X			X	X	X		X	X
	X	X	X	X	X			X	X	X		X	X
		X			X	X	X			X	X		X
		X			X	X	X			X	X		X
ess		X	X		X					X			X
istibular		X			X					X			X
		X	X		X					X			X
		X			X	X	X			X	X		X
		X			X	X	X			X	X		X

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&
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FOLDOUT FRAME 3

Table IV-4 Various Biomedical Experiment Types Concept Utilization

EXPERIMENT TYPE \ CONCEPT	DISPOSABLE WET AND DRY WIPES	SPACELAB UTENSIL/HAND CLEANSING FIXTURE	DISPOSABLE DRYING WIPE PLUS CLEANSING AGENT	ASTRO-VAC	ORBITER PERSONAL HYGIENE STATION	DISPOSABLE LABORATORY UTENSILS/TOOLS	HOT WATER SPRAY WASHING-CENTRIFUGE DRYING SYSTEM	REUSABLE WIPES	DISPOSABLE WIPES WITH WETTER UNIT	ORBITER PERSONAL HYGIENE STATION AND SOLID WASTE COMPACTOR	DISPOSABLE LABORATORY UTENSILS/TOOLS AND SOLID WASTE COMPACTOR	DISPOSABLE WET AND DRY WIPES WITH SOLID WASTE COMPACTOR	SPACELAB UTENSIL/HAND CLEANSING FIXTURE WITH SOLID WASTE COMPACTOR
Human	X	X	X	X	X			X	X	X		X	X
Monkey	X	X	X	X	X			X	X	X		X	X
Rat		X			X	X	X			X			X
Mice		X			X	X	X			X	X	X	X
Bacteria		X	X		X					X			X
Frogs		X	X	X	X	X				X			X
Drosophila	X	X	X		X	X	X	X	X	X		X	X
Dogs		X	X		X	X	X		X	X	X		X

V. TASK THREE - TRADEOFF ANALYSIS

A. TASK OBJECTIVE

The objective of this task was to conduct a tradeoff analysis to determine the optimum approach for space flight missions of varying lengths to achieve a wash/rinse capability. This task was accomplished by determining the impact of each characteristic on each mission and then assessing the relative importance of each characteristic so that the approaches could be compared on a competitive basis.

B. WASH/RINSE CAPABILITY CONCEPT SPECIFICATIONS

The first step of this subtask was to establish effects on concept characteristics for each of the approaches described in Section IV of this report for the missions shown in Table V-1. Those characteristics that were examined are listed in Table V-2. Each concept was considered to be totally self-sustained except for equipment needed for power generation which is supplied by the Spacelab or Space Station. Fixed Weights and Volumes refer to the system and relating structural weight and volume which will remain constant during each mission. Expendable weights include wipes, water, soap, sponges, disinfectant, or any other commodity that is used up during the mission. Equivalent weights for environmental impact (latent and sensible heat loads) and power are found by using the appropriate equivalent weight ratios which are calculated based on the extra spacecraft equipment necessary to accommodate the additional weight. Total weight includes fixed weight, expendable weight, spares weight, power penalty and environmental impact equivalent weights. Total volume for each concept/mission type equals the corresponding fixed volume since the expendable and spares volumes are encompassed by the structural volume.

A matrix sheet was constructed for each of the concepts which listed these characteristics versus the various mission types. Tables V-3 thru V-15 show these matrices for each of the concepts. Quantitative data derivation for each concept and mission type can be found in Appendix A of this report. Ten handwashings per crewman per day were used as the common calculative link between all the concepts except for the Disposable Laboratory Utensils/Tools Concept and the Hot Water Spray Washing - Centrifuge Drying System. Here the data were based upon experiment need on a per day basis.

Table V-1 Missions to be Utilized for Tradeoff Analysis

PERSONNEL	MISSION	MISSION DURATION	WASH WATER RECOVERY SYSTEM
4 Man	Shuttle/Spacelab	7 Day	No
7 Man	Shuttle/Spacelab	7 Day	No
7 Man	Shuttle/Spacelab	30 Day	No
7 Man	Space Station	180 Day	No
7 Man	Shuttle/Spacelab	30 Day	Yes
7 Man	Space Station	180 Day	Yes

Table V-2 Characteristics Determined for Each Concept

- Cost
- Functional Performance
- Maintainability
- Reliability
- Fixed Structural Weight
- Fixed Structural Volume
- Maximum and Average Power Requirements
- Safety
- Time Requirements
- Expendable Weight
- Expendable Volume
- Environmental Impact (Latent and Sensible Heat Loads)
- Crew Acceptability
- Cleansing Action
- Training Requirements
- Concept Complexity

Table V-3 Disposable Wet and Dry Wipe Concept Specifications

FUNCTIONAL PERFORMANCE: ■ HANDWASHING
■ WORK AREA CLEANUP
■ UTENSIL CLEANSING
■ "SPONGE-TYPE" BODY WASH

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITHOUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Fixed Weight kg (lb)	3.4 (7.4)	4.6 (10.15)	10.2 (22.55)	31.8 (70.2)	N/A	N/A
Fixed Volume m ³ (in. ³)	.113 (6908)	.16 (9692)	.5 (30,032)	2.65 (161,855)	N/A	N/A
Expendable Weight kg (lb)	4.45 (9.9)	7.85 (17.3)	33.5 (73.8)	200.9 (443)	N/A	N/A
Expendable Volume m ³ (in. ³)	.01 (630)	.018 (1103)	.078 (4725)	.465 (28,350)	N/A	N/A
Number of Spares	None	None	None	None	N/A	N/A
Spares Weight kg (lb)	None	None	None	None	N/A	N/A
Maximum Power Watts	None	None	None	None	N/A	N/A
Average Power Joules (Watt-hr)	None	None	None	None	N/A	N/A
Maximum Latent Heat Load 10 ³ joules/day (Btu/day)	591.4 (560)	1034.9 (980)	1034.9 (980)	1034.9 (980)	N/A	N/A
Maximum Sensible Heat Load Joules/day (Btu/day)	Negligible	Negligible	Negligible	Negligible	N/A	N/A
Total Weight kg (lb)	9.2 (20.3)	14.8 (32.65)	46.1 (101.6)	235.2 (518.4)	N/A	N/A
Maintenance	Disposal	Disposal	Disposal	Disposal	N/A	N/A
Safety	- Fire Hazard - Microbial Growth in Waste Storage if not completely dry	- Fire Hazard - Microbial Growth in Waste Storage if not completely dry	- Fire Hazard - Microbial Growth in Waste Storage if not completely dry	- Fire Hazard - Microbial Growth in Waste Storage if not completely dry	N/A	N/A
Time Requirements sec	- Handwash: 90 - Work Area Cleanup: 180 - Utensil Cleansing: 60 - Body Wash: 300	- Handwash: 90 - Work Area Cleanup: 180 - Utensil Cleansing: 60 - Body Wash: 300	- Handwash: 90 - Work Area Cleanup: 180 - Utensil Cleansing: 60 - Body Wash: 300	- Handwash: 90 - Work Area Cleanup: 180 - Utensil Cleansing: 60 - Body Wash: 300	N/A	N/A
Training Requirements	Minimum	Minimum	Minimum	Minimum	N/A	N/A
Cost Factor	BL	1.3 BL	1.5 BL	3.2 BL	N/A	N/A
Crew Acceptability	Fair	Fair	Fair	Fair	N/A	N/A
Cleansing Action	Fair	Fair	Fair	Fair	N/A	N/A
Reliability No. Component Single Point Failure	3 None	3 None	3 None	3 None	N/A N/A	N/A N/A
Complexity	Very Simple	Very Simple	Very Simple	Very Simple	N/A	N/A

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Table V-4 Spacelab Utensil/Hand Cleansing Fixture Concept Specifications

FUNCTIONAL PERFORMANCE: • HANDWASHING
• HAIR WETTING
• BRUSHING TEETH
• "SPONGE-TYPE" BODY WASH
• LIQUID WASTE (BLOOD, URINE, ETC) DUMP
• SHAVING
• VOMITUS SYSTEM
• CHEMICAL DUMP
• WORK AREA CLEANUP

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Fixed Weight kg (lb)	26.5 (58.45)	29.55 (65.14)	44.96 (99.12)	150.1 (330.95)	109.5 (241.4)	121.3 (267.5)
Fixed Volume m ³ (in. ³)	.65 (39,660)	.79 (43,251)	1.15 (70,395)	4.05 (247,214)	1.06 (64,471)	2.05 (124,981)
Expendable Weight kg (lb)	53.2 (117.26)	92.87 (204.75)	398 (877.5)	2390.3 (5269.7)	29.8 (65.7)	116.96 (257.9)
Expendable Volume m ³ (in. ³)	.064 (3926)	.113 (6918)	.49 (29,605)	2.9 (177,030)	.12 (7124)	.63 (38,242)
Number of Spares	None	None	None	One	None	Two*
Spares Weight kg (lb)	None	None	None	.9 (2)	None	1.13 (2.5)*
Maintenance - Wipes - Cleansing Fixture - Wash Water Re- covery System	- Disposal - Clean Drainage Screen - Disinfect Enclos- ure - Clean Water & Soap Nozzles N/A	- Disposal - Clean Drainage Screen - Disinfect Enclos- ure - Clean Water & Soap Nozzles N/A	- Disposal - Clean Drainage Screen - Disinfect Enclos- ure - Clean Water & Soap Nozzles N/A	- Disposal - Replace Maintain- able Filter - Clean Drainage Screen - Disinfect Enclos- ure - Clean Water & Soap Nozzles N/A	- Disposal - Clean Drainage Screen - Disinfect Enclos- ure - Clean Water & Soap Nozzles None	- Disposal - Replace Maintain- able Filter - Clean Drainage Screen - Disinfect Enclos- ure - Clean Water & Soap Nozzles - Replace Bacteria Filter
Maximum Power Watts AC DC	26 99	26 99	26 99	26 99	81 199	81 199
Average Power 10 ³ Joules (watt-hr) per wash	28.8 (8)	28.8 (8)	28.8 (8)	28.8 (8)	39.24 (10.9)	39.24 (10.9)
Maximum Latent Load 10 ³ Joules/day (Btu/ day)	553.3 (524)	958.4 (917)	958.4 (917)	958.4 (917)	**	**
Maximum Sensible Heat Load 10 ³ Joules/day (Btu/ day)	274.6 (260)	480.5 (455)	480.5 (455)	480.5 (455)	**	**
Total Weight kg (lb)	116.5 (255.9)	160.7 (354.2)	481.2 (1060.9)	2579.6 (5686.9)	222.1 (489.5)**	322.2 (710.3)**
Safety - Wipes - Cleansing Fixture - Wash Water Re- covery System	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry - None N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry - None N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry - None N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry - None N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry - None None	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry - None None
Time Requirements (sec)	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180
Training	Small	Small	Small	Small	Small	Small
Cost Factor	24 BL	24.2 BL	24.3 BL	24.6 BL	36.2 BL	36.4 BL
Crew Acceptability	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Cleansing Action	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent

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Table V-4 (Continued)

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Reliability - No. of Components - Single Point Failures • Cleansing Fixture • Water Heater • Thermostat Sensor Failure • Ruptured Hot Water Holding Tank • Blower Power Discontinuity • Blower Fan Structural Failure • Water Pump Power Discontinuity • Wash Water Recovery System	36 N/A	36 N/A	36 N/A	36 N/A	64 • Check Valve Clogged in "open" position • Pump mechanical breakage • Pump power discontinuity • 3-way electrical valve power discontinuity	64 • Check Valve Clogged in "open" position • Pump mechanical breakage • Pump power discontinuity • 3-way electrical valve power discontinuity
Complexity	Moderate	Moderate	Moderate	Moderate	Moderately High	Moderately High

* Estimated number of spares and their weight for wash water recovery system.

** Maximum latent and sensible heat load not known for wash water recovery system at this time.

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Table V-5 Disposable Dry Wipes and Cleansing Agents Concept Specifications

FUNCTIONAL PERFORMANCE: ■ HANDWASHING ■ BRUSHING TEETH
 ■ WORK AREA CLEANUP ■ SHAVING
 ■ UTENSIL CLEANSING ■ HAIR WETTING
 ■ "SPONGE-TYPE" BODY WASH

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Fixed Weight kg (lb)	2.7 (5.94)	4.08 (9)	10.3 (22.7)	37.9 (83.6)	N/A	N/A
Fixed Volume m ³ (in. ³)	.05 (3608)	.11 (6408)	.46 (27,798)	2.72 (165,640)	N/A	N/A
Expendable Weight kg (lb)	4.35 (9.6)	7.3 (16.1)	31.1 (68.5)	186.4 (411)	N/A	N/A
Expendable Volume m ³ (in. ³)	.011 (674.4)	.018 (1116.6)	.079 (4803.6)	.47 (28,652)	N/A	N/A
Number of Spares	None	None	None	None	N/A	N/A
Spares Weight kg (lb)	None	None	None	None	N/A	N/A
Maintenance - Wipes - Cleansing Agent Container	- Disposal - Clean Dispensing Valve	- Disposal - Clean Dispensing Valve	- Disposal - Clean Dispensing Valve	- Disposal - Clean Dispensing Valve	N/A	N/A
Maximum Power AC DC	None None	None None	None None	None None	N/A N/A	N/A N/A
Average Power 10 ³ joules (watt-hr) per wash	None	None	None	None	N/A	N/A
Maximum Latent Heat Load 10 ³ joules/day (Btu/ day)	278.7 (264)	487.7 (462)	487.7 (462)	487.7 (462)	N/A	N/A
Maximum Sensible Heat Load 10 ³ joules/day (Btu/ day)	Negligible	Negligible	Negligible	Negligible	N/A	N/A
Total Weight kg (lb)	7.7 (16.95)	12.52 (27.6)	42.5 (93.7)	225.5 (497.1)	N/A	N/A
Safety - Wipes - Cleansing Agent Container	- Fire Hazard - Microbial Growth in Waste Storage if not completely dry - Propellant Leakage if Container Damaged	- Fire Hazard - Microbial Growth in Waste Storage if not completely dry - Propellant Leakage if Container Damaged	- Fire Hazard - Microbial Growth in Waste Storage if not completely dry - Propellant Leakage if Container Damaged	- Fire Hazard - Microbial Growth in Waste Storage if not completely dry - Propellant Leakage if Container Damaged	N/A	N/A
Time Requirements (sec)	- Handwash: 90 - Work Area Cleanup: 180 - Utensil Cleansing: 60 - Body Wash: 300 - Shaving: 297 - Hair Wetting: 180 - Brushing Teeth: 163	- Handwash: 90 - Work Area Cleanup: 180 - Utensil Cleansing: 60 - Body Wash: 300 - Shaving: 297 - Hair Wetting: 180 - Brushing Teeth: 163	- Handwash: 90 - Work Area Cleanup: 180 - Utensil Cleansing: 60 - Body Wash: 300 - Shaving: 297 - Hair Wetting: 180 - Brushing Teeth: 163	- Handwash: 90 - Work Area Cleanup: 180 - Utensil Cleansing: 60 - Body Wash: 300 - Shaving: 297 - Hair Wetting: 180 - Brushing Teeth: 163	N/A	N/A
Training	Minimum	Minimum	Minimum	Minimum	N/A	N/A
Cost Factor	1.05 BL	1.3 BL	1.57 BL	3.2 BL	N/A	N/A
Crew Acceptability	Fair	Fair	Fair	Fair	N/A	N/A
Cleansing Action	Fair	Fair	Fair	Fair	N/A	N/A
Reliability - No. of Components - Single Point Failures - Cleansing Agent Container	8 - Nozzle Clogs - Valve Damage	8 - Nozzle Clogs - Valve Damage	8 - Nozzle Clogs - Valve Damage	8 - Nozzle Clogs - Valve Damage	N/A	N/A
Complexity	Simple	Simple	Simple	Simple	N/A	N/A

Table V-6 Astro-Vac Concept Specifications

FUNCTIONAL PERFORMANCE: • HANDWASHING
• "SPONGE-TYPE" BODY WASH
• WORK AREA CLEANUP

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Fixed Weight kg (lb)	17.7 (39.0)	21 (46.34)	41.68 (91.88)	159.5 (351.63)	100.9 (222.5)	112.6 (249.2)
Fixed Volume m ³ (in. ³)	.16 (9515)	.23 (13,787)	.74 (45,308)	4.11 (251,154)	.55 (33,756)	1.54 (94,218)
Expendable Weight kg (lb)	65.64 (144.7)	114.85 (253.2)	491.7 (1094)	2950.4 (6505)	31.2 (68.9)	108.6 (239.5)
Expendable Volume m ³ (in. ³)	.058 (4189.1)	.12 (7273)	.51 (30,966.5)	3.04 (185,744)	.047 (2859)	.2 (12251)
Number of Spares	None	None	None	One	None	Two*
Spares Weight kg (lb)	None	None	None	.9 (2)	None	1.13 (2.5)*
Maintenance - Wipes - Astro-Vac - Wash Water Re- covery System	- Disposal - Clean Washing Head N/A	- Disposal - Clean Washing Head N/A	- Disposal - Clean Washing Head N/A	- Disposal - Clean Washing Head - Replace Filter N/A	- Disposal - Clean Washing Head	- Disposal - Clean Washing Head - Replace Filter - Replace Bacteria Filter
Maximum Power AC DC	None 50	None 90	None 90	None 90	55 190	55 190
Average Power 10 ³ joules (watt-hr) per wash	47.2 (13.1)	47.2 (13.1)	47.2 (13.1)	47.2 (13.1)	75 (20.9)	75 (20.9)
Maximum Latent Load 10 ³ joules/day (Btu/ day)	1150.6 (1090)	2026.8 (1920)	2026.8 (1920)	2026.8 (1920)	**	**
Maximum Sensible Heat Load 10 ³ joules/day (Btu/ day)	23.2 (22)	40.4 (38.3)	40.4 (38.3)	40.4 (38.3)	**	**
Total Weight kg (lb)	110.1 (242.8)	164.8 (363.2)	562.2 (1239.5)	3140.4 (6923.3)	205.5 (453.1)**	295.7 (651.9)**
Safety - Wipes - Astro-Vac - Wash Water Re- covery System	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry - Potential Micro- bial Growth Areas in Sponge and Wash- ing Head N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry - Potential Micro- bial Growth Areas in Sponge and Wash- ing Head N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry - Potential Micro- bial Growth Areas in Sponge and Wash- ing Head N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry - Potential Micro- bial Growth Areas in Sponge and Wash- ing Head N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry - Potential Micro- bial Growth Areas in Sponge and Wash- ing Head None	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry - Potential Micro- bial Growth Areas in Sponge and Wash- ing Head None
Time Requirements (sec)	- Handwash: 180 - Body Wash: 900 - Work Area Cleanup: 240	- Handwash: 180 - Body Wash: 900 - Work Area Cleanup: 240	- Handwash: 180 - Body Wash: 900 - Work Area Cleanup: 240	- Handwash: 180 - Body Wash: 900 - Work Area Cleanup: 240	- Handwash: 180 - Body Wash: 900 - Work Area Cleanup: 240	- Handwash: 180 - Body Wash: 900 - Work Area Cleanup: 240
Training	Small	Small	Small	Small	Small	Small
Cost Factor	24 BL	24.2 BL	24.3 BL	24.6 BL	36.2 BL	36.4 BL
Crew Acceptability	Good	Good	Good	Good	Good	Good
Cleansing Action	Good	Good	Good	Good	Good	Good
Reliability - No. of Components - Single Point Failure • Astro-Vac • Wash Water Re- covery System	19 • Water Heater Thermostat Sensor Failure • Ruptured Hot Water Holding Tank • Blower Power Dis- continuity • Blower Structural Failure • Water Pump Power Discontinuity • Separator Motor Power Discontinuity N/A	19 • Water Heater Thermostat Sensor Failure • Ruptured Hot Water Holding Tank • Blower Power Dis- continuity • Blower Structural Failure • Water Pump Power Discontinuity • Separator Motor Power Discontinuity N/A	20 • Water Heater Thermostat Sensor Failure • Ruptured Hot Water Holding Tank • Blower Power Dis- continuity • Blower Structural Failure • Water Pump Power Discontinuity • Separator Motor Power Discontinuity N/A	20 • Water Heater Thermostat Sensor Failure • Ruptured Hot Water Holding Tank • Blower Power Dis- continuity • Blower Structural Failure • Water Pump Power Discontinuity • Separator Motor Power Discontinuity N/A	48 • Water Heater Thermostat Sensor Failure • Ruptured Hot Water Holding Tank • Blower Power Dis- continuity • Blower Structural Failure • Water Pump Power Discontinuity • Separator Motor Power Discontinuity • Check Valve Clog- ged in "Open" Position • Pump Mechanical Breakage • Pump Power Discon- tinuity • 3-way Electrical Valve Power Discon- tinuity	48 • Water Heater Thermostat Sensor Failure • Ruptured Hot Water Holding Tank • Blower Power Dis- continuity • Blower Structural Failure • Water Pump Power Discontinuity • Separator Motor Power Discontinuity • Check Valve Clog- ged in "Open" Position • Pump Mechanical Breakage • Pump Power Discon- tinuity • 3-way Electrical Valve Power Discon- tinuity
Complexity	Moderately Simple	Moderately Simple	Moderately Simple	Moderately Simple	Moderate	Moderate

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Table V-7 Orbiter Personal Hygiene Station Concept Specifications

FUNCTIONAL PERFORMANCE:
 • HANDWASHING
 • HAIR WETTING
 • BRUSHING TEETH
 • "SPONGE-TYPE" BODY WASH
 • LIQUID WASTE (BLOOD, URINE, ETC) DUMP
 • SHAVING
 • VOMITUS SYSTEM
 • CHEMICAL DUMP
 • WORK AREA CLEANUP

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH-OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Fixed Weight kg (lb)	26.5 (58.5)	29.6 (65.2)	44.5 (98)	149.3 (329.1)	110 (242.5)	121.1 (266.9)
Fixed Volume m ³ (in. ³)	.65 (39,641)	.71 (43,217)	1.15 (70,249)	4.04 (246,352)	1.05 (64,324.4)	2.03 (124,119.4)
Expendable Weight kg (lb)	53.2 (117.3)	92.9 (204.8)	397.9 (877.25)	2390.4 (5269.8)	29.7 (65.5)	117 (257.95)
Expendable Volume m ³ (in. ³)	.055 (3346.8)	.095 (5843.3)	.41 (25,048.9)	2.47 (150,412)	.042 (2567.9)	.19 (11,624)
Number of Spares	None	None	None	One	None	Two*
Spares Weight kg (lb)	None	None	None	.9 (2)	None	1.13 (2.5)*
Maintenance - Wipes - Personal Hygiene Station - Wash Water Recovery System	- Disposal - Clean Drainage Screen - Disinfect Enclosure - Clean Water Nozzles N/A	- Disposal - Clean Drainage Screen - Disinfect Enclosure - Clean Water Nozzles N/A	- Disposal - Clean Drainage Screen - Disinfect Enclosure - Clean Water Nozzles N/A	- Disposal - Clean Drainage Screen - Disinfect Enclosure - Clean Water Nozzles - Replace Filter N/A	- Disposal - Clean Drainage Screen - Disinfect Enclosure - Clean Water Nozzles - Replace Filter None	- Disposal - Clean Drainage Screen - Disinfect Enclosure - Clean Water Nozzles - Replace Filter - Replace Bacteria Filter
Maximum Power AC DC	26 99	26 99	26 99	26 99	81 199	81 199
Average Power 10 ³ Joules (watt-hr) per wash	28.8 (8)	28.8 (8)	28.8 (8)	28.8 (8)	39.24 (10.9)	39.24 (10.9)
Maximum Latent Load 10 ³ Joules/day (Btu/day)	553.3 (524)	968.4 (917)	968.4 (917)	968.4 (917)	**	**
Maximum Sensible Heat Load 10 ³ Joules/day (Btu/day)	274.6 (260)	480.5 (455)	480.5 (455)	480.5 (455)	**	**
Total Weight kg (lb)	116.6 (256.95)	160.7 (354.3)	480.6 (1059.5)	257.8 (5685.2)	222.5 (490.4)**	322 (709.8)**
Safety - Wipes - Personal Hygiene Station - Wash Water Recovery System	- Fire Hazard - Crew Slippage on Soap if not properly retained N/A	- Fire Hazard - Crew Slippage on Soap if not properly retained N/A	- Fire Hazard - Crew Slippage on Soap if not properly retained N/A	- Fire Hazard - Crew Slippage on Soap if not properly retained N/A	- Fire Hazard - Crew Slippage on Soap if not properly retained None	- Fire Hazard - Crew Slippage on Soap if not properly retained None
Time Requirements (sec)	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180
Training	Small	Small	Small	Small	Small	Small
Cost Factor	15.4 BL	18.5 BL	15.9 BL	15.92 BL	27.5 BL	27.7 BL
Crew Acceptability	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Cleansing Action	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Reliability - No. of Components - Single Point Failures • Personal Hygiene Station - Wash Water Recovery System	35 Water Heater Thermostat Failure Ruptured Hot Water Holding Tank Blower Power Discontinuity Blower Structural Failure Water Pump Power Discontinuity N/A	35 Water Heater Thermostat Failure Ruptured Hot Water Holding Tank Blower Power Discontinuity Blower Structural Failure Water Pump Power Discontinuity N/A	35 Water Heater Thermostat Failure Ruptured Hot Water Holding Tank Blower Power Discontinuity Blower Structural Failure Water Pump Power Discontinuity N/A	35 Water Heater Thermostat Failure Ruptured Hot Water Holding Tank Blower Power Discontinuity Blower Structural Failure Water Pump Power Discontinuity N/A	63 Water Heater Thermostat Failure Ruptured Hot Water Holding Tank Blower Power Discontinuity Blower Structural Failure Water Pump Power Discontinuity Check Valve Clogged in "Open" Position Pump Mechanical Breakage Pump Power Discontinuity 3-way Electrical Valve Power Discontinuity	63 Water Heater Thermostat Failure Ruptured Hot Water Holding Tank Blower Power Discontinuity Blower Structural Failure Water Pump Power Discontinuity Check Valve Clogged in "Open" Position Pump Mechanical Breakage Pump Power Discontinuity 3-way Electrical Valve Power Discontinuity
Complexity	Moderate	Moderate	Moderate	Moderate	Moderately High	Moderately High

Table V-8 Disposable Laboratory Utensils/Tools Concept Specifications

FUNCTIONAL PERFORMANCE: ■ ELIMINATES NEED FOR UTENSIL AND HAND CLEANSING
■ DRY WIPE WORK AREA CLEANUP

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Fixed Weight kg (lb)	11.2 (24.6)	12.1 (26.7)	46.1 (101.6)	253.2 (558.12)	N/A	N/A
Fixed Volume m ³ (in. ³)	.15 (9413)	.19 (11,407)	.71 (43,072)	4.03 (249,201)	N/A	N/A
Expendable Weight kg (lb)	15.6 (34.3)	16.7 (36.8)	69.5 (153.2)	409.9 (903.7)	N/A	N/A
Expendable Volume m ³ (in. ³)	.046 (2788.6)	.048 (2946.1)	.205 (12,595)	1.24 (75,451)	N/A	N/A
Number of Spares	None	None	None	None	N/A	N/A
Spares Weight kg (lb)	None	None	None	None	N/A	N/A
Maintenance						
- Wipes	Disposal	Disposal	Disposal	Disposal	N/A	N/A
- Laboratory Utensils/Tools	Disposal	Disposal	Disposal	Disposal	N/A	N/A
- Gloves	Disposal	Disposal	Disposal	Disposal	N/A	N/A
Maximum Power Watts	None	None	None	None	N/A	N/A
Average Power joules (watt-hr)	None	None	None	None	N/A	N/A
Maximum Latent Heat Load 10 ³ joules/day (Btu/ day)	1334.3 (1264)	1651 (1564)	1651 (1564)	1651 (1564)	N/A	N/A
Maximum Sensible Heat Load 10 ³ joules/day (Btu/ day)	Negligible	Negligible	Negligible	Negligible	N/A	N/A
Total Weight kg (lb)	29.8 (65.6)	32.6 (71.8)	119.3 (263.1)	666.8 (1470.1)	N/A	N/A
Safety						
- Wipes	- Fire Hazard - Microbial Growth in Waste Storage if wipes not com- pletely dry	- Fire Hazard - Microbial Growth in Waste Storage if wipes not com- pletely dry	- Fire Hazard - Microbial Growth in Waste Storage if wipes not com- pletely dry	- Fire Hazard - Microbial Growth in Waste Storage if wipes not com- pletely dry	N/A	N/A
- Laboratory Utensils/Tools	- Fire Hazard - Microbial Growth in Waste Storage if utensil/tools not completely dry	- Fire Hazard - Microbial Growth in Waste Storage if utensil/tools not completely dry	- Fire Hazard - Microbial Growth in Waste Storage if utensil/tools not completely dry	- Fire Hazard - Microbial Growth in Waste Storage if utensil/tools not completely dry	N/A	N/A
- Gloves	- Fire Hazard - Microbial Growth in Waste Storage if gloves not com- pletely dry	- Fire Hazard - Microbial Growth in Waste Storage if gloves not com- pletely dry	- Fire Hazard - Microbial Growth in Waste Storage if gloves not com- pletely dry	- Fire Hazard - Microbial Growth in Waste Storage if gloves not com- pletely dry	N/A	N/A
Time Requirements (sec)	- Laboratory Utensil/ Tools Use - Depends on Experi- ment Need	- Laboratory Utensil/ Tools Use - Depends on Experi- ment Need	- Laboratory Utensil/ Tools Use - Depends on Experi- ment Need	- Laboratory Utensil/ Tools Use - Depends on Experi- ment Need	N/A	N/A
Training	Minimal	Minimal	Minimal	Minimal	N/A	N/A
Cost Factor	6.6 BL	6.8 BL	11.5 BL	23 BL	N/A	N/A
Crew Acceptability	Fair	Fair	Fair	Fair	N/A	N/A
Cleansing Action	N/A	N/A	N/A	N/A	N/A	N/A
Reliability						
- No. of Components	20	20	20	20	N/A	N/A
- Single Point Failures	None	None	None	None	N/A	N/A
Complexity	Very Simple	Very Simple	Very Simple	Very Simple	N/A	N/A

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Table V-9 Hot Water Spray Washing - Centrifuge Drying System Concept Specifications

FUNCTIONAL PERFORMANCE:
 • ELIMINATES NEED FOR HAND CLEANSING
 • UTENSIL CLEANSING
 • WORK AREA CLEANUP

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Fixed Weight kg (lb)	52.6 (116)	53.5 (118)	73.3 (161.6)	108.5 (415.6)	136.7 (301.3)	153.5 (338.5)
Fixed Volume m ³ (in. ³)	.73 (50,703)	.85 (52,697)	1.42 (86,683)	5.05 (307,945)	1.3 (79,202)	2.88 (175,850)
Expendable Weight kg (lb)	98.7 (217.6)	99.7 (219.8)	424.8 (936.4)	2537 (5592.9)	31 (68.4)	102 (224.9)
Expendable Volume m ³ (in. ³)	.1 (6040.4)	.102 (6207)	.44 (26,570)	2.6 (159,301)	.041 (2503.2)	.175 (10,648.2)
Number of Spares	None	None	None	One	None	Two*
Spares Weight kg (lb)	None	None	None	.9 (2)	None	1.13 (2.5)*
Maintenance - Wipes - Gloves - Wash/Dry System - Wash Water Re- covery System	- Disposal - Disposal Clean Perforated Rotating Drum Compartment N/A	- Disposal - Disposal Clean Perforated Rotating Drum Compartment N/A	- Disposal - Disposal Clean Perforated Rotating Drum Compartment N/A	- Disposal - Disposal Clean Perforated Rotating Drum Compartment N/A	- Disposal - Disposal Clean Perforated Rotating Drum Compartment - Replace Filter None	- Disposal - Disposal Clean Perforated Rotating Drum Compartment - Replace Bacteria Filter
Maximum Power Watts AC DC	150 75	150 75	150 75	150 75	205 175	205 175
Average Power 10 ³ Joules/(watt-hr) per wash	2286.7 (635.2)	2286.7 (635.2)	2286.7 (635.2)	2286.7 (635.2)	2565.7 (712.7)	2565.7 (712.7)
Maximum Latent Load 10 ³ Joules/day (Btu/ day)	1037.1 (982.5)	1301.5 (1237.5)	1301.5 (1237.5)	1301.5 (1237.5)	**	**
Maximum Sensible Heat Load 10 ³ Joules/day (Btu/ day)	9123 (8642.5)	9123 (8642.5)	9123 (8642.5)	9123 (8642.5)	**	**
Total Weight kg (lb)	243 (535.6)	245.5 (541.2)	590.3 (1301.4)	2818.6 (6214)	304.5 (671.3)**	393.5 (867.5)**
Safety - Wipes - Gloves - Wash/Dry System - Wash Water Re- covery System	- Fire Hazard - Microbial Growth in Waste Storage if wipes not com- pletely dry - Fire Hazard - Microbial Growth in Waste Storage if gloves not com- pletely dry None N/A	- Fire Hazard - Microbial Growth in Waste Storage if wipes not com- pletely dry - Fire Hazard - Microbial Growth in Waste Storage if gloves not com- pletely dry None N/A	- Fire Hazard - Microbial Growth in Waste Storage if wipes not com- pletely dry - Fire Hazard - Microbial Growth in Waste Storage if gloves not com- pletely dry None N/A	- Fire Hazard - Microbial Growth in Waste Storage if wipes not com- pletely dry - Fire Hazard - Microbial Growth in Waste Storage if gloves not com- pletely dry None N/A	- Fire Hazard - Microbial Growth in Waste Storage if wipes not com- pletely dry - Fire Hazard - Microbial Growth in Waste Storage if gloves not com- pletely dry None N/A	- Fire Hazard - Microbial Growth in Waste Storage if wipes not com- pletely dry - Fire Hazard - Microbial Growth in Waste Storage if gloves not com- pletely dry None N/A
Time Requirements (sec)	- Laboratory Tool/ Utensil Cleansing: 3600	- Laboratory Tool/ Utensil Cleansing: 3600	- Laboratory Tool/ Utensil Cleansing: 3600	- Laboratory Tool/ Utensil Cleansing: 3600	- Laboratory Tool/ Utensil Cleansing: 3600	- Laboratory Tool/ Utensil Cleansing: 3600
Training	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Cost Factor	28.9 BL	29.1 BL	29.2 BL	29.5 BL	43.4 BL	43.7 BL
Crew Acceptability	Good	Good	Good	Good	Good	Good
Cleansing Action	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent

Table V-9 (Continued)

FUNCTIONAL PERFORMANCE:

MISSION/ CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Reliability - No. of Components - Single Point Failures • Wash/Dry System • Wash Water Recovery System	17 • Water Heater Thermostat Failure • Ruptured Hot Water Holding Tank • Motor Power Discontinuity • Water Pump Power Discontinuity • Valve Power Discontinuity • Motor Structural Failure • Water Pump Structural Failure N/A	17 • Water Heater Thermostat Failure • Ruptured Hot Water Holding Tank • Motor Power Discontinuity • Water Pump Power Discontinuity • Valve Power Discontinuity • Motor Structural Failure • Water Pump Structural Failure N/A	18 • Water Heater Thermostat Failure • Ruptured Hot Water Holding Tank • Motor Power Discontinuity • Water Pump Power Discontinuity • Valve Power Discontinuity • Motor Structural Failure • Water Pump Structural Failure N/A	18 • Water Heater Thermostat Failure • Ruptured Hot Water Holding Tank • Motor Power Discontinuity • Water Pump Power Discontinuity • Valve Power Discontinuity • Motor Structural Failure • Water Pump Structural Failure N/A	45 • Water Heater Thermostat Failure • Ruptured Hot Water Holding Tank • Motor Power Discontinuity • Water Pump Power Discontinuity • Valve Power Discontinuity • Motor Structural Failure • Water Pump Structural Failure • Check Valve Clogged in "Open" Position • Pump Mechanical Breakage • Pump Power Discontinuity • 3-way Electrical Valve Power Discontinuity	45 • Water Heater Thermostat Failure • Ruptured Hot Water Holding Tank • Motor Power Discontinuity • Water Pump Power Discontinuity • Valve Power Discontinuity • Motor Structural Failure • Water Pump Structural Failure • Check Valve Clogged in "Open" Position • Pump Mechanical Breakage • Pump Power Discontinuity • 3-way Electrical Valve Power Discontinuity
Complexity	High	High	High	High	Extremely High	Extremely High

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Table V-10 Reusable Wipes Concept Specifications

FUNCTIONAL PERFORMANCE: ■ HANDWASHING ■ BRUSHING TEETH
 ■ "SPONGE-TYPE" BODY WASH ■ SHAVING
 ■ WORK AREA CLEANUP
 ■ UTENSIL CLEANSING

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Fixed Weight kg (lb)	26.89 (59.3)	34.2 (75.3)	52 (114.6)	167.1 (368.3)	109.7 (241.3)	110.9 (244.5)
Fixed Volume m ³ (in. ³)	.18 (10,777.8)	.23 (14,114)	.6 (36,487)	3.02 (184,115)	.41 (24,935)	.46 (27,179)
Expendable Weight kg (lb)	64.7 (142.5)	113.27 (249.5)	481.4 (1061.3)	2885.9 (6352.3)	20.97 (46.2)	44.1 (97.3)
Expendable Volume m ³ (in. ³)	.068 (4132)	.12 (7232)	.49 (29,605)	2.89 (175,383)	.025 (1497)	.047 (2895)
Number of Spares	None	None	None	One	None	Two*
Spares Weight kg (lb)	None	None	None	.9 (2)	None	1.13 (2.5)*
Maintenance						
- Reusable Wipes	- Cabin Air Dry	- Cabin Air Dry	- Cabin Air Dry	- Cabin Air Dry - Disposal After 60 Days	- Cabin Air Dry	- Cabin Air Dry - Disposal After 60 Days
- Watter	- Clean Water Injectors	- Clean Water Injectors	- Clean Water Injectors	- Clean Water Injectors - Replace Filter	- Clean Water Injectors	- Clean Water Injectors - Replace Filter
- Drying Rack	None	None	None	None	None	None
- Wash Water Recovery System	N/A	N/A	N/A	N/A	None	- Replace Bacteria Filter
Maximum Power						
AC	None	None	None	None	55	55
DC	224	224	224	224	324	324
Average Power 10 ³ joules (watt-hr) per wash	70.6 (19.6)	70.6 (19.6)	70.6 (19.6)	70.6 (19.6)	104.04 (28.9)	104.04 (28.9)
Maximum Latent Heat Load 10 ³ joules/day (Btu/day)	7495 (7100)	13,115.8 (12,425)	13,115.8 (12,425)	13,115.8 (12,425)	**	**
Maximum Sensible Heat Load 10 ³ joules/day (Btu/day)	760 (720)	1330 (1260)	1330 (1260)	1330 (1260)	*	*
Total Weight kg (lb)	170.5 (376)	240.5 (530.2)	626.6 (1381.3)	3147 (6938)	268.3 (591.5)**	293.9 (647.8)**
Safety						
- Wipes	- Fire Hazard - Storage of Wipes Not Completely Dry Could Cause Microbial Growth	- Fire Hazard - Storage of Wipes Not Completely Dry Could Cause Microbial Growth	- Fire Hazard - Storage of Wipes Not Completely Dry Could Cause Microbial Growth	- Fire Hazard - Storage of Wipes Not Completely Dry Could Cause Microbial Growth	- Fire Hazard - Storage of Wipes Not Completely Dry Could Cause Microbial Growth	- Fire Hazard - Storage of Wipes Not Completely Dry Could Cause Microbial Growth
- Watter Unit	- Crew Slippage on Soap if Not Properly Retained	- Crew Slippage on Soap if Not Properly Retained	- Crew Slippage on Soap if Not Properly Retained	- Crew Slippage on Soap if Not Properly Retained	- Crew Slippage on Soap if Not Properly Retained	- Crew Slippage on Soap if Not Properly Retained
- Wash Water Recovery Unit	N/A	N/A	N/A	N/A	None	None
Time Requirements (sec)	- Hand Wash: 216 - Body Wash: 120 - Work Area Cleanup: 300 - Utensil Cleansing: 210 - Brushing Teeth: 163 - Shaving: 287	- Hand Wash: 216 - Body Wash: 120 - Work Area Cleanup: 300 - Utensil Cleansing: 210 - Brushing Teeth: 163 - Shaving: 287	- Hand Wash: 216 - Body Wash: 120 - Work Area Cleanup: 300 - Utensil Cleansing: 210 - Brushing Teeth: 163 - Shaving: 287	- Hand Wash: 216 - Body Wash: 120 - Work Area Cleanup: 300 - Utensil Cleansing: 210 - Brushing Teeth: 163 - Shaving: 287	- Hand Wash: 216 - Body Wash: 120 - Work Area Cleanup: 300 - Utensil Cleansing: 210 - Brushing Teeth: 163 - Shaving: 287	- Hand Wash: 216 - Body Wash: 120 - Work Area Cleanup: 300 - Utensil Cleansing: 210 - Brushing Teeth: 163 - Shaving: 287
Training	Small	Small	Small	Small	Small	Small
Cost Factor	26.5 BL	26.6 BL	26.8 BL	27.1 BL	39.8 BL	40.1 BL
Crew Acceptability	- Good if Washcloths are Clean; Poor if Dirty	- Good if Washcloths are Clean; Poor if Dirty	- Good if Washcloths are Clean; Poor if Dirty	- Good if Washcloths are Clean; Poor if Dirty	- Good if Washcloths are Clean; Poor if Dirty	- Good if Washcloths are Clean; Poor if Dirty
Cleansing Action	Good	Good	Good	Good	Good	Good
Reliability						
- No. of Components	17	17	17	17	45	45
- Single Point Failures						
■ Watter Unit	- Water Heater Thermostat Sensor Failure - Ruptured Hot Water Holding Tank - Air Transport Blower Power Discontinuity - Water Pump Power Discontinuity - Pump or Fan Structural Failure - Separator Pump Power Discontinuity	- Water Heater Thermostat Sensor Failure - Ruptured Hot Water Holding Tank - Air Transport Blower Power Discontinuity - Water Pump Power Discontinuity - Pump or Fan Structural Failure - Separator Pump Power Discontinuity	- Water Heater Thermostat Sensor Failure - Ruptured Hot Water Holding Tank - Air Transport Blower Power Discontinuity - Water Pump Power Discontinuity - Pump or Fan Structural Failure - Separator Pump Power Discontinuity	- Water Heater Thermostat Sensor Failure - Ruptured Hot Water Holding Tank - Air Transport Blower Power Discontinuity - Water Pump Power Discontinuity - Pump or Fan Structural Failure - Separator Pump Power Discontinuity	- Water Heater Thermostat Sensor Failure - Ruptured Hot Water Holding Tank - Air Transport Blower Power Discontinuity - Water Pump Power Discontinuity - Pump or Fan Structural Failure - Separator Pump Power Discontinuity	- Water Heater Thermostat Sensor Failure - Ruptured Hot Water Holding Tank - Air Transport Blower Power Discontinuity - Water Pump Power Discontinuity - Pump or Fan Structural Failure - Separator Pump Power Discontinuity

Table V-10 (Continued)

FUNCTIONAL PERFORMANCE:

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Reliability (Cont'd) - Single Point Failures (Cont'd) • Wash Water Re- covery System	N/A	N/A	N/A	N/A	• Check Valve Clog- ged in "Open" .. Position • Pump Mechanical Breakage • Pump Power Discon- tinuity • 3-way Electrical Valve Power Discon- tinuity	• Check Valve Clog- ged in "Open" Position • Pump Mechanical Breakage • Pump Power Discon- tinuity • 3-way Electrical Valve Power Discon- tinuity
Complexity	Moderate	Moderate	Moderate	Moderate	Moderately High	Moderately High

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Table V-11 Disposable Wipes with Wetter Unit
Concept Specifications

FUNCTIONAL PERFORMANCE: • HANDWASHING • BRUSHING TEETH
• "SPONGE-TYPE" BODY WASH • SHAVING
• WORK AREA CLEANUP
• UTENSIL CLEANSING

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH-OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Fixed Weight kg (lb)	25.1 (55.3)	30.3 (66.7)	56.75 (125.1)	203.3 (459.3)	114.4 (252.2)	152.2 (335.5)
Fixed Volume m ³ (in. ³)	.27 (16,637)	.38 (23,321)	1.22 (74,335)	6.65 (405,857.4)	1.03 (62,783)	4.08 (248,921)
Expendable Weight kg (lb)	68.9 (151.9)	120.4 (265.4)	515.5 (1135.5)	1,094.9 (6823)	55.1 (121.5)	253.1 (559)
Expendable Volume m ³ (in. ³)	.104 (6355.5)	.185 (11,163)	.79 (48,131.3)	4.7 (286,506)	.33 (20,024)	1.05 (113,014)
Number of Spares	None	None	None	One	None	Two*
Spares Weight kg (lb)	None	None	None	.9 (2)	None	1.13 (2.5)*
Maintenance - Wipes - Wetter - Cleansing Agent Container - Wash Water Recovery System	Disposal Clean Water Injectors Clean Dispensing Valve N/A	Disposal Clean Water Injectors Clean Dispensing Valve N/A	Disposal Clean Water Injectors Clean Dispensing Valve N/A	Disposal Clean Water Injectors - Replace Filter Clean Dispensing Valve N/A	Disposal Clean Water Injectors Clean Dispensing Valve None	Disposal Clean Water Injectors - Replace Filter Clean Dispensing Valve - Replace Bacteria Filter
Maximum Power AC DC	None 224	None 224	None 224	None 224	55 324	55 324
Average Power 10 ³ joules (watt-hr)	70.6 (19.6)	70.6 (19.6)	70.6 (19.6)	70.6 (19.6)	104.04 (28.9)	104.04 (28.9)
Maximum Latent Heat Load 10 ³ joules/day (Btu/day)	2639 (2500)	4618 (4375)	4518 (4375)	4618 (4375)	**	**
Maximum Sensible Heat Load 10 ³ joules/day (Btu/day)	760 (720)	1330 (1260)	1330 (1260)	1330 (1260)	**	**
Total Weight kg (lb)	161.8 (356.7)	224.3 (494.5)	645.9 (1424)	3377.8 (7446.7)	287.7 (634.2)**	524.6 (1156.5)**
Safety - Wipes - Wetter Unit - Cleansing Agent Container - Wash Water Recovery System	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not completely dry None - Propellant Leakage if Container Damaged N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not completely dry None - Propellant Leakage if Container Damaged N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not completely dry None - Propellant Leakage if Container Damaged N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not completely dry None - Propellant Leakage if Container Damaged N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not completely dry None - Propellant Leakage if Container Damaged None	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not completely dry None - Propellant Leakage if Container Damaged None
Time Requirements (sec) - Handwash: 216 - Body Wash: 120 - Work Area Cleanup: 300 - Utensil Cleansing: 210 - Brushing Teeth: 163 - Shaving: 287	- Handwash: 216 - Body Wash: 120 - Work Area Cleanup: 300 - Utensil Cleansing: 210 - Brushing Teeth: 163 - Shaving: 287	- Handwash: 216 - Body Wash: 120 - Work Area Cleanup: 300 - Utensil Cleansing: 210 - Brushing Teeth: 163 - Shaving: 287	- Handwash: 216 - Body Wash: 120 - Work Area Cleanup: 300 - Utensil Cleansing: 210 - Brushing Teeth: 163 - Shaving: 287	- Handwash: 216 - Body Wash: 120 - Work Area Cleanup: 300 - Utensil Cleansing: 210 - Brushing Teeth: 163 - Shaving: 287	- Handwash: 216 - Body Wash: 120 - Work Area Cleanup: 300 - Utensil Cleansing: 210 - Brushing Teeth: 163 - Shaving: 287	- Handwash: 216 - Body Wash: 120 - Work Area Cleanup: 300 - Utensil Cleansing: 210 - Brushing Teeth: 163 - Shaving: 287
Training	Small	Small	Small	Small	Small	Small
Cost Factor	26.5 BL	26.6 BL	26.8 BL	27.1 BL	39.8 BL	40.1 BL
Crew Acceptability	Fair	Fair	Fair	Fair	Fair	Fair
Cleansing Action	Good	Good	Good	Good	Good	Good
Reliability - No. of Components - Single Point Failures • Wetter Unit • Cleansing Agent Container	19 • Water Heat Thermostat Failure • Ruptured Hot Water Holding Tank • Air Transport Blower Power Discontinuity • Pump or Fan Structural Failure • Separator Pump Power Discontinuity • Nozzle Clogs • Valve Damage	19 • Water Heat Thermostat Failure • Ruptured Hot Water Holding Tank • Air Transport Blower Power Discontinuity • Pump or Fan Structural Failure • Separator Pump Power Discontinuity • Nozzle Clogs • Valve Damage	19 • Water Heat Thermostat Failure • Ruptured Hot Water Holding Tank • Air Transport Blower Power Discontinuity • Pump or Fan Structural Failure • Separator Pump Power Discontinuity • Nozzle Clogs • Valve Damage	19 • Water Heat Thermostat Failure • Ruptured Hot Water Holding Tank • Air Transport Blower Power Discontinuity • Pump or Fan Structural Failure • Separator Pump Power Discontinuity • Nozzle Clogs • Valve Damage	47 • Water Heat Thermostat Failure • Ruptured Hot Water Holding Tank • Air Transport Blower Power Discontinuity • Pump or Fan Structural Failure • Separator Pump Power Discontinuity • Nozzle Clogs • Valve Damage	47 • Water Heat Thermostat Failure • Ruptured Hot Water Holding Tank • Air Transport Blower Power Discontinuity • Pump or Fan Structural Failure • Separator Pump Power Discontinuity • Nozzle Clogs • Valve Damage

Table V-11 (Continued)
FUNCTIONAL PERFORMANCE:

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Reliability (Cont'd) - Single Point Failures (Cont'd) • Wash Water Re- covery System	N/A	N/A	N/A	N/A	• Check Valve Clog- ged in "Open" Position • Pump Mechanical Failure • Pump Power Discon- tinuity • 3-way Electrical Valve Power Discon- tinuity	• Check Valve Clog- ged in "Open" Position • Pump Mechanical Failure • Pump Power Discon- tinuity • 3-way Electrical Valve Power Discon- tinuity
Complexity	Moderate	Moderate	Moderate	Moderate	Moderately High	Moderately High

Table V-12 Spacelab Utensil/Hand Cleansing Fixture with Solid Waste Compactor
Concept Specifications

FUNCTIONAL PERFORMANCE:

- HANDWASHING
- HAIR WETTING
- BRUSHING TEETH
- "SPONGE-TYPE" BODY WASH
- LIQUID WASTE (BLOOD, URINE, ETC) DUMP
- SHAVING
- VOMITUS SYSTEM
- CHEMICAL DUMP
- WORK AREA CLEANUP

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Fixed Weight kg (lb)	57 (125.7)	59.74 (131.7)	74.4 (164)	176.3 (388.7)	138.94 (306.3)	147.5 (325.2)
Fixed Volume m ³ (in. ³)	.69 (42,360)	.73 (44,796.3)	1.13 (68,954.5)	3.7 (226,080)	1.03 (63,030)	1.7 (103,847.4)
Expendable Weight kg (lb)	53.2 (117.28)	92.87 (204.75)	399.4 (880.5)	2399.4 (5289.7)	31.2 (68.7)	126.1 (277.9)
Expendable Volume m ³ (in. ³)	.064 (3926)	.113 (6918)	.52 (31,849)	3.15 (191,990)	.154 (9368)	.87 (53,222)
Number of Spares	None	None	One	Two	One	Three
Spares Weight kg (lb)	None	None	2.27 (5)	3.2 (7)	2.27 (5)	3.4 (7.5)*
Maintenance - Wipes - Cleansing Fix- ture - Wash Water Re- covery System - Compactor	- Disposal - Clean Drainage Screen - Disinfect Enclos- ure - Clean Water & Soap Nozzles N/A - Lubricate Drive Mechanisms	- Disposal - Clean Drainage Screen - Disinfect Enclos- ure - Clean Water & Soap Nozzles N/A - Lubricate Drive Mechanisms	- Disposal - Clean Drainage Screen - Disinfect Enclos- ure - Clean Water & Soap Nozzles N/A - Lubricate Drive Mechanisms	- Disposal - Clean Drainage Screen - Disinfect Enclos- ure - Clean Water & Soap Nozzles - Replace Maintain- able Filter N/A - Lubricate Drive Mechanisms	- Disposal - Clean Drainage Screen - Disinfect Enclos- ure - Clean Water & Soap Nozzles None - Lubricate Drive Mechanisms	- Disposal - Clean Drainage Screen - Disinfect Enclos- ure - Clean Water & Soap Nozzles - Replace Maintain- able Filter - Replace Bacteria Filter - Lubricate Drive Mechanisms
Maximum Power Watts AC DC	26 99	26 99	26 99	26 99	81 199	81 199
Average Power 10 ³ joules (watt-hr) per wash	28.8 (8)	28.8 (8)	28.8 (8)	28.8 (8)	39.24 (10.9)	39.24 (10.9)
Maximum Latent Load 10 ³ joules/day (Btu/ c y)	553.3 (524)	968.4 (917)	968.4 (917)	968.4 (917)	**	**
Total Weight kg (lb)	147 (324.14)	109.8 (420.74)	514.3 (1133.8)	2617.1 (5769.7)	255.1 (562.4)**	359.7 (793)**
Safety - Wipes - Cleansing Fixture - Compactor - Wash Water Re- covery System	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry None None N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry None None N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry None None N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry None None N/A	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry None None None	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not com- pletely dry None None None
Time Requirements (sec)	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180 - Compactor: 20	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180 - Compactor: 20	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180 - Compactor: 20	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180 - Compactor: 20	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180 - Compactor: 20	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180 - Compactor: 20
Training	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Cost Factor	28.8 BL	28.9 BL	29 BL	29.3 BL	40.9 BL	41.2 BL
Crew Acceptability	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Cleansing Action	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent

Table V-12 (Continued)

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Reliability - No. of Components - Single Point Failures	57	57	57	57	85	85
- Cleansing Fixture - Water Heater Thermostat Sensor Failure - Ruptured Hot Water Holding Tank - Blower Power Discontinuity - Blower Structural Failure - Water Pump Power Discontinuity	- Water Heater Thermostat Sensor Failure - Ruptured Hot Water Holding Tank - Blower Power Discontinuity - Blower Structural Failure - Water Pump Power Discontinuity	- Water Heater Thermostat Sensor Failure - Ruptured Hot Water Holding Tank - Blower Power Discontinuity - Blower Structural Failure - Water Pump Power Discontinuity	- Water Heater Thermostat Sensor Failure - Ruptured Hot Water Holding Tank - Blower Power Discontinuity - Blower Structural Failure - Water Pump Power Discontinuity	- Water Heater Thermostat Sensor Failure - Ruptured Hot Water Holding Tank - Blower Power Discontinuity - Blower Structural Failure - Water Pump Power Discontinuity	- Water Heater Thermostat Sensor Failure - Ruptured Hot Water Holding Tank - Blower Power Discontinuity - Blower Structural Failure - Water Pump Power Discontinuity	- Water Heater Thermostat Sensor Failure - Ruptured Hot Water Holding Tank - Blower Power Discontinuity - Blower Structural Failure - Water Pump Power Discontinuity
- Compactor - Wash Water Recovery System	- Drive Mechanism Failure - N/A	- Drive Mechanism Failure - N/A	- Drive Mechanism Failure - N/A	- Drive Mechanism Failure - N/A	- Drive Mechanism Failure - Check Valve Clogged in "Open" Position - Pump Mechanical Breakage - Pump Power Discontinuity 3-way Electrical Valve Power Discontinuity	- Drive Mechanism Failure - Check Valve Clogged in "Open" Position - Pump Mechanical Breakage - Pump Power Discontinuity 3-way Electrical Valve Power Discontinuity
Complexity	Moderately High	Moderately High	Moderately High	Moderately High	High	High

* Estimated number of spares and their weight for wash water recovery system.

** Maximum latent and sensible heat load not known for wash water recovery system at this time.

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**Table V-13 Orbiter Personal Hygiene Station and Solid Waste Compactor
Concept Specifications**

FUNCTIONAL PERFORMANCE:

- HANDWASHING
- HAIR WETTING
- BRUSHING TEETH
- "SPONGE-TYPE" BODY WASH
- LIQUID WASTE (BLOOD, URINE, ETC) DUMP
- SHAVING
- VOMITUS SYSTEM
- CHEMICAL DUMP
- WORK AREA CLEANUP

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Fixed Height kg (lb)	57 (125.7)	59.8 (131.8)	74.4 (163.9)	175.4 (386.8)	139.5 (307.4)	147.2 (324.6)
Fixed Volume m ³ (in. ³)	.68 (41,591)	.73 (44,762)	1.13 (69,807)	3.69 (225,218)	1.03 (62,893)	1.69 (102,985)
Expendable Weight kg (lb)	53.2 (117.3)	92.9 (204.8)	399.3 (880.25)	2399.5 (5289.8)	31.1 (68.5)	126.1 (277.95)
Expendable Volume m ³ (in. ³)	.055 (3316.8)	.096 (5843.3)	.45 (27,293)	2.7 (165,372)	.079 (4822)	.44 (26,584)
Number of Spares	None	None	One	Two	One	Three*
Spares Weight kg (lb)	None	None	2.27 (5)	3.2 (7)	2.27 (5)	3.4 (7.5)**
Maintenance - Wipes - Personal Hygiene Station - Compactor - Wash Water Recovery System	- Disposal - Clean Drainage Screen - Disinfect Enclosure - Clean Water Nozzle - Lubricate Drive Mechanism N/A	- Disposal - Clean Drainage Screen - Disinfect Enclosure - Clean Water Nozzle - Lubricate Drive Mechanism N/A	- Disposal - Clean Drainage Screen - Disinfect Enclosure - Clean Water Nozzle - Lubricate Drive Mechanism N/A	- Disposal - Clean Drainage Screen - Disinfect Enclosure - Clean Water Nozzle - Replace Filter - Lubricate Drive Mechanism N/A	- Disposal - Clean Drainage Screen - Disinfect Enclosure - Clean Water Nozzle - Lubricate Drive Mechanism None	- Disposal - Clean Drainage Screen - Disinfect Enclosure - Clean Water Nozzle - Replace Filter - Lubricate Drive Mechanism - Replace Bacteria Filter
Maximum Power AC DC	26 99	26 99	26 99	26 99	81 199	81 199
Average Power 10 ³ joules (watt-hr) per wash	28.8 (8)	28.8 (8)	28.8 (8)	28.8 (8)	34.2 (9.5)	34.2 (9.5)
Maximum Latent Heat Load 10 ³ joules/day (Btu/day)	553.3 (524)	968.4 (917)	958.4 (917)	968.4 (917)	**	**
Maximum Sensible Heat Load 10 ³ joules/day (Btu/day)	274.6 (260)	480.5 (455)	480.5 (455)	480.5 (455)	**	**
Total Weight kg (lb)	147 (324.2)	190.9 (420.9)	514.1 (1133.4)	2616.3 (5767.9)	255.5 (563.3)**	359.5 (792.5)**
Safety - Wipes - Personal Hygiene Station - Compactor - Wash Water Recovery System	- Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry - Crew Slippage on Soap if not properly retained None N/A	- Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry - Crew Slippage on Soap if not properly retained None N/A	- Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry - Crew Slippage on Soap if not properly retained None N/A	- Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry - Crew Slippage on Soap if not properly retained None N/A	- Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry - Crew Slippage on Soap if not properly retained None None	- Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry - Crew Slippage on Soap if not properly retained None None
Time Requirements (sec)	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180 - Compactor: 20	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180 - Compactor: 20	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180 - Compactor: 20	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180 - Compactor: 20	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180 - Compactor: 20	- Handwash: 67 - Utensil Cleansing: 63 - Shaving: 287 - Brushing Teeth: 163 - Hair Wetting: 108 - Body Wash: 120 - Work Area Cleanup: 180 - Compactor: 20
Training	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Cost Factor	20.1 BL	20.2 BL	20.6 BL	20.62 BL	32.2 BL	32.4 BL
Crew Acceptability	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Cleansing Action	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent

Table V-13 (Continued)

FUNCTIONAL PERFORMANCE:

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Reliability - No. of Components - Single Point Failures	56	56	55	56	84	84
- Personal Hygiene Station - Water Heater Thermostat Failure - Ruptured Hot Water Holding Tank - Blower Power Discontinuity - Blower Structural Failure - Water Pump Power Discontinuity - Drive Mechanism Failure	- Water Heater Thermostat Failure - Ruptured Hot Water Holding Tank - Blower Power Discontinuity - Blower Structural Failure - Water Pump Power Discontinuity - Drive Mechanism Failure	- Water Heater Thermostat Failure - Ruptured Hot Water Holding Tank - Blower Power Discontinuity - Blower Structural Failure - Water Pump Power Discontinuity - Drive Mechanism Failure	- Water Heater Thermostat Failure - Ruptured Hot Water Holding Tank - Blower Power Discontinuity - Blower Structural Failure - Water Pump Power Discontinuity - Drive Mechanism Failure	- Water Heater Thermostat Failure - Ruptured Hot Water Holding Tank - Blower Power Discontinuity - Blower Structural Failure - Water Pump Power Discontinuity - Drive Mechanism Failure - Check Valve Clogged in "Open" Position - Pump Mechanical Breakage - Pump Power Discontinuity 3-way Electrical Valve Power Discontinuity	- Water Heater Thermostat Failure - Ruptured Hot Water Holding Tank - Blower Power Discontinuity - Blower Structural Failure - Water Pump Power Discontinuity - Drive Mechanism Failure - Check Valve Clogged in "Open" Position - Pump Mechanical Breakage - Pump Power Discontinuity 3-way Electrical Valve Power Discontinuity	- Water Heater Thermostat Failure - Ruptured Hot Water Holding Tank - Blower Power Discontinuity - Blower Structural Failure - Water Pump Power Discontinuity - Drive Mechanism Failure - Check Valve Clogged in "Open" Position - Pump Mechanical Breakage - Pump Power Discontinuity 3-way Electrical Valve Power Discontinuity
Complexity	Moderately High	Moderately High	Moderately High	Moderately High	High	High

* Estimated number of spares and their weight for wash water recovery system.

** Maximum latent and sensible heat load not known for wash water recovery system at this time.

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**Table V-14 Disposable Wet and Dry Wipes with Waste Compactor System
Concept Specifications**

FUNCTIONAL PERFORMANCE: • HANDWASHING
• WORK AREA CLEANUP
• UTENSIL CLEANSING
• "SPONGE-TYPE" BODY WASH

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Fixed Weight kg (lb)	33.2 (73.2)	33.9 (74.73)	37.3 (82.3)	50.4 (111.1)	N/A	N/A
Fixed Volume m ³ (in. 3)	.13 (7859)	.16 (9427.5)	.34 (20,807.6)	1.55 (94,626)	N/A	N/A
Expendable Weight kg (lb)	4.45 (9.9)	7.85 (17.3)	34.8 (76.8)	210 (463)	N/A	N/A
Expendable Volume m ³ (in. 3)	.01 (630)	.018 (1103)	.114 (6969)	.71 (43,310)	N/A	N/A
Number of Spares	None	None	One	One	N/A	N/A
Spares Weight kg (lb)	None	None	2.27 (5)	2.27 (5)	N/A	N/A
Maintenance - Wipes - Compactor	Disposal Drive Mechanism Lubrication	Disposal Drive Mechanism Lubrication	Disposal Drive Mechanism Lubrication	Disposal Drive Mechanism Lubrication	N/A	N/A
Maximum Power Watts	None	None	None	None	N/A	N/A
Average Power Joules (Watt-hr)	None	None	None	None	N/A	N/A
Maximum Latent Heat Load 10 ³ Joules/day (Btu/ day)	591.4 (560)	1034.9 (980)	1034.9 (980)	1034.9 (980)	N/A	N/A
Maximum Sensible Heat Load 10 ³ Joules/day (Btu/ day)	Negligible	Negligible	Negligible	Negligible	N/A	N/A
Total Weight kg (lb)	39.05 (86.1)	44.1 (97.2)	76.8 (169.3)	265 (584.3)	N/A	N/A
Safety	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not completely dry	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not completely dry	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not completely dry	- Fire Hazard - Microbial Growth in Waste Storage if Wipes not completely dry	N/A	N/A
Time Requirements sec	- Handwash: 90 - Work Area Cleanup: 180 - Utensil Cleansing: 60 - Body Wash: 300 - Compactor: 20	- Handwash: 90 - Work Area Cleanup: 180 - Utensil Cleansing: 60 - Body Wash: 300 - Compactor: 20	- Handwash: 90 - Work Area Cleanup: 180 - Utensil Cleansing: 60 - Body Wash: 300 - Compactor: 20	- Handwash: 90 - Work Area Cleanup: 180 - Utensil Cleansing: 60 - Body Wash: 300 - Compactor: 20	N/A	N/A
Training Require- ments	Minimum	Minimum	Minimum	Minimum	N/A	N/A
Cost Factor	5.7 BL	6.8 BL	6.3 BL	7.9 BL	N/A	N/A
Crew Acceptability	Fair	Fair	Fair	Fair	N/A	N/A
Cleansing Action	Fair	Fair	Fair	Fair	N/A	N/A
Reliability - No. Component - Single Point Failures	24 Compactor Drive Mechanism Failure	24 Compactor Drive Mechanism Failure	24 Compactor Drive Mechanism Failure	24 Compactor Drive Mechanism Failure	N/A	N/A
Complexity	Simple	Simple	Simple	Simple	N/A	N/A

**Table V-15 Disposable Laboratory Utensils/Tools and Solid Waste Compactor
Concept Specifications**

FUNCTIONAL PERFORMANCE: • ELIMINATES NEED FOR UTENSIL AND HAND CLEANSING
• DRY WIPE WORK AREA CLEANUP

MISSION CHARACTERISTIC	SHUTTLE/SPACELAB WITHOUT WASH WATER RECOVERY SYSTEM			SPACE STATION WITH- OUT WASH WATER RECOVERY SYSTEM	SHUTTLE/SPACELAB WITH WASH WATER RECOVERY SYSTEM	SPACE STATION WITH WASH WATER RECOVERY SYSTEM
	4 MAN/7 DAY	7 MAN/7 DAY	7 MAN/30 DAY	7 MAN/180 DAY	7 MAN/30 DAY	7 MAN/180 DAY
Fixed Weight kg (lb)	41.7 (91.8)	42.1 (92.8)	73.8 (162.7)	273.6 (603.3)	N/A	N/A
Fixed Volume m ³ (in. ³)	.175 (10,691)	.153 (11,781)	.6 (36,610)	3.24 (197,944)	N/A	N/A
Expendable Weight kg (lb)	15.6 (34.3)	16.7 (36.8)	70.9 (156.2)	419 (923.7)	N/A	N/A
Expendable Volume m ³ (in. ³)	.046 (2788.6)	.048 (2946.1)	.206 (12,595)	1.24 (75,451)	N/A	N/A
Number of Spares	None	None	One	One	N/A	N/A
Spare Weight kg (lb)	None	None	2.27 (5)	2.27 (5)	N/A	N/A
Maintenance - Wipes - Laboratory Utensils/Tools - Gloves - Compactor	- Disposal - Disposal - Disposal - Lubricate Drive Mechanism	- Disposal - Disposal - Disposal - Lubricate Drive Mechanism	- Disposal - Disposal - Disposal - Lubricate Drive Mechanism	- Disposal - Disposal - Disposal - Lubricate Drive Mechanism	N/A	N/A
Maximum Power Watts	None	None	None	None	N/A	N/A
Average Power joules (watt-hr)	None	None	None	None	N/A	N/A
Maximum Latent Heat Load 10 ³ joules/day (Btu/day)	1334.3 (1264)	1651 (1564)	1651 (1564)	1651 (1564)	N/A	N/A
Maximum Sensible Heat Load 10 ³ joules/day (Btu/day)	Negligible	Negligible	Negligible	Negligible	N/A	N/A
Total Weight kg (lb)	60.2 (132.8)	62.6 (137.9)	150.7 (332.2)	698.7 (1540.3)	N/A	N/A
Safety - Wipes - Laboratory Utensils/Tools - Gloves - Compactor	- Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry - Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry - Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry None	- Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry - Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry - Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry None	- Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry - Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry - Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry None	- Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry - Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry - Fire Hazard - Microbial Growth in Waste Storage if wipes not completely dry None	N/A	N/A
Time Requirements (sec)	- Laboratory Utensil/Tool Use Depends on Experiment Need - Work Area Cleanup: 180 - Compactor: 20	- Laboratory Utensil/Tool Use Depends on Experiment Need - Work Area Cleanup: 180 - Compactor: 20	- Laboratory Utensil/Tool Use Depends on Experiment Need - Work Area Cleanup: 180 - Compactor: 20	- Laboratory Utensil/Tool Use Depends on Experiment Need - Work Area Cleanup: 180 - Compactor: 20	N/A	N/A
Training	Minimal	Minimal	Minimal	Minimal	N/A	N/A
Cost Factor	11.3 BL	11.6 BL	16.3 BL	27.8 BL	N/A	N/A
Crew Acceptability	Fair	Fair	Fair	Fair	N/A	N/A
Cleansing Action	N/A	N/A	N/A	N/A	N/A	N/A
Reliability - No. of Components - Single Point Failures	41 - Compactor Drive Mechanism Failure	41 - Compactor Drive Mechanism Failure	41 - Compactor Drive Mechanism Failure	41 - Compactor Drive Mechanism Failure	N/A	N/A
Complexity	Simple	Simple	Simple	Simple	N/A	N/A

Due to the high design reliability of the components in each concept, only items that were absolutely necessary to be spared were considered. These included various forms of filters for several concepts and the wash water recovery system, and a complete drive-mechanism for the solid waste compactor. Maintenance functions considered were those crew tasks that could be performed on a scheduled basis.

Safety factors considered were those that could present a definite problem not only to the crew's well-being but also to the experiments and the Spacelab itself. All concepts were rendered to be absolutely safe except for a few possibilities that could arise and possibly present some problems. These are listed in each concept for the safety characteristic.

Timeline requirements for various functional performances of each concept were either based on data obtained through actual use or were derived on a comparative basis by considering concept operation complexity and water usage rates and analyzing these in relation to system with known timelines.

Training factors were based on concept operation complexity and the ability of each concept to have operation tasks performed on a repetitive basis by the crewmembers.

Cost factors were determined by calculating the approximate cost to design and fabricate a flight article system for each concept. After selecting that concept/mission type which was lowest in total cost and assigning it the baseline value, cost factors for the other concepts/mission types were determined as a certain percentage of this baseline value. The lowest cost of the wash/rinse capability concepts was the disposable wet and dry wipes concept for a 4 man/7 day mission profile.

Crew acceptability was determined by the psychological effect of each concept upon the crewmembers. Inbred habits have a very major effect upon this. Washing of one's hands in flowing water is more pleasant and relaxing to the crewmembers than washing one's hands with wipes, which is nonrelaxing and nonmotivative. The sponge used on the Astro-Vac concept does psychologically provide a degree of relaxation and enjoyment but is not totally acceptable since again the lack of visible water flow. Once the habit of washing one's hands was broken, wipes and sponges would become more acceptable and could be used if necessary.

Single point failures of each system were those analyzed that could impair the safety of the crew and mission.

Figure V-1 shows a graphical representation of the Fixed Weight Comparison for all the concept/mission types. Similar graphs are shown for the fixed volume (Figure V-2), expendable volume (Figure V-3), expendable weight (Figure V-4), power equivalent weight penalty (Figure V-5), environmental impact equivalent weight (Figure V-6) and total weight (Figure V-7).

The following legend was used for each of the graphs:

- Spacelab Utensil/Hand Cleansing Fixture 
- Disposable Laboratory Utensils/Tools with Solid Waste Compactor 
- Hot Water Spray Washer - Centrifuge Drying System 
- Astro-Vac 
- Disposable Wet and Dry Wipes 
- Disposable Laboratory Utensils/Tools 
- Disposable Wet and Dry Wipes with Solid Waste Compactor 
- Orbiter Personal Hygiene Station 
- Disposable Dry Wipes with Cleansing Agent 
- Reusable Wipes 

The Spacelab Utensil/Hand Cleansing Fixture and Orbiter Personal Hygiene Station with Solid Waste Compactor were not plotted. For the environmental impact and power concepts that had like penalties were represented by only one of the concepts so as to avoid confusion.

C. CONCEPT MERITS AND DEFICIENCIES

Table V-16 depicts the major merits and deficiencies for each of the concepts. This and the matrices for each of the concepts were utilized during the tradeoff analysis.

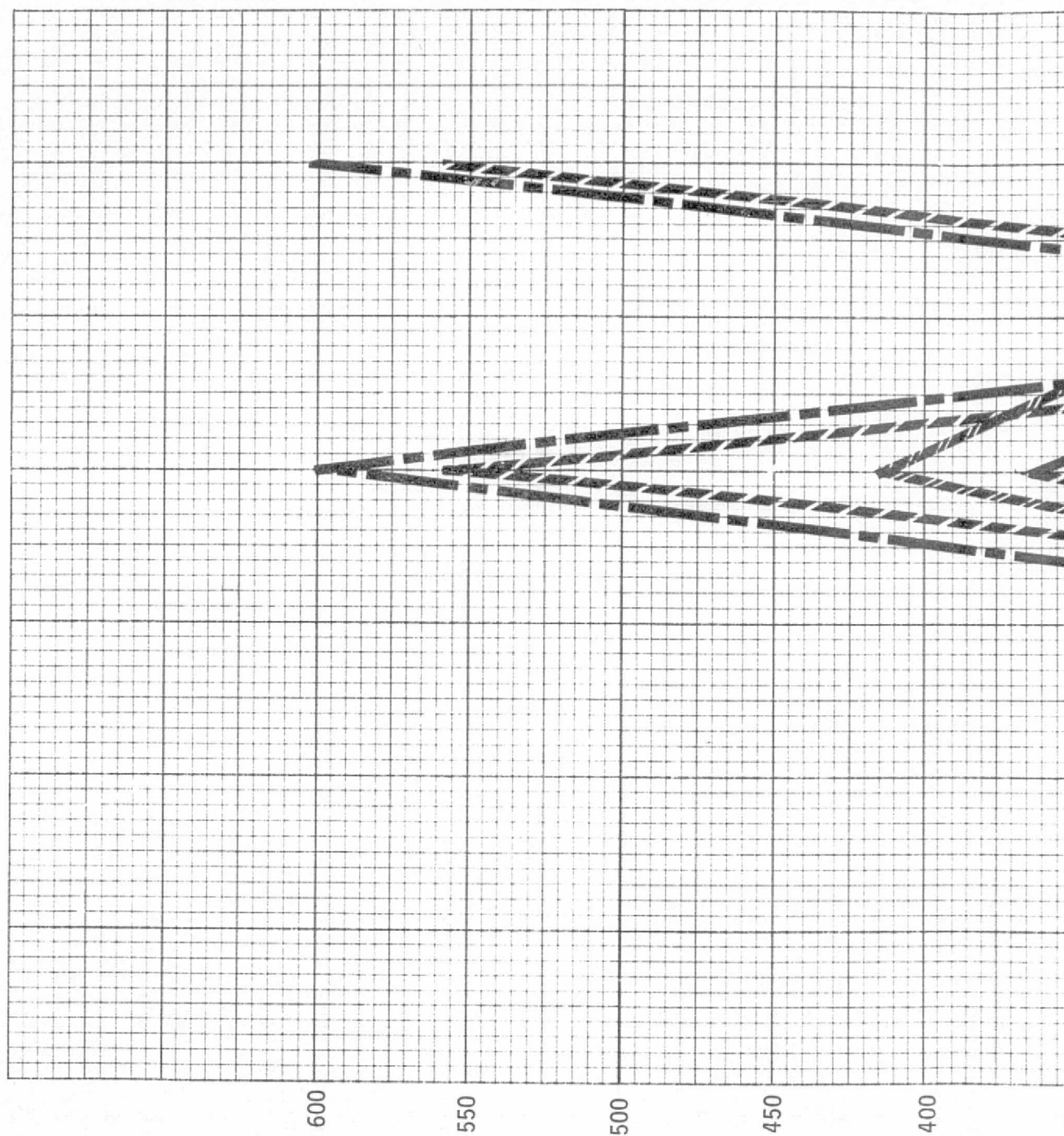
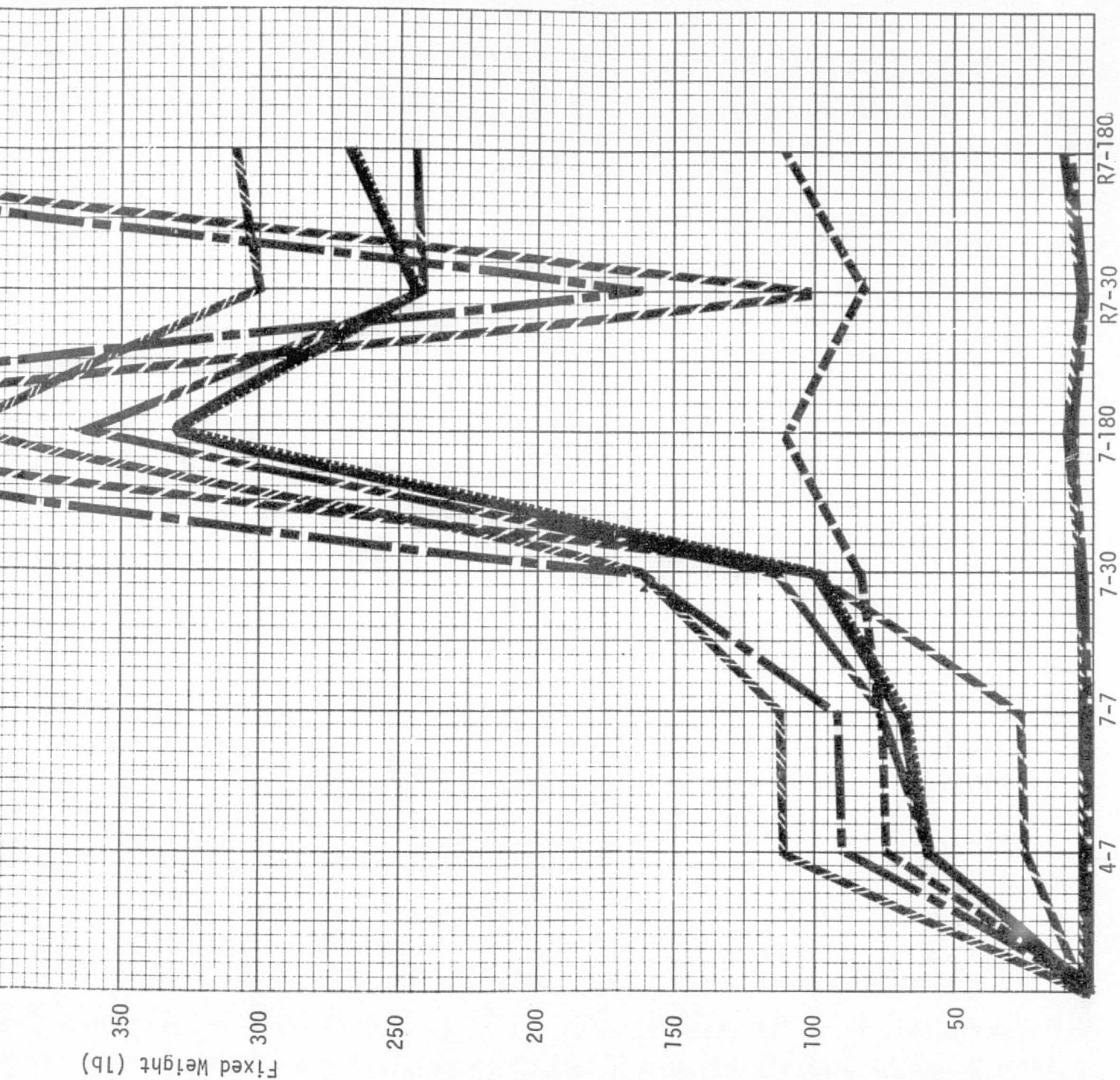


Figure V-1 Graphical Representation of Concept Fixed Weight

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Crew Size-Mission Duration (R: Wash Water Recovery Capability)

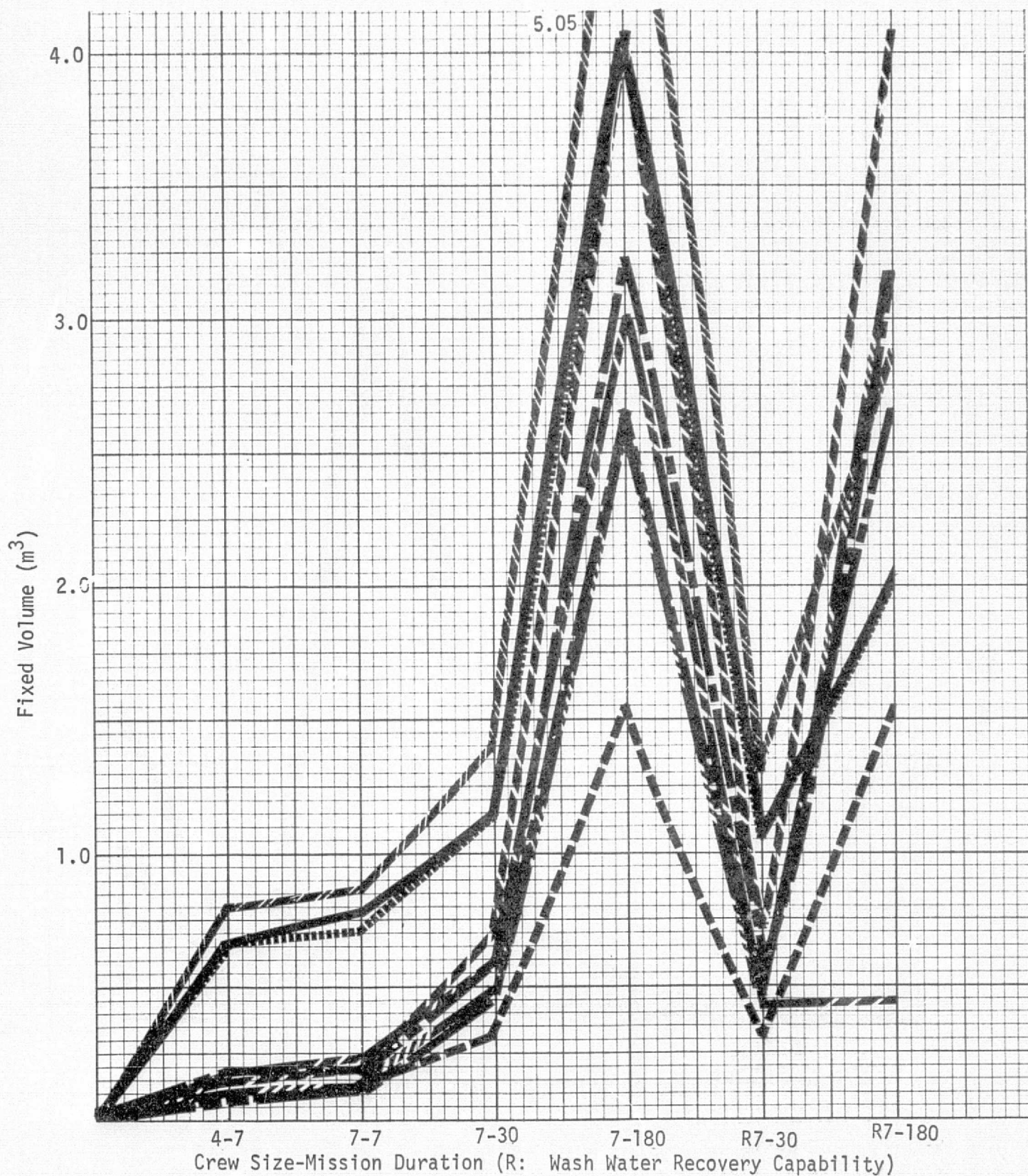


Figure V-2 Graphical Representation of Concept Fixed Volume

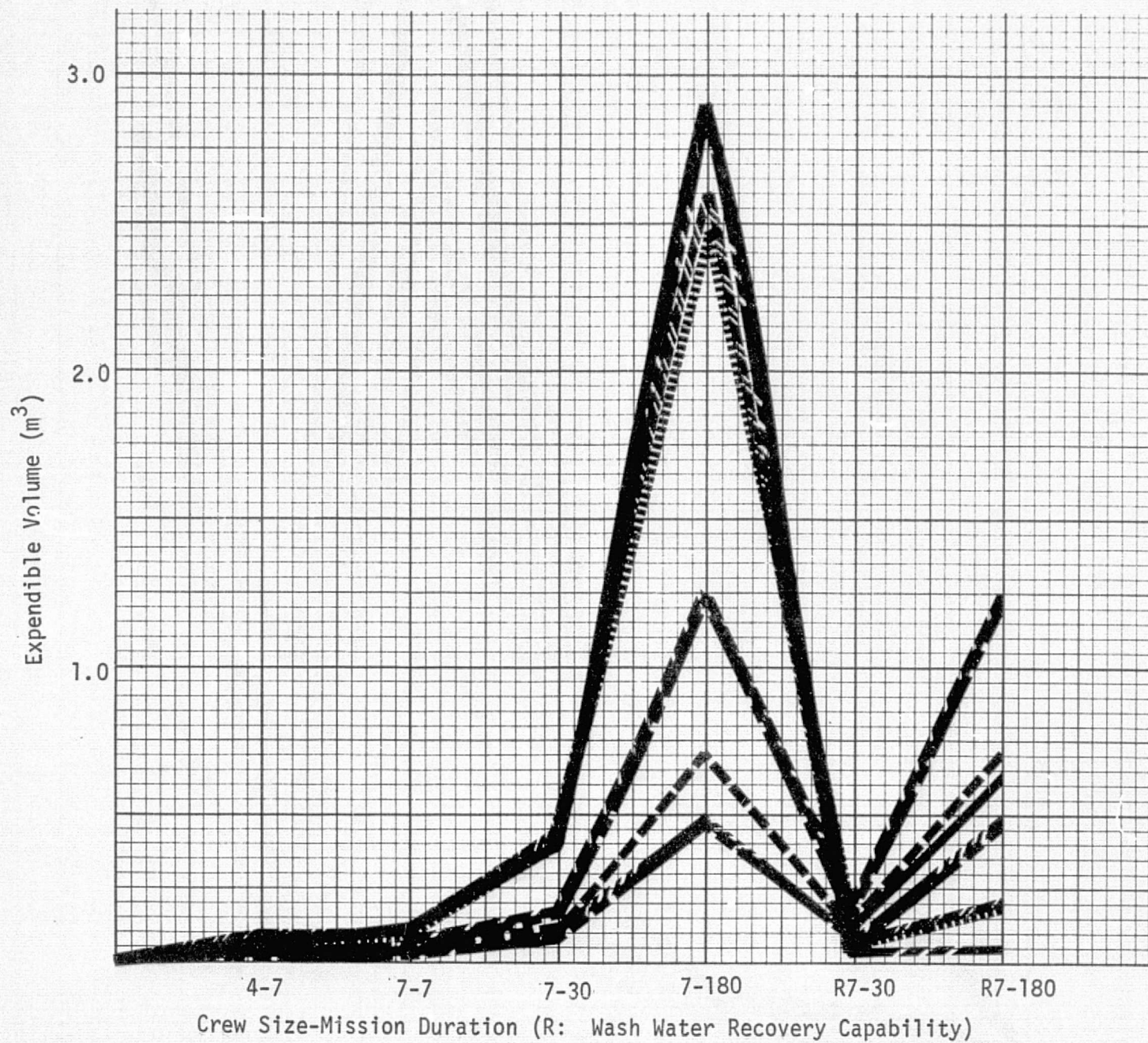


Figure V-3 Graphical Representation of Concept Expendable Volume

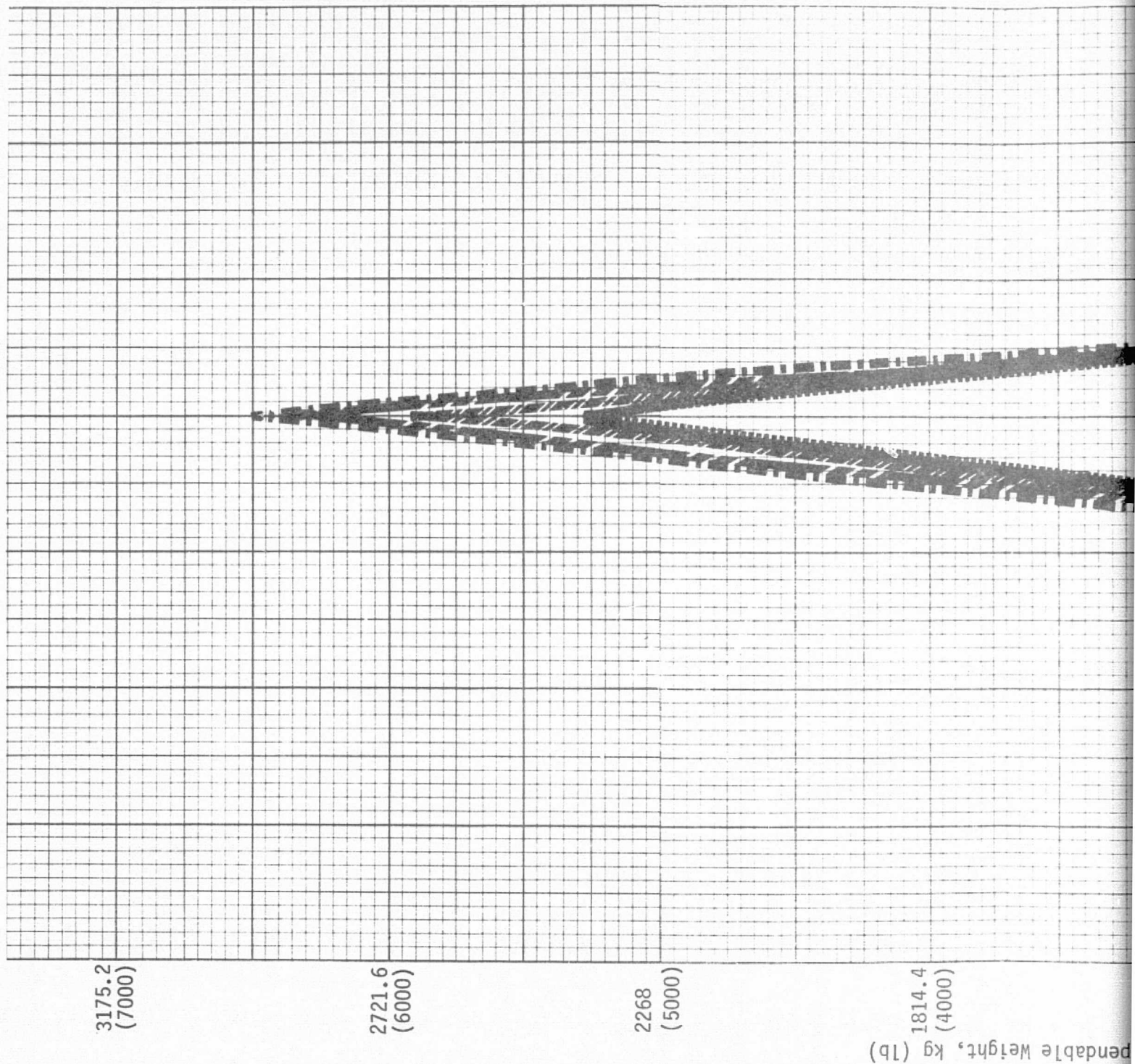
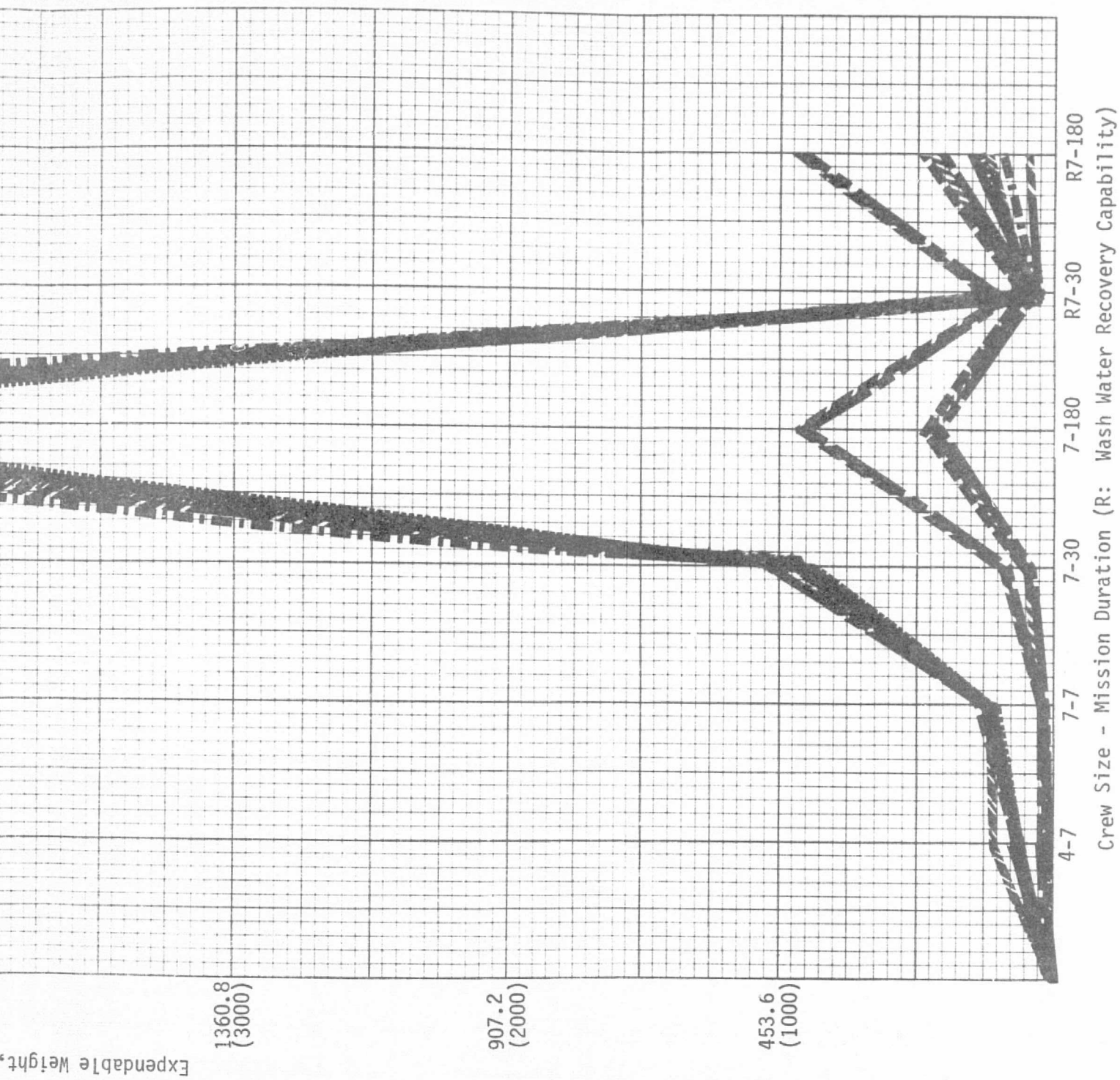


Figure V-4 Graphical Representation of Concept Expendable Weight



V-29 and V-30

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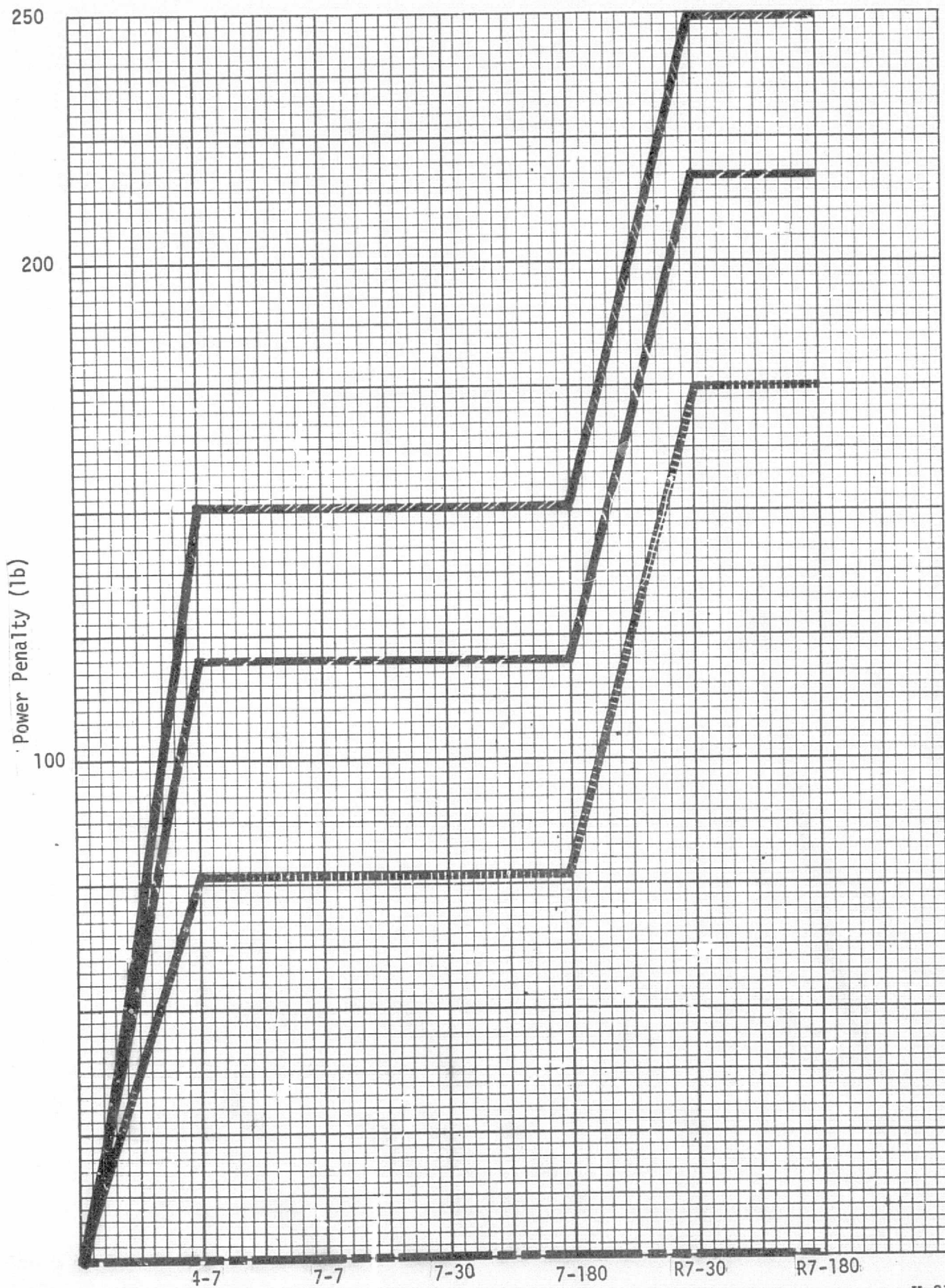


Figure V-5 Graphical Representation of Concept Power Weight Penalty

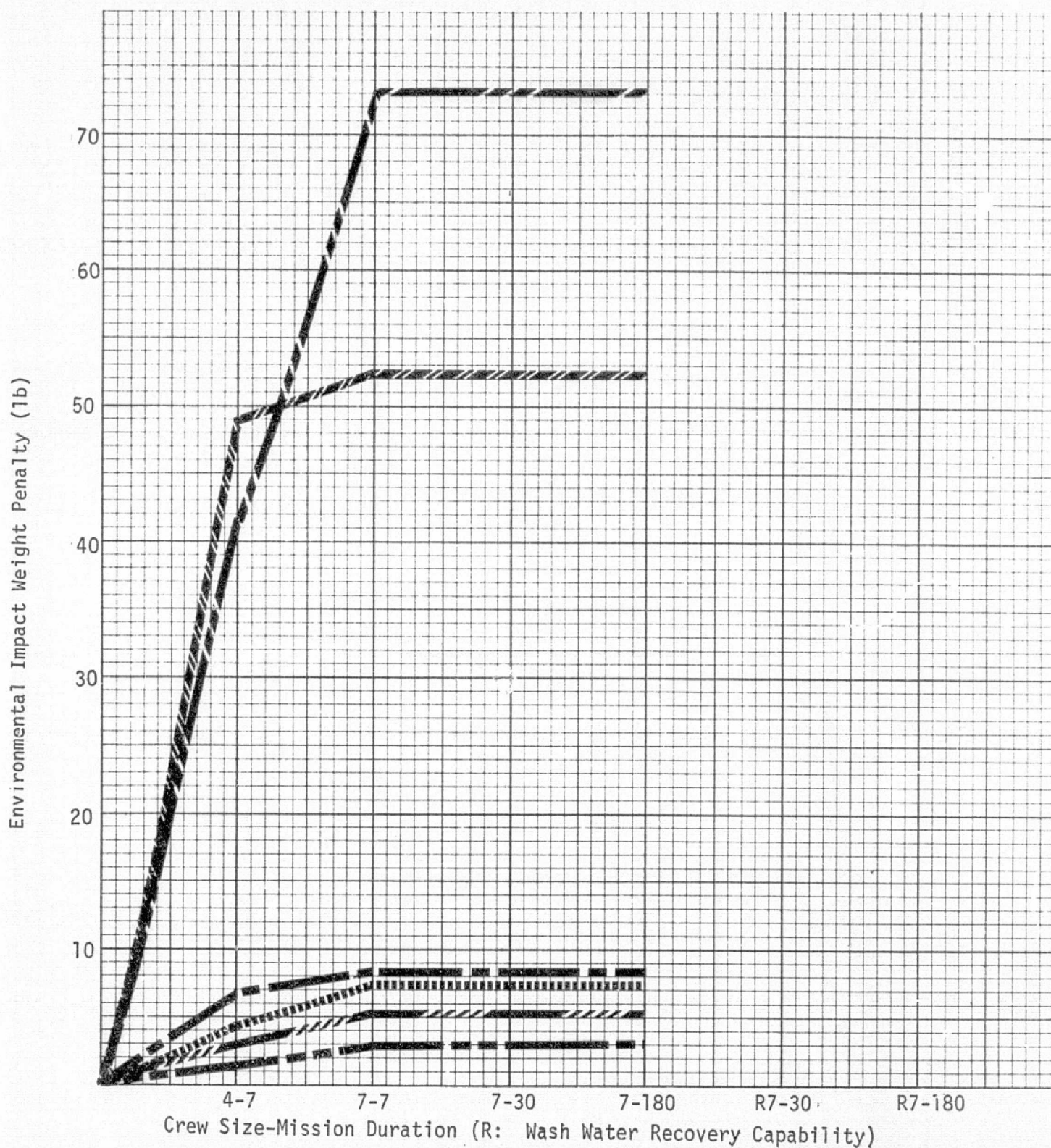


Figure V-6 Graphical Representation of Concept Environmental Impact Weight Penalty

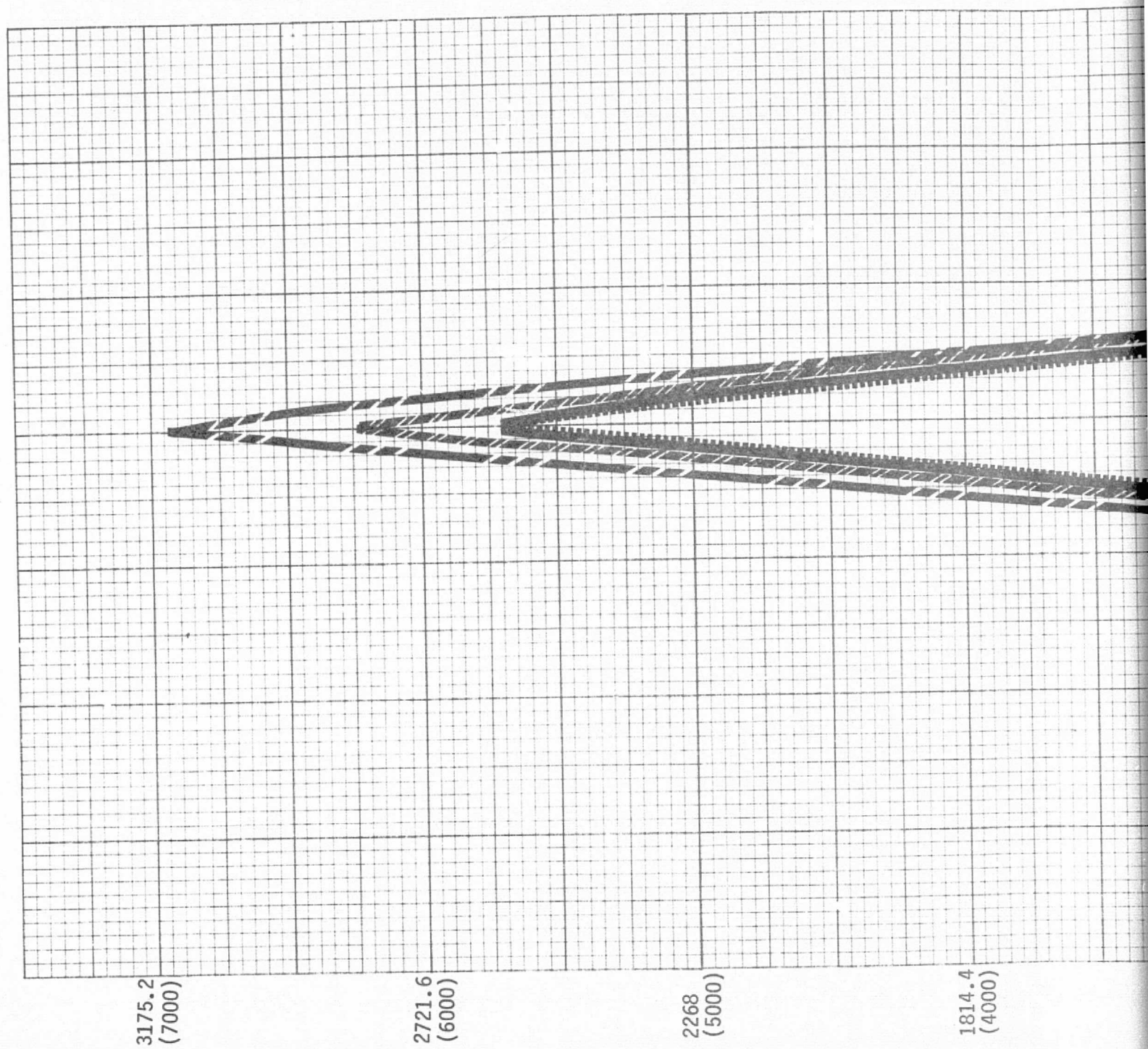
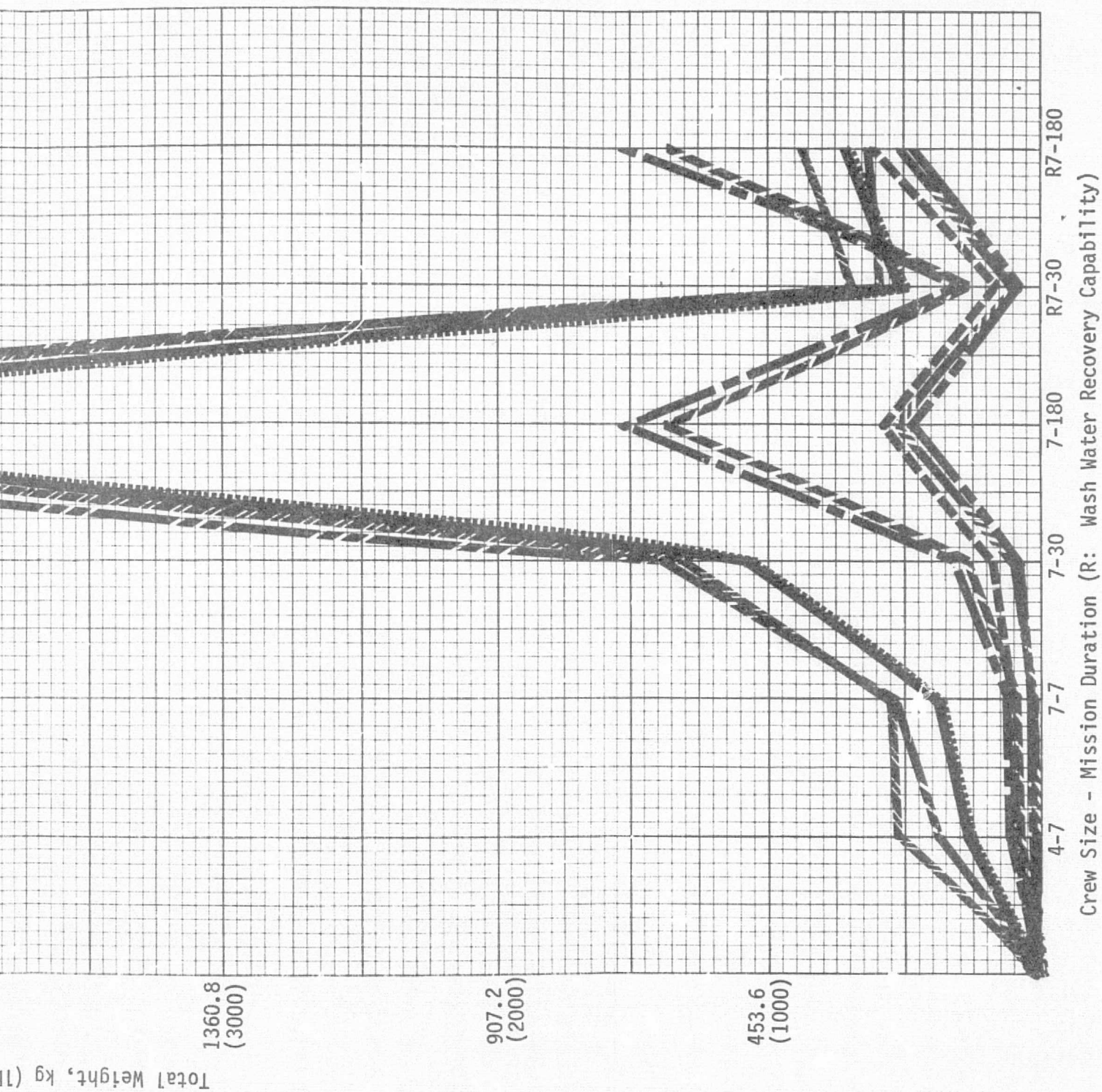


Figure V-7 Graphical Representation of Concept Total Weight



V-33 and V-34

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7

Table V-16 Wash/Rinse Capability Concept Merits and Deficiencies

CONCEPT	MERITS	DEFICIENCIES
Disposable Wet and Dry Wipes	• Low cost • Low total weight for all missions • Low volume utilization for short duration missions • System is very simple • No spares needed • Low maintenance • No power consumption • Concept easily flight-ready • No single point failures	• High volume utilization for long missions • Crew acceptability low • Cleansing action is low • Prolonged usage could cause skin rash • Evaporated alcohol and other chemicals cause a load on environment contamination control system • Damp wipes could entice microbial growth in the waste storage area
Spacelab Utensil/Hand Cleansing Fixture	• Crew acceptability high • Cleansing action high • Power consumption low • Few spares needed • Low maintenance time • Concept is highly versatile • Meets all experiment requirements • Low cleansing time	• Flight article system needs to be developed for flight readiness • High weight and volume utilization if system components not utilized by other systems • High overall water requirement if wash water recovery system not employed • Wipes could be a fire hazard • Damp wipes could entice microbial growth in the waste storage area • High cost
Disposable Dry Wipes Plus Cleansing Agent	• No power consumption • No spares needed • Low total weight for all missions • Low volume utilization for short duration missions • System is simple • Low maintenance • Few single point failures • Low cost	• High volume utilization for long mission • Fair crew acceptability • Prolonged usage of chemicals in cleansing agent could cause skin rash for some crewmembers • Evaporated chemicals cause a load on environment contamination control system • Wipes could be a fire hazard • Damp wipes could entice microbial growth in the waste storage area • Propellant leakage from a damaged cleansing agent container could put a load on the environment contamination control system and hamper crew safety

hamper crew safety

	• Propellant leakage from a damaged cleansing agent container could put a load on the environment contamination control system and hamper crew safety	
Astro-Vac	• Few spares needed • Low power consumption • Low maintenance	• Sponge presents a breeding area for bacteria • Soap residue could be left on the crewman's skin due to an incomplete rinsing phase • Potential microbial growth on sponge head and discarded wipes • Long cleansing time • High total weight for 180 day mission • High cost • High environmental impact
Orbiter Personal Hygiene Station	See Spacelab Utensil/Hand Cleansing Fixture Concept	
Disposable Laboratory Utensils/Tools	• No water or soap needed • Low weight and volume for short missions • Maintenance limited to disposal • No power consumption • No single point failures • System is very simple	• Disposable utensils/tools not able to satisfy all requirements for experiment unique utensils • High weight and volume utilization for long missions • Disposable utensils/tools not as satisfactory in all cases as regular utensils/tools • Gloves, utensils/tools and wipes present a fire hazard • Gloves, utensils/tools and wipes could entice microbial growth in waste storage area • Disposable spatulas, sticks and scalpel handles can be easily broken causing harm to the user and animal

Table V-16 (Continued)

CONCEPT	MERITS	DEFICIENCIES
Hot Water Spray Washing - Centrifuge Drying System	● Few spares needed ● Crew operation and cleansing time low ● Low maintenance ● Excellent cleansing action	● High weight ● High cost ● High water usage ● High power consumption ● High environmental impact ● Wipes and gloves are potential fire hazards ● Wipes and gloves could entice microbial growth in waste storage area ● Noisy
Reusable Wipes	● Fairly low maintenance ● Crew acceptance is good (poor is wipe is dingy) ● System is versatile	● Water can escape from the wipe if it is squeezed inadvertently during use ● Water escapes from wipe during drying phase causing a high environmental impact ● Wipes could entice microbial growth if not completely dry when stored ● High cleansing time ● High power usage
Disposable Wipes with Wetter Unit	● Fairly low maintenance ● Crew acceptance is good ● System is versatile	● Wipes are potential fire hazard ● Wipes could entice microbial growth in waste storage area ● Crew could slip on bar soap if not properly retained ● High cleansing time ● High power usage

V-37 and V-38

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D. WASH/RINSE CAPABILITY CONCEPT SELECTION

After the characteristics were established for each concept, an assessment was made to select the optimum concepts. This was accomplished on a competitive basis by comparing each individual characteristic against every other characteristic, therefore obtaining a relative importance between characteristics. The characteristic considered more important was assigned a value of one, the other characteristic, zero. The factor weight was determined by adding the values assigned to each characteristic (factor) and then expressing them as a percent of the total value. Table V-17 shows the results of the factor weight determinations for the wash/rinse capability characteristics.

A matrix was prepared for each mission listed in Table V-1 showing the concepts, characteristics, relative importance factor weight and individual ratings for each concept. The individual tallies were established by comparing each concept characteristic with every other concept characteristic. The concept with the optimum characteristic (i.e., lowest weight or highest crew acceptability) was given the highest number corresponding to the number of concepts being evaluated. A comparative numerical rating was assigned to each concept characteristic as follows:

• Superior	41 to 50
• Above Average	31 to 40
• Acceptable	21 to 30
• Below Average	11 to 20
• Marginal	1 to 10
• Unacceptable	0

The factor weight was multiplied by the individual ratings and the totals for each concept were compiled. The totals of the weighted values for each concept were compared with the highest value indicating the concept that best fulfills the characteristic requirements.

Tables V-18 through V-23 show the results of the concept tradeoff comparisons and the rank order of the top concepts.

Table V-17 Factor Weight Determination

CONSIDERATION FACTORS	FACTOR NUMBER	CHOICE TALLEY	TOTAL	FACTOR WEIGHT
Total Weight	F1	0 0 1 1 1 0 0 1 1 0 0	5	.076
Functions	F2	1 0 1 1 1 0 0 1 1 0 1	7	.106
Performance	F3	1 1 1 1 1 0 0 1 1 0 1	8	.121
Volume	F4	0 0 0 0 0 0 0 1 1 0 0	2	.03
Power	F5	0 0 0 1 0 0 0 1 1 0 0	3	.045
Cost	F6	0 0 0 1 1 0 0 1 1 0 0	4	.061
Reliability	F7	1 1 1 1 1 1 1 1 1 0 1	10	.152
Crew Acceptability	F8	1 1 1 1 1 1 0 1 1 0 1	9	.136
Crew Training	F9	0 0 0 0 0 0 0 0 0 0 0	0	0.00
Timeline	F10	0 0 0 0 0 0 0 0 1 0 0	1	.015
Safety	F11	1 1 1 1 1 1 1 1 1 1 1	11	.167
Maintainability	F12	1 0 0 1 1 1 0 0 1 1 0	6	.091
			66	1.00

Table V-18 Tradeoff Comparison for a Shuttle/Spacelab 4 Man/7 Day Mission

Consideration Factors	Factor Ident	Factor Wt	Disposable Wet & Dry Wipes		Spacelab Utensil/ Hand Cleaning Fixture		Disposable Dry Wipes Plus Cleaning Agent		Astro-Vac		Orbiter Personal Hygiene Station		Disposable Laboratory Utensils/ Tools	
			Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL
Total Weight	F1	.076	46	3.5	15	1.14	50	3.8	20	1.52	15	1.14	35	2.7
Functions	F2	.106	25	2.65	50	5.3	35	3.7	20	2.1	50	5.3	11	1.7
Performance	F3	.121	15	1.8	50	6.1	15	1.8	25	3.0	50	6.1	0	0
Volume	F4	.03	35	1.1	5	.15	50	1.5	25	.75	5	.15	28	.8
Power	F5	.045	50	2.25	45	2	50	2.3	40	1.8	45	2	50	2.3
Cost	F6	.061	50	3.1	15	.92	45	2.7	15	.92	25	1.5	38	2.3
Reliability	F7	.152	50	7.6	15	2.3	45	6.8	30	4.6	15	2.3	30	4.6
Crew Acceptability	F8	.136	15	1.8	50	6.8	15	1.8	25	3.4	50	6.8	15	1.8
Crew Training	F9	0.0	50	0	40	0	50	0	40	0	40	0	50	0
Timeline	F10	.015	40	.6	50	.75	40	.6	30	.45	50	.75	1	.0
Safety	F11	.167	50	8.4	50	8.4	50	8.4	40	6.7	40	6.7	10	1.7
Maintainability	F12	.091	50	4.6	10	.91	40	3.6	30	2.7	10	.91	30	2.7
				37.4		34.8		37.0		27.9		33.7		20
				1		3		2				4		

mission

Orbiter Personal Hygiene Station		Disposable Laboratory Utensils/Tools		Hot Water Spray Washing-Centrifuge Drying System		Reusable Wipes		Disposable Wipes With Wetter Unit		Orbiter Personal Hygiene Station & Solid Waste Compactor		Disposable Laboratory Utensils/Tools & Solid Waste Compactor		Disposable Wet & Dry Wipes With Solid Waste Compactor		Spacelab Utensil/Hand Cleaning Fixture With Solid Waste Compactor	
Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL
15	1.14	35	2.7	1	.076	5	.38	7	.53	10	.76	25	1.9	31	2.4	10	.76
50	5.3	11	1.17	20	2.1	30	3.2	30	3.2	50	5.3	11	1.17	25	2.65	50	5.3
50	6.1	0	0	50	6.1	25	3.0	25	3.0	50	6.1	0	0	15	1.8	50	6.1
5	.15	28	.84	1	.03	20	.6	15	.45	3	.09	21	.63	33	.99	3	.09
45	2	50	2.3	1	.045	35	1.6	35	1.6	45	2	50	2.3	50	2.3	45	2
25	1.5	38	2.32	1	.061	8	.49	8	.49	20	1.22	30	1.83	40	2.44	3	.18
15	2.3	30	4.6	34	5.2	35	5.3	33	5.0	3	.46	10	1.5	25	3.8	1	.152
50	6.8	15	1.8	25	3.4	5	.68	15	1.8	50	6.8	15	1.8	15	1.8	50	6.8
40	0	50	0	25	0	40	0	40	0	25	0	50	0	50	0	25	0
50	.75	1	.015	1	.015	20	.3	20	.3	50	.75	1	.015	40	.6	50	.75
40	6.7	10	1.67	30	5	40	6.7	40	6.7	40	6.7	10	1.67	50	8.4	50	8.4
10	.91	30	2.7	30	2.7	20	1.8	20	1.8	1	.091	20	1.8	40	3.6	10	.91
	33.7		20.1		24.7		24.1		24.9		30.3		14.6		30.8		31.4
	4																

Table V-19 Tradeoff Comparison for a Shuttle/Spacelab 7 Man/7 Day Mission

Consideration Factors	Factor Ident	Factor Wt	Disposable Wet & Dry Wipes		Spacelab Utensil/ Hand Cleansing Fixture		Disposable Dry Wipes Plus Cleansing Agent		Astro-Vac		Orbiter Personal Hygiene Station		Disposable Laboratorial Utensils Tools
			Compar Rating	Weigh VL	Compar Rating	Weigh VL	Compar Rating	Weigh VL	Compar Rating	Weigh VL	Compar Rating	Weigh VL	Compar Rating
Total Weight	F1	.076	46	3.5	15	1.14	50	3.8	10	.76	15	1.14	40
Functions	F2	.106	25	2.65	50	5.3	35	3.7	20	2.1	50	5.3	11
Performance	F3	.121	15	1.8	50	6.1	15	1.8	25	3.0	50	6.1	0
Volume	F4	.03	40	1.2	15	.45	50	1.5	30	.9	15	.45	38
Power	F5	.045	50	2.25	45	2	50	2.3	40	1.8	45	2.0	50
Cost	F6	.061	50	3.1	15	.92	45	2.7	15	.92	27	1.65	2
Reliability	F7	.152	50	7.6	15	2.3	45	6.8	30	4.6	15	2.3	30
Crew Acceptability	F8	.136	15	1.8	50	6.8	15	1.8	25	3.4	50	6.8	15
Crew Training	F9	0.0	50	0	40	0	50	0	40	0	40	0	50
Timeline	F10	.015	40	.6	50	.75	40	.6	30	.45	50	.75	1
Safety	F11	.167	50	8.4	50	8.4	50	8.4	40	6.7	40	6.7	10
Maintainability	F12	.091	50	4.6	10	.91	40	3.6	30	2.7	10	.91	30
				37.5		35.1		37.0		27.3		34.1	
				1		3		2				4	

Orbiter Personal Hygiene Station		Disposable Laboratory Utensils/Tools		Hot Water Spray Washing-Centrifuge Drying System		Reusable Wipes		Disposable Wipes With Wetter Unit		Orbiter Personal Hygiene Station & Solid Waste Compactor		Disposable Laboratory Utensils/Tools & Solid Waste Compactor		Disposable Wet & Dry Wipes With Solid Waste Compactor		Spacelab Utensil/Hand Cleaning Fixture With Solid Waste Compactor	
Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL
15	1.14	40	3	1	.76	2	.15	5	.38	7	.53	30	2.3	35	2.7	7	.53
50	5.3	11	1.17	20	2.1	30	3.2	30	3.2	50	5.3	11	1.17	25	2.65	50	5.3
50	6.1	0	0	50	6.1	25	3.0	25	3.0	50	6.1	0	0	15	1.8	50	6.1
15	.45	38	1.14	1	.03	25	.75	20	.6	10	.3	37	1.1	41	1.2	10	.3
45	2.0	50	2.3	1	.045	35	1.6	35	1.6	45	2.0	50	2.3	50	2.3	45	2.0
27	1.65	38	2.3	1	.061	8	.49	8	.49	20	1.2	30	1.8	40	2.4	3	.18
15	2.3	30	4.6	34	5.2	35	5.3	33	5.0	3	.46	10	1.5	25	3.8	1	.152
50	6.8	15	1.8	25	3.4	5	.68	15	1.8	50	6.8	15	1.8	15	1.8	50	6.8
40	0	50	0	25	0	40	0	40	0	25	0	50	0	50	0	25	0
50	.75	1	.015	1	.015	20	.3	20	.3	50	.75	1	.015	40	.6	50	.75
40	5.7	10	1.67	30	5	40	6.7	40	6.7	40	6.7	10	1.67	50	8.4	50	8.4
10	.91	30	2.7	30	2.7	20	1.8	20	1.8	1	.091	20	1.8	40	3.6	10	.91
	34.1		20.7		25.4		24		24.9		30.2		15.5		31.3		31.4
4																	

Table V-20 Tradeoff Comparison for a Shuttle/Spacelab 7 Man/30 Day Mission

Consideration Factors	Factor Ident	Factor Wt	Disposable Wet & Dry Wipes		Spacelab Utensil/ Hand Cleansing Fixture		Disposable Dry Wipes Plus Cleansing Agent		Astro-Vac		Orbiter Personal Hygiene Station		Disposable Laboratory Utensils Tools	
			Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL
Total Weight	F1	.076	48	3.6	15	1.14	50	3.8	7	.53		1.14	30	2
Functions	F2	.106	25	2.65	50	5.3	35	3.7	20	2.1	50	5.3	11	1
Performance	F3	.121	15	1.8	50	6.1	15	1.8	25	3.0	50	6.1	0	0
Volume	F4	.03	35	1.1	10	.3	40	.12	23	.69	10	.3	25	
Power	F5	.045	50	2.25	45	2.0	50	2.3	40	1.8	45	2.0	50	2
Cost	F6	.061	50	3.1	10	.61	48	2.9	10	.61	25	1.53	35	2
Reliability	F7	.152	50	7.6	15	2.3	45	6.8	30	4.6	15	2.3	30	4
Crew Acceptability	F8	.136	15	1.8	50	6.8	15	1.8	25	3.4	50	6.8	15	1
Crew Training	F9	0.0	50	0	40	0	50	0	40	0	40	0	50	0
Timeline	F10	.015	40	.6	50	.75	40	.6	30	.45	50	.75	1	.0
Safety	F11	.167	50	8.4	50	8.4	50	8.4	40	6.7	40	6.7	10	1
Maintainability	F12	.091	50	4.6	10	.91	40	3.6	30	2.7	10	.91	30	2
				37.5		34.6		35.8		26.6		33.8		1

Orbiter Personal Hygiene Station		Disposable Laboratory Utensils/Tools		Hot Water Spray Washing-Centrifuge Drying System		Reusable Wipes		Disposable Wipes With Wetter Unit		Orbiter Personal Hygiene Station & Solid Waste Compactor		Disposable Laboratory Utensils/Tools & Solid Waste Compactor		Disposable Wet & Dry Wipes With Solid Waste Compactor		Spacelab Utensil/Hand Cleansing Fixture With Solid Waste Compactor	
Com- par at- ing	Weigh VL	Com- par Rat- ing	Weigh VL	Com- par Rat- ing	Weigh VL	Com- par Rat- ing	Weigh VL	Com- par Rat- ing	Weigh VL	Com- par Rat- ing	Weigh VL	Com- par Rat- ing	Weigh VL	Com- par Rat- ing	Weigh VL	Com- par Rat- ing	Weigh VL
	1.14	30	2.3	5	.38	3	.23	1	.076	10	.76	25	1.9	40	3.0	10	.76
50	5.3	11	1.17	20	2.1	30	3.2	30	3.2	50	5.3	11	1.17	25	2.65	50	5.3
50	6.1	0	0	50	6.1	25	3.0	25	3.0	50	6.1	0	0	15	1.8	50	6.1
10	.3	25	.75	1	.03	30	.9	5	.15	20	.6	30	.9	50	1.5	15	.45
45	2.0	50	2.3	1	.045	35	1.6	35	1.6	45	2.0	50	2.3	50	2.3	45	2.0
25	1.53	35	2.1	1	.061	8	.49	8	.49	15	.92	23	1.4	43	2.6	2	.12
15	2.3	30	4.6	34	5.2	35	5.3	33	5.0	3	.46	10	1.5	25	3.8	1	.152
50	6.8	15	1.8	25	3.4	5	.68	15	1.8	50	6.8	15	1.8	15	1.8	50	6.8
40	0	50	0	25	0	40	0	40	0	25	0	50	0	50	0	25	0
50	.75	1	.015	1	.015	20	.3	20	.3	50	.75	1	.015	40	.6	50	.75
40	6.7	10	1.67	30	5	40	6.7	40	6.7	40	6.7	10	1.67	50	8.4	50	8.4
10	.91	30	2.7	30	2.7	20	1.8	20	1.8	1	.091	20	1.8	40	3.6	10	.91
	33.8		19.5		25		24.2		24.1		30.5		14.5		32.1		31.7

Table V-21 Tradeoff Comparison for a Space Station 7 Man/180 Day Mission

Consideration Factors	Factor Ident	Factor Wt	Disposable Wet & Dry Wipes		Spacelab Utensil/ Hand Cleaning Fixture		Disposable Dry Wipes Plus Cleaning Agent		Astro-Vac		Orbiter Personal Hygiene Station		Disposable Labora Utensi Tools
			Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing
Total Weight	F1	.076	47	3.6	10	.76	50	3.8	5	.38	10	.76	25
Functions	F2	.106	25	2.65	50	5.3	35	3.7	20	2.1	50	5.3	11
Performance	F3	.121	15	1.8	50	6.1	15	1.8	25	3.0	50	6.1	0
Volume	F4	.03	35	1.1	10	.3	31	.93	10	.3	10	.3	10
Power	F5	.045	50	2.25	45	2.0	50	2.3	40	1.8	45	2.0	50
Cost	F6	.061	50	3.1	12	.73	50	3.1	12	.73	26	1.6	17
Reliability	F7	.152	50	7.6	15	2.3	45	6.8	30	4.6	15	2.3	30
Crew Acceptability	F8	.136	15	1.8	50	6.8	15	1.8	25	3.4	50	6.8	15
Crew Training	F9	0.0	50	0	40	0	50	0	40	0	40	0	50
Timeline	F10	.015	40	.6	50	.75	40	.6	30	.45	50	.75	1
Safety	F11	.167	50	8.4	50	8.4	50	8.4	40	6.7	40	6.7	10
Maintainability	F12	.091	50	4.6	10	.91	40	3.6	30	2.7	10	.91	30
				37.5		34.4		36.8		26.2		33.5	
				1		3		2				4	

Orbiter Personal Hygiene Station		Disposable Laboratory Utensils/Tools		Hot Water Spray/Washing-Centrifuge Drying System		Reusable Wipes		Disposable Wipes With Wetter Unit		Orbiter Personal Hygiene Station & Solid Waste Compactor		Disposable Laboratory Utensils/Tools & Solid Waste Compactor		Disposable Wet & Dry Wipes With Solid Waste Compactor		Spacelab Utensil/Hand Cleansing Fixture With Solid Waste Compactor	
Com-par Rating	Weigh VL	Com-par Rating	Weigh VL	Com-par Rating	Weigh VL	Com-par Rating	Weigh VL	Com-par Rating	Weigh VL	Com-par Rating	Weigh VL	Com-par Rating	Weigh VL	Com-par Rating	Weigh VL	Com-par Rating	Weigh VL
10	.76	25	1.9	7	.53	5	.38	1	.076	9	.68	21	1.6	41	3.1	9	.68
50	5.3	11	1.17	20	2.1	30	3.2	30	3.2	50	5.3	11	1.17	25	2.65	50	5.3
50	6.1	0	0	50	6.1	25	3.0	25	3.0	50	6.1	0	0	15	1.8	50	6.1
10	.3	10	.3	5	.15	25	.75	1	.03	15	.45	21	.63	50	1.5	15	.45
45	2.0	50	2.3	1	.045	35	1.6	35	1.6	45	2.0	50	2.3	50	2.3	45	2.0
26	1.6	17	1.04	1	.061	9	.55	9	.55	20	1.22	7	.43	40	2.4	2	.122
15	2.3	30	4.6	34	5.2	35	5.3	33	5.0	3	.46	10	1.5	25	3.8	1	.152
50	6.8	15	1.8	25	3.4	5	.68	15	1.8	50	6.8	15	1.8	15	1.8	50	6.8
40	0	50	0	25	0	40	0	40	0	25	0	50	0	50	0	25	0
50	.75	1	.015	1	.015	20	3	20	.3	50	75	1	.015	40	.6	50	.75
40	6.7	10	1.67	30	5	40	6.7	40	6.7	40	6.7	10	1.67	50	8.4	50	8.4
10	.91	30	2.7	30	2.7	20	1.8	20	1.8	1	.091	20	1.8	40	3.6	10	.91
	33.5		17.5		25.3		24.3		24.1		30.6		12.9		31.95		31.7
	4																

Table V-22 Tradeoff Comparison for a Shuttle/Spacelab 7 Man/30 Day Mission
with a Wash Water Recovery Capability

Consideration Factors	Factor Ident	Factor Wt	Disposable Wet & Dry Wipes		Spacelab Utensil/Hand Cleansing Fixture		Disposable Dry Wipes Plus Cleansing Agent		Astro-Vac		Orbiter Personal Hygiene Station		Disposable Laboratory Utensils/Tools
			Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating
Total Weight	F1	.076	48	3.65	15	1.14	50	3.8	20	1.5	15	1.14	30
Functions	F2	.106	25	2.65	50	5.3	35	3.7	20	2.1	50	5.3	11
Performance	F3	.121	15	1.8	50	6.1	15	1.8	25	3	50	6.1	0
Volume	F4	.03	35	1.1	5	.15	38	1.14	30	.9	5	.15	20
Power	F5	.045	50	2.25	45	2	50	2.3	40	1.8	45	2	50
Cost	F6	.061	50	3.1	7	.43	48	2.93	7	.43	15	.92	30
Reliability	F7	.152	50	7.6	15	2.3	45	6.8	23	3.5	15	2.3	35
Crew Acceptability	F8	.136	15	1.8	50	6.8	15	1.8	25	3.4	50	6.8	15
Crew Training	F9	0.0	50	0	40	0	50	0	40	0	40	0	50
Timeline	F10	.015	40	.6	50	.75	40	.6	30	.45	50	.75	1
Safety	F11	.167	50	8.4	50	8.4	50	8.4	40	6.7	40	6.7	10
Maintainability	F12	.091	50	4.6	10	.91	40	3.6	30	2.7	10	.91	30
				37.7		34.3		36.9		26.5		33.1	
				1		3		2				4	

Mission

Orbiter Personal Hygiene Station		Disposable Laboratory Utensils/Tools		Hot Water Spray Washing-Centrifuge Drying System		Reusable Wipes		Disposable Wipes With Wetter Unit		Orbiter Personal Hygiene Station & Solid Waste Compactor		Disposable Laboratory Utensils/Tools & Solid Waste Compactor		Disposable Wet & Dry Wipes With Solid Waste Compactor		Spacelab Utensil/Hand Cleaning Fixture With Solid Waste Compactor	
Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL	Com-par Rat-ing	Weigh VL
15	1.14	30	2.3	11	.84	12	.9	10	.76	13	.99	25	1.9	41	3.1	13	.99
50	5.3	11	1.17	20	2.1	30	3.2	30	3.2	50	5.3	11	1.17	25	2.65	50	5.3
50	6.1	0	0	50	6.1	25	3.0	25	3.0	50	6.1	0	0	15	1.8	50	6.1
5	.15	20	.6	1	.03	40	1.2	15	.45	15	.45	25	.75	50	1.5	10	.3
45	2	50	2.3	1	.045	35	1.6	35	1.6	45	2.0	50	2.3	50	2.3	45	2
15	.92	30	1.83	1	.061	4	.24	4	.24	10	.61	25	1.53	35	2.1	3	.18
15	2.3	35	5.3	20	3	20	3	23	3.5	1	.152	25	3.8	33	5	1	.152
50	6.8	15	1.8	25	3.4	5	.68	15	1.8	50	6.8	15	1.8	15	1.8	50	6.8
40	0	50	0	25	0	40	0	40	0	25	0	50	0	50	0	25	0
50	.75	1	.015	1	.015	20	.3	20	.13	50	.75	1	.015	40	.6	50	.75
40	6.7	10	1.67	30	5	40	6.7	40	6.7	40	6.7	10	1.67	50	8.4	50	8.4
10	.91	30	2.7	30	2.7	20	1.8	20	1.8	1	.091	20	1.8	40	3.6	10	.91
	33.1		19.7		23.3		22.6		23.4		29.9		16.7		32.9		31.9
4																	

Table V-23 Tradeoff Comparison for a Space Station 7 Man/180 Day Mission
with a Wash Water Recovery Capability

Consideration Factors	Factor Ident	Factor Wt	Disposable Wet & Dry Wipes		Spacelab Utensil/ Hand Cleansing Fixture		Disposable Dry Wipes Plus Cleansing Agent		Astro-Vac		Orbiter Personal Hygiene Station		Disposable Laboratory Utensils Tools	
			Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL	Compar Rating	Weight VL
Total Weight	F1	.076	47	3.6	30	2.3	50	3.8	38	2.9	30	2.3	22	1
Functions	F2	.106	25	2.65	50	5.3	35	3.7	20	2.1	50	5.3	11	1
Performance	F3	.121	15	1.8	50	6.1	15	1.8	25	3	50	6.1	0	0
Volume	F4	.03	15	.45	20	.6	13	.39	30	.9	20	.6	1	
Power	F5	.045	50	2.25	45	2	50	2.3	40	1.8	45	2	50	2
Cost	F6	.061	50	3.1	10	.61	50	3.1	10	.61	20	1.22	25	1
Reliability	F7	.152	50	7.6	15	2.3	45	6.8	23	3.5	15	2.3	35	5
Crew Acceptability	F8	.136	15	1.8	50	6.8	15	1.8	25	3.4	50	6.8	15	1
Crew Training	F9	0.0	50	0	40	0	50	0	40	0	40	0	50	0
Timeline	F10	.015	40	.6	50	.75	40	.6	30	.45	50	.75	1	0
Safety	F11	.167	50	8.4	50	8.4	50	8.4	40	6.7	40	6.7	10	1
Maintainability	F12	.091	50	4.6	10	.91	40	3.6	30	2.7	10	.91	30	2
				36.9		36.1		36.3		28.1		35		18
				1		3		2				4		

Orbiter Personal Hygiene Station		Disposable Laboratory Utensils/Tools		Hot Water Spray Washing-Centrifuge Drying System		Reusable Wipes		Disposable Wipes With Wetter Unit		Orbiter Personal Hygiene Station & Solid Waste Compactor		Disposable Laboratory Utensils/Tools & Solid Waste Compactor		Disposable Wet & Dry Wipes With Solid Waste Compactor		Spacelab Utensil/Hand Cleaning Fixture With Solid Waste Compactor	
Comparing	Weight VL	Comparing	Weight VL	Comparing	Weight VL	Comparing	Weight VL	Comparing	Weight VL	Comparing	Weight VL	Comparing	Weight VL	Comparing	Weight VL	Comparing	Weight VL
30	2.3	22	1.7	24	1.8	39	2.9	20	1.5	25	1.9	21	1.6	38	2.8	25	1.9
50	5.3	11	1.17	20	2.1	30	3.2	30	3.2	50	5.3	11	1.17	25	2.65	50	5.3
50	6.1	0	0	50	6.1	25	3.0	25	3.0	50	6.1	0	0	15	1.8	50	6.1
20	.6	1	.03	10	.3	50	1.5	5	.15	25	.75	10	3	30	.9	25	.75
45	2	50	2.3	1	.045	35	1.6	35	1.6	45	2.0	50	2.3	50	2.3	45	2
20	1.22	25	1.53	1	.061	5	.31	5	.31	15	.92	20	1.22	40	2.44	3	.18
15	2.3	35	5.3	20	3.0	20	3.0	23	3.5	1	.152	25	3.8	33	5	1	.152
50	6.8	15	1.8	25	3.4	5	6.8	15	1.8	50	6.8	15	1.8	15	1.8	50	6.8
40	0	50	0	25	0	40	0	40	0	25	0	50	0	50	0	25	0
50	.75	1	0.15	1	.015	20	.3	20	.3	50	.75	1	.015	40	.6	50	.75
40	6.7	10	1.67	30	5	40	6.7	40	6.7	40	6.7	10	1.67	50	8.4	50	8.4
10	.91	30	2.7	30	2.7	20	1.8	20	1.8	1	.091	20	1.8	40	3.6	10	.91
	35		18.2		24.5		31.1		23.9		31.5		15.7		32.3		33.2
	4																

For the types of crew size and mission durations evaluated, the rank ordering of the top concepts remained the same; however, the variance between their total weighted values differ to quite an extent. Four concepts were determined to be the preliminary optimum approaches to a wash/rinse capability since their total weighted values in all six mission types were substantially and consistently higher than any of the other concepts and were also relatively close in their total weighted values. Among these four concepts, the disposable wet and dry wipe concept or the disposable dry wipes plus cleansing agent have a higher credibility to be the final concept selections for the shorter missions (4 man/7 day and 7 man/7 day) since they clearly have higher total weighted values from the other two. For the 7 man/30 day and 7 man/180 day mission, the variances of the total weighted values among the four concepts are not so clearly defined, yet the disposable wet and dry wipe concept again would appear to be a higher choice for the optimum approach. For missions capable of wash water recovery, however, the total weighted values are extremely close to each other and final concept selection is not as clearly defined. For those missions final selection is based on the desire for flowing water for washing purposes or the appropriateness of the wipes alone and the ability of each concept to accommodate the biomedical experiments requirements that were established in Section IV of this report.

Since the total weighted values for the other mission types are close, these factors, too, should also be considered before making final selection. It must be remembered that there is an inbred psychological desire for the washing of hands, utensils, etc., in flowing water among most sections of the populace, and breaking of this habit is an unnatural, time consuming process. Also prolonged usage of premoistened wet wipes or the chemicals involved in the cleansing agents could cause dryness and produce harmful skin epidermis reactions as mentioned earlier in the merits/deficiencies table. Also, wipes are not fully capable of meeting every experiment requirement established in Section IV. These factors could not fully be accounted for in the tradeoff comparison where the characteristics were assigned a value of either one or zero. Also, for our tradeoff analysis each concept was treated as if it was totally self-sustaining and was therefore charged with structural weight and volume that in actuality could be shared with other systems. This would greatly cause the total weight of several concepts to decline. Examples of items that could be utilized by other systems are the wash water recovery system, blowers, water pumps, separators (liquid-gas or centrifugal), and water heaters. In our top four concepts, this factor would reduce the total weight and volume, and therefore, increase the total weighted

APPENDIX A - SUPPORTING CALCULATIONS

1. DISPOSABLE WET AND DRY WIPES

a. *Expendable Weight*

1) Wet Wipes:

Expendable Weight = (weight one wipe)
(number handwashing per crewman per
day)(number crewman)(mission duration)
(number wipes per handwashing)

- 4 man/7 day mission: $(5.3g)(10)(4)(7)(2) = 3 \text{ kg } (6.6 \text{ lb})$
- 7 man/7 day mission: $(5.3g)(10)(7)(7)(2) = 5.2 \text{ kg } (11.5 \text{ lb})$
- 7 man/30 day mission: $(5.3g)(10)(7)(30)(2) = 22.3 \text{ kg } (49.2 \text{ lb})$
- 7 man/180 day mission: $(5.3g)(10)(7)(180)(2) = 133.8 \text{ kg } (295 \text{ lb})$

2) Dry Wipes: See formula for Wet Wipes

- 4 man/7 day mission: $(5.3g)(10)(4)(7)(1) = 1.5 \text{ kg } (3.3 \text{ lb})$
- 7 man/7 day mission: $(5.3g)(10)(7)(7)(1) = 2.6 \text{ kg } (5.75 \text{ lb})$
- 7 man/30 day mission: $(5.3g)(10)(7)(30)(1) = 11.15 \text{ kg } (24.6 \text{ lb})$
- 7 man/180 day mission: $(5.3g)(10)(7)(180)(1) = 116.9 \text{ kg } (147.5 \text{ lb})$

3) Total Expendable Weight:

Weight Dry Wipes + Weight Wet Wipes

- 4 man/7 day mission: 4.45 kg (9.9 lb)
- 7 man/7 day mission: 7.85 kg (17.3 lb)
- 7 man/30 day mission: 33.5 kg (73.8 lb)
- 7 man/180 day mission: 200.9 kg (443 lb)

b. *Expendable Volume*

1) Wet Wipes:

Expendable Volume = (volume one wipe)
(number handwashings per crewman per
day)(number crewman)(mission duration)
(number of wipes per handwashing)

- 4 man/7 day mission: $(.75 \text{ in}^3)(10)(4)(7)(2) = .0068 \text{ m}^3 (420 \text{ in}^3)$
- 7 man/7 day mission: $(.75 \text{ in}^3)(10)(7)(7)(2) = .012 \text{ m}^3 (735 \text{ in}^3)$
- 7 man/30 day mission: $(.75 \text{ in}^3)(10)(7)(30)(2) = .052 \text{ m}^3 (3150 \text{ in}^3)$
- 7 man/180 day mission: $(.75 \text{ in}^3)(10)(7)(180)(2) = .31 \text{ m}^3 (18,900 \text{ in}^3)$

2) Dry Wipes: See formula for Wet Wipes

- 4 man/7 day mission: $(.75)(10)(4)(7)(1) = .0034 \text{ m}^3 (210 \text{ in}^3)$
- 7 man/7 day mission: $(.75)(10)(7)(7)(1) = .006 \text{ m}^3 (367.5 \text{ in}^3)$
- 7 man/30 day mission: $(.75)(10)(7)(30)(1) = .026 \text{ m}^3 (1575 \text{ in}^3)$
- 7 man/180 day mission: $(.75)(10)(7)(180)(1) = .155 \text{ m}^3 (9450 \text{ in}^3)$

3) Total Expendable Volume: Volume Dry Wipes + Volume Wet Wipes

- 4 man/7 day mission: $.01 \text{ m}^3 (630 \text{ in}^3)$
- 7 man/ 7 day mission: $.018 \text{ m}^3 (1103 \text{ in}^3)$
- 7 man/30 day mission: $.078 \text{ m}^3 (4725 \text{ in}^3)$
- 7 man/180 day mission: $.465 \text{ m}^3 (28,350 \text{ in}^3)$

c. Fixed Weight

Density Aluminum = $.1 \text{ lb/in}^3$
 Wall Thickness of Aluminum to be Used = $.03 \text{ in}$
 Size of Wet Wipe Package = $2'' \times 3'' \times .125''$
 Volume of One Used Wipe = 2.7 in^3

1) Wet Wipes:

- 4 man/7 day mission: Storage Cabinet Size = $8'' \times 6'' \times 9''$
 Surface Area of Cabinet = 294 in^2
 Volume Material = (surface area)(wall thickness) = $(.03)(294) = 8.82 \text{ in}^3$

Weight Material = (volume)(density) =
 $(8.82)(.1) = .9 \text{ lb}$

Waste Storage Cabinet Size = $10'' \times 10'' \times 15''$

Surface Area of Storage = 650 in^2

Volume Material = $(650)(.03) = 19.5 \text{ in}^3$

Weight Material = $(19.5)(.1) = 1.95 \text{ lb}$

Total Fixed Weight = Weight Storage
Cabinet + Weight Waste Storage Cabinet =
 $1.3 \text{ kg } (2.85 \text{ lb})$

• 7 man/7 day mission:

Storage Cabinet Size = $8'' \times 12'' \times 8''$

Surface Area of Cabinet = 416 in^2

Volume Material = $(.03)(416) = 12.5 \text{ in}^3$

Weight = $(12.5)(.1) = 1.25 \text{ lb}$

Waste Storage Cabinet Size = $15'' \times 15'' \times 12''$

Surface Area of Storage = 990 in^2

Volume Material = $(.03)(990) = 29.7 \text{ in}^3$

Weight Material = $(29.7)(.1) = 2.97 \text{ lb}$

Total Fixed Weight = $1.9 \text{ kg } (4.22 \text{ lb})$

• 7 man/30 day mission:

Storage Cabinet Size = $8'' \times 12'' \times 33''$

Surface Area of Cabinet = 1116 in^2

Volume Material = $(.03)(1116) = 33.5 \text{ in}^3$

Weight Material = $(.1)(33.5) = 3.35 \text{ lb}$

Waste Storage Cabinet Size = $22'' \times 22'' \times 24''$

Surface Area of Cabinet = 2552 in^2

Volume Material = $(.03)(2552) = 76.6 \text{ in}^3$

Weight Material = $(.1)(76.6) = 7.7 \text{ lb}$

Total Fixed Weight = $5 \text{ kg } (11.05 \text{ lb})$

• 7 man/180 day mission:

Storage Cabinet Size: 32" x 24" x 25"

Surface Area of Cabinet = 3736 in^2

Volume Material = $(.03)(3736) = 112.1 \text{ in}^3$

Weight Material = $(.1)(112.1) = 11.2 \text{ lb}$

Waste Storage Cabinet Size = 40" x 40" x 43"

Surface Area of Cabinet = 8360 in^2

Volume Material = $(.03)(8360) = 250.8 \text{ in}^3$

Weight Material = $(.1)(250.8) = 25.1 \text{ lb}$

Total Fixed Weight: 16.5 kg (36.3 lb)

2) Dry Wipes

• 4 man/7 day mission:

Storage Cabinet Size = 4" x 11" x 17.5"

Surface Area of Cabinet = 420.5 in^2

Volume Material = $(.03)(420.5) = 12.6 \text{ in}^3$

Weight Material = $(.1)(12.6) = 1.26 \text{ lb}$

Waste Storage Cabinet Size = 5" x 10" x 15"

Surface Area of Cabinet = 400 in^2

Volume Material = $(.03)(400) = 12 \text{ in}^3$

Weight Material = $(.1)(12) = 1.2 \text{ lb}$

Total Fixed Weight: 1.13 kg (2.5 lb)

• 7 man/7 day mission:

Storage Cabinet Size = 8" x 11" x 16"

Surface Area of Cabinet = 608 in^2

Volume Material = $(.03)(608) = 18.24 \text{ in}^3$

Weight Material = $(.1)(18.24) = 1.8 \text{ lb}$

Waste Storage Cabinet Size = 6" x 15" x 15"

Surface Area of Cabinet = 685 in^2

Volume Material = $(.03)(685) = 20.6 \text{ in}^3$

- 7 man/30 day mission:

Weight Material = $(.1)(20.6) = 2.1 \text{ lb}$

Total Fixed Weight: 1.8 kg (3.9 lb)

Storage Cabinet Size = 16" x 22" x 17"

Surface Area of Cabinet = 1622 in^2

Volume Material = $(.03)(1622) = 48.7 \text{ in}^3$

Weight Material = $(.1)(48.7) = 4.9 \text{ lb}$

Waste Storage Cabinet Size = 12" x 22" x 22"

Surface Area of Cabinet = 1540 in^2

Volume Material = $(.03)(1540) = 46.2 \text{ in}^3$

Weight Material = $(.1)(46.2) = 4.6 \text{ lb}$

Total Fixed Weight: 4.3 kg (9.5 lb)

- 7 man/180 day mission:

Storage Cabinet Size = 32" x 44" x 25"

Surface Area of Cabinet = 5516 in^2

Volume Material = $(.03)(5516) = 165.5 \text{ in}^3$

Weight Material = $(.1)(165.5) = 16.5 \text{ lb}$

Waste Storage Cabinet Size = 22" x 40" x 40"

Surface Area of Cabinet = 5120 in^2

Volume Material = $(.03)(5120) = 153.6 \text{ in}^3$

Weight Material = $(.1)(153.6) = 15.4 \text{ lb}$

Total Fixed Weight: 14.5 kg (31.9 lb)

- 3) Wipe Dispenser:

.454 kg (1 lb) each for Wet and Dry Wipes

- 4) Total Fixed Weight:

Storage and Waste Storage Weight for Wet and Dry Wipes + Wet and Dry Wipes Dispenser Weights

- 4 man/7 day mission:

3.4 kg (7.4 lb)

- 7 man/7 day mission:

4.6 kg (10.15 lb)

- 7 man/30 day mission: 10.2 kg (22.55 lb)
- 7 man/180 day mission: 31.8 kg (70.2 lb)

d. Fixed Volume

1) Wet Wipes

- 4 man/7 day mission:
 - Volume Storage Cabinet = 432 in³
 - Volume Waste Storage Cabinet = 1500 in³
 - Total Fixed Volume = .032 m³ (1.932 in³)
- 7 man/7 day mission:
 - Volume Storage Cabinet = 768 in³
 - Volume Waste Storage Cabinet = 2700 in³
 - Total Fixed Volume = .057 m³ (3468 in³)
- 7 man/30 day mission:
 - Volume Storage Cabinet = 3168 in³
 - Volume Waste Storage Cabinet = 11,616 in³
 - Total Fixed Volume = .24 m³ (14,784 in³)
- 7 man/180 day mission:
 - Volume Storage Cabinet = 19,200 in³
 - Volume Waste Storage Cabinet = 68,800 in³
 - Total Fixed Volume = 1.44 m³ (88,000 in³)

2) Dry Wipes

- 4 man/7 day mission:
 - Volume Storage Cabinet = 770 in³
 - Volume Waste Storage Cabinet = 750 in³
 - Total Fixed Volume = .025 m³ (1520 in³)
- 7 man/7 day mission:
 - Volume Storage Cabinet = 1408 in³
 - Volume Waste Storage Cabinet = 1350 in³
 - Total Fixed Volume = .045 m³ (2758 in³)

- 7 man/30 day mission:
 - Volume Storage Cabinet = 5984 in³
 - Volume Waste Storage Cabinet = 5808 in³
 - Total Fixed Volume = .193 m³ (11,792 in³)
- 7 man/180 day mission:
 - Volume Storage Cabinet = 35,200 in³
 - Volume Waste Storage Cabinet = 35,200 in³
 - Total Fixed Volume = 1.15 m³ (70,400 in³)
- 3) Wipe Dispenser:
 - .028 m³ (1728 in³) each for Wet and Dry Wipes
- 4) Total Fixed Volume:
 - Storage and Waste Storage Volume for Wet and Dry Wipes + Wet and Dry Wipe Dispenser Volumes
- 4 man/7 day mission:
 - .113 m³ (6908 in³)
- 7 man/7 day mission:
 - .16 m³ (9682 in³)
- 7 man/30 day mission:
 - .5 m³ (30,032 in³)
- 7 man/180 day mission:
 - 2.65 m³ (161,856 in³)

e. *Environmental Impact*

1) Maximum Latent Heat Load Per Day

Wet Wipes - Each wet wipe contains 2.9 ml (.007 lb) moisture which will all eventually be vaporized.

$$\begin{aligned} \text{Latent Heat Load} &= (\text{water loss})(\text{heat of vaporization}) \\ &= (.007)(1000) = 7 \text{ Btu/towel} \end{aligned}$$

Since two wet wipes are used per washing -

$$\begin{aligned} \text{Latent Heat Load per Washing} &= 14 \text{ Btu/towel} \\ \text{Latent Heat Load per Day} &= (\text{latent heat load per washing})(\text{number crewman})(\text{number handwashing per crewman per day}) \end{aligned}$$

- 4 men:
 - $(14)(4)(10) = 591.4 \times 10^3 \text{ joules/day}$
(560 Btu/day)

- 7 men: $(14)(7)(10) = 1034.9 \times 10^3 \text{ joules/day (980 Btu/day)}$

Based on the Equivalent Weight Ratio, .128 lbs/Btu/hr, the equivalent weights equal 1.4 kg (3 lb) for 4-man crew size and 2.4 kg (5.2 lb) for 7-man crew size.

f. *Total Weight*

Total Weight = Fixed Weight + Expendable Weight + Environmental Impact Equivalent Weight

- 4 man/7 day mission: 9.2 kg (20.3 lb)
- 7 man/7 day mission: 14.8 kg (32.65 lb)
- 7 man/30 day mission: 46.1 kg (101.6 lb)
- 7 man/180 day mission: 235.2 kg (518.4 lb)

2. DISPOSABLE WET AND DRY WIPES WITH SOLID WASTE COMPACTOR

a. *Expendable Weight*

- 1) Wet Wipes: See calculations for Disposable Wet and Dry Wipes
- 2) Dry Wipes: See calculations for Disposable Wet and Dry Wipes
- 3) Solid Waste Compactor Bags: Each compactor bag will hold approximately 2450 in³ of solid trash, therefore, three extra bags weighing .454 kg (1 lb) each will be needed for the 30 day mission and 20 extra bags will be needed for the 180 day mission.
- 4) Total Expendable Weight: Weight Wet and Dry Wipes + Weight Solid Waste Compactor Bags (for 30 and 180 day missions)
 - 4 man/7 day mission: 4.45 kg (9.9 lb)
 - 7 man/7 day mission: 7.85 kg (17.3 lb)
 - 7 man/30 day mission: 34.8 kg (76.8 lb)
 - 7 man/180 day mission: 210 kg (463 lb)

b. Expendable Volume

- 1) Wet Wipes: See calculations for Disposable Wet and Dry Wipes
- 2) Dry Wipes: See calculations for Disposable Wet and Dry Wipes
- 3) Solid Waste Compactor Bags: Volume of each compactor bag in a stored, compacted state = 748 in³.
 - 30 day mission: Volume = (748)(3) = .004 m³ (2244 in³)
 - 180 day mission: Volume = (748)(20) = .25 m³ (14,960 in³)
- 4) Total Expendable Volume: Volume Wet and Dry Wipes + Volume Solid Waste Compactor Bags (for 30 and 180 day missions)
 - 4 man/7 day mission: .01 m³ (630 in³)
 - 7 man/7 day mission: .018 m³ (1103 in³)
 - 7 man/7 day mission: .114 m³ (6969 in³)
 - 7 man/180 day mission: .71 m³ (43,310 in³)

c. Fixed Weight - The solid waste compactor reduces waste volume to 30% of original size. Assuming that there is a proportional relationship between container volume and weight, the solid waste compactor also reduced the container weight to 30% of original weight.

- 1) Wet Wipes
 - Storage Cabinet: see calculations for Disposable Wet and Dry Wipes
 - Waste Storage Cabinet: data obtained from Disposable Wet and Dry Wipes
 - 4 man/7 day mission: (1.95 lb)(.33) = .3 kg (.64 lb)
 - 7 man/7 day mission: (2.97)(.33) = .44 kg (.98 lb)
 - 7 man/30 day mission: (7.7)(.33) = 1.15 kg (2.54 lb)
 - 7 man/180 day mission: (25.1)(.33) = 3.76 kg (8.3 lb)

2) Dry Wipes

Storage Cabinet: see calculations for Disposable Wet and Dry Wipes.

Waste Storage Cabinet: data obtained from Disposable Wet and Dry Wipes calculations.

- 4 man/7 day mission: $(1.2)(.33) = .18 \text{ kg } (.4 \text{ lb})$
- 7 man/7 day mission: $(2.1)(.33) = .32 \text{ kg } (.7 \text{ lb})$
- 7 man/30 day mission: $(4.6)(.33) = .7 \text{ kg } (1.52 \text{ lb})$
- 7 man/180 day mission: $(15.4)(.33) = 2.3 \text{ kg } (5.1 \text{ lb})$

3) Wipe Dispenser: See Calculations for Disposable Wet and Dry Wipes

4) Compactor Weight: 30.8 kg (68 lb)

5) Total Fixed Weight: Storage and Waste Storage Weights for Wet and Dry Wipes + Wipe Dispenser Weights + Compactor Weight

- 4 man/7 day mission: 33.2 kg (73.2 lb)
- 7 man/7 day mission: 33.9 kg (74.73 lb)
- 7 man/30 day mission: 37.3 kg (82.31 lb)
- 7 man/180 day mission: 50.4 kg (111.1 lb)

d. *Fixed Volume* - The solid waste compactor reduces waste volume to 30% of original volume.

1) Wet Wipes

Storage Cabinet Volume: see calculations for Disposable Wet and Dry Wipes.

Waste Storage Cabinet Volume: data obtained from Disposable Wet and Dry Wipe calculations.

- 4 man/7 day mission: $(1500)(.33) = .008 \text{ m}^3 (500 \text{ in}^3)$
- 7 man/7 day mission: $(2700)(.33) = .015 \text{ m}^3 (900 \text{ in}^3)$
- 7 man/30 day mission: $(11,616)(.33) = .06 \text{ m}^3 (3833 \text{ in}^3)$
- 7 man/180 day mission: $(68,800)(.33) = .37 \text{ m}^3 (22,704 \text{ in}^3)$

2) Dry Wipes

Storage Cabinet Volume: see calculations for Disposable Wet and Dry Wipes.

Waste Storage Cabinet Volume: data obtained from Disposable Wet and Dry Wipes calculations.

- 4 man/7 day mission: $(750)(.33) = .004 \text{ m}^3 (250 \text{ in}^3)$
- 7 man/7 day mission: $(1350)(.33) = .007 \text{ m}^3 (445.5 \text{ in}^3)$
- 7 man/30 day mission: $(5808)(.33) = .031 \text{ m}^3 (1916.6 \text{ in}^3)$
- 7 man/180 day mission: $(35,200)(.33) = .19 \text{ m}^3 (11,616 \text{ in}^3)$

3) Wipe Dispenser: See calculations for Disposable Wet and Dry Wipes

- 4) Compactor Volume: $.04 \text{ m}^3 (2450 \text{ in}^3)$

5) Total Fixed Volume: Storage and Waste Storage Volume for Wet and Dry Wipes + Wipe Dispenser Volumes + Compactor Volume

- 4 man/7 day mission: $.13 \text{ m}^3 (7858 \text{ in}^3)$
- 7 man/7 day mission: $.16 \text{ m}^3 (9427.5 \text{ in}^3)$
- 7 man/30 day mission: $.34 \text{ m}^3 (20,807.6 \text{ in}^3)$
- 7 man/180 day mission: $1.55 \text{ m}^3 (94,626 \text{ in}^3)$

e. *Environmental Impact*

Maximum Latent Heat Load per Day: see calculations for Disposable Wet and Dry Wipes

f. *Spares Weight* - One complete drive mechanism for compactor weighing 2.27 kg (5 lb) for the 30 and 180 day mission.

g. *Total Weight*

Total Weight =

Fixed Weight + Expendable Weight +
Environmental Impact Equivalent Weight
+ Spares Weight

- 4 man/7 day mission: 39.05 kg (86.1 lb)

- 7 man/7 day mission: 44.1 kg (97.2 lb)
- 7 man/30 day mission: 76.8 kg (169.3 lb)
- 7 man/180 day mission: 265 kg (584.3 lb)

3. SPACELAB UTENSIL/HAND CLENASING FIXTURE

a. *Expendable Weight*

1) Dry Wipes: See calculations for Disposable Wet and Dry Wipes Concept

2) Water: Use 182.6g (.4 lb) per handwash.

Water Usage per Mission = (water usage
per handwash)(number of handwashes per day)
(number crewman)(mission duration)

- 4 man/7 day mission: $(.4)(10)(4)(7) = 50.8 \text{ kg (112 lb)}$
- 7 man/7 day mission: $(.4)(10)(7)(7) = 88.9 \text{ kg (196 lb)}$
- 7 man/30 day mission: $(.4)(10)(7)(30) = 381 \text{ kg (840 lb)}$
- 7 man/180 day mission: $(.4)(10)(7)(180) = 2286.1 \text{ kg (5040 lb)}$

For the 30 and 180 day mission with
wash water recovery capability, water
usage = 12.8 kg (28.2 lb) (assuming 100%
efficiency in water recovery)

3) Soap: Use 2g (.0044 lb) per handwash.

Soap Usage per Mission = (soap usage
per handwash)(number of handwashes per
day)(number of crewman)(mission duration)

- 4 man/7 day mission: $(.0044)(10)(4)(7) = .56 \text{ kg (1.23 lb)}$
- 7 man/7 day mission: $(.0044)(10)(7)(7) = 1 \text{ kg (2.2 lb)}$
- 7 man/30 day mission: $(.0044)(10)(7)(30) = 4.2 \text{ kg (9.2 lb)}$
- 7 man/180 day mission: $(.0044)(10)(7)(180) = 25.1 \text{ kg (55.4 lb)}$

- 4) Disinfectant: Disinfect the cleansing fixture enclosure once every five days using .34 kg (.75 lb) of disinfectant each time.

Disinfectant Usage per Mission = (disinfectant usage per spray)(number sprays)

- 4 man/7 day mission: $(.75)(1) = .34 \text{ kg } (.75 \text{ lb})$
- 7 man/7 day mission: $(.75)(1) = .34 \text{ kg } (.75 \text{ lb})$
- 7 man/30 day mission: $(.75)(5) = 1.7 \text{ kg } (3.75 \text{ lb})$
- 7 man/180 day mission: $(.75)(35) = 11.9 \text{ kg } (26.25 \text{ lb})$

5) Total Expendable Weight:

Weight Dry Wipes + Weight Water + Weight Soap + Weight Disinfectant

- 4 man/7 day mission: 53.2 kg (117.28 lb)
- 7 man/7 day mission: 92.87 kg (204.75 lb)
- 7 man/30 day mission: 398 kg (877.5 lb)
- 7 man/180 day mission: 2390.3 kg (6269.7 lb)
- 7 man/30 day mission with wash water recovery capability: 29.8 kg (65.7 lb)
- 7 man/180 day mission with wash water recovery capability: 116.9 kg (257.9 lb)

b. Expendable Volume

- 1) Dry Wipes: See calculations for Disposable Wet and Dry Wipes Concept

2) Water

Density of water = 62.4 lb/ft^3

Water Volume = $(\text{water weight})(1728 \text{ in}^3/\text{ft}^3) \div \text{water density}$

- 4 man/7 day mission: $\frac{(112)(1728)}{62.4} = .051 \text{ m}^3 (3101 \text{ in}^3)$
- 7 man/7 day mission: $\frac{(196)(1728)}{62.4} = .089 \text{ m}^3 (5428 \text{ in}^3)$

- 7 man/30 day mission: $\frac{(840)(1728)}{62.4} = .38 \text{ m}^3 (2326 \text{ in}^3)$
- 7 man/180 day mission: $\frac{(5040)(1728)}{62.4} = 2.29 \text{ m}^3 (139,569 \text{ in}^3)$
- 30 and 180 day missions with wash water recovery: $\frac{(28.2)(1728)}{62.4} = .013 \text{ m}^3 (781 \text{ in}^3)$

3) Soap - Assume that the density of soap equals the density of water.

Soap Volume = (soap weight)(1728 in³/ft³) ÷ soap density

- 4 man/7 day mission: $\frac{(1.23)(1728)}{62.4} = .0006 \text{ m}^3 (34.1 \text{ in}^3)$
- 7 man/7 day mission: $\frac{(2.2)(1728)}{62.4} = .001 \text{ m}^3 (61 \text{ in}^3)$
- 7 man/30 day mission: $\frac{(9.2)(1728)}{62.4} = .0042 \text{ m}^3 (255 \text{ in}^3)$
- 7 man/180 day mission: $\frac{(55.4)(1728)}{62.4} = .025 \text{ m}^3 (1534 \text{ in}^3)$

4) Disinfectant - Assume that the density of disinfectant equals the density of water.

Disinfectant Volume = (disinfectant weight)(1728 in³/ft³) ÷ disinfectant density

- 4 man/7 day mission: $\frac{(.75)(1728)}{62.4} = .00034 \text{ m}^3 (20.8 \text{ in}^3)$
- 7 man/7 day mission: $\frac{(.75)(1728)}{62.4} = .00034 \text{ m}^3 (20.8 \text{ in}^3)$
- 7 man/30 day mission: $\frac{(3.75)(1728)}{62.4} = .0017 \text{ m}^3 (103.85 \text{ in}^3)$
- 7 man/180 day mission: $\frac{(26.25)(1728)}{62.4} = .012 \text{ m}^3 (726.9 \text{ in}^3)$

- 5) Total Expendable Volume: Volume Dry Wipe + Volume Water + Volume Soap + Volume Disinfectant
- 4 man/7 day mission: .064 m³ (3926 in³)
 - 7 man/7 day mission: .113 m³ (6918 in³)
 - 7 man/30 day mission: .49 m³ (29,605 in³)
 - 7 man/180 day mission: 2.9 m³ (177,030 in³)
 - 7 man/30 day mission with wash water recovery capability: .12 m³ (7124 in³)
 - 7 man/180 day mission with wash water recovery capability: .63 m³ (38,242 in³)

c. Fixed Weight

- 1) Dry Wipes Storage and Waste Storage Cabinet: See calculations for Disposable Wet and Dry Wipes Concept.
- 2) Wipe Dispenser: See calculations for Disposable Wet and Dry Wipes Concept.
- 3) Fixture Weight:

Hot Water Holding Tank,
Thermostat and Heater

Element:	3.89 kg (8.58 lb)
Valves:	1.45 kg (3.2 lb)
Filters:	2.8 kg (6.2 lb)
Nozzles:	.32 kg (.7 lb)
Pressure Regulator:	.5 kg (1.11 lb)
Liquid-Gas Separator:	2.25 kg (5 lb)
Blower:	.11 kg (.25 lb)
Water Pump:	1.6 kg (3.5 lb)
Waste Water Bladder Tank:	2.6 kg (5.7 lb)
Miscellaneous:	6.2 kg (13.6 lb)
Structure:	5 kg (11.04 lb)

Total: 22.7 kg (50 lb)

4) Ambient Water Holding Tank (cylindrical shape)

- 4 man/7 day mission:

Tank must hold 112 lb - 5 lb water that is in the hot water holding tank = 107 lb

$$\text{Volume 107 lb water} = 2963.1 \text{ in}^3$$

Assume tank diameter of 12 in.;

$$\text{Area of Tank} = \frac{\pi d^2}{4} = 113 \text{ in}^2$$

Since volume = area x length, then
$$\text{length} = \frac{2963.1}{113} = 26.2 \text{ in.}$$

Assume maximum water pressure of 100 psi

$$\text{Hoop stress} = \frac{pr}{t} = 15,000 \text{ psi, therefore}$$

$$t = \frac{pr}{15000} = \frac{(100)(6)}{15000} = .04 \text{ in.}$$

$$\text{Surface area} = (2)(113) + \pi (12)(26.2) = 1214 \text{ in}^2$$

$$\text{Volume Material} = (\text{area})(t) = (1214)(.04) = 48.55 \text{ in}^3$$

$$\begin{aligned} \text{Weight Material} &= (\text{volume material}) \\ &(\text{density aluminum}) = (48.55)(.1) = 2.2 \text{ kg} \\ &(4.86 \text{ lb}) \end{aligned}$$

- 7 man/7 day mission:

$$196 \text{ lb} - 5 \text{ lb} = 191 \text{ lb}$$

$$\text{Volume 191 lb} = 5289 \text{ in}^3$$

Assume tank diameter of 18 in.

$$\text{Area} = \frac{\pi d^2}{4} = 254.5 \text{ in}^2$$

$$L = \frac{V}{A} = \frac{5289}{254.5} = 20.8 \text{ in.}$$

$$t = \frac{(100)(9)}{15000} = .06 \text{ in.}$$

$$\text{Surface area} = (2)(254.5) + \pi(18)(20.8) = 1685 \text{ in}^2$$

$$\text{Volume Material} = (1685)(.06) = 101.1 \text{ in}^3$$

$$\text{Weight Material} = (101.1)(.1) = 4.58 \text{ kg} \\ (10.1 \text{ lb})$$

• 7 man/30 day mission:

$$840 \text{ lb} - 5 \text{ lb} = 835 \text{ lb}$$

$$\text{Volume } 835 \text{ lb} = 23.123 \text{ in}^3$$

Assume tank diameter of 24 in.

$$\text{Area} = \frac{\pi d^2}{4} = 452.4 \text{ in}^2$$

$$L = \frac{V}{A} = \frac{23.123}{452.4} = 51 \text{ in.}$$

$$t = \frac{(100)(12)}{15000} = .08 \text{ in.}$$

$$\text{Surface area} = (2)(452.4) + \pi(24)(51) = 4750 \text{ in}^2$$

$$\text{Volume Material} = (4750)(.08) = 380 \text{ in}^3$$

$$\text{Weight Material} = (380)(.1) = 17.2 \text{ kg} \\ (38 \text{ lb})$$

• 7 man/180 day mission:

$$5040 \text{ lb} - 5 \text{ lb} = 5035 \text{ lb}$$

$$\text{Volume } 5035 \text{ lb} = 139,431 \text{ in}^3$$

Assume tank diameter of 48 in.

$$\text{Area} = \frac{\pi d^2}{4} = 1810 \text{ in}^2$$

$$L = \frac{V}{A} = \frac{139,431}{1810} = 77 \text{ in.}$$

$$t = \frac{(100)(24)}{15000} = .16 \text{ in.}$$

$$\text{Surface area} = (2)(1810) + \pi(48)(77) = 15,231 \text{ in}^2$$

$$\text{Volume Material} = (15,231)(.16) = 2437 \text{ in}^3$$

$$\text{Weight Material} = (2437)(.1) = 110.5 \text{ kg} \\ (243.7 \text{ lb})$$

- 30 and 180 day missions with wash water recovery capability:

$$28.2 \text{ lb} - 5 \text{ lb} = 23.2 \text{ lb}$$

$$\text{Volume } 23.2 \text{ lb} = 642.5 \text{ in}^3$$

Assume tank diameter of 9 in.

$$\text{Area} = \frac{\pi d^2}{4} = 63.6 \text{ in}^2$$

$$L = \frac{V}{A} = \frac{642.5}{63.6} = 10.1 \text{ in.}$$

$$t = \frac{(100)(4.5)}{15000} = .03 \text{ in.}$$

$$\text{Surface area} = (2)(63.6) + \pi(9)(10.1) = 412.8 \text{ in}^2$$

$$\text{Volume Material} = (412.8)(.03) = 12.4 \text{ in}^3$$

$$\text{Weight Material} = (12.4)(.1) = .56 \text{ kg} \\ (1.24 \text{ lb})$$

5) Soap Tank (cylindrical tank)

- 4 man/7 day mission

Tank Must Hold 1.23 lb of soap.

$$\text{Volume } 1.23 \text{ lb soap} = 34.1 \text{ in}^3$$

Assume tank diameter of 3 in.

$$\text{Area} = \frac{\pi d^2}{4} = 7.1 \text{ in}^2$$

$$L = \frac{V}{A} = \frac{34.1}{7.1} = 4.8 \text{ in.}$$

$$t = \frac{(100)(1.5)}{15000} = .01 \text{ in.}$$

$$\text{Surface area} = (2)(7.1) + \pi(3)(4.8) = 59.4 \text{ in}^2$$

$$\text{Volume Material} = (59.4)(.01) = .6 \text{ in}^3$$

$$\text{Weight Material} = (.6)(.1) = .027 \text{ kg} \\ (.06 \text{ lb})$$

• 7 man/7 day mission:

Tank Must Hold 2.2 lb of soap.

$$\text{Volume 2.2 lb soap} = 61 \text{ in}^3$$

Assume tank diameter of 4 in.

$$\text{Area} = \frac{\pi d^2}{4} = 12.6 \text{ in}^2$$

$$L = \frac{V}{A} = \frac{61}{12.6} = 4.8 \text{ in.}$$

$$t = \frac{(100)(2)}{15000} = .013 \text{ in.}$$

$$\text{Surface area} = (2)(12.6) + \pi(4)(4.8) = 85.5 \text{ in}^2$$

$$\text{Volume material} = (85.5)(.013) = 1.11 \text{ in}^3$$

$$\text{Weight material} = (1.11)(.1) = .05 \text{ kg} \\ (.11 \text{ lb})$$

• 7 man/30 day mission:

Tank Must Hold 9.2 lb of soap.

$$\text{Volume 9.2 lb soap} = 255 \text{ in}^3$$

Assume tank diameter of 6"

$$\text{Area} = \frac{\pi d^2}{4} = 28.3 \text{ in}^2$$

$$L = \frac{V}{A} = \frac{255}{28.3} = 9 \text{ in.}$$

$$t = \frac{(100)(3)}{15000} = .02 \text{ in.}$$

$$\text{Surface area} = (2)(28.3) + \pi(6)(9) = 226.25 \text{ in}^2$$

$$\text{Volume material} = (226.25)(.02) = 4.52 \text{ in}^3$$

$$\text{Weight material} = (4.52)(.1) = .2 \text{ kg} \\ (.45 \text{ lb})$$

- 7 man/180 day mission:

Tank Must Hold 55.4 lb soap.

$$\text{Volume 55.4 soap} = 1534 \text{ in}^3$$

Assume tank diameter of 12 in.

$$\text{Area} = \frac{\pi d^2}{4} = 113 \text{ in}^2$$

$$L = \frac{V}{A} = \frac{1534}{113} = 13.6 \text{ in.}$$

$$t = \frac{(100)(6)}{15000} = .04 \text{ in.}$$

$$\text{Surface area} = (2)(113) + \pi (12)(13.6) = 738.7 \text{ in}^2$$

$$\text{Volume material} = (738.7)(.04) = 29.55 \text{ in}^3$$

$$\text{Weight material} = (29.55)(.1) = 1.4 \text{ kg} \\ (3 \text{ lb})$$

6) Disinfectant Tank (cylindrical tank)

- 4 man/7 day mission:

Tank Must Hold .75 lb disinfectant

$$\text{Volume .75 lb disinfectant} = 20.8 \text{ in}^3$$

Assume tank diameter of 2 in.

$$\text{Area of tank} = \frac{\pi d^2}{4} = 3.14 \text{ in}^2$$

$$L = \frac{V}{A} = \frac{20.8}{3.14} = 6.62 \text{ in.}$$

Assume maximum pressure of disinfectant
= 100 psi

$$t = \frac{(100)(1)}{15000} = .007 \text{ in.}$$

$$\text{Surface area} = (2)(3.14) + \pi (2)(6.62) = 47.88 \text{ in}^2$$

$$\text{Volume material} = (47.88)(.007) = .34 \text{ in}^3$$

$$\text{Weight material} = (.34)(.1) = .015 \text{ kg} \\ (.034 \text{ lb})$$

• 7 man/7 day mission:

Same calculations as for 4 man/7day mission.

• 7 man/30 day mission:

Tank Must Hold 3.75 lb disinfectant

$$\text{Volume } 3.75 \text{ lb disinfectant} = 103.85 \text{ in}^3$$

Assume tank diameter size of 4 in.

$$\text{Area} = \frac{\pi d^2}{4} = 12.6 \text{ in}^2$$

$$L = \frac{V}{A} = \frac{103.85}{12.6} = 8.24 \text{ in.}$$

$$t = \frac{(100)(2)}{15000} = .013 \text{ in.}$$

$$\text{Surface area} = (2)(12.6) + \pi(4)(8.24) = 128.75 \text{ in}^2$$

$$\text{Volume material} = (128.75)(.013) = 1.67 \text{ in}^3$$

$$\text{Weight material} = (1.67)(.1) = .08 \text{ kg} \\ (.17 \text{ lb})$$

• 7 man/180 day mission:

Tank Must Hold 26.25 lb disinfectant

$$\text{Volume } 26.25 \text{ lb disinfectant} = 726.9 \text{ in}^3$$

Assume tank diameter size of 9 in.

$$\text{Area} = \frac{\pi d^2}{4} = 63.62 \text{ in}^2$$

$$L = \frac{V}{A} = \frac{726.9}{63.62} = 11.4 \text{ in.}$$

$$t = \frac{(100)(4.5)}{15000} = .03 \text{ in.}$$

$$\text{Surface area} = (2)(63.62) + \pi(9)(11.4) = 449.6 \text{ in}^2$$

$$\text{Volume material} = (449.6)(.03) = 13.5 \text{ in}^3$$

$$\text{Weight material} = (13.5)(.1) = .61 \text{ kg} \\ (1.35 \text{ lb})$$

7) Wash Water Recovery System for 30 and 180 day Missions:

81.2 kg (179 lb)

8) Total Fixed Weight:

Weight Storage and Waste Storage for Dry Wipes + Weight Wipe Dispenser + Fixture Weight + Water, Soap and Disinfectant Holding Tank Weight + Wash Water Recovery System Weight (30 and 180 day missions)

- 4 man/7 day mission: 26.5 kg (58.45 lb)
- 7 man/7 day mission: 29.55 kg (65.14 lb)
- 7 man/30 day mission: 44.96 kg (99.12 lb)
- 7 man/180 day mission: 150.1 kg (330.95 lb)
- 7 man/30 day mission with wash water recovery capability: 109.5 kg (241.4 lb)
- 7 man/180 day mission with wash water recovery capability: 121.3 kg (267.5 lb)

d. Fixed Volume

- 1) Dry Wipes Storage and Waste Storage Cabinet: See calculations for Disposable Wet and Dry Wipes Concept.
- 2) Wipe Dispenser: See calculations for Disposable Wet and Dry Wipes Concept.
- 3) Fixture Volume: .55 m³ (33.394 in³)
- 4) Ambient Water Holding Tank: Data obtained from fixed weight calculations.
 - 4 man/7 day mission: .048 m³ (2963.1 in³)
 - 7 man/7 day mission: .087 m³ (5989 in³)
 - 7 man/30 day mission: .38 m³ (23,123 in³)

• 7 man/180 day mission: 2.29 m^3 (139,431 in^3)

• 30 and 180 day missions with wash water recovery capability: $.011 \text{ m}^3$ (642.5 in^3)

5) Soap Tank: Data obtained from fixed weight calculations.

• 4 man/7 day mission: $.0006 \text{ m}^3$ (34.1 in^3)

• 7 man/7 day mission: $.001 \text{ m}^3$ (61 in^3)

• 7 man/30 day mission: $.0042 \text{ m}^3$ (255 in^3)

• 7 man/180 day mission: $.025 \text{ m}^3$ (1534 in^3)

6) Disinfectant Tank: Data obtained from fixed weight calculations.

• 4 man/7 day mission: $.00034 \text{ m}^3$ (20.8 in^3)

• 7 man/7 day mission: $.00034 \text{ m}^3$ (20.8 in^3)

• 7 man/30 day mission: $.0017 \text{ m}^3$ (103.85 in^3)

• 7 man/180 day mission: $.012 \text{ m}^3$ (726.9 in^3)

7) Wash Water Recovery System for 30 and 180 Day Missions:

$.27 \text{ m}^3$ (16,556 in^3)

8) Total Fixed Volume:

Volume Storage and Waste Storage for Dry Wipes + Volume Wipe Dispenser + Fixture Volume + Water, Soap and Disinfectant Holding Tank Volume + Wash Water Recovery System Volume (30 and 180 day missions)

• 4 man/7 day mission: $.65 \text{ m}^3$ (39,660 in^3)

• 7 man/7 day mission: $.79 \text{ m}^3$ (43,251 in^3)

• 7 man/30 day mission: 1.15 m^3 (70,396 in^3)

• 7 man/180 day mission: 4.05 m^3 (247,214 in^3)

• 7 man/30 day mission with wash water recovery capability: 1.06 m^3 (64,471 in^3)

- 7 man/180 day mission with wash water recovery capability: $2.05 \text{ m}^3 (124,981 \text{ in}^3)$

e. *Spares Weight*

- 7 man/180 day mission: one filter .9 kg (2 lb)
- 7 man/180 day mission with wash water recovery capability: one filter for fixture .9 kg (2 lb)
one filter for recovery unit .23 kg (.5 lb)

f. *Power Penalty* - Based upon equivalent weight ratios for continuous AC and DC voltage (see Section II), the equivalent weights are calculated as follows:

$$.026 \text{ kw (AC)} \times \frac{710 \text{ lb}}{\text{kw}} = 8.4 \text{ kg (18.46 lb)}$$

$$.099 \text{ kw (DC)} \times \frac{591 \text{ lb}}{\text{kw}} = 26.5 \text{ kg (58.5 lb)}$$

$$.081 \text{ kw (AC)} \times \frac{710 \text{ lb}}{\text{kw}} = 26 \text{ kg (57.5 lb)}$$

$$.199 \text{ kw (DC)} \times \frac{591 \text{ lb}}{\text{kw}} = 53.3 \text{ kg (117.6 lb)}$$

g. *Average Power*

- Water Heater Energy Requirement = $\frac{(\text{water usage per handwash})(\Delta T)(1.056)}{3.6} =$

$$\frac{(.4)(117-55^{\circ}\text{F})(1.056)}{3.6} = 7.3 \text{ watt-hr/wash}$$

- Blower Energy Requirement = (time blower is on)(blower power) =

$$\left(\frac{67}{3600}\right)(18) = .335 \text{ watt-hr/wash}$$

- Water Pump Energy Requirement =

$$(\text{time pump on})(\text{pump power}) =$$

$$\left(\frac{11}{3600}\right)(42) = .13 \text{ watt-hr/wash}$$

- Water Solenoid Valve Energy Requirement = $(\text{time solenoid valve open})(\text{valve power}) = \left(\frac{16.6}{3600}\right)(7) = .03 \text{ watt-hr/wash}$
- Soap Solenoid Valve Energy Requirement = $\left(\frac{3.3}{3600}\right)(7) = .006 \text{ watt-hr/wash}$
- Light Energy Requirement = $(\text{time light is on})(\text{light power}) = \left(\frac{67}{3600}\right)(8) = .15 \text{ watt-hr/wash}$
- Total Average Power = $28.2 \times 10^3 \text{ joules/wash (8 watt-hr/wash)}$
- Assume Wash Water Recovery System Components on for entire duration of one handwash (67 sec). $\left(\frac{67}{3600}\right)(55) = 1.02 \text{ watt-hr/wash}$
 $\left(\frac{67}{3600}\right)(100) = 1.86 \text{ watt-hr/wash}$

h. Environmental Impact

1) Maximum Latent Heat Load Per Day

Dry Wipes: see calculation for Disposable Wet and Dry Wipes Concept.

Cleansing Unit:

$$\text{Latent Load} = (\text{usage})(\text{mass})(\Delta\text{grains})$$

$$\left(\frac{1 \text{ lb}}{7000 \text{ grains}}\right) (\text{heat of vaporization})$$

• 4 man mission:

$$\text{Latent Load} = \frac{.019 \text{ hr}}{\text{washing}} \times \frac{5616}{\text{hr}} \times \frac{46.7 \text{ grains}}{1 \text{ lb}}$$

$$\times \frac{1 \text{ lb}}{7000 \text{ grains}} \times 1000 =$$

7.1 Btu washing x 10 hand-

washing per crewman per day =

284 Btu/day

• 7 man mission:

$$\text{Latent Load} = (7.1)(10)(7) = 497 \text{ Btu/day}$$

Total Latent Load:

Latent Load Dry Wipes + Latent Load
Cleansing Unit

- 4 man mission: 553.3×10^3 joules/day (524 Btu/day)
- 7 man mission: 968.4×10^3 joules/day (917 Btu/day)

Equivalent Weight: based upon equivalent weight ratio .128 lbs/Btu/hr, the equivalent weights equal:

- 4 man mission: 1.27 kg (2.8 lb)
- 7 man mission: 2.22 kg (4.9 lb)

2) Maximum Sensible Heat Load Per Day

Cleansing Unit:

Sensible Load = (usage) $M \Delta h$

$\Delta h = 13.67$ Btu/kg (6.2 Btu/lb)
(refer to reference n in Appendix B)

Blower flow rate = 15 cfm = 7.1×10^{-3} kg
sec (56 lb/hr)

- 4 man mission:
$$\left(\frac{67 \text{ sec}}{\text{wash}} \right) \left(\frac{6.2 \text{ Btu}}{\text{lb}} \right) \left(\frac{56 \text{ lb}}{\text{hr}} \right) \left(\frac{\text{hr}}{3600 \text{ sec}} \right) =$$

6.5 Btu/washing

(6.5 Btu/washing) (10 washing per crewman
per day) (4 crewman) = 260 Btu/day

- 7 man mission: $(6.5)(10)(7) = 455$ Btu/day

Equivalent Weight: based upon equivalent weight ratio .128 lb/Btu/hr, the equivalent weights equal:

- 4 man mission: .64 kg (1.4 lb)
- 7 man mission: 1.1 kg (2.43 lb)

i. Total Weight

Total Weight =

Fixed Weight + Expendable Weight + Power
Penalty + Environmental Impact Equival-
ent Weights + Spares Weight

- 4 man/7 day mission: 116.5 kg (256.9 lb)
- 7 man/7 day mission: 160.7 kg (354.2 lb)
- 7 man/30 day mission: 481.2 kg (1060.9 lb)
- 7 man/180 day mission: 2579.6 kg (5686.9 lb)
- 7 man/30 day mission with wash water recovery capability: 222.1 kg (489.5 lb)
- 7 man/180 day mission with wash water recovery capability: 322.2 kg (710.3 lb)

4. SPACELAB UTENSIL/HAND CLEANSING FIXTURE WITH COMPACTOR

a. *Expendable Weight*

- 1) Dry Wipes: see calculations for Disposable Wet and Dry Wipes Concept.
- 2) Solid Waste Compactor Bags: see calculation for Disposable Wet and Dry Wipes with Solid Waste Compactor Concept.
- 3) Water: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 4) Soap: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 5) Disinfectant: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 6) Total Expendable Weight: Weight Dry Wipes + Weight Solid Waste Compactor Bags + Weight Water + Weight Soap + Weight Disinfectant
 - 4 man/7 day mission: 53.2 kg (117.28 lb)
 - 7 man/7 day mission: 92.87 kg (204.75 lb)
 - 7 man/30 day mission: 399.4 kg (880.5 lb)
 - 7 man/180 day mission: 2399.4 kg (5289.7 lb)

- 7 man/30 day mission with wash water recovery capability: 31.2 kg (68.7 lb)
- 7 man/180 day mission with wash water recovery capability: 126.1 kg (277.9 lb)

b. *Expendable Volume*

- 1) Dry Wipes: see calculations for Disposable Wet and Dry Wipes Concept.
- 2) Solid Waste Compactor Bags: see calculation for Disposable Wet and Dry Wipes with Solid Waste Compactor Concept.
- 3) Water: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 4) Soap: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 5) Disinfectant: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 6) Total Expendable Volume: Volume Dry Wipes + Volume Solid Waste Compactor Bags + Volume Water + Volume Soap + Volume Disinfectant
 - 4 man/7 day mission: .064 m³ (3926 in³)
 - 7 man/7 day mission: .113 m³ (6918 in³)
 - 7 man/30 day mission: .522 m³ (31,849 in³)
 - 7 man/180 day mission: 3.15 m³ (191,990 in³)
 - 7 man/30 day mission with wash water recovery capability: .154 m³ (9368 in³)
 - 7 man/180 day mission with wash water recovery capability: .87 m³ (53,222 in³)

c. *Fixed Weight*

- 1) Dry Wipes Storage and Waste Storage Cabinets: see calculations for Disposable Wet and Dry Wipes with Solid Waste Compactor Concept.
- 2) Wipe Dispenser: see calculations for Disposable Wet and Dry Wipes Concept.
- 3) Fixture Weight: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 4) Ambient Water Holding Tank (cylindrical shape): see calculation for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 5) Soap Tank (cylindrical shape): see calculation for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 6) Disinfectant Tank (cylindrical shape): see calculation for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 7) Compactor Weight: 30.8 kg (68 lb)
- 8) Wash Water Recovery System for 30 and 180 Day Mission:
81.2 kg (179 lb)
- 9) Total Fixed Weight: Weight Storage and Waste Storage for Dry Wipes + Weight Wipe Dispenser + Fixture Weight + Water, Soap, and Disinfectant Holding Tank Weight + Compactor Weight + Wash Water Recovery System Weight (30 and 180 day missions)
 - 4 man/7 day mission: 57 kg (125.7 lb)
 - 7 man/7 day mission: 59.74 kg (131.7 lb)
 - 7 man/30 day mission: 74.4 kg (164 lb)
 - 7 man/180 day mission: 176.3 kg (388.7 lb)
 - 7 man/30 day mission with wash water recovery capability: 138.94 kg (306.3 lb)
 - 7 man/180 day mission with wash water recovery capability: 147.5 kg (325.2 lb)

d. Fixed Volume

- 1) Dry Wipes Storage and Waste Storage Cabinet: see calculations for Disposable Wet and Dry Wipes with Solid Waste Compactor Concept.
- 2) Wipe Dispenser: see calculation for Disposable Wet and Dry Wipe Concept.
- 3) Fixture Volume: see calculation for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 4) Ambient Water Holding Tank: see calculation for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 5) Soap Tank: see calculation for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 6) Disinfectant Tank: see calculation for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 7) Compactor Volume: .04 m³ (2450 in³)
- 8) Wash Water Recovery System for 30 and 180 Day Mission:
.27 m³ (16,556 in³)
- 9) Total Fixed Volume: Volume Storage and Waste Storage for Dry Wipes + Volume Wipe Dispenser + Fixture Volume + Water, Soap, and Disinfectant Holding Tank Volume + Compactor Volume + Wash Water Recovery System Volume (30 and 180 day missions)
 - 4 man/7 day mission: .69 m³ (42,360 in³)
 - 7 man/7 day mission: .73 m³ (44,796.3 in³)
 - 7 man/30 day mission: 1.13 m³ (68,954.5 in³)
 - 7 man/180 day mission: 3.7 m³ (226,079.9 in³)
 - 7 man/30 day mission with wash water recovery capability: 1.03 m³ (63,030 in³)
 - 7 man/180 day mission with wash water recovery capability: 1.7 m³ (103,847.4 in³)

e. *Spares Weight*

- 7 man/30 day mission: one complete drive mechanism for solid waste compactor 2.27 kg (5 lb)
- 7 man/180 day mission: one complete drive mechanism for solid waste compactor 2.27 kg (5 lb)

one filter for cleansing fixture .9 kg (2 lb)
- 7 man/30 day mission with wash water recovery capability: one complete drive mechanism for solid waste compactor 2.27 kg (5 lb)
- 7 man/180 day mission with wash water recovery capability: one complete drive mechanism for solid waste compactor 2.27 kg (5 lb)

one filter for cleansing fixture .9 kg (2 lb)

one filter for water recovery unit .23 kg (.5 lb)

f. *Power Penalty* - See calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.

g. *Average Power* - See calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.

h. *Environmental Impact* - See calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.

i. *Total Weight*

Total Weight: Fixed Weight + Expendable Weight + Power Penalty + Environmental Impact Equivalent Weight + Spares Weight

- 4 man/7 day mission: 147 kg (324.14 lb)
- 7 man/7 day mission: 190.8 kg (420.74 lb)

- 7 man/30 day mission: 514.3 kg (1133.8 lb)
- 7 man/180 day mission: 2617.1 kg (5769.7 lb)
- 7 man/30 day mission with wash water recovery capability: 255.1 kg (562.4 lb)
- 7 man/180 day mission with wash water recovery capability: 359.7 kg (793 lb)

5. DISPOSABLE DRY WIPES AND CLEANSING AGENTS

a. *Expendable Weight*

1) Dry Wipes:

Expendable Weight = (weight one wipe)
(number handwashings per crewman)(number
crewman)(mission duration)(number wipes
per handwashing)

- 4 man/7 day mission: $(5.3g)(10)(4)(7)(2) = 3 \text{ kg } (6.6 \text{ lb})$
- 7 man/7 day mission: $(5.3g)(10)(7)(7)(2) = 5.2 \text{ kg } (11.6 \text{ lb})$
- 7 man/30 day mission: $(5.3g)(10)(7)(30)(2) = 22.3 \text{ kg } (49 \text{ lb})$
- 7 man/180 day mission: $(5.3g)(10)(7)(180)(2) = 233.8 \text{ kg } (296 \text{ lb})$

2) Cleansing Agent:

Weight one can fill with cleansing agent
and propellant = .23 kg (.5 lb)

Soap usage per handwash = 3 ml

Assume 5 handwashings per container

Number of containers per mission =
(number of handwashing per mission) -
(number handwashing per container)

Expendable weight = (number containers)
(weight one container)

- 4 man/7 day mission: $\frac{280}{55} \approx 6$ containers = 1.36 kg (3 lb)
- 7 man/7 day mission: $\frac{(490)}{55}$ 9 containers = 2.04 kg (4.5 lb)
- 7 man/30 day mission: $\frac{(2100)}{55} = 39$ containers = 8.9 kg (19.5 lb)
- 7 man/180 day mission: $\frac{(12,600)}{55} = 230$ containers = 52.2 kg (115 lb)
- 3) Total Expendable Weight: Weight Dry Wipes + Weight Cleansing Agent
- 4 man/7 day mission: 4.34 kg (9.6 lb)
- 7 man/7 day mission: 7.3 kg (16.1 lb)
- 7 man/30 day mission: 31.1 kg (68.5 lb)
- 7 man/180 day mission: 186.4 kg (411 lb)

b. Expendable Volume

1) Dry Wipes:

Expendable Volume (volume one wipe)
(number handwashings per crewman per day)
(number crewman) (mission duration) (number
of wipes per handwashing)

- 4 man/7 day mission: $(.75 \text{ in}^3)(10)(4)(7)(2) = .0068 \text{ m}^3 (420 \text{ in}^3)$
- 7 man/7 day mission: $(.75 \text{ in}^3)(10)(7)(7)(2) = .012 \text{ m}^3 (735 \text{ in}^3)$
- 7 man/30 day mission: $(.75 \text{ in}^3)(10)(7)(30)(2) = .052 \text{ m}^3 (3150 \text{ in}^3)$
- 7 man/180 day mission: $(.75 \text{ in}^3)(10)(7)(180)(2) = .31 \text{ m}^3 (18,900 \text{ in}^3)$

2) Cleansing Agent:

Container length = 6"

Container diameter = 3"

Volume Container = 42.4 in^3

Expendable Volume = (number of containers
per mission) (volume one container)

- 4 man/7 day mission: $(6)(42.4) = .004 \text{ m}^3 (254.4 \text{ in}^3)$
 - 7 man/7 day mission: $(9)(42.4) = .006 \text{ m}^3 (381.6 \text{ in}^3)$
 - 7 man/30 day mission: $(39)(42.4) = .027 \text{ m}^3 (1653.6 \text{ in}^3)$
 - 7 man/180 day mission: $(230)(42.4) = .16 \text{ m}^3 (9752 \text{ in}^3)$
- 3) Total Expendable Volume: Volume Dry Wipes + Volume Cleansing Agent
- 4 man/7 day mission: $.011 \text{ m}^3 (674.4 \text{ in}^3)$
 - 7 man/7 day mission: $.018 \text{ m}^3 (1116.6 \text{ in}^3)$
 - 7 man/30 day mission: $.079 \text{ m}^3 (4803.6 \text{ in}^3)$
 - 7 man/180 day mission: $.47 \text{ m}^3 (38652 \text{ in}^3)$

c. *Fixed Weight*

- 1) Dry Wipes: Using the data from the Disposable Wet and Dry Wipes Concept for the Storage and Waste Storage Fixed Weight for Dry Wipes, the fixed weight for this concept is twice (for two wipes per handwashing) that amount.

Storage Cabinet:

- 4 man/7 day mission: $1.3 \text{ lb} \times 2 = 1.18 \text{ kg} (2.6 \text{ lb})$
- 7 man/7 day mission: $1.8 \text{ lb} \times 2 = 1.63 \text{ kg} (3.6 \text{ lb})$
- 7 man/30 day mission: $4.9 \text{ lb} \times 2 = 4.45 \text{ kg} (9.8 \text{ lb})$
- 7 man/180 day mission: $16.5 \text{ lb} \times 2 = 15 \text{ kg} (33 \text{ lb})$

Waste Storage Cabinet:

- 4 man/7 day mission: $1.2 \text{ lb} \times 2 = 1.09 \text{ kg} (2.4 \text{ lb})$
- 7 man/7 day mission: $2.1 \text{ lb} \times 2 = 1.9 \text{ kg} (4.2 \text{ lb})$
- 7 man/30 day mission: $4.6 \text{ lb} \times 2 = 4.2 \text{ kg} (9.2 \text{ lb})$
- 7 man/180 day mission: $15.4 \text{ lb} \times 2 = 14 \text{ kg} (30.8 \text{ lb})$

- 2) Storage and Waste Storage Cleansing Agent Containers: Used containers will be replaced into a unit of equal size as the storage cabinet.

Density of Aluminum = $.1 \text{ lb/in}^3$

Wall Thickness of Aluminum to be used =
.02 in.

- 4 man/7 day mission:

size of storage = $6'' \times 9'' \times 6''$

area = 234 in^2

volume material = $(234)(.02) = 4.68 \text{ in}^3$

weight material = $(4.68)(.1) = .21 \text{ kg}$
(.47 lb)

weight storage and waste storage = (2)
(4.7) = .43 kg (.94 lb)

- 7 man/7 day mission:

size of storage = $6'' \times 9'' \times 9''$

area = 297 in^2

volume material = $(297)(.02) = 6 \text{ in}^3$

weight material = $(6)(.1) = .27 \text{ kg}$ (.6 lb)

weight storage and waste storage = (2)(.6)
= .54 kg (1.2 lb)

- 7 man/30 day mission:

size of storage = $6'' \times 9'' \times 39''$

area = 927 in^2

volume material = $(927)(.02) = 18.54 \text{ in}^3$

weight material = $(18.54)(.1) = .84 \text{ kg}$
(1.85 lb)

weight storage and waste storage = (2)(1.85)
= 1.68 kg (3.7 lb)

- 7 man/180 day mission:

size of storage = $6'' \times 9'' \times 230''$

area = 4938 in^2

volume material = $(4938)(.02) = 98.76 \text{ in}^3$

weight material = $(98.76)(.1) = 4.5 \text{ kg}$
(9.9 lb)

weight storage and waste storage = (2)(9.9)
= 9 kg (19.8 lb)

3) Total Fixed Weight:

Weight of Storage and Waste Storage for
Dry Wipes + Weight of Storage and Waste
Storage for Cleansing Agent Containers

- 4 man/7 day mission: 2.7 kg (5.94 lb)
- 7 man/7 day mission: 4.08 kg (9 lb)
- 7 man/30 day mission: 10.3 kg (22.7 lb)
- 7 man/180 day mission: 37.9 kg (83.6 lb)

d. Fixed Volume

1) Dry Wipes

Storage Cabinet

- 4 man/7 day mission: $(770 \text{ in}^3)(2) = .025 \text{ m}^3 (1540 \text{ in}^3)$
- 7 man/7 day mission: $(1408 \text{ in}^3)(2) = .046 \text{ m}^3 (2816 \text{ in}^3)$
- 7 man/30 day mission: $(5984 \text{ in}^3)(2) = .196 \text{ m}^3 (11,968 \text{ in}^3)$
- 7 man/180 day mission: $(35,200 \text{ in}^3)(2) = 1.15 \text{ m}^3 (70,400 \text{ in}^3)$

Waste Storage Cabinet

- 4 man/7 day mission: $(750 \text{ in}^3)(2) = .025 \text{ m}^3 (1500 \text{ in}^3)$
- 7 man/7 day mission: $(1350 \text{ in}^3)(2) = .044 \text{ m}^3 (2700 \text{ in}^3)$
- 7 man/30 day mission: $(5808 \text{ in}^3)(2) = .19 \text{ m}^3 (11,616 \text{ in}^3)$
- 7 man/180 day mission: $(35,200 \text{ in}^3)(2) = 1.15 \text{ m}^3 (70,400 \text{ in}^3)$

2) Storage and Waste Storage for Cleansing Agent Containers

- 4 man/7 day mission: $(324 \text{ in}^3)(2) = .011 \text{ m}^3 (648 \text{ in}^3)$
- 7 man/7 day mission: $(486 \text{ in}^3)(2) = .016 \text{ m}^3 (972 \text{ in}^3)$
- 7 man/30 day mission: $(2106 \text{ in}^3)(2) = .07 \text{ m}^3 (4212 \text{ in}^3)$
- 7 man/180 day mission: $(12,420 \text{ in}^3)(2) = .41 \text{ m}^3 (24,840 \text{ in}^3)$

3) Total Fixed Volume:

Storage and Waste Storage Cabinet Volume
for Dry Wipes + Storage and Waste Storage
Cabinet Volume for Cleansing Agent Con-
tainers

- 4 man/7 day mission: .06 m³ (3688 in³)
- 7 man/7 day mission: .11 m³ (6488 in³)
- 7 man/30 day mission: .46 m³ (27,798 in³)
- 7 man/180 day mission: 2.72 m³ (165,640 in³)

e. *Environmental Impact*

- 1) Maximum Latent Heat Load Per Day: Approximately 3g (.0066 lb) of moisture will be vaporized per handwash.

Latent Heat Load = (water loss)(heat of
vaporization) = (.0066)(1000) = 6.6 Btu/
wash

Latent Heat Load per Day = (latent heat
load per washing)(number crewman)(number
handwashings per crewman per day)

- 4 men: (6.6)(4)(10) = 278.7 x 10³ joules/day
(264 Btu/day)
- 7 men: (6.6)(7)(10) = 487.7 x 10³ joules/day
(462 Btu/day)

Based on the equivalent weight ratio .128 lb/Btu/hr, the equivalent weights equal .64 kg (1.41 lb) for 4-man crew size and 1.13 kg (2.5 lb) for 7-man crew size.

f. *Total Weight*

Total Weight:

Fixed Weight + Expendable Weight +
Environmental Impact Equivalent Weight

- 4 man/7 day mission: 7.7 kg (16.95 lb)
- 7 man/7 day mission: 12.52 kg (27.6 lb)
- 7 man/30 day mission: 42.5 kg (93.7 lb)
- 7 man/180 day mission: 225.5 kg (497.1 lb)

6. ORBITER PERSONAL HYGIENE STATION

a. Expendable Weight

- 1) Dry Wipes: see calculations for Disposable Wet and Dry Wipes Concept.
- 2) Water: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 3) Soap: this concept uses bar soap.

Weight of one soap bar: 133.4g (.25 lb)

Assume soap usage rate of 2g per hand-wash.

Soap weight = (soap usage per handwash)
(number crewman)(mission duration)(number
handwashings per crewman per day)

- 4 man/7 day mission:

$$(2g)(14)(7)(10) = 560 \text{ g (1.23 lb)}$$

This equals approximately 5 bars of soap

$$\left(\frac{1.23}{.25}\right); \text{ therefore, total soap weight}$$

equals 570 g (1.25 lb)

- 7 man/7 day mission:

$$(2g)(7)(7)(10) = 980 \text{ g (2.16 lb)}$$

This equals approximately 9 bars of soap;
therefore, total soap weight equals
1.02 kg (2.25 lb)

- 7 man/30 day mission:

$$(2g)(7)(30)(10) = 4.2 \text{ kg (9 lb)}$$

This equals 36 bars of soap.

- 7 man/180 day mission:

$$(2g)(7)(180)(10) = 25.2 \text{ kg (55.5 lb)}$$

This equals 222 bars of soap.

- 4) Disinfectant: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.

5) <u>Total Expendable Weight:</u>	Weight Dry Wipes + Weight Water + Weight Soap + Weight Disinfectant
• 4 man/7 day mission:	53.2 kg (117.3 lb)
• 7 man/7 day mission:	92.9 kg (204.8 lb)
• 7 man/30 day mission:	397.9 kg (877.25 lb)
• 7 man/180 day mission:	2390.4 kg (5269.8 lb)
• 7 man/30 day mission with wash water recovery capability:	29.7 kg (65.5 lb)
• 7 man/180 day mission with wash water recovery capability:	117 kg (257.95 lb)

53.2 kg (117.3 lb)

92.9 kg (204.8 lb)

397.9 kg (877.25 lb)

2390.4 kg (5269.8 lb)

29.7 kg (65.5 lb)

117 kg (257.95 lb)

1) Dry Wipes: see calculations for Disposable Wet and Dry Wipes Concept.

3) Soap:

Dimensions of soap bar = 2" x 3" x .5"

Volume of soap bar = 3 in^3

e 4 man/7 day mission: $(5 \text{ bars of soap})(3 \text{ in}^3) = .00025 \text{ m}^3$
(15 in³)

• 7 man/7 day mission: $(9 \text{ bars of soap})(3 \text{ in}^3) = .00044 \text{ m}^3$
(27 in³)

• 7 man/30 day mission: $(36 \text{ bars of soap})(3 \text{ in}^3) = .0018 \frac{\text{m}^3}{(108 \text{ in}^3)}$

- 7 man/180 day mission: $(222 \text{ bars of soap})(3 \text{ in}^3) = .011 \text{ m}_3$
(66 in³)

4) Disinfectant: see calculation for Spacelab Utensil/Hand Cleansing Fixture Concept.

5) Total Expendable Volume: Volume Dry Wipes + Volume Water + Volume Soap + Volume Disinfectant

$$\text{Volume Dry Wipes} + \text{Volume Water} + \text{Volume Soap} + \text{Volume Disinfectant}$$

- 4 man/7 day mission: .055 m³ (3346.8 in³)
- 7 man/7 day mission: .096 m³ (5843.3 in³)
- 7 man/30 day mission: .41 m³ (25,048.9 in³)
- 7 man/180 day mission: 2.47 m³ (150,412 in³)
- 7 man/30 day mission with wash water recovery capability: .042 m³ (2567.9 in³)
- 7 man/180 day mission with wash water recovery capability: .19 m³ (11,624 in³)

• 7 man/7 day mission: Soap Cabinet Dimensions = 2" x 3" x 4.5"
 Surface area = 43.5 in^2
 Volume material = $(43.5)(.03) = 1.31 \text{ in}^3$
 Weight material = $(1.31)(.1) = .06 \text{ kg}$
 (.13 lb)

• 7 man/30 day mission: Soap Cabinet Dimensions = 2" x 6" x 9"
 Surface area = 114 in^2
 Volume material = $(114)(.03) = 3.42 \text{ in}^3$
 Weight material = $(3.42)(.1) = .15 \text{ kg}$
 (.34 lb)

• 7 man/180 day mission: Soap Cabinet Dimensions = 4" x 12" x 14"
 Surface area = 376 in^2
 Volume material = $(376)(.03) = 11.3 \text{ in}^3$
 Weight material = $(11.3)(.1) = .51 \text{ kg}$
 (1.13 lb)

6) Disinfectant Tank: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.

7) Wash Water Recovery System for 30 and 180 Day Missions:

81.2 kg (179 lb)

8 Total Fixed Weight: Weight Storage and Waste Storage for Dry Wipes + Weight Wipe Dispenser + Fixture Weight + Water and Disinfectant Holding Tank Weight + Soap Storage Weight + Wash Water Recovery System Weight (30 and 180 Day Missions)

• 4 man/7 day mission: 26.5 kg (58.5 lb)

• 7 man/7 day mission: 29.6 kg (65.2 lb)

• 7 man/30 day mission: 44.5 kg (98 lb)

- 7 man/180 day mission: 149.3 kg (329.1 lb)
- 7 man/30 day mission with wash water recovery capability: 110 kg (242.5 lb)
- 7 man/180 day mission with wash water recovery capability: 121.1 kg (266.9 lb)

d. *Fixed Volume*

- 1) Dry Wipes Storage and Waste Storage Cabinet: see calculations for Disposable Wet and Dry Wipes.
- 2) Wipe Dispenser: see calculation for Disposable Wet and Dry Wipes Concept.
- 3) Fixture Volume: .55 m³ (33,394 in³)
- 4) Ambient Water Holding Tank: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 5) Soap Storage Cabinet
 - 4 man/7 day mission: .00025 m³ (15 in³)
 - 7 man/7 day mission: .00044 m³ (27 in³)
 - 7 man/30 day mission: .0018 m³ (108 in³)
 - 7 man/180 day mission: .011 m³ (666 in³)
- 6) Disinfectant Tank: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.
- 7) Wash Water Recovery System: .27 m³ (16,556 in³)
- 8) Total Fixed Weight: Volume Storage and Waste Storage for Dry Wipes + Volume Wipe Dispenser + Fixture Volume + Water and Disinfectant Holding Tank Volume + Soap Cabinet Volume + Wash Water Recovery System (30 and 180 day missions)

- 4 man/7 day mission: .65 m³ (39,641 in³)
- 7 man/7 day mission: .71 m³ (43,217 in³)
- 7 man/30 day mission: 1.15 m³ (70,249 in³)
- 7 man/180 day mission: 4.04 m³ (246,352 in³)
- 7 man/30 day mission with wash water recovery capability: 1.05 m³ (64,324.4 in³)
- 7 man/180 day mission with wash water recovery capability: 2.03 m³ (124,119.4 in³)

- e. *Spares Weight* - See calculations for Spacelab Utensil/Hand Cleansing Fixture.
- f. *Power Penalty* - See calculations for Spacelab Utensil/Hand Cleansing Fixture.
- g. *Average Power* - See calculations for Spacelab Utensil/Hand Cleansing Fixture.
- h. *Environmental Impact* - See calculations for Spacelab Utensil/Hand Cleansing Fixture.
- i. *Total Weight*

- 4 man/7 day mission: 116.6 kg (256.96 lb)
- 7 man/7 day mission: 160.7 kg (354.3 lb)
- 7 man/30 day mission: 480.6 kg (1059.5 lb)
- 7 man/180 day mission: 2578.8 kg (5685.2 lb)
- 7 man/30 day mission with wash water recovery capability: 222.5 kg (490.4 lb)
- 7 man/180 day mission with wash water recovery capability: 322 kg (709.8 lb)

7. ORBITER PERSONAL HYGIENE STATION WITH SOLID WASTE COMPACTOR

- a. *Expendable Weight* - See calculations for Orbiter Personal Hygiene Station but add 3 lb for the 7 day/30 day missions and 20 lbs for the 7 day/180 day missions for the solid waste compactor bags.
- b. *Expendable Volume* - See calculations for Orbiter Personal Hygiene Station but add 748 in³ for each solid waste compactor bag for the 30 and 180 day missions.
- c. *Fixed Weight* - See calculations for Orbiter Personal Hygiene Station except substitute data from disposable wet and dry wipes with solid waste compactor concept for dry wipe storage and waste storage weight and add compactor weight.
- d. *Fixed Volume* - See calculations for Orbiter Personal Hygiene Station Concept except substitute data from disposable wet and dry wipes with solid waste compactor concept for dry wipe storage and waste storage volume and add compactor volume.
- e. *Spares Weight* - See calculations for Spacelab Utensil/Hand Cleansing Fixture with solid waste compactor concept.
- f. *Power Penalty* - See calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.
- g. *Average Power* - See calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.
- h. *Environmental Impact* - See calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.
- i. *Total Weight*
 - 4 man/7 day mission: 147 kg (324.2 lb)
 - 7 man/7 day mission: 190.9 kg (420.9 lb)
 - 7 man/30 day mission: 514.1 kg (1133.4 lb)
 - 7 man/180 day mission: 2616.3 kg (5767.9 lb)
 - 7 man/30 day mission with wash water recovery capability: 255.5 kg (563.3 lb)

- 7 man/180 day mission with wash water recovery capability: 359.5 kg (792.5 lb)

8. DISPOSABLE LABORATORY TOOLS/UTENSILS

a. Expendable Weight

- 1) Laboratory Utensils/Tools: Assume 12 experiments per mission
- Number of tools are based on experiment need
- 2.5 ml syringe 5.71 g ea, two per experiment per day
 - 10 ml syringe 19.2 g ea, two per experiment per day
 - Hypodermic needles 1.92 g ea, four per experiment per day
 - 10 ml pipettes .53 g ea, two per experiment per day
 - 25 ml pipettes .5 g ea, two per experiment per day
 - forceps 25.98 g ea, one per experiment per day
 - spatula 4.5 g ea, one per experiment per day
 - centrifuge tubes 20 g ea, two per experiment per day
 - small sticks .36 g ea, five per experiment per day
 - scalpel 10 g ea, one per experiment per day
 - hemostat 4.5 g ea, two per experiment per day

Based on 7, 30, and 180 day missions, the expendable weights =

- 7 day mission: 12.6 kg (27.72 lb)
- 30 day mission: 53.9 kg (118.8 lb)
- 180 day mission: 323.3 kg (712.8 lb)

2) Dry Wipes: see calculations for Disposable Wet and Dry Wipes Concept.

3) Disposable Gloves: One glove weighs 1.5 g

Assume that each crewman will need 5 pairs/
day

Gloves are packaged in 1000 glove rolls
with dimensions = 6" x 2" x 2"

Number of gloves per mission = (crew size)
(mission duration)(10 gloves per day)

- 4 man/7 day mission: $(4)(7)(10) = 280$ gloves
- 7 man/7 day mission: $(7)(7)(10) = 490$ gloves
- 7 man/30 day mission: $(7)(30)(10) = 2100$ gloves
- 7 man/180 day mission: $(7)(180)(10) = 12,600$ gloves

Therefore, the number containers of
gloves =

- 4 man/7 day mission: 1 box
- 7 man/7 day mission: 1 box
- 7 man/30 day mission: 3 boxes
- 7 man/180 day mission: 13 boxes

Multiply the number of boxes by the weight
of each box =

- 4 man/7 day mission: 1.5 kg (3.3 lb)
- 7 man/7 day mission: 1.5 kg (3.3 lb)
- 7 man/30 day mission: 4.5 kg (9.9 lb)
- 7 man/180 day mission: 19.5 kg (42.9 lb)

4) Total Expendable Weight

- 4 man/7 day mission: 15.6 kg (34.3 lb)
- 7 man/7 day mission: 16.7 kg (36.8 lb)

- 7 man/30 day mission: 69.5 kg (153.2 lb)
- 7 man/180 day mission: 409.9 kg (903.7 lb)

b. *Expendable Volume*

1) Laboratory Utensil/Tools: Dimensions of Utensil/Tools =

- 2.5 ml syringe 2" long, .25" diameter
- 10 ml syringe 2" long, .25" diameter
- hypodermic needles 1" long, .0625" diameter
- 10 ml pipettes 7" long, .25" diameter
- 25 ml pipettes 10" long, .25" diameter
- forceps 3" long, 1.5" wide
- spatula 6" long, .125" diameter
- centrifuge tubes 3" long, 1" diameter
- small sticks 4" long, .125" diameter
- scapel 6" long, .5" wide
- hemostat 3" long, 1.5" wide

Based on the number needed per experiment as indicated in the Expendable Weight calculations and the mission duration, the expendable volume =

- 7 day mission: .042 m³ (2554.6 in³)
- 30 day mission: .18 m³ (10,948 in³)
- 180 day mission: 1.08 m³ (65,689 in³)

2) Dry Wipes: see calculations for Disposable Wet and Dry Wipe Concept

3) Disposable Gloves: Dimension for each box = 6" x 2" x 2",
Volume = 24 in³

Based upon the number of boxes, the expendable volume =

- 4 man/7 day mission: .0004 m³ (24 in³)
- 7 man/7 day mission: .0004 m³ (24 in³)
- 7 man/30 day mission: .001 m³ (72 in³)
- 7 man/180 day mission: .005 m³ (312 in³)

4) Total Expendable Volume

- 4 man/7 day mission: .046 m³ (2788.6 in³)
- 7 man/7 day mission: .048 m³ (2946.1 in³)
- 7 man/30 day mission: .206 m³ (12,595 in³)
- 7 man/180 day mission: 1.24 m³ (75,451 in³)

c. *Fixed Weight*

1) Laboratory Utensils/Tools Storage and Waste Storage

Each set utensil/tool is individually housed in its own cabinet.

Assume aluminum thickness of .03 in. for cabinet, .02 in. for dividers.

Density aluminum = .1 lb/in³.

a) 2.5 ml syringe:

- 7 day mission:

Waste storage area size = 3.25" x 3.25" x 2"

Surface area = 36.5 in²

Volume material = (36.5)(.03) = 1.09 in³

Weight material = (1.09)(.1) = .05 kg
(.11 lb)

Storage area size = 3.25" x 3.25" x 2"

Weight material = weight waste storage cabinet + weight cabinet dividers

Total surface area of dividers =
(2)(3.25)(number of dividers) =
(3.25)(2)(12) = 78 in²

Volume divider material = (78)(.02) =
1.56 in²

Weight divider material = (1.56)(.1) =
.07 kg (.16 lb)

Total weight = .17 kg (.38 lb)

- 30 day mission: assume that the weight of both cabinets is proportional to the number of utensils/tools. There is approximately 4.3 more utensils/tools for the 30 day mission than the 7 day mission, so the total weight for the storage and waste storage is approximately 4.3 the total weight of the 7 day mission or .74 kg (1.63 lb).

- 180 day mission: (6)(1.63) = 4.44 kg (9.78 lb)

b) 10 ml syringe: see calculations for 2.5 ml syringe.

c) Hypodermic Needles:

- 7 day mission: Waste storage area size = 1" x 1" x 3.25"
Two cabinets for each type of needle
Surface area = 11.75 in²
Volume material = (11.75)(.03) = .35 in³
Weight material = (.35)(.1) = .016 kg
(.035 lb) x 2 = .032 kg
(.07 lb)

Storage area size = 1" x 1" x 3.25"

Two cabinets for each type of needle

Weight material = weight waste storage
cabinet + weight cabinet dividers

Total surface area of dividers = (1)(1)
(12) = 12 in²

Volume divider material = $(12)(.02) = .24 \text{ in}^3$

Weight divider material = $(.24)(.1) = .01 \text{ kg } (.024 \text{ lb}) \times 2 = .02 \text{ kg } (.048 \text{ lb})$

Total weight = $.085 \text{ kg } (.188 \text{ lb})$

• 30 day mission: $(4.3)(.188) = .37 \text{ kg } (.81 \text{ lb})$

• 180 day mission: $(6)(.81) = 2.2 \text{ kg } (4.86 \text{ lb})$

d) 10 ml Pipettes:

• 7 day mission: Waste storage area size = $3.25'' \times 3.25'' \times 7''$

Surface area = 101.5 in^2

Volume material = $(101.5)(.03) = 3.045 \text{ in}^3$

Weight material = $(3.045)(.1) = .14 \text{ kg } (.31 \text{ lb})$

Storage area size = $3.25'' \times 3.25'' \times 7''$

Weight material = weight waste storage cabinet + weight cabinet dividers

Total surface area of dividers = $(7)(3.25)(12) = 273 \text{ in}^2$

Volume divider material = $(273)(.02) = 5.5 \text{ in}^3$

Weight divider material = $(5.5)(.1) = .25 \text{ kg } (.55 \text{ lb})$

Total weight = $.53 \text{ kg } (1.17 \text{ lb})$

• 30 day mission: $(4.3)(1.17) = 2.28 \text{ kg } (5.03 \text{ lb})$

• 180 day mission: $(6)(5.03) = 13.7 \text{ kg } (30.18 \text{ lb})$

e) 25 ml Pipettes:

• 7 day mission:

Waste storage area size = $3.25'' \times 3.25'' \times 10''$

Surface area = 140.5 in^2

Volume material = $(140.5)(.03) = 4.22 \text{ in}^3$

Weight material = $(4.22)(.1) = .19 \text{ kg}$
(.42 lb)

Storage area size = $3.25'' \times 3.25'' \times 10''$

Weight material = weight waste storage
cabinet + weight cabinet dividers

Total surface area of dividers = $(3.25)(10)(12) = 390 \text{ in}^2$

Volume divider material = $(390)(.02) = 7.8 \text{ in}^3$

Weight divider material = $(7.8)(.1) = .35 \text{ kg}$ (.78 lb)

Total weight = .73 kg (1.62 lb)

• 30 day mission:

$(4.3)(1.62 \text{ lb}) = 3.16 \text{ kg}$ (7 lb)

• 180 day mission:

$(6)(7) = 19.1 \text{ kg}$ (42 lb)

f) Forceps:

• 7 day mission:

Waste storage and storage area size =
 $3'' \times 13.5'' \times 13.5''$

Using similar calculations as presented
previously, the total weight = 1.37 kg
(3.03 lb)

• 30 day mission:

$(4.3)(3.03) = 5.91 \text{ kg}$ (13.03 lb)

• 180 day mission:

$(6)(13.03) = 35.5 \text{ kg}$ (78.2 lb)

g) Spatula:

- 7 day mission: Waste storage and storage area size =
1.125" x 1.125" x 6"

Using similar calculations as presented previously, the total weight = .15 kg (.33 lb)

- 30 day mission: $(4.3)(.33) = .64 \text{ kg } (1.42 \text{ lb})$
- 180 day mission: $(6)(1.42) = 3.9 \text{ kg } (8.52 \text{ lb})$

h) Centrifuge Tubes:

- 7 day mission: Waste storage and storage area size =
3" x 13" x 13"

Using similar calculations as presented previously, the total weight = 1.31 kg (2.9 lb)

- 30 day mission: $(4.3)(2.9) = 5.66 \text{ kg } (12.5 \text{ lb})$
- 180 day mission: $(6)(12.5) = 34 \text{ kg } (75)$

i) Small Sticks:

- 7 day mission: Waste storage and storage area size =
2.875" x 2.875" x 4"

Total weight = .27 kg (.61 lb)

- 30 day mission: $(4.3)(.61) = 1.19 \text{ kg } (2.6 \text{ lb})$
- 180 day mission: $(6)(2.6) = 7.1 \text{ kg } (15.6 \text{ lb})$

j) Scalpel:

- 7 day mission: Waste storage and storage area size =
1.125" x 13.5" x 6"

Total weight = .6 kg (1.3 lb)

- 30 day mission: $(4.3)(1.3) = 2.53 \text{ kg } (5.6 \text{ lb})$
- 180 day mission: $(6)(5.6) = 15.2 \text{ kg } (33.6 \text{ lb})$

k) Hemostat:

- 7 day mission: Waste storage and storage area size =
19.5" x 19.5" x 3"

Total weight = 2.3 kg (5.1 lb)

- 30 day mission: (4.3)(5.1) = 9.95 kg (21.9 lb)

- 180 day mission: (6)(21.9) = 59.6 kg (131.4 lb)

j) Total Fixed Weight: Total weight waste storage and storage cabinet plus 15%

- 7 day mission: 8.8 kg (19.5 lb)

- 30 day mission: 38.1 kg (83.9 lb)

- 180 day mission: 228.4 kg (503.6 lb)

2) Dry Wipes: see calculations for Disposable Wet and Dry Wipes Concept

3) Wipe Dispenser: see calculations for Disposable Wet and Dry Wipes Concept

4) Disposable Gloves

- 4 man/7 day mission:

Storage size for one box = 6" x 2" x 2"

Area = 44 in²

Assume aluminum thickness = .03 in.

Volume material = (44)(.03) = 1.32 in³

Weight material = (1.32)(.1) = .06 kg
(.132 lb)

Waste Storage

Volume of one used glove = 3.6 in²

Total volume = (volume one glove)(number gloves used per mission) = (3.6)(280) = 1008 in³

Assume that the waste storage cabinet is cubic with sides equal to approximately 10"

$$\text{Surface area} = 500 \text{ in}^2$$

$$\text{Volume material} = (500)(.03) = 15 \text{ in}^3$$

$$\text{Weight material} = (15)(.1) = .68 \text{ kg (1.5 lb)}$$

• 7 man/7 day mission:

Storage area weight equals that for the 7 day mission

Waste storage - using calculations as in the 7 day mission, volume wipes = $(3.6)(490) = 1764 \text{ in}^3$

$$\text{Length of side} = 12.05 \text{ in.}$$

$$\text{Surface area} = 726 \text{ in}^2$$

$$\text{Volume material} = 21.8 \text{ in}^3$$

$$\text{Weight material} = .99 \text{ kg (2.18 lb)}$$

• 7 man/30 day mission:

Storage area - assume that the weight of the container is proportional to the number of boxes of wipes weight material = $(3 \text{ boxes})(.132 \text{ lb}) = .18 \text{ kg (.4 lb)}$

Waste storage

$$\text{Volume} = (2100)(3.6) = 7560 \text{ in}^3$$

$$\text{Length of side} = 19.6 \text{ in.}$$

$$\text{Surface area} = 1920.8 \text{ in}^2$$

$$\text{Volume material} = 56.6 \text{ in}^3$$

$$\text{Weight material} = 2.6 \text{ kg (5.76 lb)}$$

• 7 man/180 day mission:

$$\text{Storage area} = (13 \text{ boxes})(.132 \text{ lb}) = .78 \text{ kg (1.72 lb)}$$

Waste storage

$$\text{Volume} = (12,600)(3.6) = 45,360 \text{ in}^3$$

Length side = 35.5 in.

Surface area = 6301 in²

Volume material = 189 in³

Weight material = 8.6 kg (18.9 lb)

- 5) Glove Dispenser: For missions with multiple boxes of gloves (30 and 180 day mission) add .45 kg (1 lb) for a dispenser.

6) Total Fixed Weight

- 4 man/7 day mission: 11.2 kg (24.6 lb)
- 7 man/7 day mission: 12.1 kg (26.7 lb)
- 7 man/30 day mission: 46.1 kg (101.6 lb)
- 7 man/180 day mission: 253.2 kg (558.12 lb)

d. *Fixed Volume*

- 1) Laboratory Utensils/Tools Storage and Waste Storage: see size of cabinets for each set of tools. From that the total volume equals

- 7 day mission: .084 m³ (5109 in³)
- 30 day mission: .36 m³ (21,896 in³)
- 180 day mission: 2.15 m³ (131,377 in³)

- 2) Dry Wipes: see calculations for Disposable Wet and Dry Wipes Concept

- 3) Wipe Dispenser: see calculations for Disposable Wet and Dry Wipes Concept

- 4) Disposable Gloves: see storage size and waste storage volume used during fixed weight calculations.

- 4 man/7 day mission: .017 m³ (1032 in³)
- 7 man/7 day mission: .03 m³ (1788 in³)
- 7 man/30 day mission: .125 m³ (7632 in³)
- 7 man/180 day mission: .75 m³ (45,672 in³)

5) Glove Dispenser: 24 in^3

6) Total Fixed Volume:

- 4 man/7 day mission: $.15 \text{ m}^3$ (9413 in^3)
- 7 man/7 day mission: $.19 \text{ m}^3$ ($11,407 \text{ in}^3$)
- 7 man/30 day mission: $.71 \text{ m}^3$ ($43,072 \text{ in}^3$)
- 7 man/180 day mission: 4.08 m^3 ($249,201 \text{ in}^3$)

e. *Environmental Impact*

1) Maximum Latent Heat Load Per Day:

a) Dry Wipes - Assume that the amount of moisture left on the wipes is equal to .006 lb/wash

- 4 man mission: Latent Heat Load = $(.006)(1000)(4 \text{ crewmen})(10 \text{ handwashings per crewman per day}) = 240 \text{ Btu}$
- 7 man mission: Latent Heat Load = $(.006)(1000)(7)(10) = 420 \text{ Btu}$

b) Disposable Gloves - Assume that .004 lb of moisture is left on the gloves to vaporize to the cabin atmosphere.

- 4 man mission: Latent Heat Load = $(.004)(1000)(4)(10) = 160 \text{ Btu}$
- 7 man mission: Latent Heat Load = $(.004)(1000)(7)(10) = 280 \text{ Btu}$

c) Laboratory Utensils/Tools - Assume that .003 lb per tool of moisture is left on the tool to vaporize.

$$\begin{aligned} \text{Latent Heat Load} &= (\text{number of tools per experiment})(\text{number of experiments})(\text{water loss})(\text{heat of vaporization}) \\ &= (24)(12)(.003)(1000) = 864 \text{ Btu} \end{aligned}$$

d) Total Latent Heat Load

- 4 man mission: $1334.3 \times 10^3 \text{ joules/day}$ (1264 Btu/day)
- 7 man mission: $1651 \times 10^3 \text{ joules/day}$ (1564 Btu/day)

e) Based upon the equivalent weight ratio .128 lb/At₁/hr, the equivalent weights equal:

- 4 man mission: 3.04 kg (6.7 lb)
- 7 man mission: 3.8 kg (8.3 lb)

f) Total Weight

- 4 man/7 day mission: 29.8 kg (65.6 lb)
- 7 man/7 day mission: 32.6 kg (71.8 lb)
- 7 man/30 day mission: 119.3 kg (263.1 lb)
- 7 man/180 day mission: 666.8 kg (1470.1 lb)

9. DISPOSABLE LABORATORY TOOLS/UTENSILS AND SOLID WASTE COMPACTOR

a. *Expendable Weight* - See calculations for Disposable Laboratory Tools/Utensils Concept except add 3 lb and 20 lb to the 30 and 180 day missions, respectively for the solid waste compactor bags.

b. *Expendable Volume* - See calculations for Disposable Laboratory Tools/Utensils Concept except add 748 in.³ for each bag (3 and 20) to the 30 and 180 day missions for the solid waste compactor bags.

c. *Fixed Weight*

- 1) Laboratory Utensils/Tools: There is no compaction of these rigid materials, so the waste storage cabinet weight will remain the same as calculated previously for the Disposable Laboratory Utensil/Tools Concept. Storage cabinet weight will also remain the same.
- 2) Dry Wipes Storage and Waste Storage: see calculations for Disposable Wet and Dry Wipes and Solid Waste Compactor Concept.
- 3) Wipe Dispenser: see calculations for Disposable Laboratory Utensil/Tool Concept.
- 4) Disposable Gloves Storage and Waste Storage: Storage cabinet weight will remain the same as in the Disposable Laboratory Utensil/Tool Concept. The compactor will reduce to volume of the gloves to 30%, therefore assuming that there is a proportional relationship between container volume and weight, the waste storage weight equals:

- 4 man/7 day mission: .22 kg (.5 lb)
 - 7 man/7 day mission: .33 kg (.73 lb)
 - 7 man/30 day mission: .87 kg (1.92 lb)
 - 7 man/180 day mission: 2.86 kg (6.3 lb)
- 5) Glove Dispenser: see calculation for Disposable Laboratory Utensil/Tool Concept.
 - 6) Total Fixed Weight:
 - 4 man/7 day mission: 41.7 kg (91.8 lb)
 - 7 man/7 day mission: 42.1 kg (92.8 lb)
 - 7 man/30 day mission: 73.8 kg (162.7 lb)
 - 7 man/180 day mission: 273.6 kg (603.3 lb)

d. *Fixed Volume*

- 1) Laboratory Utensils/Tools: see calculations for Disposable Laboratory Utensil/Tools Concept.
- 2) Dry Wipes Storage and Waste Storage: see calculations for Disposable Wet and Dry Wipes and Solid Waste Compactor Concept.
- 3) Wipe Dispenser: see calculations for Disposable Laboratory Utensil/Tools Concept.
- 4) Disposable Gloves: see calculations for Disposable Laboratory Utensil/Tools Concept except divide Waste Storage Volume by one-third.
- 5) Glove Dispenser: see calculations for Disposable Laboratory Utensil/Tools Concept.
- 6) Total Fixed Volume:
 - 4 man/7 day mission: .175 m³ (10,691 in³)
 - 7 man/7 day mission: .193 m³ (11,781 in³)
 - 7 man/30 day mission: .6 m³ (36,610 in³)
 - 7 man/180 day mission: 3.24 m³ (197,944 in³)

- e. *Spares Weight* - See calculations for Disposable Wet and Dry Wipes and Solid Waste Compactor Concept.
- f. *Environmental Impact* - See calculations for Disposable Laboratory Utensil/Tool Concept.
- g. *Total Weight*

• 4 man/7 day mission:	60.2 kg (132.8 lb)
• 7 man/7 day mission:	62.6 kg (137.9 lb)
• 7 man/30 day mission:	150.7 kg (332.2 lb)
• 7 man/180 day mission:	698.7 kg (1540.3 lb)

10. HOT WATER SPRAY WASHING - CENTRIFUGE DRYING SYSTEM WITH DISPOSABLE GLOVES AND DRY WIPES

a. *Expendable Weight*

- 1) Dry Wipes (for hands): see calculations for Disposable Wet and Dry Wipes Concept.
- 2) Disposable Gloves: see calculations for Disposable Laboratory Utensils/Tools Concept.
- 3) Water: Assume 30 lb of water used per wash (reference m in Appendix B).
Assume one wash per day.
 - 7 day mission: (30 lb)(7 days) = 95.3 kg (210 lb)
 - 30 day mission: (30)(30) = 408.2 kg (900 lb)
 - 180 day mission: (30)(180) = 2449.4 kg (5400 lb)
 - Wash water recovery capability missions: 14.5 kg (32 lb)

b. *Expendable Volume*

- 1) Dry Wipes: see calculations for Disposable Wet and Dry Wipes Concept.

- 2) Disposable Gloves: see calculations for Disposable Laboratory Utensils/Tools Concept.

3) Water:

The density of water = 62.4 lb/ft^3

- a) 7 day mission: $.095 \text{ m}^3$ (5815.4 in^3)
- 30 day mission: $.41 \text{ m}^3$ ($24,923.1 \text{ in}^3$)
- 180 day mission: 2.45 m^3 ($149,538.5 \text{ in}^3$)
- Wash water recovery capability missions: $.0145 \text{ m}^3$ (886.15 in^3)

c. *Fixed Weight*

- 1) Dry Wipes: see calculations for Disposable Wet and Dry Wipes Concept.
- 2) Disposable Gloves: see calculations for Disposable Laboratory Utensils/Tools Concept.
- 3) Wipe and Glove Dispensers: see calculations for Disposable Laboratory Utensils/Tools Concept.
- 4) Washer/Dryer:

Filter:	2 lb
Pump:	4 lb
Two Accumulators:	11 lb
Valves:	6 lb
Water Separator:	3 lb
Structure:	40 lb
Miscellaneous:	32 lb
	98 lb

5) Hot Water Holding Tank

Holds 40 lb of water

Assume tank: diameter = 9 in.

Using calculations similar to those used for Spacelab Utensil/Hand Cleansing Fixture ambient water holding tank, the weight of the hot water holding tank = 1.86 lb

Water heater element weight = .88 lb

Thermostat = 5 lb

For missions with wash water recovery capability, assume the tank will hold all of the 32 lb of water

Weight tank = 1.57 lb

- 6) Ambient Water Holding Tank: Calculations are similar to those for the ambient water holding tank for the Spacelab Utensil/Hand Cleansing Fixture.

- 7 day mission: Tank must hold 170 lb of water
Assume tank diameter of 15 in.
Weight = 6.1 lb
- 30 day mission: Tank must hold 860 lb of water
Assume tank diameter of 24 in.
Weight = 39 lb
- 180 day mission: Tank must hold 5360 lb of water
Assume tank diameter of 48 in.
Weight = 255.8 lb

- 7) Wash Water Recovery System: 81.2 kg (179 lb)

d. *Fixed Volume*

- 1) Dry Wipes: see calculations for Disposable Wet and Dry Wipes Concept
- 2) Disposable Gloves: see calculations for Disposable Laboratory Utensils/Tools Concept
- 3) Wipe and Glove Dispensers: see calculations for Disposable Laboratory Utensils/Tools Concept
- 4) Washer/Dryer: .694 m³ (42,336 in³)

5) Hot Water Holding Tank: .018 m³ (1107.7 in³) for 40 lb holding tank

.015 m³ (886.2 in³) for 32 lb holding tank

6) Ambient Water Holding Tank:

• 7 day mission: $\frac{(170 \text{ lb})(1728)}{62.4} = 4707.7 \text{ in}^3$

• 30 day mission: 23,815.4 in³

• 180 day mission: 148,431 in³

7) Wash Water Recovery System: .27 m³ (16,556 in³)

e. *Spares Weight* - See calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.

f. *Power Penalty* - Based upon equivalent weight ratios for continuous AC and DC voltage, the equivalent weights are calculated as follows:

$$15 \text{ kw (AC)} \times \frac{710 \text{ lb}}{\text{kw}} = 48.3 \text{ kg (106.5 lb)}$$

$$.075 \text{ kw (DC)} \times \frac{591}{\text{kw}} = 20.1 \text{ kg (44.3 lb)}$$

$$.205 \text{ kw (AC)} \times \frac{710 \text{ lb}}{\text{kw}} = 66 \text{ kg (145.6 lb)}$$

$$.175 \text{ kw (DC)} \times \frac{591 \text{ lb}}{\text{kw}} = 26.9 \text{ kg (103.4 lb)}$$

g. *Average Power*

• Water Heater Energy Requirement

$$\frac{(\text{water usage per wash})(\Delta T)(1.056)}{3.6} =$$

$$\frac{(30)(117 - 55^\circ\text{F})(1.056)}{3.6} = 545.6 \text{ watt-hr wash}$$

• Dryer Motor Energy Requirement

$$(\text{time motor on})(\text{motor power}) =$$

$$\left(\frac{30 \text{ min}}{60}\right)(150 \text{ w}) = 75 \text{ watt-hr/wash}$$

- Valves Energy Requirement (time valves on)(valve power) =

$$\left(\frac{5}{60}\right) (55 \text{ w}) = 4.6 \text{ watt-hr/wash}$$
- Water Pump Energy Requirement (time pump on)(pump power) =

$$\left(\frac{30}{60}\right) (20) = 10 \text{ watt-hr/wash}$$
- Assume wash water recovery system components on for entire duration of one wash (1800 sec)

$$\left(\frac{1800}{3600}\right) (55) = 27.5 \text{ watt-hr/wash}$$

$$\left(\frac{1800}{3600}\right) (100) = 50 \text{ watt-hr/wash}$$

h. Environmental Impact

1) Maximum Latent Heat Load Per Day

- a) Dry Wipes: see calculations for Disposable Laboratory Utensil/Tool Concept
- b) Disposable Gloves: see calculations for Disposable Laboratory Utensil/Tool Concept
- c) Washer/Dryer: 532.5 Btu/day
- d) Based upon the equivalent weight ratio .128 lb/Btu/hr, the equivalent weights equal:
 - 4 man mission: 2.4 kg (5.24 lb)
 - 7 man mission: 3 kg (6.6 lb)

2) Maximum Sensible Heat Load Per Day

- a) Washer/Dryer: 8642.5 Btu/day
- b) Equivalent Weight: 20.9 kg (46 lb)

i. Total Weight

- 4 man/7 day mission: 243 kg (535.6 lb)
- 7 man/7 day mission: 245.5 kg (541.2 lb)

- 7 man/30 day mission: 590.3 kg (1301.4 lb)
- 7 man/180 day mission: 2818.6 kg (6214 lb)
- 7 man/30 day mission with wash water recovery capability: 304.5 kg (671.3 lb)
- 7 man/180 day mission with wash water recovery capability: 393.5 kg (867.5 lb)

11. ASTRO-VAC (Refer to Reference g and o in Appendix B)

a. *Expendable Weight*

- 1) Sponges: Each sponge weighs .03 lb
 Assume that each crewman will use one sponge per 30 days
 Weight = (sponge weight)(no. crewman)
 - 4 man/7 day mission: $(.03)(4) = .006 \text{ kg } (.12 \text{ lb})$
 - 7 man/7 day mission: $(.03)(7) = .095 \text{ kg } (.21 \text{ lb})$
 - 7 man/30 day mission: $(.03)(7) = .095 \text{ kg } (.21 \text{ lb})$
 - 7 man/180 day mission: $(.03)(7)(5 \text{ changes}) = .5 \text{ kg } (1.05 \text{ lb})$
- 2) Dry Wipes: see calculations for Disposable Wet and Dry Wipes
- 3) Water: Assume .5 lb of water is used per washing
 Weight = (water usage per washing)(no. crewman)(mission duration)(no. washings per crewman per day)
 - 4 man/7 day mission: $(.5)(4)(7)(10) = 63.5 \text{ kg } (140 \text{ lb})$
 - 7 man/7 day mission: 111.1 kg (245 lb)
 - 7 man/30 day mission: 476.3 kg (1050 lb)

- 7 man/180 day mission: 2857.7 kg (6300 lb)
- Missions with wash water recovery capability: 15.9 kg (35 lb)
- 4) Soap: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept

b. *Expendable Volume*

- 1) Sponges: Each sponge is 8.5 in^3
 Volume = $(8.5)(\text{number of crewman})$
 - 4 man/7 day mission: $(8.5)(4) = .0006 \text{ m}^3 (34 \text{ in}^3)$
 - 7 man/7 day mission: $.001 \text{ m}^3 (59.5 \text{ in}^3)$
 - 7 man/30 day mission: $.001 \text{ m}^3 (59.5 \text{ in}^3)$
 - 7 man/180 day mission: $.005 \text{ m}^3 (297.5 \text{ in}^3)$
- 2) Dry Wipes: see calculations for Disposable Wet and Dry Wipes Concept
- 3) Water:
 - 4 man/7 day mission: $.063 \text{ m}^3 (3877 \text{ in}^3)$
 - 7 man/7 day mission: $.11 \text{ m}^3 (6785 \text{ in}^3)$
 - 7 man/30 day mission: $.48 \text{ m}^3 (29,077 \text{ in}^3)$
 - 7 man/180 day mission: $2.9 \text{ m}^3 (174,462 \text{ in}^3)$
 - Wash water recovery capability missions: $.016 \text{ m}^3 (969.2 \text{ in}^3)$
- 4) Soap: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept

c. *Fixed Weight*

- 1) Sponges:
 - 180 day mission: length of side of storage cabinet = $6.6''$
 area = 217.8 in^2

$$\text{volume} = (217.8)(.02) = 4.4 \text{ in}^3$$

$$\text{weight material} = (4.4)(.1) = .19 \text{ kg} \\ (.44 \text{ lb})$$

$$\text{waste storage} = .19 \text{ kg} (.44 \text{ lb})$$

- 2) Dry Wipes: see calculations for Disposable Wet and Dry Wipes Concept
- 3) Wipe Dispenser: see calculations for Disposable Wet and Dry Wipes Concept
- 4) Soap Tank: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept

5) Fixture:

Fan	1.6 lb
Centrifugal Separator	4 lb
Filter	2 lb
Hose	1.5 lb
Scrubber	.5 lb
Pump Unit	5 lb
Water Supply Unit	6 lb
Hot Water Holding Tank, Thermostat and Heater Element	8.58 lb
	29.18 lb

- 6) Ambient Water Holding Tank: Refer to calculations in Spacelab Utensil/Hand Cleansing Fixture Concept

- 4 man/7 day mission: Tank Must Hold 135 lbs of water
Assume tank diameter = 12 in.
Weight = 2.7 kg (6 lb)
- 7 man/7 day mission: Tank Must Hold 240 lbs of water
Assume tank diameter = 18 in.
Weight = 5.4 kg (11.9 lb)
- 7 man/30 day mission: Tank Must Hold 1045 lb of water
Assume tank diameter = 30 in.

Weight = 23.4 kg (51.5 lb)

- 7 man/180 day mission:

Tank Must Hold 6295 lbs of water

Assume tank diameter = 48 in.

Weight = 129.5 kg (285.5 lb)

- Wash water recovery missions: Tank Must Hold 30 lbs of water

Assume tank diameter = 9 in.

Weight = 1.4 kg (3.1 lb)

- 7) Soap Dispenser: .11 kg (.25 lb)
- 8) Wash Water Recovery System: 81.2 kg (179 lb)

d. *Fixed Volume*

- 1) Sponges

- 180 day mission: .005 m³ (287.5 in³) for both storage and waste storage areas

- 2) Dry Wipes: see calculations for Disposable Wet and Dry Wipes Concept

- 3) Wipe Dispenser: see calculations for Disposable Wet and Dry Wipes Concept

- 4) Soap Tank: see calculations for Spacelab Utensil/Hand Cleansing Fixture Concept

- 5) Fixture: .042 m³ (2592 in³)

- 6) Ambient Water Holding Tank:

- 4 man/7 day mission: .061 m³ (3738.5 in³)
- 7 man/7 day mission: .109 m³ (6646.2 in³)
- 7 man/30 day mission: .47 m³ (28,938.5 in³)
- 7 man/180 day mission: 2.86 m³ (174,323 in³)
- Wash water recovery missions: .014 m³ (830.8 in³)

- 7) Soap Dispenser: 2 in^3
- 8) Wash Water Recovery System: $.27 \text{ m}^3 (16,556 \text{ in}^3)$

e. *Spares Weight* - See calculations for Spacelab Utensil/Hand Cleansing Fixture Concept

f. *Power Penalty* - Based upon equivalent weight ratios for continuous AC and DC voltage, the equivalent weights are calculated as follows:

$$.09 \text{ kw (DC)} \times \frac{591 \text{ lb}}{\text{kw}} = 24.1 \text{ kg (53.2 lb)}$$

$$.055 \text{ kw (AC)} \times \frac{710 \text{ lb}}{\text{kw}} = 17.7 \text{ kg (39 lb)}$$

$$.190 \text{ kw (DC)} \times \frac{591 \text{ lb}}{\text{kw}} = 51 \text{ kg (112.3 lb)}$$

g. *Average Power*

- Water Heater Energy Requirement

$$\frac{(\text{water usage per wash})(\Delta T)(1.056)}{3.6} =$$

$$\frac{(.5)(117 - 55^\circ\text{F})(1.056)}{3.6} = 9.1 \text{ watt-hr/wash}$$

- Centrifugal Separator Motor, Fan and Water Pump Energy Requirements (see reference g and o in Appendix B)

4 watt-hr/wash

- Assume wash water recovery system components on for entire duration of wash (180 sec)

$$\frac{180}{3600} \times 55 = 2.75 \text{ watt-hr/wash}$$

$$\frac{180}{3600} \times 100 = 5 \text{ watt-hr/wash}$$

h. *Environmental Impact*

1) Maximum Latent Heat Load Per Day

a) Dry Wipes:

- 4 man mission: 240 Btu/day

• 7 man mission: 420 Btu/day

b) Fixture: Water Vapor rejected to atmosphere =
water usage per day) (T)C_p

• 4 man mission: (20)(47)(1) = 850 Btu/day

• 7 man mission: (35)(47)(1) = 1500 Btu/day

c) Based upon the equivalent weight ratio .128 lb/Btu/hr, the equivalent weight =

• 4 man mission: 2.63 kg (5.8 lb)

• 7 man mission: 4.6 kg (10.24 lb)

2) Maximum Sensible Heat Load Per Day:

a) Fixture: Sensible Heat Load = (usage time per day)
(fan power)(.034)

• 4 man mission: (120 min)(5 w)(.034) = 22 Btu/day

• 7 man mission: (210)(5)(.034) = 38.3 Btu/day

b) Based upon the equivalent weight ratio, .128 lb/Btu/hr, the equivalent weights equal:

• 4 man mission: .05 kg (.12 lb)

• 7 man mission: .09 kg (.2 lb)

i. Total Weight

• 4 man/7 day mission: 114.1 kg (251.6 lb)

• 7 man/7 day mission: 168.7 kg (372 lb)

• 7 man/30 day mission: 566.2 kg (1248.3 in³)

• 7 man/180 day mission: 3144.4 kg (6932.1 lb)

• 7 man/30 day mission with
wash water recovery capability:
209.5 kg (461.9 lb)

- 7 man/180 day mission with wash water recovery capability: 299.7 kg (660.7 lb)

12. REUSABLE WIPES (Refer to reference g and o in Appendix B)

a. Expendable Weight

- 1) Wipes: Each wipe weighs .04 lb/wipe
Need two per handwash
Wipes are thrown away after 60 washes
Towels will dry in approximately 8 hr.
Weight = (no. of wipes per mission)(.04)
 - 4 man/7 day mission: $(32)(.04) = .58 \text{ kg (1.28 lb)}$
 - 7 man/7 day mission: $(56)(.04) = 1.02 \text{ kg (2.24 lb)}$
 - 7 man/30 day mission: $(56)(.04) = 1.02 \text{ kg (2.24 lb)}$
 - 7 man/180 day mission: $(168)(.04) = 3.08 \text{ kg (6.8 lb)}$
- 2) Water: Use .5 lb/wash - see calculation for Astro-Vac Concept
- 3) Soap: see Orbiter Personal Hygiene Station Concept

b. Expendable Volume

- 1) Wipes: Volume of each wipe = 7.5 in^3
 - 4 man/7 day mission: $(32)(7.5) = .004 \text{ m}^3 (240 \text{ in}^3)$
 - 7 man/7 day mission: $(56)(7.5) = .007 \text{ m}^3 (420 \text{ in}^3)$
 - 7 man/30 day mission: $(56)(7.5) = .007 \text{ m}^3 (420 \text{ in}^3)$
 - 7 man/180 day mission: $(168)(7.5) = .021 \text{ m}^3 (1260 \text{ in}^3)$
- 2) Water: see calculation for Astro-Vac Concept
- 3) Soap: see Orbiter Personal Hygiene Concept

c. Fixed Weight

1) Fixture

Filter	2 lb
Enclosure	8 lb
Centrifugal Separator	4 lb
Fan	3.3 lb
Pump Unit	5 lb
Water Supply Unit	6 lb
Ducting	.2 lb
Hot Water Holding Tank, Thermostat and Heater Element	<u>8.58 lb</u>
	16.8 kg (37.08 lb)

2) Wipe Drying Rack

- 4 man mission:

$$72" \times 18" \times .06" = 77.8 \text{ in}^3$$

$$\text{Density of aluminum} = .1 \text{ lb/in}^3$$

$$\text{Weight} = 3.54 \text{ kg (7.8 lb)}$$

- 7 man mission:

$$72" \times 31" \times .06" = 134 \text{ in}^3$$

$$\text{Weight} = 6.1 \text{ kg (13.4 lb)}$$

3) Wash Cloth Restraints:

Assume 6 restraint units/lb

- 4 man mission:

$$\text{Need 30 restraints} = 2.3 \text{ kg (5 lb)}$$

- 7 man mission:

$$\text{Need 50 restraints} = 3.8 \text{ kg (8.3 lb)}$$

4) Dry Towel Storage:

$$\text{Volume one wipe} = 7.5 \text{ in}^3$$

$$\text{Folded size of wipe} = 10" \times 3" \times .25"$$

$$\text{Thickness of Aluminum} = .02 \text{ in.}$$

- 4 man/7 day mission:

$$\text{Cabinet Size} = 3" \times 10" \times 4"$$

$$\text{Surface area} = 124 \text{ in}^2$$

$$\text{Volume material} = (124)(.02) = 2.48 \text{ in}^3$$

$$\text{Weight material} = .11 \text{ kg (.25 lb)}$$

- 7 man/7 day mission: Cabinet Size = 3" x 10" x 7"
 Surface area = 172 in²
 Volume material = 3.44 in³
 Weight material = .15 kg (.34 lb)
- 7 man/30 day mission: See 7 man/7 day mission calculation
- 7 man/180 day mission: Cabinet Size = 3" x 10" x 21"
 Surface area = 396 in²
 Volume material = 7.92 in³
 Weight material = .36 kg (.8 lb)
- 5) Towel Waste Storage: Cabinet size is equal to storage cabinet size except for 180 day mission which is .66 the cabinet size.
- 4 man/7 day mission: .11 kg (.25 lb)
- 7 man/7 day mission: .15 kg (.34 lb)
- 7 man/30 day mission: .15 kg (.34 lb)
- 7 man/180 day mission: .24 kg (.53 lb)
- 6) Soap Storage: see calculations for Orbiter Personal Hygiene Station
- 7) Ambient Water Holding Tank: see calculations for Astro-Vac Concept
- 8) Wash Water Recovery System: 81.2 kg (179 lb)

d. *Fixed Volume*

- 1) Fixture: .01 m³ (6048 in³)
- 2) Wipe Drying Rack:
 - 4 man mission: .0013 m³ (77.8 in³)
 - 7 man mission: .0022 m³ (133.9 in³)

3) Wash Cloth Restraints: Restraint diameter = 3 in., length = 1.5 in.

Volume each restraint = 14 in^3

• 4 man mission: $.007 \text{ m}^3$ (420 in^3)

• 7 man mission: $.011 \text{ m}^3$ (700 in^3)

4) Dry Towel Storage: see cabinet dimensions in fixed weight calculations

• 4 man/7 day mission: $.002 \text{ m}^3$ (120 in^3)

• 7 man/7 day mission: $.003 \text{ m}^3$ (210 in^3)

• 7 man/30 day mission: $.003 \text{ m}^3$ (210 in^3)

• 7 man/180 day mission: $.021 \text{ m}^3$ (1260 in^3)

5) Towel Waste Storage: Cabinet volume equals that of storage cabinet volume except for 180 day mission which is $2/3$ of the storage cabinet size.

• 4 man/7 day mission: $.002 \text{ m}^3$ (120 in^3)

• 7 man/7 day mission: $.003 \text{ m}^3$ (210 in^3)

• 7 man/30 day mission: $.003 \text{ m}^3$ (210 in^3)

• 7 man/180 day mission: $.014 \text{ m}^3$ (840 in^3)

6) Soap Storage: see calculations for Orbiter Personal Hygiene Station

7) Ambient Water Holding Tank: see calculations for Astro-Vac Concept

8) Wash Water Recovery System: $.27 \text{ m}^3$ ($16,556 \text{ in}^3$)

e. Spares Weight - See calculations for Spacelab Utensil/Hand Cleansing Fixture Concept

f. Power Penalty - Based upon equivalent weight ratios for continuous AC and DC voltage, the equivalent weights are calculated as follows:

$$.224 \text{ kw (DC)} \times \frac{591 \text{ lb}}{\text{kw}} = 60 \text{ kg (132.4 lb)}$$

$$.055 \text{ kw (AC)} \times \frac{710 \text{ lb}}{\text{kw}} = 17.7 \text{ kg (39 lb)}$$

$$.324 \text{ kw (DC)} \times \frac{591 \text{ lb}}{\text{kw}} = 86.9 \text{ kg (191.5 lb)}$$

g. *Average Power*

- Water Heater Energy Requirement:

$$\frac{(\text{water usage per handwash})(\Delta T)(1.056)}{3.6} =$$

$$\frac{(.5)(117 - 55^{\circ}\text{F})(1.056)}{3.6} = 9.1 \text{ watt-hr/wash}$$

- Water Pump, Fan and Centrifugal Separator Motor Energy Requirement:

$$10.5 \text{ watt-hr/wash}$$

- Assume wash water recovery system components are on the entire duration of one wash (216 sec):

$$\left(\frac{216}{3600}\right)(55) = 3.3 \text{ watt-hr/wash}$$

$$\left(\frac{216}{3600}\right)(100) = .6 \text{ watt-hr/wash}$$

h. *Environmental Impact*

1) Maximum Latent Heat Load Per Day

- a) Wipes: Assume that 70 ml (.154 lb) of water is left on each towel to vaporize to the cabin atmosphere.

$$\text{Latent Heat Load} = (\text{water loss per wash})(\text{no. crewman})(\text{no. washings per crewman per day})(\text{heat of vaporization})$$

- 4 man mission: $(.154)(4)(10)(1000) = 6160 \text{ Btu/day}$

- 7 man mission: $(.154)(7)(10)(1000) = 10,780 \text{ Btu/day}$

- b) Fixture: Assume ambient air temperature of 70°F, water temp = 117°F

$$\text{Latent Load} = (\text{water usage per day})(117 - 70)(C_p) \text{ of vaporization}$$

- 4 man mission: $(20 \text{ lb})(47)(1) = 940 \text{ Btu/day}$

- 7 man mission: $(35 \text{ lb})(47)(1) = 1645 \text{ Btu/day}$

c) Based upon the equivalent weight ratio .128 lb/Btu/hr, the equivalent weights equal:

- 4 man mission: 17.2 kg (37.9 lb)
- 7 man mission: 30 kg (66.3 lb)

2) Maximum Sensible Heat Load Per Day

a) Fixture: Sensible Heat Load = (minutes use per day) (fan power) (.034)

- 4 man mission: (144) (5) = 720 Btu/day
- 7 man mission: (252) (5) = 1260 Btu/day

b) Based upon the equivalent weight ratio .128 lb/Btu/hr, the equivalent weights equal:

- 4 man mission: 1.74 kg (3.84 lb)
- 7 man mission: 3 kg (6.72 lb)

i. Total Weight

- 4 man/7 day mission: 120.5 kg (376 lb)
- 7 man/7 day mission: 240.5 kg (530.2 lb)
- 7 man/30 day mission: 626.6 kg (1381.3 lb)
- 7 man/180 day mission: 3147 kg (6938 lb)
- 7 man/30 day mission with wash water recovery capability: 268.3 kg (591.5 lb)
- 7 man/180 day mission with wash water recovery capability: 243.9 kg (647.8 lb)

13. DISPOSABLE WIPES WITH WETTER UNIT (Refer to reference g and o in Appendix B)

a. *Expendable Weight*

1) Wipes: Assume 3 wipes/handwash, therefore multiply the weight of wipes in the disposable wet and dry wipes by three.

2) Water: see calculation for Astro-Vac Concept

3) Soap: Use 2 ml soap per washing

Assume 83 washings per container (see disposable wipe with cleansing agent concept)

Weight one can = .5 lb

- 4 man/7 day mission: Need 4 cans = .91 kg (2 lb)
- 7 man/7 day mission: Need 6 cans = 1.36 kg (3 lb)
- 7 man/30 day mission: Need 26 cans = 5.9 kg (13 lb)
- 7 man/180 day mission: Need 152 cans = 34.5 kg (76 lb)

b. *Expendable Volume*

1) Wipes: Multiply the volume of dry wipe from the Disposable Wet and Dry Wipes Concept by three.

2) Water: see calculations for Astro-Vac Concept

3) Soap: Volume one can = 42.4 in^3

- 4 man/7 day mission: $(4)(42.4) = .003 \text{ m}^3 (169.6 \text{ in}^3)$
- 7 man/7 day mission: $(6)(42.4) = .004 \text{ m}^3 (254.4 \text{ in}^3)$
- 7 man/30 day mission: $(26)(42.4) = .018 \text{ m}^3 (1102.4 \text{ in}^3)$
- 7 man/180 day mission: $(152)(42.4) = .106 \text{ m}^3 (6444.8 \text{ in}^3)$

c. *Fixed Weight*

- 1) Fixture: see calculations for Reusable Wipes Concept.
- 2) Dry Wipes: Assume that there is a proportional relationship between the number of wipes and storage cabinet weight and volume. Therefore, multiply the storage and weight storage cabinet weights for the dry wipes in the disposable wet and dry wipes concept by three.
- 3) Wipe Dispenser: see calculations for Disposable Wet and Dry Wipes Concept
- 4) Ambient Water Holding Tank: see calculations for Astro-Vac Concept
- 5) Soap Container Storage and Waste Storage: Based on calculations similar to those from the Disposable Wipes with Cleansing Agent Concept, the total storage and waste storage cabinet weights equal:
 - 4 man/7 day mission: .43 kg (.94 lb)
 - 7 man/7 day mission: .54 kg (1.2 lb)
 - 7 man/30 day mission: 1.68 kg (3.7 lb)
 - 7 man/180 day mission: 8.98 kg (19.8 lb)
- 6) Wash Water Recovery Capability: 81.2 kg (179 lb)

d. *Fixed Volume*

- 1) Fixture: see calculations for Reusable Wipes Concept.
- 2) Dry Wipes: Assume that there is a proportional relationship between the number of wipes and storage cabinet volume. Therefore, multiply the storage and waste storage cabinet volumes for the dry wipes in the disposable wet and dry wipes concept by three.
- 3) Wipe Dispenser: see calculations for Disposable Wet and Dry Wipes Concept.
- 4) Ambient Water Holding Tank: see calculations for Astro-Vac Concept.
- 5) Soap Container Storage and Waste Storage: Based on calculations similar to those from the Disposable Wipes with Cleansing Agent Concept, the total storage and waste storage cabinet volumes equal:

- 4 man/7 day mission: .005 m³ (324 in³)
- 7 man/7 day mission: .008 m³ (486 in³)
- 7 man/30 day mission: .035 m³ (2106 in³)
- 7 man/180 day mission: .204 m³ (12,420 in³)
- 6) Wash Water Recovery System: .27 m³ (16,556 in³)

- e. *Spares Weight* - See calculations for Spacelab Utensil/Hand Cleansing Fixture Concept.
- f. *Power Penalty* - See calculations for Reusable Wipes Concept.
- g. *Average Power* - See calculations for Reusable Wipes Concept.
- h. *Environmental Impact* -

1) Maximum Latent Heat Load:

- a) Wipes: Assume that 6 ml (.013 lb) is left on each towel to vaporize

- 4 man mission: (.013)(4)(10)(3)(1000) = 1560 Btu/day
- 7 man mission: (.013)(7)(10)(3)(1000) = 2730 Btu/day

- b) Fixture: see calculations for Reusable Wipes Concept

- c) Based upon the equivalent weight ratio .128 lb/Btu/hr, the equivalent weights equal:

- 4 man mission: 6.03 kg (13.3 lb)
- 7 man mission: 10.6 kg (23.3 lb)

2) Maximum Sensible Heat Load Per Day: see calculations for Reusable Wipes Concept

i. *Total Weight*

- 4 man/7 day mission: 161.8 kg (356.7 lb)
- 7 man/7 day mission: 224.3 kg (494.5 lb)

- 7 man/30 day mission: 645.9 kg (1424 lb)
- 7 man/180 day mission: 3377.8 kg (7446.7 lb)
- 7 man/30 day mission with wash water recovery capability: 287.7 kg (634.2 lb)
- 7 man/180 day mission with wash water recovery capability: 524.6 kg (1156.5 lb)

APPENDIX B - REFERENCES AND CONTACTS

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2. SPACELAB MISSION DEMONSTRATION (II & III) EXPERIMENTER CONTACTS

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- b. Dr. Paul X. Callahan
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- c. Dr. Stanley Ellis
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- d. Dr. David D. Feller
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- e. Dr. W. J. Frome
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- f. Dr. Edward Hawthorne
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