(NASA-CR-171830) IMPROVED CREEPER WASTE COLLECTION SYSTEM STUDY Final Report
(McDonnell-Douglas Astronautics Co.) 143 p
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G3/54 13437

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
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</tr>
</tbody>
</table>
1.0 ABSTRACT

This report is the result of a three month study under NASA contract NAS 9-17181 to develop design concepts for improved fecal waste collection both on the Space Shuttle Orbiter and as a precursor for Space Station. The Study was initiated to resolve the inflight usage problems associated with the existing Orbiter waste collection subsystem and to provide a basis for the selection of an optimum waste collection system concept which may ultimately result in the development of an Orbiter flight test article for concept verification and subsequent production of new flight hardware.

Two concepts have been selected for Orbiter and are shown in detail in Section 6.0, Task 4. Additionally, Section 6.0, Appendix A contains one concept selected for application to Space Station. The contractually required Systems Requirements Definition Document and a packet of layouts are included as appendices under separate covers.

This document constitutes completion of the final task in the study.
2.0 RESULTS

The study culminated in the selection of two concepts which are feasible for installation into the Orbiter. The first concept is a repackaged Skylab waste collection system (WCS) requiring very little development. The second concept is a centrifugal compaction device which requires additional development but is retrofittable directly into the existing Orbiter commode structure. A third system, the closed loop macerator, is suggested as a Space Station WCS as it has no venting requirements (see Figure 1). These concepts are discussed in detail in the text of Section 6. The data is in the format of the Design Concept Presentation given at Johnson Space Center on November 2, 1984.

The Design Concept Presentation is organized as shown below. Note the addition of Appendices D and E which are under separate cover.
SELECTED CONCEPTS

CENTRIFUGAL COMPACTION CONCEPT

1-G SKYLAB CONFIGURATION

CLOSED LOOP MACERATOR CONCEPT

FIGURE 1
3.0 CONCLUSIONS
The 1-G Skylab Configuration and Centrifugal Compaction Concept Waste Collection Systems have been defined as optimal choices for retrofit into the Shuttle Orbiter. The first concept has the advantages of being a simple, proven system with minimal risk and low development. The need for fecal bag handling is present, but bag sealing and handling
methods have been significantly improved over the original Skylab system. Similarly, the Centrifugal Compaction Concept utilizes a collection method similar to that of the existing Shuttle system while adding the ability to compact waste to increase storage capacity. Additionally, this concept utilizes the existing commode structure and plumbing network, making it easier to retrofit into the Orbiter. Key features of both concepts include their use of existing Orbiter commode flight hardware when possible and the capability to perform in-vehicle turnaround.

4.0 RECOMMENDATIONS

Implementation of follow-on tasks such as additional study, preliminary design, development of specific concepts, or test hardware procurement are options recommended to NASA.

5.0 APPLICABLE DOCUMENTS

The documents applicable to the Improved Orbiter Waste Collection System Study are given below.
5.1 NASA Documents


WCS 2102B Waste Collection System Workbook, JSC, March 2, 1984

TM X-64814 MSFC Skylab Mission Report - Saturn Workshop, October, 1974


Improved Waste Collection System Initial Review [Handout], JSC, July 20, 1984

5.2 MDAC Documents

1B87234-1 Separator, Centrifugal Urine, February 2, 1971

5.3 Rockwell International Documents

MC282-0069 Waste Collection Subsystem Procurement Document, January 24, 1984

5.4 General Electric Documents

47J232750 WCS Assembly [Drawing], October 5, 1982
6.0 DESIGN CONCEPT PRESENTATION MATERIAL

The following text contains material from the November 2, 1984 Design Concept Presentation at Johnson Space Center.
IMPROVED ORBITER WASTE COLLECTION SYSTEM DESIGN CONCEPT PRESENTATION JSC

2 NOVEMBER 1984
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Background

Task 1   Review
Task 2   Design Studies
Task 3   Selection Process
Task 4   Design Concept Presentation
Task 5   Review Requirements
Task 6   Document Requirements

Appendix A   Space Station WCS Concept
Appendix B   Other Semi-Final Concepts
Appendix C   Skylab System Data
BACKGROUND
<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>Initial Contact by JSC</td>
<td>March 30, 1984</td>
</tr>
<tr>
<td>RFP</td>
<td>May, 1984</td>
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<tr>
<td>Study Proposal Submitted</td>
<td>July 6, 1984</td>
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<tr>
<td>ATP</td>
<td>July 20, 1984</td>
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<tr>
<td>JSC Initial Review</td>
<td>September 27, 1984</td>
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<tr>
<td>Midterm Review</td>
<td>November 2, 1984</td>
</tr>
<tr>
<td>Formal Presentation</td>
<td>November 16, 1984</td>
</tr>
<tr>
<td>Final Report Due</td>
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TASK 1
ORBITER WASTE COLLECTION SYSTEM INITIAL REVIEW

- Overview of Existing Shuttle WCS
- Subsystem Operating History
- Identification of Development Needs
Summary of Inflight Problems to Resolve in Improved Waste Collection System

- Generation of Fecal Dust/Particulate Matter
- Odor
- Paper Storage Separate From Feces
- Lack of Compaction Capability
- Corrosion
- Buildup of Urine Solids
- Noise
- Lengthy Turnaround Time
- Component Failures
- Excessive Crew Involvement and Cleanup
TASK 2
DESIGN STUDIES

- Analytical Studies
- Sketches and Layouts
REQUIREMENTS

GENERAL REQUIREMENTS
0 EFFECTIVELY AND HYGIENICALLY SEPARATE WASTES FROM THE CREWMEMBER
0 STORE THE WASTES IN A SAFE, ODORLESS FORM SEPARATE FROM THE CREW COMPARTMENT

SPECIFIC REQUIREMENTS
0 ACCOMMODATE USE BY BOTH MALES AND FEMALES
0 URINE COLLECTION INTERFACE SHOULD BE INDIVIDUAL
0 BE STRAIGHT-FORWARD AND SIMPLE IN USE AND NOT TAKE EXCESSIVE TIME
0 CAPACITY SHOULD NOT BE LIMITED BY PAPER; I.E., SEPARATE PAPER COMPARTMENT OR COMPACTION FOR PAPERS AND/OR FECES.
0 REQUIRE ONLY MINIMAL TRAINING FOR SUCCESSFUL CREW USE
0 PROVIDE NO HANDLING OF WASTES BY THE CREW
0 PROVIDE PROPER STOOL SEPARATION DURING USE
0 PROVIDE ADEQUATE BODY STABILIZATION FOR USE
0 PROVIDE POSITIVE COLLECTION AND RETENTION OF WASTES AND PAPER FOR A MINIMUM OF 210 MAN-DAYS OF USE
0 INCLUDE PROVISIONS FOR BACTERIA AND ODOR CONTROL
0 BE QUIET DURING OPERATION; NOT DISTURB SLEEP (GOAL: NOISE CRITERIA (NC) 40)
0 BE MAINTAINABLE AT THE LAUNCH SITE; REQUIRE MINIMAL TURNAROUND TIME/IMPACTS (GOAL: IN-VEHICLE GROUND MAINTENANCE)
0 MINIMIZE EXPENDABLES, WEIGHT, POWER, AND VOLUME WITHOUT COMPROMISING SUBSYSTEM OPERATIONAL CHARACTERISTICS
0 BE RELIABLE AND SHOULD INCLUDE REDUNDANT ELECTRICAL COMPONENTS AND DUAL SEALS WHERE PRACTICAL
0 BE RETROFITTABLE WITHIN CURRENT SYSTEM COMPARTMENT INTO THE ORBITER FLEET IN THE FIELD, I.E., KSC
CRITICAL DESIGN/TRADEOFF PARAMETERS

- Feces Separation, Collection, and Containment
- Paper Disposal
- Ease of Operation
- Body Stabilization
- Noise
- Maintainability
- Weight
- Power
- Retrofittability
- Design Risk
- Cost
TASK 3
DESIGN CONCEPT SELECTION

- Evaluate Concepts With Respect to Waste Collection Subsystem Requirements
- Ranking of Concepts in Order of Desirability
- Selection of an Optimum Concept
SELECTION PROCESS

3 Optimum Concepts

Discussion

NASA Midterm Review

4 Most Feasible Concepts

Ranking Discussion Selection

Survey

6 Feasible Concepts

Discussion Selection

Requirements, Advantages/ Disadvantages

15 Initial Concepts
## WCS SURVEY RESULTS

### Rank Score

<table>
<thead>
<tr>
<th>Rank</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
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<tr>
<td>3</td>
<td>4</td>
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<td>4</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
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</table>

Sample Size: 10

### Concept | Avg Score | Std Dev |
<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Centrifugal Compaction</td>
<td>4.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Closed Loop Macerator</td>
<td>4.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Skylab Repackaged</td>
<td>3.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Modified Skylab</td>
<td>3.3</td>
<td>0.9</td>
</tr>
<tr>
<td>MDTSCO Trash Ejector</td>
<td>2.9</td>
<td>2.5</td>
</tr>
<tr>
<td>1 Week Wall Mount</td>
<td>2.7</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Respondents: 1. Snyder  
2. Bastin  
3. Hofbauer  
4. Gallo  
5. Secord  
6. Kelly  
7. A-MDTSCO  
8. B-MDTSCO  
9. C-MDTSCO  
10. D-MDTSCO
TASK 4
DESIGN CONCEPT PRESENTATION

☑ Summary of Candidate Concepts
☑ Rationale and Analyses Leading to Selection of the Optimum Concept
☑ Provide NASA With a Total Understanding of the Selected Concept
☑ Define GSE and Hardware Impacts on the Shuttle System
CANDIDATE CONCEPTS
PRELIMINARY WCS CONCEPTS

Simple Drop Through

- Eliminated Due To . . .
  - Large Volume — High Air Loss
  - Inefficient Packing

Push-Pull Compactor

- Large Volume — High Air Loss
- Active Sliding Seals
- Handle Protrudes Into Crew Compartment
Eliminated Due To ...

- Large Volume — High Air Loss
- Bag Hang-Up
- Bellows Decreases Usable Volume

- Inefficient Use of Volume
- No Area for Stowage
- Active Sliding Seals
PRELIMINARY WCS CONCEPTS
(cont'd)

12/24 Station Rotating Wheel

Eliminated Due To . . .

- No Area For Stowage
- Active Sliding Seals
- Complexity

One Week Push Through

- Inadequate Stowage Volume
- Psychologically Undesirable
Eliminated Due To . . .

- Poor Psychological Acceptance
- Weight
- Marginal Stowage Volume

- Mechanical Complexity
- Active Sliding Seals
- Weight
- No Area For Stowage
Eliminated Due To . . .

- Active Sliding Seals
- Mechanical Complexity
- Inefficient Packing
- Weight
- Mechanical Complexity
- No Area For Storage
Eliminated Due To . . .

- Mechanical Complexity
- Questionable Feasibility

Disposer/Shredder/Grinder
MOST FEASIBLE CONCEPTS

1. Skylab Repackaged Configuration
   A Repackaged Version of the Proven Skylab Collection System With a Re-configured Processor

2. Modified Skylab Concept
   A “Large Bag” Concept (Similar to Skylab) With Significantly Reduced Crew Handling, Weight, and Air Loss

3. Centrifugal Compaction Concept
   An Air Entrainment System Featuring Compaction of Paper and Wastes in a Rotating Chamber

4. Closed Loop Macerator Concept
   A Recirculating Fluid System Which Creates a Filterable Slurry of Waste and Water Soluble Biocide
MOST FEASIBLE CONCEPTS

CENTRIFUGAL COMPACTION CONCEPT

CLOSED LOOP MACERATOR CONCEPT

SKYLAB REPACKAGED CONFIGURATION

MODIFIED SKYLAB CONCEPT
ORBITER WCS CONCEPT WEIGHT

210 Man-Day Mission

System Weight (lb)

- Air
- Liquid
- Bags
- Hardware

Modified Skylab
Centrifugal Compaction
Existing System
Closed Loop Macerator
Skylab Repackaged

VEC915.1
# EXISTING SHUTTLE WCS SYSTEM

Estimated Weight Breakdown

<table>
<thead>
<tr>
<th>Component</th>
<th>Wt (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Vessel Drum</td>
<td>50.0</td>
</tr>
<tr>
<td>Bacteria Filter</td>
<td>6.0</td>
</tr>
<tr>
<td>Fiberglass Shroud</td>
<td>9.0</td>
</tr>
<tr>
<td>Seat Assy</td>
<td>3.0</td>
</tr>
<tr>
<td>Restraint System + Hdw</td>
<td>7.0</td>
</tr>
<tr>
<td>2 Fan/Separators</td>
<td>5.0</td>
</tr>
<tr>
<td>Gate Valve + Hdw</td>
<td>3.0</td>
</tr>
<tr>
<td>Hoses/Ducts</td>
<td>5.0</td>
</tr>
<tr>
<td>Brackets, Supports, Base, Fasteners</td>
<td>14.0</td>
</tr>
<tr>
<td>Controls/Wiring</td>
<td>7.0</td>
</tr>
</tbody>
</table>

**Software Total**

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware Total</td>
</tr>
<tr>
<td>109.0</td>
</tr>
<tr>
<td>Bag</td>
</tr>
<tr>
<td>1.5</td>
</tr>
<tr>
<td><strong>Total System Weight</strong></td>
</tr>
<tr>
<td>110.5 lb</td>
</tr>
</tbody>
</table>

Note: Current System Omits Motor and Slinger Apparatus

**Air Loss:**

\[210 \text{ Uses} \times 2.4 \text{ ft}^3 \times 0.0752 \text{ lb} = 37.9 \text{ lb}\]
ORBITER WCS CONCEPT WEIGHT

- **Air**
- **Bags**
- **Hardware**

System Weight (lb)

<table>
<thead>
<tr>
<th>56 Man-Day Mission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centrifugal Compaction</td>
</tr>
<tr>
<td>1-G Skylab</td>
</tr>
<tr>
<td>Existing Shuttle System</td>
</tr>
</tbody>
</table>
Practicality

Proven Capability

Ease of Retrofittability into Orbiter Structure and Interfaces

Use of Existing Concepts and Flight Qualified Hardware

In-Vehicle Maintenance

Psychological Acceptability
SELECTED CONCEPTS
1-G SKYLAB
CONFIGURATION
1-G SKYLAB CONFIGURATION

Thigh Bar
Urinal
Foot Restraint
Odor/Bacteria Filter
Fan/Separator
Processor
Collector
Outboard Side
1-G SKYLAB CONFIGURATION
COLLECTOR

Seat

Heat Sealing Element

Bag

Bag Cover Flap

Rubber Pad

Screen Mesh Liner

Spindle

Receptacle

VEC843
1-G SKYLAB CONFIGURATION
PROCESSOR
**1-G SKYLAB CONFIGURATION**

**COLLECTION**

- Bolus Entrained by Airflow From Holes Around Base of Seat
- Air Passes Through Hydrophobic Filter, Mesh Liner and Out of Receptacle
1-G SKYLAB CONFIGURATION
BAG SEALING

- Seat Hinged Up
- Bag Cover Flap Secured On Spindles
- Seat Down and Latched
- Push Start Button, Allow Cycle to Finish
- Seat Hinged Up
- Remove Sealed Bag From Spindles
1-G SKYLAB CONFIGURATION
BAG STOWAGE

- Sealed Bag is Folded at Creases
- Processor Vacuum Valve to Cabin
- Open Processor Door
- Release Bag Retaining Bar
- Insert Bag
- Replace Retaining Bar
- Close Processor Door
- Processor Vacuum Valve to Vacuum
1-G SKYLAB CONFIGURATION
BAG INSTALLATION

- Unfold Bag
- Place Bag in Receptacle
- Secure Four Corners on Spindles
- Hinge Seat Down and Latch
1-G SKYLAB CONFIGURATION DUCTING AND INTERFACES

Side View

VAC
PHS
Trash
EMU
Urine
## 1-G SKYLAB CONFIGURATION
### CREW PROCEDURES

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Crew Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Turn mode switch to WCS/EMU*</td>
<td>2 Min.</td>
</tr>
<tr>
<td>2.</td>
<td>Position body and restraint system</td>
<td>30 Sec.</td>
</tr>
<tr>
<td>3.</td>
<td>Perform defecation and cleanup</td>
<td>12 Min. 0 Sec.</td>
</tr>
<tr>
<td>4.</td>
<td>Remove restraint system</td>
<td>15 Min.</td>
</tr>
<tr>
<td>5.</td>
<td>Unlatch and lift seat</td>
<td>10 Min.</td>
</tr>
<tr>
<td>6.</td>
<td>Seal bag</td>
<td>15 Min.</td>
</tr>
<tr>
<td>7.</td>
<td>Verify or close processor vacuum valve, wait for repressurization</td>
<td>5 Min.</td>
</tr>
<tr>
<td>8.</td>
<td>Open processor door</td>
<td>5 Min.</td>
</tr>
<tr>
<td>9.</td>
<td>Remove bag from collector</td>
<td>5 Min.</td>
</tr>
<tr>
<td>10.</td>
<td>Place bag into processor</td>
<td>15 Min.</td>
</tr>
<tr>
<td>11.</td>
<td>Close processor door</td>
<td>5 Min.</td>
</tr>
<tr>
<td>12.</td>
<td>Open processor vacuum valve</td>
<td>3 Min.</td>
</tr>
<tr>
<td>13.</td>
<td>Disinfect seat</td>
<td>30 Min.</td>
</tr>
<tr>
<td>14.</td>
<td>Open clean bag dispenser</td>
<td>5 Min.</td>
</tr>
<tr>
<td>15.</td>
<td>Install clean bag</td>
<td>15 Min.</td>
</tr>
<tr>
<td>16.</td>
<td>Close clean bag dispenser</td>
<td>5 Min.</td>
</tr>
<tr>
<td>17.</td>
<td>Lower seat &amp; latch</td>
<td>10 Min.</td>
</tr>
<tr>
<td>18.</td>
<td>Turn mode switch to off</td>
<td>2 Min.</td>
</tr>
</tbody>
</table>

Total time: 14 Min. 57 Sec.

*FOR URINATION ONLY (AFTER STEP 1), PERFORM URINATION AND CLEANUP AND GO TO STEP 18.


## 1-G Skylab Configuration Ground Turnaround

<table>
<thead>
<tr>
<th>Step Description</th>
<th>Time (HR.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Move processor valve to cabin position</td>
<td></td>
</tr>
<tr>
<td>2. Open processor door</td>
<td></td>
</tr>
<tr>
<td>3. Remove bags, place into air-tight transport container</td>
<td>.5</td>
</tr>
<tr>
<td>4. Remove spent odor/bacteria filter</td>
<td></td>
</tr>
<tr>
<td>5. Place filter in transport container</td>
<td></td>
</tr>
<tr>
<td>6. Remove transport container from orbiter</td>
<td></td>
</tr>
<tr>
<td>7. Clean &amp; disinfect interior of collector, processor and urine system</td>
<td>1.0</td>
</tr>
<tr>
<td>8. Clean &amp; disinfect exterior of wcs</td>
<td>.5</td>
</tr>
<tr>
<td>9. Install fresh bag</td>
<td></td>
</tr>
<tr>
<td>10. Install fresh odor/bacteria filter</td>
<td>.5</td>
</tr>
<tr>
<td>11. Return system to initial condition configuration</td>
<td></td>
</tr>
<tr>
<td>12. Verify operation of system</td>
<td>.5</td>
</tr>
<tr>
<td>13. Move transport container to service area</td>
<td></td>
</tr>
<tr>
<td>14. Remove waste from transport container</td>
<td>1.0</td>
</tr>
<tr>
<td>15. Clean and store transport container</td>
<td></td>
</tr>
</tbody>
</table>

**Total Time**: 4.0 HR.
1-G SKYLAB CONFIGURATION
POTENTIAL GSE REQUIREMENTS

- Biological Isolation Garment
- Clean Up Equipment
  - Brushes
  - Wipes
  - Biocide/Cleaner
  - Trash Bags
- Fluid Circulation and Flush System (for flushing out urine system)
- Standard Tools
- Transport Container
1-G SKYLAB CONFIGURATION
POWER CONSUMPTION

- Fan/Separator (Existing) 100W Air  200W Air/Liq

- Processor Htr (if Req'd) 86W Peak  30W Avg.

Total Max  286W
Assumptions

- $\Delta P$ Same as Present Bag = 0.6 in $\text{H}_2\text{O}$ at 30 CFM
- Laminar Flow Through Filter Material

Test Results of Pall Filter Material
$\Delta P = 4.9$ in $\text{H}_2\text{O}$, $Q = 28$ CFM, As $1/20 \text{ Ft}^2 = .05 \text{ Ft}^2$

Calculations:

$\Delta P = K \frac{Q}{A}$ or $K = \frac{\Delta PA}{Q}$

$K = 4.9 \times .05/28 = .00875$

Bag Area $A = .00875 \times 30 \times 144/.6 = 63 \text{ in.}^2$

Use Two 8 in. $\times$ 4 in. Filters
Expendables; 56 Man-Days + Contingency

- **Total Bag Weight** = Bag No. × Weight/Bag
  = 75 × 2.2 lb = 17.0 lb

- **Overboard Air Loss** = No. of Uses × Air Loss Per Use
  Air Loss/Use = Processor Volume × Air Density
  = 1.62 ft³ × 0.0752 lb/ft³ = 0.122 lb

- **Total Air Loss Overboard (Max)** = 75 × 0.122 lb = 9.14 lb
1-G SKYLAB CONFIGURATION
HARDWARE FABRICATION FEASIBILITY

Machined Body

Machined Door

Existing Seat

Machined Flanges and Fittings

Heat Formed Bag

Welded Screen

Welded Receptacle
1-G SKYLAB CONFIGURATION
BAG COST

Skylab Bag Cost = $100/Bag in 1972

Add Inflation Factor of 2.90 From 1972 to 1985

Cost of 75 New Bags = $100 \times 2.90 \times 75 = 21,750.00

Bag Cost Per Mission
1-G SKYLAB CONFIGURATION
DEVELOPMENT ITEMS

- Heat Sealing Device
- Heat Sealable Material Compatibility/Outgassing
- Adjustment of Airflow/ΔP of System
- Compaction Plate/Spring Constant
I-G SKYLAB CONFIGURATION
REQUIREMENTS REVIEW

GENERAL REQUIREMENTS
0 AIRFLOW SEPARATES WASTE FROM CREWMEMBER
0 WASTES STORES IN PROCESSOR UNDER VACUUM

SPECIFIC REQUIREMENTS
0 MALE/FEMALE FECES AND URINE COLLECTION INTERFACES SAME AS EXISTING SYSTEM
0 INDIVIDUAL URINE CAPS PROVIDED
0 USE TIME EXCEEDS THAT OF EXISTING SYSTEM BY ONLY 1-1/2 MINUTES (APPROX.)
0 PAPER IS DEPOSITED INTO FECAL COLLECTOR DURING USE
0 CREW TRAINING SIMILAR TO CURRENT CONTINGENCY MODE OPERATIONS WITH SIMPLIFICATIONS
0 CREW HANDLES ONLY CLEAN OR SEALED BAGS
0 SEPARATION METHOD IDENTICAL TO EXISTING SYSTEM
0 BODY STABILIZATION SAME AS EXISTING SYSTEM
*0 CAPACITY FOR 56 BAGS (7 MAN X 8 DAY) PLUS 12% TO 34% (6 TO 19 BAGS) CONTINGENCY
(ASSUMING BAGS ARE BETWEEN 0.40 AND 0.33 INCHES THICK)
0 BACTERIA AND ODOR CONTROLLED BY VACUUM STORAGE AND ODOR FILTERS
0 NOISE LEVEL EQUIVALENT TO EXISTING SYSTEM
*0 MAINTENANCE IS IN-VEHICLE
*0 WEIGHT, POWER AND EXPENDABLES ARE LESS THAN OR EQUAL TO EXISTING SYSTEM
*0 MECHANICAL AND ELECTRICAL SYSTEMS ARE SIMPLIFIED TO INCREASE RELIABILITY
0 SYSTEM IS RETROFITTABLE INTO ORBITER

DIFFERS FROM EXISTING SYSTEM
**PER REDIRECTION OF D. GERMANY DURING MIDTERM REVIEW
### 1-G SKYLAB CONFIGURATION
WEIGHT ESTIMATE SUMMARY

<table>
<thead>
<tr>
<th>Component</th>
<th>Wt (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector Receptacle</td>
<td>1.0</td>
</tr>
<tr>
<td>Mesh Screen Liner</td>
<td>0.4</td>
</tr>
<tr>
<td>1 Processor (Enlarged 50%)</td>
<td>27.0</td>
</tr>
<tr>
<td>1 Storage Compartment</td>
<td>6.0</td>
</tr>
<tr>
<td>Seat + Heat Sealer</td>
<td>5.0</td>
</tr>
<tr>
<td>Structural Supports</td>
<td>14.0</td>
</tr>
<tr>
<td>Switches, Cables, Elect. Conn.</td>
<td>3.0</td>
</tr>
<tr>
<td>Odor Bacteria Filter*</td>
<td>6.0</td>
</tr>
<tr>
<td>Restraint System*</td>
<td>7.0</td>
</tr>
<tr>
<td>2 Fan/Separators*</td>
<td>5.0</td>
</tr>
<tr>
<td>Hoses, Ducts*</td>
<td>5.0</td>
</tr>
<tr>
<td>Hardware Total</td>
<td>79.4</td>
</tr>
<tr>
<td>75 Bags**</td>
<td>17.0</td>
</tr>
<tr>
<td>Air** (75 Uses)</td>
<td>9.1</td>
</tr>
<tr>
<td>Total System Wt</td>
<td>105.5 lb</td>
</tr>
</tbody>
</table>

*Existing System Hardware

**Expendables
### WCS WEIGHT ESTIMATE SUMMARY (POUNDS)

<table>
<thead>
<tr>
<th>System</th>
<th>Man-Days</th>
<th>Hdwe</th>
<th>Bags</th>
<th>Air</th>
<th>Liquid</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-G Skylab</td>
<td>56</td>
<td>79.4</td>
<td>17.0</td>
<td>9.1</td>
<td>0</td>
<td>105.5</td>
</tr>
<tr>
<td>Centrifugal Comp</td>
<td>56</td>
<td>112.0</td>
<td>1.5</td>
<td>14.1</td>
<td>0</td>
<td>127.6</td>
</tr>
<tr>
<td>Centrifugal Comp</td>
<td>210</td>
<td>112.0</td>
<td>1.5</td>
<td>52.9</td>
<td>0</td>
<td>166.4</td>
</tr>
<tr>
<td>Skylab Repackaged</td>
<td>210</td>
<td>110.4</td>
<td>52.3</td>
<td>24.6</td>
<td>0</td>
<td>187.3</td>
</tr>
<tr>
<td>Modified Skylab</td>
<td>210</td>
<td>85.3</td>
<td>4.0</td>
<td>7.0</td>
<td>0</td>
<td>96.3</td>
</tr>
<tr>
<td>Closed Loop Macerator</td>
<td>210</td>
<td>88.5</td>
<td>0</td>
<td>0</td>
<td>93.6</td>
<td>182.1</td>
</tr>
<tr>
<td>Existing System</td>
<td>56</td>
<td>109.0</td>
<td>1.5</td>
<td>10.1</td>
<td>0</td>
<td>120.6</td>
</tr>
<tr>
<td>Existing System</td>
<td>210</td>
<td>109.0</td>
<td>1.5</td>
<td>37.9</td>
<td>0</td>
<td>148.4</td>
</tr>
</tbody>
</table>
ADVANTAGES

1. Skylab Collection Method Is Proven
2. Hardware Is Practical and Proven
3. Valves and Airflow System are Simple and Straightforward
4. Unit is Immediately Retrofittable Into Orbiter Structure and Interfaces
5. Air Loss Is Low Due to Smaller Processor Volume
6. Compaction and Heat Application are a Feature of Processor
7. Advanced Bag Sealing Concept Assures That Handling Is Limited to Clean or Sealed Bags
8. Existing Fan/Separators are Used
9. Direct Valve Linkages are Mechanically Simple
10. Unit Is Serviceable on Orbit
11. Odor Is Contained by Airflow During Bag Sealing
12. Used Bag Processing and Storage Occur in Same Chamber
13. Odor From Used Bags in Processors Is Contained by Airflow During Bag Insertion
14. Orderly Used Bag Storage in Processors Is More Volume Efficient and Simplifies Ground Changeout
15. Fresh Bag Stowage Area is Provided
16. Sized to Accommodate Orbiter Mission and Crew Requirements

DISADVANTAGES

1. Fecal Bag Handling and Sealing are Present
CENTRIFUGAL COMPACTION CONCEPT
CENTRIFUGAL COMPACTION CONCEPT

Thigh Bar

Seat

Urinal

Commode Control

Spacer Fabric

Velcro

Aluminum Stave

Valve A Linkage

Valve C, D Linkage

Valve B Linkage

Fan/Separator

Note:

Valves A, B, C, D

See Schematic

Side View

56
CENTRIFUGAL COMPACTION CONCEPT COLLECTION AND PROCESSING CHAMBER

- Outer Drum Lid
- Inner Drum Lid
- Outer V-Band
- Inner V-Band
- Bag Liner
- Inner Drum (Rotating)
- Outer Drum (Stationary)
- Pip Pin
- Clevis
- Slide Valve
- Link
- Motor
CENTRIFUGAL COMPACTION CONCEPT
COLLECTION

- Bolus Entrained by Airflow From Holes Around Base of Seat

- Inner Drum Rotates — Airflow and Centrifugal Force Move Bolus Toward Bag Liner

- Waste Is Compacted Against Inner Drum Wall — Center Collection Area Is Open

- Air Flows Out Through Bag, Spacer Fabric, Vents, and Outlet at Bottom

<table>
<thead>
<tr>
<th>Rotation Speed</th>
<th>Compaction Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 RPS</td>
<td>1 G Approx</td>
</tr>
<tr>
<td>2 RPS</td>
<td>4 G Approx</td>
</tr>
<tr>
<td>3 RPS</td>
<td>12 G Approx</td>
</tr>
</tbody>
</table>
CENTRIFUGAL COMPACTION CONCEPT
BAG PLUGGING

Stopper/Sealing Plug
Used Prior to
Bag Replacement

Inner Drum Cover

Outer Drum Cover

Bag
CENTRIFUGAL COMPACTION CONCEPT
BAG REMOVAL

- Raise Seat
- Unfasten Slide Valve Clevis From Slide Valve and Swing Slide Valve Link Out of the Way
- Lower Seat
- Remove Outer V-Band Clamp
- Remove Outer Drum Lid
- Remove Inner V-Band Clamp
- Remove Inner Drum Lid and Bag Liner From Inner Drum
- Remove Pip Pins From Neck of Inner Drum Lid
- Detach Bag Liner From Underside of Inner Drum Lid
CENTRIFUGAL COMPACTION CONCEPT
BAG INSTALLATION

- Insert Neck of Fresh Bag Into Underside of Inner Drum Lid
- Replace Pip Pins
- Insert Bag Into Inner Drum, Secure Velcro Attachment Points
- Align Inner Drum Lid and Replace Inner V-Band Clamp
- Align Outer Drum Lid and Replace Outer V-Band Clamp
- Raise Seat
- Re-Attach Slide Valve Clevis and Linkage to Slide Valve
- Lower Seat
CENETIFUGAL COMPACTION CONCEPT
VALVE POSITIONS (SEE SCHEMATIC)

Mode-Off
A Closed
B Open to Vacuum
C Open
d Open to Ballast Line

Urine Collection:
Model-WCS/EMU
A Closed
B Open to Vacuum
C Open
d Open to Ballast Line

Urine/Feces Collection:
Mode-WCS/EMU
■ Handle Up
A Closed
B Open to Air Collection Line
c Open
d Open to Ballast Line

■ Handle Forward
A Open
B Open to Air Collection Line
c Closed
d Open to Commode
CENTRIFUGAL COMPACCTION CONCEPT
VALVE LINKAGE IMPROVEMENT

Control Handle

Sector/Guide
VALVE LINKAGE IMPROVEMENT
OPTION 1

Control Handle

Handle Release Button

Sector/Guide

Ball Lock
CENTRIFUGAL COMPACTION CONCEPT
CREW PROCEDURES

TYPICAL USE CYCLE

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Crew Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TURN MODE SWITCH TO WCS/EMU*</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>PULL UP ON COMMODE CONTROL</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>POSITION BODY AND RESTRAINT SYSTEM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WHILE WAITING (20 SECONDS MIN.)</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>PUSH COMMODE CONTROL FORWARD</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>PERFORM DEFECATION AND CLEANUP</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>REMOVE RESTRAINT SYSTEM</td>
<td>15</td>
</tr>
<tr>
<td>7</td>
<td>PUSH COMMODE CONTROL TO REAR AND DOWN (OFF)</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>TURN MODE SWITCH TO OFF</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>DISINFECT SEAT (STOW PAPER IN WET TRASH)</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>TOTAL TIME</td>
<td>13 MIN. 30 SEC.</td>
</tr>
</tbody>
</table>

*FOR URINATION ONLY (AFTER STEP 1), PROCEED TO PERFORM URINATION AND CLEANUP AND GO TO STEP 8.
<table>
<thead>
<tr>
<th>Step Description</th>
<th>Time (HR.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Open vacuum valve</td>
<td></td>
</tr>
<tr>
<td>2. Open slide valve</td>
<td>.25</td>
</tr>
<tr>
<td>3. Install plug into bag neck</td>
<td></td>
</tr>
<tr>
<td>4. Raise seat</td>
<td></td>
</tr>
<tr>
<td>5. Disconnect slide valve cable clevis</td>
<td>.25</td>
</tr>
<tr>
<td>6. Lower and latch seat</td>
<td></td>
</tr>
<tr>
<td>7. Remove outer V-Clamp</td>
<td></td>
</tr>
<tr>
<td>8. Remove outer vessel lid</td>
<td>.25</td>
</tr>
<tr>
<td>9. Remove inner V-Clamp</td>
<td></td>
</tr>
<tr>
<td>10. Lift inner drum lid, pull bag out of inner drum</td>
<td></td>
</tr>
<tr>
<td>11. Remove PIP pins from bag neck</td>
<td></td>
</tr>
<tr>
<td>12. Pull bag free, place in transport container</td>
<td>.50</td>
</tr>
<tr>
<td>13. Remove spent odor/bacteria filter, place in transport container</td>
<td></td>
</tr>
<tr>
<td>14. Remove transport container from orbiter</td>
<td></td>
</tr>
<tr>
<td>15. Clean &amp; disinfect interior of drum, outer vessel and urine system</td>
<td>1.50</td>
</tr>
<tr>
<td>16. Clean &amp; disinfect exterior of WCS</td>
<td>.50</td>
</tr>
<tr>
<td>17. Install new bag into inner drum lid</td>
<td></td>
</tr>
<tr>
<td>18. Replace PIP pins in bag neck</td>
<td>1.00</td>
</tr>
<tr>
<td>19. Lower inner drum lid while installing bag into drum</td>
<td></td>
</tr>
<tr>
<td>20. Replace inner V-Clamp</td>
<td></td>
</tr>
</tbody>
</table>
21. REPLACE OUTER VESSEL LID
22. REPLACE OUTER V-CLAMP
23. RAISE SEAT
24. RE-CONNECT SLIDE VALVE CABLE CLEVIS
25. LOWER AND LATCH SEAT
26. INSTALL NEW ODOR/BACTERIA FILTER
27. RESTORE TO INITIAL CONDITIONS CONFIGURATION
28. VERIFY OPERATION OF SYSTEM
29. MOVE TRANSPORT CONTAINER TO SERVICE AREA
30. DISPOSE OF FECAL BAG
31. CLEAN & STORE TRANSPORT CONTAINER

TOTAL TIME

TIME (HR.)

.25

.25

.25

.50

1.00

6.50 HR.
CENTRIFUGAL COMPACTION CONCEPT
POTENTIAL GSE REQUIREMENTS

- Biological Isolation Garment
- Clean Up Equipment
  - Brushes
  - Wipes
  - Biocide/Cleaner
  - Trash Bag
- Fluid Circulation and Flush System (for flushing out Urine System)
- Standard Tools
- Transport Container
CENTRIFUGAL COMPACATION CONCEPT
POWER CONSUMPTION

- Fan/Separators (Existing) 100W Air  200W Air/Liq.
- Drum Motor  40W Max
  - Modify Existing Flight Qualified Slinger Motor
  - Add a 39:1 Reduction Gear Box
CENTRIFUGAL COMPACTION CONCEPT

Bag Pressure Drop:

- Bag Approximately Same Area as Existing Bag
  \[ \Delta P_{\text{max}} = 6 \text{ in. H}_2\text{O at 30 CFM} \]

Overboard Air Loss:

- Air Loss Per Usage = Volume \times Air Density
  \[ = 3.35 \text{ ft}^3 \times 0.0752 \text{ lb/ft}^3 = 0.252 \text{ lb} \]

- Total Air Loss for 210 Man Day Uses
  \[ = \text{Man Days} \times \text{Air Loss/Usage} = 210 \times 0.252 \text{ lb} = 52.9 \text{ lb} \]

- Total Air Loss for 56 Man Day Uses
  \[ = \text{Man Days} \times \text{Air Loss/Usage} = 56 \times 0.252 \text{ lb} = 14.1 \text{ lb} \]
Sizing of Rectangular Exhaust Air Duct Extension To Have Same ΔP as Present 1.5 in. OD Duct

- Let Outside Width (W) = 1 in. for Personal Hygiene Tray Clearance. Wall Thickness = 0.030 in.
- Let Hydraulic Dia., (DH) = 4 × Area (A)/Perimeter (S), Equal Diameter of Round Duct
- ID of Round Duct × 1.5 - 0.060 = 1.44 in.
  Inside Width (WINS) of Rect. Duct = 1 - 0.060 = 0.94 in.

\[
LINS = \frac{DH \times WINS}{2 \times WINS - DH} = \frac{1.44 \times 0.94}{2 \times 0.94 - 1.44} = 3.08 \text{ in.}
\]

Outside Dimensions = 1 in × (3.08 + 0.060) = 1 in. × 3.14 in.
CENTRIFUGAL COMPACTION CONCEPT
HARDWARE FABRICATION FEASIBILITY

Machined Air Hole Ring
Existing Shuttle Seat
Machined Slide Valve
Formed Inner Lid
Formed V-Bands

Composite Lay-up Outer Vessel
Formed, Welded Inner Vessel

Bag: Porous Filter Medium Bonded at Joints
CENTRIFUGAL COMPACTION CONCEPT
DEVELOPMENT ITEMS

- Motor Drive/Gearbox
- Rotating Bearing
- Drum Spin Speed
CENTRIFUGAL COMPACTION CONCEPT
REQUIREMENTS REVIEW

GENERAL REQUIREMENTS
0 AIRFLOW SEPARATES WASTE FROM CREWMEMBER
0 WASTES STORED EN MASSE IN VACUUM CONTAINER

SPECIFIC REQUIREMENTS
0 MALE/ FEMALE FECES AND URINE COLLECTION INTERFACES SAME AS EXISTING SYSTEM
0 INDIVIDUAL URINE CAPS PROVIDED
0 CREW PROCEDURES IDENTICAL TO EXISTING SYSTEM
0 PAPER IS DEPOSITED INTO FECAL COLLECTOR DURING USE
0 CREW TRAINING IDENTICAL TO EXISTING SYSTEM
0 NO HANDLING OF WASTE
0 SEPARATION METHOD IDENTICAL TO EXISTING SYSTEM
0 BODY STABILIZATION SAME AS EXISTING SYSTEM
0 CAPACITY EQUAL TO EXISTING SYSTEM WITH COMPACTION CAPABILITY ADDED
0 BACTERIA AND ODOR CONTROLLED BY VACUUM STORAGE AND FILTERS
0 NOISE LEVEL EQUIVALENT TO EXISTING SYSTEM
0 MAINTENANCE IN VEHICLE
0 WEIGHT, POWER, AND EXPENDABLES ARE EQUIVALENT TO EXISTING SYSTEM
0 VALVE MECHANISM RELIABILITY IS INCREASED; ROTATING CHAMBER IS DESIGNED WITH FAIL-OPERATIONAL CHARACTERISTICS
0 SYSTEM IS RETROFITTABLE INTO ORBITER

*DIFFERS FROM EXISTING SYSTEM
<table>
<thead>
<tr>
<th>Component</th>
<th>Wt (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner Drum</td>
<td>11.0</td>
</tr>
<tr>
<td>Outer Drum (Composite)</td>
<td>41.0</td>
</tr>
<tr>
<td>Slide Valve</td>
<td>3.0</td>
</tr>
<tr>
<td>Seat</td>
<td>3.0</td>
</tr>
<tr>
<td>Motor</td>
<td>3.0</td>
</tr>
<tr>
<td>Structural Supports</td>
<td>14.0</td>
</tr>
<tr>
<td>Switches, Cables, Elect. Conn.</td>
<td>7.0</td>
</tr>
<tr>
<td>Odor Bacteria Filter*</td>
<td>6.0</td>
</tr>
<tr>
<td>Restraint System*</td>
<td>7.0</td>
</tr>
<tr>
<td>Fiberglass Shroud</td>
<td>7.0</td>
</tr>
<tr>
<td>2 Fan/Separators*</td>
<td>5.0</td>
</tr>
<tr>
<td>Hoses, Ducts*</td>
<td>5.0</td>
</tr>
<tr>
<td><strong>Hardware Total</strong></td>
<td>112.0</td>
</tr>
<tr>
<td>Bags**</td>
<td>1.5</td>
</tr>
<tr>
<td>Air**</td>
<td>52.9</td>
</tr>
<tr>
<td><strong>Total System Wt</strong></td>
<td>166.4</td>
</tr>
</tbody>
</table>

*Existing System Hardware  210 Uses  56 Uses

**Expendables
## WCS WEIGHT ESTIMATE SUMMARY
(POUNDS)

<table>
<thead>
<tr>
<th>System</th>
<th>Man-Days</th>
<th>Hdwe</th>
<th>Bags</th>
<th>Air</th>
<th>Liquid</th>
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<td>9.1</td>
<td>0</td>
<td>105.5</td>
</tr>
<tr>
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<td>112.0</td>
<td>1.5</td>
<td>14.1</td>
<td>0</td>
<td>127.6</td>
</tr>
<tr>
<td>Centrifugal Ccmp</td>
<td>210</td>
<td>112.0</td>
<td>1.5</td>
<td>52.9</td>
<td>0</td>
<td>166.4</td>
</tr>
<tr>
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<td>210</td>
<td>109.0</td>
<td>1.5</td>
<td>37.9</td>
<td>0</td>
<td>148.4</td>
</tr>
</tbody>
</table>
ADVANTAGES
1. Collector Mounts Directly Onto Existing Commode Structure Which Is Immediately Retrofittable Into Orbiter Compartment
2. Existing Fan/Separators, Valves, Hardware and Interfaces are Used
3. Commode Control and Valve Linkage Is Improved
4. Compaction of Tissues and Fecal Material Is Provided By Centrifugal Force
5. Rotation Moves Fecal Material Out of View of Crew
6. Large Bag Collection Method is Simple and Proven
7. Low Rotation Speed Enhances Mechanical and Functional Reliability
8. Motor and Rotating Drum Revert to Simple Bag Operation in Event of Failure
9. Motor and Shaft Located Within Pressure Vessel – Eliminates Need for a Rotating Seal Around Shaft
10. Crew Handles No Waste
11. Waste Material Is Deactivated by Vacuum Drying and/or Freezing
12. Air Loss Similar to Current System
13. Complete Enclosure of Bag Minimizes Stress on Bag Material
14. Plug Provides for Simple, Positive, and Hygienic Closure of Bag for Convenient and Sanitary Ground Handling
15. Big Bag Concept Eliminates Bag Handling for Shuttle Application
16. Bag May be Easily Changed on Orbit for a Longer Duration Space Station Mission

DISADVANTAGES
1. Rotating Bearing at Bag Opening Is Required
2. An Out of Balance Condition Due to Non-Uniform Buildup of Fecal Material May Lead to Bearing Wear or the Need for a Balancing Device
TASK 5
PROGRAM REVIEW REQUIREMENTS

- Initial Subsystem Review at JSC
- Mid-Term Status Review at MDAC-HB
- Formal Presentation at JSC
TASK 6
PROGRAM DOCUMENT REQUIREMENTS

Final Report
APPENDIX A
SPACE STATION WCS CONCEPT
CLOSED LOOP
MACERATOR SYSTEM
CONCEPT
CLOSED LOOP MACERATOR CONCEPT

- Seat
- Receptacle
- Macerator
- Base
- Motor
- Slide Valve
- Air Separation Area
- Blade
- Shaft/Air Tube
CLOSED LOOP MACERATOR
SYSTEM CONCEPT
SYSTEM SCHEMATIC
CLOSED LOOP MACERATOR SYSTEM CONCEPT
GROUND OPERATIONS

1. Close filter isolation valves
2. Disconnect bellows/filter unit
3. Place bellows/filter unit in transport container
4. Remove transport container from orbiter
5. Connect fluid flush/recharge system to line shutoff valve connectors
6. Open line shutoff valves and flush out system to disinfect
7. Cycle volume control reservoir, biocide injector, and slurry pump while flushing
8. Stop flushing momentarily, open slide valve
9. Inspect slide valve, clean if necessary, close
10. Continue flushing to clear system of slide valve debris
11. When fluid is clear, fill volume control reservoir
12. Stop flushing, close filter isolation valve
13. Disconnect fluid flush system
14. Install new fluid charged bellows/filter unit
15. Open filter isolation valves
16. Recharge biocide injector
17. Install new odor/bacteria filter
18. Verify system back to initial conditions
19. Service bellows/filter unit as necessary
CLOSED LOOP MACERATOR SYSTEM CONCEPT
POTENTIAL GSE REQUIREMENTS

- Biological Isolation Garment
- Odor/Bacteria Filter
- Recharged Bellows/Filter Unit
- Clean Up Equipment
  - Brushes
  - Wipes
  - Biocide/Cleaner
  - Trash Bags
- Fluid Circulation and Flush/Recharge System
- Standard Tools
- Transport Container
- Servicing Equipment for Bellows/Filter Unit
CLOSED LOOP MACERATOR SYSTEM
EXPENDABLES SUMMARY

No Expendables

- Air Used Only for Collection and Entrainment — Recirculated Back to Cabin Through Odor/Bacteria Filter

- Liquid Used Only to Circulate Fecal Material and Carry Biocide for Deactivation — Recirculated Through System and Filter
# CLOSED LOOP MACERATOR SYSTEM

## Biocide Data

<table>
<thead>
<tr>
<th>Material</th>
<th>Formula</th>
<th>Solvents</th>
<th>Dosage*</th>
<th>Toxicity</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cupric Bromide</td>
<td>CuBr₂</td>
<td>Water¹ &lt;br&gt; Ethanol²</td>
<td>7 — 8 g/100g Feces</td>
<td>Minimal</td>
<td>$13.00/100g</td>
</tr>
<tr>
<td>Silver Sulphate</td>
<td>AgSO₄</td>
<td>Water²</td>
<td>8 — 10 g/100g Feces</td>
<td>Minimal</td>
<td>$220.00/100g</td>
</tr>
<tr>
<td>Silver Oxide</td>
<td>Ag₂O</td>
<td>Ethanol³</td>
<td>~8g /100g Feces</td>
<td>Minimal</td>
<td>$240.00/100g</td>
</tr>
</tbody>
</table>

*Dosage is Amount of Crystalline Material Mixed Into Feces To stop Production of Gaseous Byproducts*

1. Very Soluble
2. Moderately Soluble
3. Low Solubility
CLOSED LOOP MACERATOR CONCEPT
HARDWARE FABRICATION FEASIBILITY

- Machined Air Hole Ring
- Machined Slide Valve
- Machined Receptacle
- Machined Spinner
- Formed and Welded Blades
- Machined Base
- Machined and Formed Grating
CLOSED LOOP MACERATOR CONCEPT
HARDWARE FABRICATION FEASIBILITY (CONT'D)

TBD

Filter Section
CLOSED LOOP MACERATOR CONCEPT DEVELOPMENT ITEMS

- Macerator/Separator
- Collection Bowl
- Filter Section
- Macerator Motor and Seals
- Slurry Pump
- Volume Control Reservoir
- Sensors
- Biocide Quantity and Type
- Adjustment of Flow/ΔP Characteristics of System
## CLOSED LOOP MACERATOR SYSTEM

### WEIGHT ESTIMATE SUMMARY

<table>
<thead>
<tr>
<th>Component</th>
<th>Wt (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector Vessel</td>
<td>3.1</td>
</tr>
<tr>
<td>Seat Adapter</td>
<td>0.5</td>
</tr>
<tr>
<td>Bottom Plate</td>
<td>0.5</td>
</tr>
<tr>
<td>Macerator Blades</td>
<td>0.3</td>
</tr>
<tr>
<td>Spinner</td>
<td>2.3</td>
</tr>
<tr>
<td>Seat</td>
<td>3.0</td>
</tr>
<tr>
<td>Slide Valve</td>
<td>3.0</td>
</tr>
<tr>
<td>Motor</td>
<td>3.0</td>
</tr>
<tr>
<td>Slurry Pump</td>
<td>4.0</td>
</tr>
<tr>
<td>Filter Section</td>
<td>31.2</td>
</tr>
<tr>
<td>Accumulator, Injector, Valving</td>
<td>10.0</td>
</tr>
<tr>
<td>Piping</td>
<td>10.0</td>
</tr>
<tr>
<td>Structural Supports</td>
<td>14.3</td>
</tr>
<tr>
<td>Switches, Cables, Elect. Conn.</td>
<td>2.6</td>
</tr>
<tr>
<td>Hardware Total</td>
<td>88.5</td>
</tr>
<tr>
<td>Fluid</td>
<td>93.6</td>
</tr>
<tr>
<td>Total System Wt</td>
<td>182.1</td>
</tr>
</tbody>
</table>
**WCS WEIGHT ESTIMATE SUMMARY**  
**(POUNDS)**

<table>
<thead>
<tr>
<th>System</th>
<th>Man-Days</th>
<th>Hdwe</th>
<th>Bags</th>
<th>Air</th>
<th>Liquid</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-G Skylab</td>
<td>56</td>
<td>79.4</td>
<td>17.0</td>
<td>9.1</td>
<td>0</td>
<td>105.5</td>
</tr>
<tr>
<td>Centrifugal Comp</td>
<td>56</td>
<td>112.0</td>
<td>1.5</td>
<td>14.1</td>
<td>0</td>
<td>127.6</td>
</tr>
<tr>
<td>Centrifugal Comp</td>
<td>210</td>
<td>112.0</td>
<td>1.5</td>
<td>52.9</td>
<td>0</td>
<td>166.4</td>
</tr>
<tr>
<td>Skylab Repackaged</td>
<td>210</td>
<td>110.4</td>
<td>52.3</td>
<td>24.6</td>
<td>0</td>
<td>187.3</td>
</tr>
<tr>
<td>Modified Skylab</td>
<td>210</td>
<td>85.3</td>
<td>4.0</td>
<td>7.0</td>
<td>0</td>
<td>96.3</td>
</tr>
<tr>
<td>Closed Loop Macerator</td>
<td>210</td>
<td>88.5</td>
<td>0</td>
<td>0</td>
<td>93.6</td>
<td>182.1</td>
</tr>
<tr>
<td>Existing System</td>
<td>56</td>
<td>109.0</td>
<td>1.5</td>
<td>10.1</td>
<td>0</td>
<td>120.6</td>
</tr>
<tr>
<td>Existing System</td>
<td>210</td>
<td>109.0</td>
<td>1.5</td>
<td>37.9</td>
<td>0</td>
<td>148.4</td>
</tr>
</tbody>
</table>
CLOSED LOOP MACERATOR SYSTEM

ADVANTAGES
1. Configuration is Applicable to Space Station
2. Air and Water Entrapment is More Effective Than Air Alone
3. Crew Use Time is Minimal-Similar to Conventional Toilet
4. Crew Training Time is Minimal
5. Waste is Flushed Completely Out of Sight
6. Water Continually Cleans Collection Surface During Use
7. Unit is Psychologically Very Acceptable
8. Biocide is Thoroughly Mixed with Feces to Provide Deactivation
9. No Air Loss – Closed System
10. Entire System Operates in a Cabin Pressure Environment
11. Compaction and Containment Capability are Provided by a Macerator and Filter
12. Filter Section is Self Contained and Can be Hygienically Changed Out on Orbit or Ground
13. With Removal of Filter Only, Entire Unit Can be Flushed Out on Ground
14. Use of Slide Valve Permits More Flexibility in Choice of Biocide – Scent is Isolated From Cabin Environment

DISADVANTAGES
1. A Biocide Which is Effective Yet Non-Toxic to Crew Must be Found
2. Macerator/Air Separator Requires Development
3. Filtration Section Requires Development
4. Development Cost May be High
5. System is Somewhat Complex Due to Mechanical, Electrical, and Sensing Devices
APPENDIX B

Other Semi-Final Concepts
SKYLAB REPACKAGED
CONFIGURATION
SKYLAB REPACKAGED CONFIGURATION

Valve Control

Bag Retainer

Heater

Damper

Mesh Liner

Receptacle

Heat Sealing Element

COLLECTOR

Bag

Gasket

Seat

Pressure Plate

Spring

Vacuum Valve

PROCESSOR

VEC874
SKYLAB REPACKAGED CONFIGURATION
SYSTEM SCHEMATIC
<table>
<thead>
<tr>
<th>Crew Procedure</th>
<th>Crew Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Turn on air collection system</td>
<td>2</td>
</tr>
<tr>
<td>2. Position body and restraint system</td>
<td>30</td>
</tr>
<tr>
<td>3. Perform defecation and cleanup</td>
<td>12 0</td>
</tr>
<tr>
<td>4. Remove restraint system</td>
<td>15</td>
</tr>
<tr>
<td>5. Unlatch and lift seat</td>
<td>10</td>
</tr>
<tr>
<td>6. Seal bag</td>
<td>15</td>
</tr>
<tr>
<td>7. Verify or close processor vacuum valve, wait for repressurization</td>
<td>5</td>
</tr>
<tr>
<td>8. Open processor door</td>
<td>5</td>
</tr>
<tr>
<td>9. Remove bag from collector</td>
<td>5</td>
</tr>
<tr>
<td>10. Place bag into processor</td>
<td>15</td>
</tr>
<tr>
<td>11. Close processor door</td>
<td>5</td>
</tr>
<tr>
<td>12. Open processor vacuum valve</td>
<td>3</td>
</tr>
<tr>
<td>13. Disinfect seat</td>
<td>30</td>
</tr>
<tr>
<td>14. Open clean bag dispenser</td>
<td>5</td>
</tr>
<tr>
<td>15. Install clean bag</td>
<td>15</td>
</tr>
<tr>
<td>16. Close clean bag dispenser</td>
<td>5</td>
</tr>
<tr>
<td>17. Lower seat &amp; latch</td>
<td>10</td>
</tr>
<tr>
<td>18. Turn off air collection system</td>
<td>2</td>
</tr>
</tbody>
</table>

Total time: 14 Min. 57 Sec.
SKYLAB REPACKAGED CONFIGURATION
GROUND OPERATIONS

1. Attach filter (GSE*) to vacuum line(s)
2. Start cabin ventilation fan
3. Open vacuum line(s) to atmosphere
4. Open processor door(s)
5. Remove bags, place into air-tight transport container
6. Remove spent odor/bacteria filter
7. Place filter in transport container
8. Remove transport container from orbiter
9. Clean & disinfect interior of collector, processors and vacuum system
10. Clean & disinfect exterior of WCS
11. Install fresh bag
12. Install fresh odor/bacteria filter
13. Return system to initial condition configuration
14. Remove filter (GSE) from vacuum line(s)
15. Move transport container to service area
16. Remove waste from transport container
17. Clean & store transport container

*Ground Support Equipment
SKYLAR REPACKAGED CONFIGURATION

POTENTIAL GSE REQUIREMENTS

- Biological isolation garment
- Odor/bacteria filter
- Clean up equipment:
  - Brushes
  - Wipes
  - Biocide/cleaner
  - Trash bags
- Fluid circulation and flush system (for flushing out vacuum lines and air flow system)
- Standard tools
- Transport container
SKYLAB REPACKAGED CONFIGURATION

0 Air Loss = Uses x Processor Vol x Air Density (STD Cond)

\[ \text{Air Loss} = 210 \text{ Uses} \times \frac{1.55 \text{ ft}^3}{\text{USE}} \times \frac{.0752 \text{ LB}}{\text{ft}^3} = 24.6 \text{ LB} \]

0 Bag Weight = No. of Bags x WT per Bag x Contingency Factor

(Skylab bag weighed 103.9 = .2266 LB)

\[ \text{Bag Weight} = 210 \text{ Bags} \times \frac{.2266 \text{ LB}}{\text{Bag}} \times 1.10 = 52.3 \text{ LB} \]
SKYLAB REPACKAGED CONFIGURATION
HARDWARE FABRICATION FEASIBILITY

COLLECTOR (EXISTING)

Welded Screen
Heat Formed Bag
Existing Shuttle Seat
Machined Ring With Air Holes

Welded Receptacle
Machined Flanges and Fittings

PROCESSOR (RE-CONFIGURED)

Machined Body
Machined Door

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SKYLAB REPACKAGED

ANALYSES TO BE COMPLETED
BY END OF DESIGN PHASE

- AIRFLOW: ΔP OF BAG FILTER MATERIAL
  INTERACTION OF SYSTEM COMPONENTS - CORRECT FLOWS, ETC

- EXPENDABLES: AIR LOSS (COMPLETED)
  BAGS - VOLUME, WEIGHT (COMPLETED)

- CREW TIME: CREW TIME LINES (COMPLETED)

- THERMAL: HEAT TRANSFER OF BAG MATERIAL
  MULTIPLE BAG EFFECTS ON DEACTIVATION

- STRUCTURAL: MOUNTING OF SYSTEM COMPONENTS ON ORBITER PRIMARY STRUCTURE
  STRUCTURAL INTEGRITY OF COLLECTOR AND PROCESSORS
  SYSTEM WEIGHT ESTIMATE (COMPLETED)

- MASS BALANCE: EFFECTS OF SYSTEM ON VEHICLE ORBITAL AND FLIGHT DYNAMICS

- POWER: POWER CONSUMPTION OF FAN/SEPARATOR
  POWER CONSUMPTION OF HEATER ELEMENT
## Skylab Repackaged Configuration

### Weight Estimate Summary

<table>
<thead>
<tr>
<th>Component</th>
<th>WT (LB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector Receptacle</td>
<td>1.0</td>
</tr>
<tr>
<td>Mesh Screen Liner</td>
<td>0.4</td>
</tr>
<tr>
<td>4 Processors</td>
<td>47.0</td>
</tr>
<tr>
<td>3 Storage Compartments</td>
<td>19.0</td>
</tr>
<tr>
<td>Seat</td>
<td>3.0</td>
</tr>
<tr>
<td>Structural Supports</td>
<td>14.0</td>
</tr>
<tr>
<td>Swtiches, Cables, Elect. Conn.</td>
<td>3.0</td>
</tr>
<tr>
<td>Odor/Bacteria Filter *</td>
<td>6.0</td>
</tr>
<tr>
<td>Restraint System *</td>
<td>7.0</td>
</tr>
<tr>
<td>2 Fan-Separators *</td>
<td>5.0</td>
</tr>
<tr>
<td>Hoses, Ducts *</td>
<td>5.0</td>
</tr>
<tr>
<td><strong>Hardware Total</strong></td>
<td>110.4</td>
</tr>
<tr>
<td>Bases **</td>
<td>52.3</td>
</tr>
<tr>
<td>Air **</td>
<td>24.6</td>
</tr>
<tr>
<td><strong>Total System WT</strong></td>
<td>187.3 LB</td>
</tr>
</tbody>
</table>

* Existing System Hardware

** Expendables
SKYLAB REPACKAGED CONFIGURATION
SUMMARY

ADVANTAGES
1. Storage Is Orderly – Easier Ground Changeout
2. Processing and Storage Occur in Same Container
3. Skylab Collection Method Is Proven
4. Efficient Use of Shuttle Envelope
5. Low Air Loss Due to Smaller Volume of Processor
6. Compaction and Heat Application are a Feature of Processor
7. Crew Handles Only Clean or Sealed Bags With Advanced Bag Sealing Concept
8. Utilizes Existing Fan/Separator System
9. Mechanically Simple
10. Serviceable on Orbit
11. Airflow Is Used to Contain Odor During Bag Sealing
12. Airflow Is Used to Contain Odor From Processors During Bag Insertion
13. Stowage Area for Fresh Bags Is Provided

DISADVANTAGES
1. Fecal Bag and Associated Handling, Sealing, and Outgassing are Present
2. Required Bag Stowage Space Is Large but Adequate
3. Door to Personal Hygiene Compartment May Need to be Removed and a More Compact Restraining Device Installed
4. Use of Wall Towel Restraints and Personal Hygiene Stowage Compartment May be Lost on Orbiter
5. Space Station Applicability Is Low
6. Old Fecal Bags May Have to be Touched While Inserting Newly Used Bags Into Processor
7. Crew Acceptance May be Low
MODIFIED SKYLAB
CONCEPT
MODIFIED SKYLAB CONCEPT
CREW PROCEDURES

1. Verify or close vacuum valve 1, wait for repressurization 15
2. Open slide valve 1 5
3. Turn on air collection system 2
4. Position body and restraint system 30
5. Perform defecation and clean up 12 0
6. Remove restraints 15
7. Close slide valve 1 5
8. Turn off air collection system 2
9. Open vacuum valve 1 3
10. Disinfect seat 30

Total Time 13 Min. 47 Sec.
MODIFIED SKYLAB CONCEPT
CREW PROCEDURES (CONTINUED)

BAG DISPOSAL

1. Close vacuum valve 1  
2. Close vacuum valve 2  
3. Turn on air collection system  
4. Open slide valve 1  
5. Unlatch and lift seat  
6. Seal bag  
7. Obtain push through tool  
8. Use push through tool to compact/deflate bag  
9. Open slide valve 2  
10. Push bag into return container using push through tool  
11. Close slide valve 2  
12. Turn off air collection system  
13. Install new bag in receptacle  
14. Lower seat and latch  
15. Close slide valve 1  
16. Open vacuum valve 1  
17. Open vacuum valve 2  

Total Time  2 Min. 54 Sec.

CREW TIME
Min.  Sec.
15  
20  
2  
5  
15  
15  
15  
10  
20  
5  
15  
5  
2  
15  
15  
5  
5  
5  
5  
2  
54  
112
1. Attach filter (GSE**) to vacuum line(s)
2. Vent vacuum line(s) to atmosphere
3. Open return container compartment door
4. Remove return container
5. Install lid (GSE) on return container
6. Remove spent odor/bacteria filter
7. Briefly remove lid of return container
8. Place spent filter into return container
9. Re-cap return container
10. Remove return container from orbiter
11. Clean and disinfect interior of collector and return container compartment
12. Clean and disinfect exterior of WCS
13. Install a replacement return container
14. Install a new bag in receptacle
15. Install fresh odor/bacteria filter
16. Return system to initial conditions/configuration
17. Remove filter (GSE) from vacuum line(s)
18. Transport return container to service area
19. Remove waste from return container
20. Clean and store return container for future use

*Assumes no bag in collector area upon return to earth

** Ground Support Equipment
MODIFIED SKYLAB CONCEPT
POTENTIAL GSE REQUIREMENTS

- Biological isolation garment
- Odor/bacteria filter
- Return container
- Clean up equipment
  - Brushes
  - Wipes
  - Biocide/cleaner
  - Trash bag
- Fluid circulation and flush system (for flushing out vacuum lines and air flow system)
- Standard tools
- Vacuum pump assembly (for contingency use only - to complete processing and allow examination of WCS equipment while waste is still present)
MODIFIED SKYLAB CONCEPT

\[ \text{Air Loss} = \text{Loss Due to Use} + \text{Loss Due to Bag Change (STD Cond)} \]

\[ = \text{Uses} \times \frac{\text{Vol}}{\text{Use}} \times \text{Air Density} + \text{Changes} \times \frac{\text{Vol}}{\text{Change}} \times \text{Air Density} \]

\[ = 210 \times \frac{0.34 \text{ ft}^3}{\text{Use}} \times 0.0752 \text{ lb/ft}^3 + 10 \times \frac{2.19 \text{ ft}^3}{\text{Change}} \times 0.0752 \text{ lb/ft}^3 \]

\[ = 5.4 \text{ lb} + 1.6 \text{ lb} = 7.0 \text{ lb} \]

\[ \text{Bag Weight} = \text{WT per Bag} \times \text{No. of Bags} \times \text{Contingency Factor} \]

(ESTIMATE BAG WT: 162 g per bag = .356 lb)

\[ = \frac{0.356 \text{ lb}}{\text{Bag}} \times 10 \text{ Bags} \times 1.10 = 3.92 = 4.0 \text{ lb} \]
MODIFIED SKYLAB CONCEPT
HARDWARE FABRICATION FEASIBILITY

Existing Seat
Machined Slide Valve
Machined Slide Valve and Air Hole Ring

Formed and Welded Receptacle
Drilled, Formed and Welded Liner

Formed and Welded Sheet Metal Return Container

Machined Pressure Door and Evacuable Chamber
MODIFIED SKYLAB CONCEPT

ANALYSES TO BE COMPLETED
BY END OF DESIGN PHASE

- AIRFLOW:
  - Air flow through bag filter material
  - Interaction of system components - correct flows, etc.

- EXPENDABLES:
  - Air loss (completed)
  - Bags - volume, weight (completed)

- CREW TIME:
  - Crew time lines (completed)

- THERMAL:
  - Heat transfer of bag material and receptacle/liner
  - Effect of multiple defecations on deactivation

- STRUCTURAL:
  - Mounting of system components on orbiter primary structure
  - Structural integrity of collector and evacuable areas
  - System weight estimate (completed)

- MASS BALANCE:
  - Effects of system on vehicle orbital and flight dynamics

- POWER:
  - Power consumption of fan/sePARATOR
# MODIFIED SKYLAB CONCEPT

## Weight Estimate Summary

<table>
<thead>
<tr>
<th>Component</th>
<th>WT (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector Receptacle</td>
<td>2.3</td>
</tr>
<tr>
<td>Collector Liner</td>
<td>3.2</td>
</tr>
<tr>
<td>Upper Slide Valve</td>
<td>3.0</td>
</tr>
<tr>
<td>Lower [Double] Slide Valve</td>
<td>6.0</td>
</tr>
<tr>
<td>Seat</td>
<td>3.0</td>
</tr>
<tr>
<td>Return Container</td>
<td>6.1</td>
</tr>
<tr>
<td>Storage Chamber</td>
<td>26.2</td>
</tr>
<tr>
<td>Structural Supports</td>
<td>10.0</td>
</tr>
<tr>
<td>Switches, Cables, Elect. Conn.</td>
<td>2.5</td>
</tr>
<tr>
<td>Odor/Bacteria Filter*</td>
<td>6.0</td>
</tr>
<tr>
<td>Restraint System*</td>
<td>7.0</td>
</tr>
<tr>
<td>2 Fan/Separators*</td>
<td>5.0</td>
</tr>
<tr>
<td>Hoses, Ducts*</td>
<td>5.0</td>
</tr>
<tr>
<td><strong>Hardware Total</strong></td>
<td><strong>85.3</strong></td>
</tr>
<tr>
<td>Bags**</td>
<td>4.0</td>
</tr>
<tr>
<td>Air**</td>
<td>7.0</td>
</tr>
<tr>
<td><strong>Total System Weight</strong></td>
<td><strong>96.3</strong></td>
</tr>
</tbody>
</table>

* Existing System Hardware

**Expendables
MODIFIED SKYLAB CONCEPT SUMMARY

Advantages
1. Periodic Bag Ejection Removes Waste From Cabin
2. Utilizes Existing Hardware Concepts
3. Low Air Loss During Evacuation of Collecting Chamber Between Defecations
4. Crew Operations Minimized by Extending Bag Use Period To Three Days
5. Fecal Material Deactivated by Vacuum and Heat Absorption Between Defecations
6. Serviceable On Orbit
7. Bag Push Through Done at Cabin Pressure — Not a Remote Operation
8. Space Station Applicability
9. Moderate to Low Bag Consumption
10. Utilizes Existing Fan/separator System
11. Storage/Processing Area Is Pressurized During Pass Through
12. Skylab Collection Method Is Proven
13. Airflow Is Used to Contain Odor During Pass Through
14. Crew Handles Only Clean or Sealed Bags With Advanced Bag Sealing Concept

Disadvantages
1. Fecal Material From Previous Defecations Will Be In View of Other Crew Members
2. Old Fecal Material In Bag May Obstruct Collection of New Waste
3. Fecal Bag and Associated Handling, Sealing, and Outgassing Are Present
4. Randomly Stored Bags Do Not Utilize Stowage Space Efficiently
5. Psychological Acceptance May Be Poor
APPENDIX C
SKYLAB SYSTEM DATA
Performance of Urine System

Airflow Only — 1 CFM $\Delta P(A-C) = 1.9$ in. H$_2$O $\Delta P(A-B) \approx 1$ in. H$_2$O
Urine Only — 45 ml/sec $\Delta P(A-B) \approx 1.8$ in. H$_2$O
No Flow — Max. $\Delta P(A-C) = 8$ in. H$_2$O

SKYLAB URINE/FECAL COLLECTOR
Flow Schematic
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blower/Motor Assembly (1883241)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Flow Rate (Nominal)</strong></td>
<td></td>
</tr>
<tr>
<td>Fecal</td>
<td>10.4 cfm (^1), 8.7 to 9.2 cfm (^2)</td>
</tr>
<tr>
<td>Urine</td>
<td>1.0 cfm (^1), 0.83 cfm (^2)</td>
</tr>
<tr>
<td><strong>Differential Pressure at Flow Rate</strong></td>
<td>14.0 in. H(_2)O across blower</td>
</tr>
<tr>
<td><strong>Motor Input Voltage</strong></td>
<td>24 to 30 Vdc (28 Vdc nominal)</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td></td>
</tr>
<tr>
<td>Steady Run Mode</td>
<td></td>
</tr>
<tr>
<td>Starting Transient</td>
<td>115 W (max.) (^3) (109.2 W nominal) (^2)</td>
</tr>
<tr>
<td>Locked Rotor (Current limited)</td>
<td>14 A @ 28 Vdc for 1.0 msec</td>
</tr>
<tr>
<td>Overload Protection (Circuit breaker)</td>
<td>5 A</td>
</tr>
<tr>
<td><strong>Pressure Range</strong></td>
<td></td>
</tr>
<tr>
<td>Nominal Operating Gas Inlet Pressure</td>
<td>Cabin ambient (5 psia nominal)</td>
</tr>
<tr>
<td><strong>Temperature Range</strong></td>
<td></td>
</tr>
<tr>
<td>Nominal Operating</td>
<td>58° to 90°F</td>
</tr>
<tr>
<td>Operational</td>
<td>58° to 90°F</td>
</tr>
<tr>
<td>Nonoperating (Storage)</td>
<td>0° to 140°F</td>
</tr>
<tr>
<td><strong>Operational Life</strong></td>
<td>250 hr</td>
</tr>
<tr>
<td><strong>Odor Removal Assembly (Charcoal 'bed)'</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Charcoal Weight</strong></td>
<td>613 gm</td>
</tr>
<tr>
<td><strong>Flow Rate Across Bed</strong></td>
<td>11.4 cfm</td>
</tr>
<tr>
<td><strong>Differential Pressure at Flow Rate</strong></td>
<td>2 in. H(_2)O</td>
</tr>
<tr>
<td><strong>Operating Pressure Range</strong></td>
<td>Cabin ambient (5 psia nominal)</td>
</tr>
<tr>
<td><strong>Centrifugal Urine Separator Assembly (CUSA)</strong> (1887234)</td>
<td>10 units (5 with motors) (5 without motors)</td>
</tr>
<tr>
<td><strong>Separator</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Flow Rate</strong></td>
<td></td>
</tr>
<tr>
<td>Urine (Through inlet)</td>
<td>0 to 45 ml/sec</td>
</tr>
<tr>
<td>Urine (Through outlet with 3 (\geq) 0.25 in. H(_2)O AP)</td>
<td>5 ml/sec (nominal)</td>
</tr>
<tr>
<td>Gas (Cabin air @ 5 psia)</td>
<td>1 cfm (^1), 1.03 to 1.195 cfm (^2) (seated) (\star), 1.145 to 1.150 cfm (^2) (unseated) (\star)</td>
</tr>
<tr>
<td><strong>Pressure Range</strong></td>
<td>Cabin ambient</td>
</tr>
<tr>
<td>Operating</td>
<td>37.3 psid</td>
</tr>
<tr>
<td>Burst</td>
<td>52.0 psid</td>
</tr>
</tbody>
</table>

\(^{1}\) Drawers 1, 2, and 3 tested at 28 Vdc, 14.7 psia, and 70°F.

\(^{2}\) Drawers 1, 2, and 3 tested at 28 Vdc and \(\gamma = 0.0271 \text{ lb/ft}^3\).

\(^{3}\) *SPECIFICATION

\(^{\star}\) *TEST

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Table 3-95. Fecal/Urine Collection Module Characteristics (Continued)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urine Inlet to Plenum Differential (Blower running)</td>
<td></td>
</tr>
<tr>
<td>With Astronaut Standing (Urine inlet closed)</td>
<td>14.0 in. H₂O (min.)</td>
</tr>
<tr>
<td>With Astronaut Seated on Fecal Collector (Urine inlet closed)</td>
<td>12.2 in. H₂O (min.)</td>
</tr>
<tr>
<td>With Astronaut Seated (Urine inlet open)</td>
<td>1.9 in. H₂O (min.)</td>
</tr>
<tr>
<td>Temperature Range</td>
<td></td>
</tr>
<tr>
<td>Urine Inlet</td>
<td>98.6°F</td>
</tr>
<tr>
<td>Gas Inlet</td>
<td>58°F to 90°F</td>
</tr>
<tr>
<td>Separator Capacity</td>
<td></td>
</tr>
<tr>
<td>Range (Micturition input)</td>
<td>35 to 600 ml</td>
</tr>
<tr>
<td>Nominal</td>
<td>350 ml*</td>
</tr>
<tr>
<td>Quantity of Gas in Discharged Liquid</td>
<td>1%/day (max.)</td>
</tr>
<tr>
<td>Quantity of Liquid in Discharged Gas</td>
<td>0.0</td>
</tr>
<tr>
<td>Leakage Rate</td>
<td></td>
</tr>
<tr>
<td>Gas Liquid</td>
<td>1.4 scs (max.)</td>
</tr>
<tr>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Electrical</td>
<td></td>
</tr>
<tr>
<td>Voltage</td>
<td>24 to 30 Vdc (28 Vdc nominal)</td>
</tr>
<tr>
<td>Power</td>
<td>28 W</td>
</tr>
<tr>
<td>Locked Rotor</td>
<td>3 A @ 28 Vdc</td>
</tr>
<tr>
<td>Overload Protection (Circuit breaker)</td>
<td>3 A</td>
</tr>
<tr>
<td>Motor Speed @ 28 Vdc</td>
<td>15,000 rpm</td>
</tr>
<tr>
<td>Drum Speed (Dry)</td>
<td></td>
</tr>
<tr>
<td>@ 24 Vdc (Drawers 1, 2, and 3)</td>
<td>205, 198, 184 rpm</td>
</tr>
<tr>
<td>@ 26 Vdc (Drawers 1, 2, and 3)</td>
<td>228, 218, 208 rpm</td>
</tr>
<tr>
<td>@ 28 Vdc (Drawers 1, 2, and 3)</td>
<td>250, 239, 229 rpm</td>
</tr>
<tr>
<td>@ 30 Vdc (Drawers 1, 2, and 3)</td>
<td>271, 258, 250 rpm</td>
</tr>
<tr>
<td>Time Delay Between Uses</td>
<td>5 min (min.)</td>
</tr>
<tr>
<td>Time Period Between Blower Motor Off and Separator Motor Off</td>
<td>4 min 59 sec to 5 min 19 sec</td>
</tr>
<tr>
<td>Filter Rating (Separator)</td>
<td>10 to 20 µ</td>
</tr>
<tr>
<td>Chiller Assembly</td>
<td></td>
</tr>
<tr>
<td>Refrigerant Loop Flow Characteristics</td>
<td>See Paragraph 3.1.2.6</td>
</tr>
<tr>
<td>Urine Sample Chilled Temperature</td>
<td>41°F to 59°F</td>
</tr>
<tr>
<td>Urine Pool Chilldown Time to 59°F</td>
<td>2 hr (max.)</td>
</tr>
<tr>
<td>Bladder Assembly (1889060)</td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>4000 ml (min.)</td>
</tr>
<tr>
<td>Bladder Internal Pressure (Pressure plate)</td>
<td>0.5 to 4.0 in. H₂O</td>
</tr>
<tr>
<td>Umbrella Valve Cracking Pressure (Urine inlet)</td>
<td>0.5 in. H₂O</td>
</tr>
</tbody>
</table>

*Filling above 700 ml results in degraded flow.

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<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Range</td>
<td></td>
</tr>
<tr>
<td>Nonoperating</td>
<td>-40°F to 160°F</td>
</tr>
<tr>
<td>Operational</td>
<td>58°F to 90°F</td>
</tr>
<tr>
<td>Leakage (Max.)</td>
<td></td>
</tr>
<tr>
<td>Shut-off Valve (Bladder pressurized with ( \text{GN}_2 ) to ( \Delta P ) of 12 ±2 in. ( \text{H}_2\text{O} ))</td>
<td>None detectable at 12 ±2 in. ( \text{H}_2\text{O} ) ( \Delta P ) of ( \text{GN}_2 )</td>
</tr>
<tr>
<td>Umbrella Check Valve</td>
<td></td>
</tr>
<tr>
<td>Collection Capability</td>
<td></td>
</tr>
<tr>
<td>Maximum Collection Capability (Using blowermotor)</td>
<td></td>
</tr>
<tr>
<td>Maximum Initial Preparation Duration</td>
<td></td>
</tr>
<tr>
<td>Maximum Duration of Each Complete Cycle (including preparation and initiation of processing but excluding elimination)</td>
<td></td>
</tr>
<tr>
<td>Normal Collection Unit Usage</td>
<td></td>
</tr>
<tr>
<td>Cycles/Day/Man</td>
<td></td>
</tr>
<tr>
<td>Daily Duration (3 crewmen)</td>
<td></td>
</tr>
<tr>
<td>Operational Life</td>
<td></td>
</tr>
<tr>
<td>Maximum Time for Removal and Replacement of 3 Urine Collection and Sample Bags and Preparation for Freezing</td>
<td></td>
</tr>
<tr>
<td>24-hr Urine Pooling Volume Measurement Accuracy</td>
<td></td>
</tr>
<tr>
<td>Mechanical Method (On-orbit)</td>
<td>+15%</td>
</tr>
<tr>
<td>Lithium Chloride (LiCl) Method (on ground after sample return)</td>
<td>+22%</td>
</tr>
</tbody>
</table>

Table 3-95. Fecal/Urine Collection Module Characteristics (Continued)
Table 3-96. Waste Processor Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processor (1B79136)</td>
<td></td>
</tr>
<tr>
<td>Processing Chambers (Drawers)</td>
<td>6</td>
</tr>
<tr>
<td>Processing Chamber Volume</td>
<td>304 in³</td>
</tr>
<tr>
<td>Processing Operating Temperature</td>
<td>105 ±5°F, 109.6°, 106.9°, 104.8°, 108.8°, 106.2°, 105.4°F (Drawers 1 through 6, respectively, @ 28 Vdc)</td>
</tr>
<tr>
<td>Input Voltage Range</td>
<td>24 to 30 Vdc (28 Vdc nominal)</td>
</tr>
<tr>
<td>Power Rating</td>
<td></td>
</tr>
<tr>
<td>Heater (Drawers 1 through 6)</td>
<td>93.5 W @ 28 Vdc, 81.2 to 81.8 W</td>
</tr>
<tr>
<td>Heater Controller/Sensor</td>
<td>2.5 W</td>
</tr>
<tr>
<td>Timer</td>
<td>2.1 W</td>
</tr>
<tr>
<td>Timer Delay Relay</td>
<td></td>
</tr>
<tr>
<td>During First 15-min Processor Operation</td>
<td>1.0 W</td>
</tr>
<tr>
<td>After 15-min Processor Operation</td>
<td>0.4 W</td>
</tr>
<tr>
<td>Overload Protection (Circuit breaker)</td>
<td>5.0 A</td>
</tr>
<tr>
<td>Vacuum Line Flow Rate</td>
<td>400 gm/hr @ 0.015 psid and 50° to 105°F</td>
</tr>
<tr>
<td>Over-Temperature Control Circuit</td>
<td></td>
</tr>
<tr>
<td>Opens</td>
<td>165 ±5°F*</td>
</tr>
<tr>
<td>Closes</td>
<td>145 ±5°F</td>
</tr>
<tr>
<td>Timer Range (Manually adjustable and set as a function of sample weight, automatic shutoff at end of selected drying cycle)</td>
<td>0 to 20 hr</td>
</tr>
<tr>
<td>Temperature Range</td>
<td></td>
</tr>
<tr>
<td>Operational</td>
<td>58°F to 90°F</td>
</tr>
<tr>
<td>Nonoperating</td>
<td>-40°F to 160°F</td>
</tr>
<tr>
<td>Operational Life</td>
<td>280 heating cycles/processor</td>
</tr>
<tr>
<td>Processed Waste Volume/Jump</td>
<td>0.176 ft³</td>
</tr>
<tr>
<td>Waste Processor Exhaust Pressure (Vacuum vent valve open)</td>
<td>0.0005 to 0.06 psia</td>
</tr>
<tr>
<td>Vent Screen Mesh Opening</td>
<td>0.062 in.</td>
</tr>
</tbody>
</table>

*The heater and timer stops, showing required drying time remaining.

SPECIFICATION = S
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<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processor Control Valve (1878648)</td>
<td>1 per processor</td>
</tr>
<tr>
<td>Flow Rate</td>
<td>2.0 in. H₂O aP ≤ 5.5 scfm chamber to vacuum flow</td>
</tr>
<tr>
<td>Nominal Pressure Range</td>
<td>0 to 6 psid</td>
</tr>
<tr>
<td>Proof</td>
<td>39 °-0 psid</td>
</tr>
<tr>
<td>Burst</td>
<td>65 psid</td>
</tr>
<tr>
<td>Temperature Range</td>
<td>45° to 90°F</td>
</tr>
<tr>
<td>Nonoperating</td>
<td>45° to 105°F</td>
</tr>
<tr>
<td>Operational</td>
<td>55° to 105°F</td>
</tr>
<tr>
<td>Flow Media</td>
<td>20 in lb (max.)</td>
</tr>
<tr>
<td>Handle Torque (Manual)</td>
<td></td>
</tr>
<tr>
<td>Leakage</td>
<td></td>
</tr>
<tr>
<td>Internal at 6 °+2 psid G₂₁</td>
<td>&lt;0.6 scfm</td>
</tr>
<tr>
<td>External at 6 °+2 psid G₂₁</td>
<td>&lt;0.1 scfm</td>
</tr>
<tr>
<td>Pressure Indicator Range</td>
<td>0 to 0.2 psia</td>
</tr>
</tbody>
</table>
Fecal Processor Power Requirements

- 3 Defecations / day total
- 200 gm/defecation average
- 300 gm/defecation maximum
- 8.5 hours required to process 200 gm at 105°F heater temperature
- 10.5 hours required to process 300 gm at 105°F heater temperature
- 86 watts peak power per processor
- 35 watts average power per processor during operation
DIARRHEA PROCESSING POWER REQUIREMENTS (CONTINGENCY)

- THREE DIARRHEA DEFECATIONS/WEEK
- 1000 CC/WEEK
- 200 CC/DEFECATION MINIMUM
- 300 CC/DEFECATION AVERAGE
- 500 CC/DEFECATION MAXIMUM
- 13.7 HOURS REQUIRED TO PROCESS 200 CC AT 105°F HEATER TEMPERATURE
- 18.2 HOURS REQUIRED TO PROCESS 300 CC AT 105°F HEATER TEMPERATURE
- 31.2 HOURS REQUIRED TO PROCESS 500 CC AT 105°F HEATER TEMPERATURE
- 86 WATTS PEAK POWER PER PROCESSOR
- 30 WATTS AVERAGE POWER PER PROCESSOR DURING OPERATION
VOMITUS PROCESSING POWER REQUIREMENTS (CONTINGENCY)

3 VOMITUS COLLECTIONS PER WEEK
1000 CC/WK
200 CC MINIMUM
300 CC NOMINAL
500 CC MAXIMUM

8.1 HOURS REQUIRED TO PROCESS 200 CC AT 105°F HEATER TEMPERATURE
11.7 HOURS REQUIRED TO PROCESS 300 CC AT 105°F HEATER TEMPERATURE
27.0 HOURS REQUIRED TO PROCESS 500 CC AT 105°F HEATER TEMPERATURE

86 WATTS PEAK POWER PER PROCESSOR
35 WATTS AVERAGE POWER PER PROCESSOR DURING OPERATION
<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity onboard at launch</th>
<th>First manned period</th>
<th>Second manned period</th>
<th>Third manned period</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Expected usage</td>
<td>Actual usage</td>
<td>Total remaining</td>
<td>Expected usage</td>
</tr>
<tr>
<td>Fecal bags</td>
<td>465</td>
<td>84</td>
<td>48</td>
<td>417</td>
<td>160</td>
</tr>
<tr>
<td>Contingency fecal bags</td>
<td>185</td>
<td>*</td>
<td>1</td>
<td>184</td>
<td>*</td>
</tr>
<tr>
<td>Urine collection bags</td>
<td>432</td>
<td>84</td>
<td>75</td>
<td>360</td>
<td>168</td>
</tr>
<tr>
<td>Urine sample bags</td>
<td>375</td>
<td>66</td>
<td>63</td>
<td>312</td>
<td>132</td>
</tr>
<tr>
<td>One-half urine sample bags</td>
<td>125</td>
<td>18</td>
<td>21</td>
<td>104</td>
<td>36</td>
</tr>
<tr>
<td>MISSION DURATION</td>
<td></td>
<td>28 DAYS</td>
<td>59 DAYS</td>
<td>84 DAYS</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX D
SYSTEM REQUIREMENTS
DEFINITION DOCUMENT
(CONTAINED IN OTHER BOOKLET)
APPENDIX E

LAYOUTS OF WCS DESIGN CONCEPTS