ALSSAT DEVELOPMENT STATUS AND ITS APPLICATIONS IN TRADE STUDIES

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ABSTRACT

The development of the Advanced Life Support (ALS) Sizing Analysis Tool (ALSSAT) using Microsoft® Excel was initiated by the Crew and Thermal Systems Division (CTSD) of Johnson Space Center (JSC) in 1997 to support the ALS and Exploration Offices in Environmental Control and Life Support System (ECLSS) design and studies. It aids the user in performing detailed sizing of the ECLSS based on suggested default values or user inputs for different combinations of the ALS regenerative system technologies (Ref. 1, 2). This analysis tool will assist the user in performing ECLSS preliminary design and trade studies as well as system optimization efficiently and economically. Since ALSSAT's latest publication in ICES 2001 (Ref. 1) describing the development of ALSSAT with its Air Revitalization Subsystem (ARS), Water Management Subsystem (WMS), and Biomass Subsystem (Biomass) mass balance sheets, ALSSAT has been expanded to include mass balance and sizing models for the remaining three ALS subsystems, namely, the Solid Waste Management Subsystem (SWMS), the Food Management Subsystem (FMS), and the Thermal Control Subsystem (TCS). The external interfaces, including the Extravehicular Activities (EVA) and Human Accommodations (HA), were implemented into ALSSAT in 2002. The overall mass balance sheet, which integrates the six ALS subsystems and the external interfaces applicable to the ECLSS, was also developed. In 2003, ALSSAT was upgraded to include the consideration of redundancy and contingency options in the ECLSS, as well as more ALS regenerative technology selections. ALSSAT has been used for the Metric Calculation for FY02 and FY03 (Ref. 3). Several trade studies were conducted in 2003. The analytical results will be presented in this paper.

INTRODUCTION

Human exploration missions to Mars will be costly for a long mission duration if resources such as clean air, water, and food for life support have to be stored and transported from Earth. It becomes a necessity for the space exploration program to develop an optimum regenerative advanced life support system for resource regeneration.

Although numerous physical-chemical processes and biological regenerative processes for space applications have been developed for air reclamation, potable water reclamation, and human waste processing (Ref. 6-26), the process of selecting an optimum regenerative ALS system without the aide of a powerful analysis tool will be time-consuming and costly. JSC Crew and Thermal System Division initiated the development of ALSSAT using a Microsoft® Excel spreadsheet program (Ref. 1) in 1997.

ALSSAT has been constantly upgraded to update the equipment sizing data, to improve its calculation methods, and for the addition of new technologies whenever data become available.

Since ALSSAT's publication by ICES in 2001 (Ref. 1), ALSSAT was expanded to include the SWMS, the FMS, the TCS, and the External Interfaces directly related to the ECLSS, including the EVA and HA. Equivalent System Mass (ESM) calculations, a standard measure for trade studies of the ALS system defined by the System Integration, Modeling, and Analysis Project (SIMA), were also implemented. The Overall Mass balance sheet integrating the six ALS subsystems and the external interfaces applicable to the ECLSS was developed. The consideration of redundancy and contingency options in the ECLSS was also implemented into ALSSAT.

More ALS regenerative technology selections were added to ALSSAT in order to support the FY02 and FY03 Metric calculations. Trade studies were conducted using ALSSAT. Some of the evaluation results are included in this paper.

ALSSAT DEVELOPMENT STATUS UPDATE

The relationship describing the linkages between ALSSAT's different modules, including the Main Module, Integration Module, Mass Balance Module, Sizing Module, User Interface Module, Data Handling Module, and Result Presentation Module, is included in Reference 1.

Reference 1 also includes a detailed description of the ALSSAT model and its structure.

Figure 1 shows ALSSAT's current structure with data flow in between the different modules.

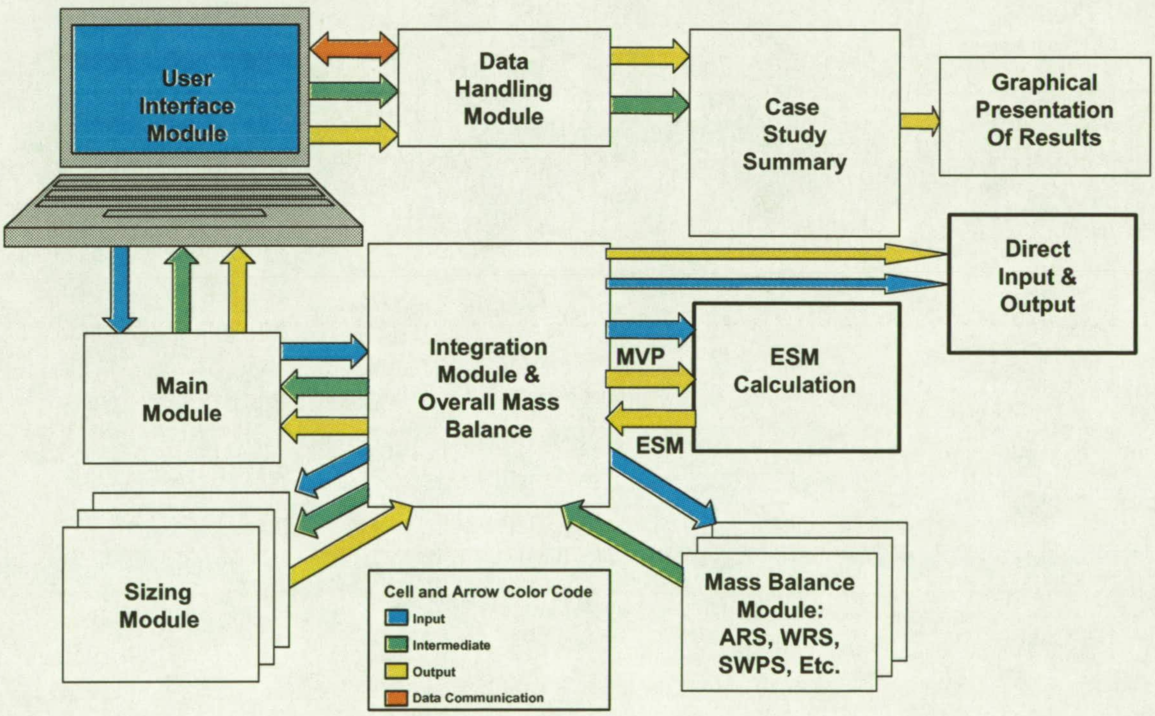


Figure 1. Current Structure of ALSSAT

A Direct Input/Output worksheet was developed to show the instantaneous calculation results of changes made to the current case. It can be used for parametric study without going through the whole series of data input once the desired data has been entered.

Sizing models for different regenerative technologies included in ALSSAT were constantly upgraded to improve the calculation accuracies. For example, the original baseline nominal capacity (BNC) for all regenerative subsystem sizing data in ALSSAT was that of a four-person load. The improved ISS WRS sizing data was designed based on treating wastewater generated by a 4-to-7-person load. Logic has been implemented into ALSSAT so that the equipment sizing result will remain the same if the wastewater processing rate falls in between the minimum and maximum BNC instead of scaling it up or down based on the original BNC.

Assumptions used in all mass balance and sizing calculations were specified and included as comments within individual Excel® cells to assist in traceability purposes.

Detailed upgrades of the AMS, WMS, and Biomass, and the inclusion of the SWMS, the TCS, the FMS, the EVA, the HA, and the ESM calculation worksheets, are depicted in the following sections.

Air Management Subsystem (AMS) (Ref. 27-36)

The AMS mass balance sheets and block flow diagrams were redesigned using the format widely accepted in the chemical industry for process design.

The newly developed mass balance sheets are self-explanatory and easy to maintain. The mass balance sheets are summarized in one worksheet that replaces the original 21 mass balance worksheets developed in 1999.

The Carbon Dioxide and Moisture Removal Subsystem (CMRS) and Electrochemical CO_2 Removal Technology (EDC) were added to CO_2 removal technology option list. The CO_2 removal technologies now available in ALSSAT include the 4-Bed Molecular Sieve (4BMS), Solid Amine Vacuum Desorption (SAVD), CMRS, EDC, and the Lithium Hydroxide (LiOH) CO_2 removal technologies.

Individual block flow diagrams and mass balance sheets were developed for the AMS using different CO_2 removal technologies. They were developed separately for the ease of maintenance and future updates.

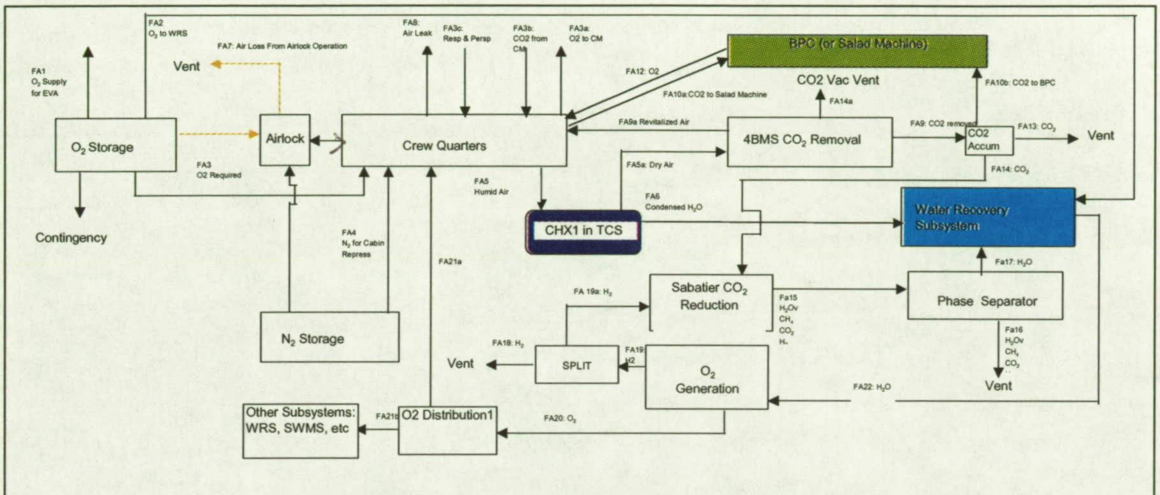
The AMS Block Flow Diagram (BFD) shows the relationship of the secondary subsystems included in the AMS Subsystem and how the AMS and its secondary subsystems are directly and indirectly related to the other ALS subsystems. The inlet and outlet streams of each subsystem are clearly defined and labeled with stream numbers. The mass balance sheet, a summary of the stream properties, was developed in conjunction with the block flow diagram. Stream properties, such as mass flow rates of all chemical species for a certain stream (e.g. FA1), are included in stream "FA1" column of the mass balance sheet. The mass balance sheet also shows the source block and destination block that the stream is flowing from and to inside the BFD.

The AMS BFD and mass balance sheet for a specific mission scenario are presented in Figures 2 and 3, respectively.

Figure 2 is the AMS BFD with 4BMS as its CO_2 removal technology, Sabatier reaction as its CO_2 Reduction technology, and Solid Polymer Electrolysis (SPE) as its Oxygen Generation Subsystem (OGS) technology.

Figure 3 is the AMS mass balance sheet developed in conjunction with the BFD shown in Figure 2. The AMS mass balance sheet cannot be displayed/fitted into one single page; therefore, it is shown in four sections as labeled. Please refer to Reference 5 for further details.

Figure 4 shows the ARS mass balance summary table. The table further summarizes the resources required that are not included in the closed loop regenerative system due to their non-daily consumption (e.g. air for the cabin repress) and the resources required for contingency. The total O_2 and N_2 to be stored and transported for the mission are calculated. The amount of N_2 and O_2 to be brought up the space will be passed to the corresponding sizing worksheet for sizing the storage tanks.



Block Flow Diagram of ARS Using 4BMS CO2 Removal and Sabatier Reduction

Figure 2. Block Flow Diagram of the ARS using 4BMS CO2 Removal and Sabatier Reduction

4BMS for CO2 Removal Calculation Procedure presented by step number		(0)	(0)	(1)	(2)	(3)	(10) for open loop system	(20)	(4)-0
Stream Name:		O_2 Supply to EVA	O_2 to WRS	Metabolic O2	CO2 Generated	Resp & Persp	O_2 Req'd (1)	N2 Req'd (1)	Dry Air Basis
Stream No.:		FA1 (kg/day)	FA2 (kg/day)	FA3a (kg/day)	FA3b (kg/day)	FA3c (kg/day)	FA3 (kg/day)	FA4 (kg/day)	Calculation only
From:		O_2 stor	O_2 stor	Crew Quarter	CM	CM	O_2 stor	N_2 stor	Crew Quarter
To:		EVA	WRS	CM	Crew Quarter	Crew Quarter	Crew Quarter	Crew Quarter	Crew Quarter
	MW (kg/kmol)		From Overall Mass						
O_2 Mass Flow, kg/day	32	0.0000	0.0000	5.0100	0.0000	0.0000	0.0000	0.0000	231.8989
N_2 Mass Flow, kg/day	28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1527	372.4808
CO_2 Mass Flow, kg/day	44	0.0000	0.0000	0.0000	5.9880	0.0000	0.0000	0.0000	5.9880
H_20 Mass Flow, kg/day	18	0.0000	0.0000	0.0000	0.0000	13.6620	0.0000	0.0000	0.0000
H_2gas Mass Flow, kg/day	2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CH_4 Mass Flow, kg/day	16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C Mass Flow, kg/day	12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total Mass Flow, kg/day		0.0000	0.0000	5.0100	5.9880	13.6620	0.0000	0.1527	610.3677
Total Mass per mission		0.0000	0.0000	3006.0000	3592.8000	8197.2000	0.0000	91.6404	366220.6364
O_2 Molar Flow (kmol/day)		0.0000	0.0000	0.1566	0.0000	0.0000	0.0000	0.0000	7.2468
N_2 Molar Flow (kmol/day)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0055	13.3029
CO_2 Molar Flow (kmol/day)		0.0000	0.0000	0.0000	0.1361	0.0000	0.0000	0.0000	0.1361
H_20 Molar Flow (kmol/day)		0.0000	0.0000	0.0000	0.0000	0.7590	0.0000	0.0000	0.0000
H_2gas Molar Flow (kmol/day)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CH_4 Molar Flow (kmol/day)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C molar flow (kmol/day)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total Molar Flow, kmole/day		0.0000	0.0000	0.1566	0.1361	0.7590	0.0000	0.0055	20.6858

Figure 3.1 Mass Balance Sheet of the AMS (Part 1)

4BMS for CO2 Removal Calculation Procedure presented by step number	(5)-1	(5)-2	(6)	(7)	(9)	(0)	(8)-1	(0)	(0)
Stream Name:	Humid air	Dry Air	H_2O condensate	Air leak	Revitalized air	CO_2 to Salad Machine	Net CO_2 Removal	CO_2 to BPC	O2 from BPC
Stream No.:	FA5 (kg/day)	FA5a (kg/day)	FA6 (kg/day)	FA8 (kg/day)	FA9a (kg/day)	FA10a (kg/day)	FA9 (kg/day)	FA10b (kg/day)	FA12 (kg/day)
From:	Crew Quarter	CHX1 in TCS	CHX1 in TCS	Crew Quarter	CO_2 removal	CO2 Accum	BMS CO2 removal	CO2 Accum	BPC Chamber
To:	CHX1 in TCS	CO2 Removal	WRS	Atmosphere	Crew Quarter	BPC (Salad Machine)	CO2 Accum	BPC Chamber	Crew Quarter
									From overall balance
O_2 Mass Flow, kg/day	231.8989	231.8989	0.0000	0.0008	231.8557	0.0000	0.0433	0.0000	0.0294
N_2 Mass Flow, kg/day	372.4808	372.4808	0.0000	0.0014	372.3294	0.0000	0.1514	0.0000	0.0000
CO_2 Mass Flow, kg/day	5.9472	5.9472	0.0000	0.0000	0.0000	0.0408	5.6498	0.0000	0.0000
H_2O Mass Flow, kg/day	13.6620	0.0000	13.6620	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2gas Mass Flow, kg/day	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CH_4 Mass Flow, kg/day	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C Mass Flow, kg/day	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total Mass Flow, kg/day	623.9889	610.3269	13.6620	0.0022	604.1851	0.0408	5.8445	0.0000	0.0294
Total Mass per mission	374393.3564	366196.1564	8197.2000	1.3150	362511.0550	24.4800	3506.6854	0.0000	17.6400
							Need to check w FJ on CO2 removal		
O_2 Molar Flow (kmol/day)	7.2468	7.2468	0.0000	0.0000	7.2455	0.0000	0.0014	0.0000	0.0009
N_2 Molar Flow (kmol/day)	13.3029	13.3029	0.0000	0.0000	13.2975	0.0000	0.0054	0.0000	0.0000
CO_2 Molar Flow (kmol/day)	0.1352	0.1352	0.0000	0.0000	0.0000	0.0009	0.1284	0.0000	0.0000
H_2O Molar Flow (kmol/day)	0.7590	0.0000	0.7590	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2gas Molar Flow (kmol/day)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CH_4 Molar Flow (kmol/day)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C molar flow (kmol/day)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total Molar Flow, kmole/day	21.4439	20.6849	0.7590	0.0001	20.5430	0.0009	0.1352	0.0000	0.0009

Figure 3.2 Mass Balance Sheet of the AMS (Part 2)

4BMS for CO2 Removal Calculation Procedure presented by step number	(15)	(14)	(8)-0	(16)	(18)	(17)	(13)	(12)	(11)
Stream Name:	CO_2 vent	CO_2	CO2 Vac Vent	CO2 Redx Prod	Redx Prod Vent	H_2O from CRS to WRS	H_2 vent	H2 to CO2 Red	H_2 from OGS
Stream No.:	FA13 (kg/day)	FA14 (kg/day)	FA14a (kg/day)	FA15 (kg/day)	FA16 (kg/day)	FA17 (kg/day)	FA18 (kg/day)	FA19a (kg/day)	FA19 (kg/day)
From:	CO2 Accum	CO2 Accum	CO_2 removal	CO2 red	Phase Sep.	Phase Sep.	SPLIT	SPLIT	OGS
To:	Atmosphere	CO_2 red	Space	Phase Sep./intermediate Step	Atmosphere	WRS	Atmosphere	CO2 Red	SPLIT
O_2 Mass Flow, kg/day	0.0168	0.0264	0.0000	0.0264	0.0264	0.0000	0.0000	0.0000	0.0000
N_2 Mass Flow, kg/day	0.0588	0.0926	0.0000	0.0926	0.0926	0.0000	0.0000	0.0000	0.0000
CO_2 Mass Flow, kg/day	2.1954	3.4545	0.2974	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O Mass Flow, kg/day	0.0000	0.0000	0.0000	2.8264	0.0000	2.8264	0.0000	0.0000	0.0000
H_2gas Mass Flow, kg/day	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6281	0.6281
CH_4 Mass Flow, kg/day	0.0000	0.0000	0.0000	1.2562	1.2562	0.0000	0.0000	0.0000	0.0000
C Mass Flow, kg/day	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total Mass Flow, kg/day	2.2710	3.5735	0.2974	4.2016	1.3752	2.8264	0.0000	0.6281	0.6281
Total Mass per mission	1362.5959	2144.0895	178.4160	2520.9415	825.1075	1695.8340	0.0000	376.8520	376.8520
O_2 Molar Flow (kmol/day)	0.0005	0.0008	0.0000	0.0008	0.0008	0.0000	0.0000	0.0000	0.0000
N_2 Molar Flow (kmol/day)	0.0021	0.0033	0.0000	0.0033	0.0033	0.0000	0.0000	0.0000	0.0000
CO_2 Molar Flow (kmol/day)	0.0499	0.0785	0.0068	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O Molar Flow (kmol/day)	0.0000	0.0000	0.0000	0.1570	0.0000	0.1570	0.0000	0.0000	0.0000
H_2gas Molar Flow (kmol/day)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3140	0.3140
CH_4 Molar Flow (kmol/day)	0.0000	0.0000	0.0000	0.0785	0.0785	0.0000	0.0000	0.0000	0.0000
C molar flow (kmol/day)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total Molar Flow, kmole/day	0.0525	0.0826	0.0068	0.2397	0.0826	0.1570	0.0000	0.3140	0.3140

Figure 3.3 Mass Balance Sheet of the AMS (Part 3)

4BMS for CO2 Removal Calculation Procedure presented by step number	(10)-2 Closed	(10)-1 for closed system	(19)	(0)	(0)	(10)-0	(10)-0	(21)	(22)
Stream Name:	O2 from OGS	O2 from OGS Distribution	Potable H2O for OGS	Clean Air for WAD	Used Air Return from SWMS	O2 Req'd (2)	N2 Req'd (2)	O2 Req'd for Open System	N2 Req'd (3)
Stream No.:	FA20 (kg/day)	FA21a (kg/day)	FA22 (kg/day)			FA21b			
From:	OGS	OGS Distributi	WRS	AMS	SWMS	O2 storage/OGS	N2 Storage	O2 Storage	N2 Storage
To:	OGS Distribution	Crew Quarters	OGS	SWMS	AMS	Other Subsystem	Other Subsystem	Crew Quarter + Other Subsys	Crew Quarter + Other Subsys
O_2 Mass Flow, kg/day	5.0247	5.0247	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N_2 Mass Flow, kg/day	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1527
CO_2 Mass Flow, kg/day	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_20 Mass Flow, kg/day	0.0000	0.0000	5.6528	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2gas Mass Flow, kg/day	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CH_4 Mass Flow, kg/day	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C Mass Flow, kg/day	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total Mass Flow, kg/day	5.0247	5.0247	5.6528	0.0000	0.0000	0.0000	0.0000	0.0000	0.1527
Total Mass per mission	3014.8160	3014.8160	3391.6680	0.0000	0.0000	0.0000	0.0000	0.0000	91.6404
O_2 Molar Flow (kmol/day)	0.1570	0.1570	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N_2 Molar Flow (kmol/day)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0055
CO_2 Molar Flow (kmol/day)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_20 Molar Flow (kmol/day)	0.0000	0.0000	0.3140	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2gas Molar Flow (kmol/day)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CH_4 Molar Flow (kmol/day)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C molar flow (kmol/day)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total Molar Flow, kmole/day	0.1570	0.1570	0.3140	0.0000	0.0000	0.0000	0.0000	0.0000	0.0055

Figure 3.4 Mass Balance Sheet of the AMS (Part 4)

Stream Description	Air or N2 for EVA Activities	Air for PMA	Air for Cabin Repress	Air Loss from Waste Venting (Open Loop)	O2 for EVA, PMA, Repress, Waste Venting, etc	N2 for EVA, PMA, Repress, Waste Venting, etc.	O2 for other Subsystems (Open Loop)	N2 for other subsystems	Total O2 w/o Contingency	Total N2
	kg/mission	kg/mission	kg/mission	kg/mission	kg/mission	kg/mission	kg/mission	kg/mission	kg/mission	kg/mission
From	O2 & N2 Storage	O2 & N2 Storage	O2 & N2 Storage	Cabin					O2 Storage	N2 Storage
To:	EVA	Cabin	Cabin	Vent						
O2	717.1443	0.0000	27.1514	62.9126	807.2083	0.0000	3032.6340	0.0000	3839.8423	0.0000
N2	115.6119	0.0000	43.6111	207.0874	0.0000	366.3104	0.0000	92.2635	0.0000	458.5739
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CH4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total Mass, kg/mission	832.7562	0.0000	70.7625	270.0000	807.2083	366.3104	3032.6340	92.2635	3839.8423	458.5739

Figure 4.1 ARS Mass Balance Summary Table (Part 1)

Stream Description	N2 due contingent EVA (Airlock depress)	O2 due contingent EVA (Airlock loss)	O2 due contingent EVA (Crew Breathing)	Actual O2 due contingent EVA	Contingent O2 for crew input and cabin leakage	Total O2 for contingency	CO2 generated due Contingent EVA	Contingent CO2 Removal for crew cabin	Total O2 w/ Contingency	Total N2 w/ contingency	Total CO2 to be removed for contingency
	kg/mission	kg/mission	kg/mission	kg/mission	kg/mission	kg/mission	kg/mission	kg/mission	kg/mission	kg/mission	kg/mission
From					Additional O2				O2 Storage w/ Contingency	N2 Storage w/ Contingency	
To:											
O2	0.0000	1.0283	12.0000	10.2449	50.1084	60.3533	0.0000	0.0000	3900.1956	0.0000	0.0000
N2	1.6516	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	460.2255	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	14.3550	59.8800	0.0000	0.0000	74.2350
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CH4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total Mass, kg/mission	1.6516	1.0283	12.0000	10.2449	50.1084	60.3533	14.3550	59.8800	3900.1956	460.2255	74.2350

Figure 4.2 ARS Mass Balance Summary Table (Part 2)

When CO_2 reduction is selected by the user for recovering part of the O_2 contained in the CO_2 species through electrolysis of the H_2O, the amount of CO_2 to be reduced is based on the available amount of H_2 generated as a byproduct through the O_2 Generation Subsystem (OGS). Excess CO_2 will be dumped overboard. H_2 will not be transported for complete CO_2 reduction due to the safety concerns associated with bringing extra H_2 into space.

Ambient Temperature Catalytic Oxidizer (ATCO) was added as an option to the Trace Contaminant Control Subsystem (TCCS) for its application in short duration missions.

The sizing data in the Nitrogen and Oxygen Cryogenic Storage sizing worksheet were updated with data from the Power Reactant Storage and Distribution (PRSD) Handbook (Ref. 46) prepared by JSC/EP4. A two-tank series was assumed for contingency and redundancy sizing purposes. Based upon recommendations from members of the Vehicle Integrated Performances and Resources (VIPeR) team, sizing data for oxygen and nitrogen high-pressure gaseous storage tanks and assemblies (Ref. 47) were updated using available International Space Station (ISS) values.

Detailed assumptions for the development of the mass balance sheet can be found in the comments included in ALSSAT 3.0. (Ref. 5)

Biomass Subsystem (Ref. 5)

The Biomass Subsystem is based on the assumption that a small salad crop will be grown to supplement one of the diets listed in the Food Subsystem. It is assumed that the salad machine will be capable of producing lettuce, carrot, radish, spinach, tomato, and cabbage. The harvested vegetables will supplement the diet as salads, snacks, and steamed entrees.

The mass balance performed over the salad machine uses individual values for each of the listed crops to determine the total biomass productivity. Using biomass productivity, along with crop harvest indices, and knowing the area required for each crop allows calculation of the total edible biomass storage requirement, amount of wasted inedible biomass to be treated by the Waste Subsystem, required growth area, and estimated chamber volume. The individual average crop CO_2 removal rates, O_2 generation rates, and carbon uptakes serve to perform a gas balance. A water balance is performed using the total crop water uptake and transpiration value.

Food Management Subsystem (FMS) (Ref. 38-39)

The Food Subsystem includes four diets, each based on the original Shuttle Training Menu (STM). Options 1 is identical to the original STM and consists of beverages, fresh food items, irradiated food items, intermediate-moisture food items, natural form food items, rehydratable food items, and thermostabilized food items. Option 2 uses the STM as a menu basis but replaces certain intermediate-moisture content food items with low-moisture content food items. A third diet contains frozen foods in addition to those food types outlined under the Shuttle Training Menu. User selection includes an optional salad crop with each of these menus. The fourth option is based on the STM; however, the natural form and fresh food items have been combined to reduce the packaging wastage. The bulk packaging option automatically assumes a salad crop. The vitamin and nutrition content is similar in all diets.

Each menu option requires the use of a rehydrating unit and a convection oven. Additionally, the frozen food diet requires refrigerator/freezer units and a microwave oven. These appliances are used to calculate the Food Subsystem power contribution. Volume contributions are from the rehydrating unit, oven, refrigerators, freezers, microwaves, and food lockers.

The mass balance performed over the Food Workbook has been used in the overall mass balance to account for impacts by CO_2, O_2, water, human waste, and trash values.

Figure 5 shows the block flow diagram of the Food Subsystem.

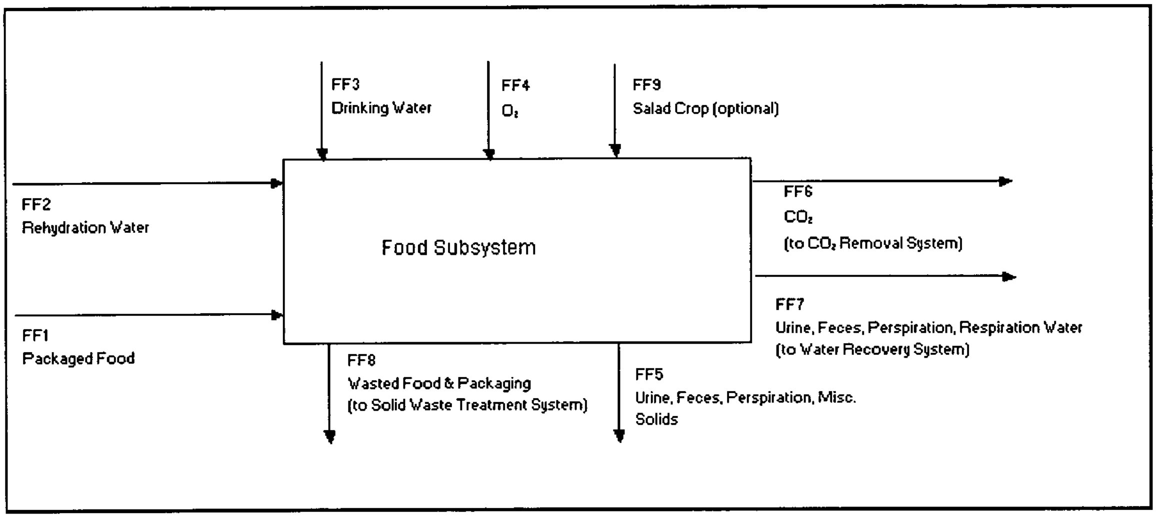


Figure 5. Block Flow Diagram of the Food Subsystem

Thermal Control Subsystem (TCS)

The Temperature and Humidity Control (THC) calculations, previously contained in the AMS, have been relocated to the TCS as suggested by the ALS community, and the Peer Review Committee during the peer review conducted in 2001.

The Internal Thermal Control Subsystem (ITCS) of the TCS workbook was integrated into ALSSAT to account for the ITCS mass, volume, and power in conjunction with the heat removal of the ECLSS.

Validation of the calculations and correlations in sizing the ITCS pump of the TCS worksheet in ALSSAT was completed. The calculation procedures and correlations adopted in the TCS workbook were reviewed and verified.

Waste Management Subsystem (SWMS) (Ref. 40)

The Waste Management Subsystem was implemented into ALSSAT with four technology options. They are Storage, Warm Air Drying (WAD), Lyophilization, and a combination of Solid Waste Treatment technologies, namely Storage+WAD+Lyophilization.

Solid waste streams considered in ALSSAT include the plant biomass, paper/wipes/tissues, filters, miscellaneous dry waste, disposable dirty clothes from crew quarter, packaging material from Food Subsystem, fecal waste from crew quarter, brine from the WRS, and the used Maximum Absorbency Garment (MAG) as Extravehicular Mobilitiy Unit (EMU) waste from EVA activities.

The user can select one of the technology options based on the mission scenarios.

For the Storage option, all the waste streams will be combined and sent to the waste collection station for storage.

The WAD option allows user to recover the water from the wet waste. The WAD option separates the odorless waste streams from the fecal waste, the brine and EMU waste. The odorless streams are combined and dried with dry air while the fecal waste, brine from the WRS, and EMU waste streams will be combined and treated with the TCCS before being sent to the dryer for further treatment with dry air from the blower. The wastewater recovered from the dryer is sent to the Water Management Subsystem (WMS) for purification. The dry waste will be compacted and sent to the dry waste collection station for storage.

The Lyophilization option also allows the user to recover the water from wet waste using the sublimation process. Some of the bulk mass streams will have to be shredded before being sent to the lyophilization unit for processing. The wastewater recovered from sublimation will be sent to the WMS for purification, while the dry waste will be compacted and sent for storage.

The last option used a combination of the first three technologies to treat the waste streams based upon the characteristics of the different waste streams in SWMS. It classifies the waste streams into three categories and treats them with the most appropriate technologies. The fecal waste, brine, and EMU waste are included in Category 1. They are sent to the shredder for grinding, then delivered to the lyophilization unit for treatment. The plant biomass from plant growth chamber, the waste paper from crew quarter, the wipes/tissues from crew quarter, and the packaging material from Food Subsystem are classified as Category 2. They are sent to the dryer for drying using dry air. Category 3 is the dry trash. It includes the tapes and filters from the crew quarter, miscellaneous dry trash, and disposable dirty clothes. These waste items are combined and sent to the dry trash compactor for volume reduction before being sent to the storage tank.

BFD and mass balance sheets for all four SWMS options were developed and integrated into ALSSAT.

The SWMS Master worksheet contains the BFD and mass balance sheet of the primary SWMS. They are presented in Figures 6 and 7.

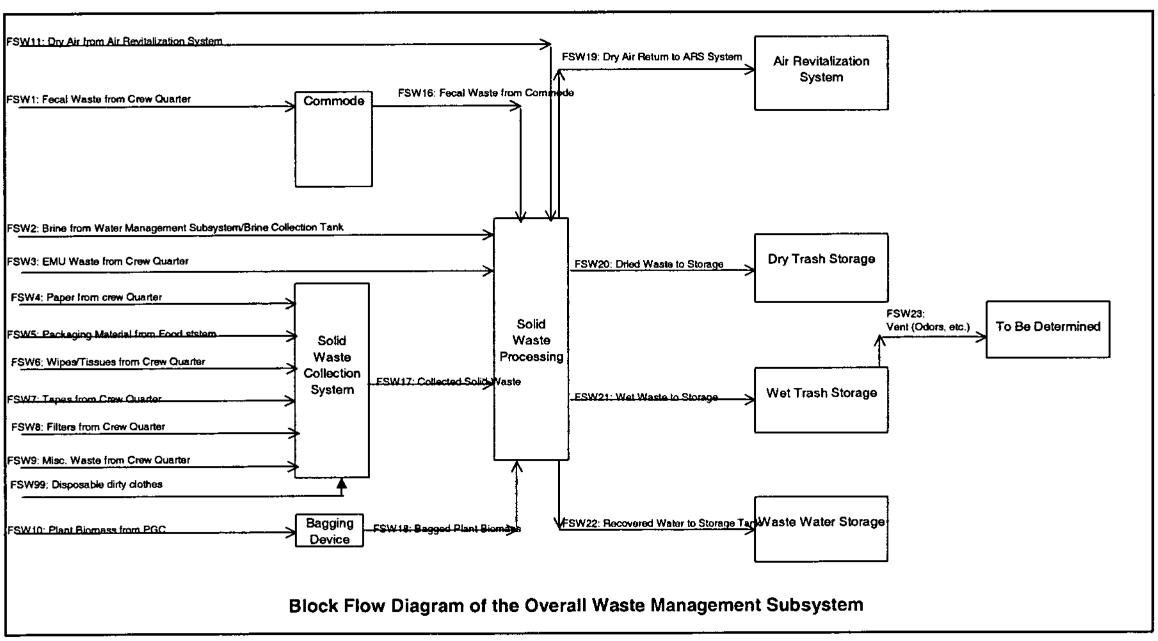


Figure 6. Block Flow Diagram for the Overall SWMS

The primary SWMS mass balance sheet shown in Figure 7 interfaces with the Integration and Overall Mass Balance Module by accepting the waste streams from the other ALS subsystems and the external interfaces. It summarizes all the solid waste streams. Based on the Solid Waste Treatment Technology selected by the user, the primary mass balance sheet transfers the waste streams to the corresponding columns in the mass balance sheet of the selected SWMS technology, i.e. Storage+WAD+Lyophilization for this sample case.

Overall Mass Balance of SWMS								
Equipment								
Stream Name	Fecal Waste	Brine	EMU Waste	Paper	Packaging Materi	Wipes/Tissues	Tapes	Filters
Stream No.	FSW1	FSW2	FSW3	FSW4	FSW5	FSW6	FSW7	FSW8
From:	Crew Quarter	WMS/Brine Tank	Crew Quarter	Crew Quarter	Food Subsystem	Crew Quarter	Crew Quarter	Crew Quarter
To:	Commode	Solid Waste Proc	Solid Waste Proc	Solid Waste Coll	Solid Waste Coll	Solid Waste Coll	Solid Waste Coll	Solid Waste Coll
Air, kg/CM-d								
H_2O Mass, kg/CM-d	0.091	0.2394	0.5500	0.0288	0.0000	0.1358	0.0000	0.0000
Solids, kg/CM-d	0.032	0.0590	0.1730	0.0407	0.3266	0.0582	0.0410	0.0543
Daily Mass Flow per crew, kg/CM-d	0.1230	0.2984	0.7230	0.0695	0.3266	0.1940	0.0410	0.0543
Total Daily Mass Flow, kg/d	0.7380	1.7904	1.6870	0.4172	1.9595	1.1640	0.2460	0.3260
Total Mass per mission, kg	**442.8000**	**1074.2400**	**1012.2000**	**250.3188**	**1175.6931**	**698.4000**	**147.6000**	**195.5880**

Figure 7.1 Primary Mass Balance Sheet of the SWMS (Part 1)

Overall Mass Balance of SWMS								
Equipment								
Stream Name	Fecal Waste	Brine	EMU Waste	Paper	Packaging Materi	Wipes/Tissues	Tapes	Filters
Stream No.	FSW1	FSW2	FSW3	FSW4	FSW5	FSW6	FSW7	FSW8
From:	Crew Quarter	WMS/Brine Tank	Crew Quarter	Crew Quarter	Food Subsystem	Crew Quarter	Crew Quarter	Crew Quarter
To:	Commode	Solid Waste Proc	Solid Waste Proc	Solid Waste Coll	Solid Waste Coll	Solid Waste Coll	Solid Waste Coll	Solid Waste Coll
Air, kg/CM-d								
H_2O Mass, kg/CM-d	0.091	0.2394	0.5500	0.0288	0.0000	0.1358	0.0000	0.0000
Solids, kg/CM-d	0.032	0.0590	0.1730	0.0407	0.3266	0.0582	0.0410	0.0543
Daily Mass Flow per crew, kg/CM-d	0.1230	0.2984	0.7230	0.0695	0.3266	0.1940	0.0410	0.0543
Total Daily Mass Flow, kg/d	0.7380	1.7904	1.6870	0.4172	1.9595	1.1640	0.2460	0.3260
Total Mass per mission, kg	**442.8000**	**1074.2400**	**1012.2000**	**250.3188**	**1175.6931**	**698.4000**	**147.6000**	**195.5880**

Figure 7.2 Primary Mass Balance Sheet of the SWMS (Part 2)

Overall Mass Balance of SWMS (Cont'd)								
Equipment								
Stream Name	Misc. Waste	Plant Biomass	Soiled Clothes	Clean Dry Air	Fecal Waste	Collected Solid W	Plant Biomass	Used Dry Air
Stream No.	FSW9	FSW10	FSW99	FSW11	FSW16	FSW17	FSW18	FSW19
From:	Crew Quarter	Plant Growth Cha	CM	Air Revitalization S	Commode	Solid Waste Colle	Bagging Device	Solid Waste Proc
To:	Solid Waste Coll	Bagging Device	Disposable Clothe	Waste MS for SW	Solid Waste Proc	Solid Waste Proc	Solid Waste Proc	ARS Subsystem
Air, kg/CM-d				3.815794154				3.815794154
H_2O Mass, kg/CM-d	0.0000	0.0000	0.0000		0.0910	0.1647	0.0000	
Solids, kg/CM-d	0.0115	0.0000	0.0000	0	0.0320	0.5323	0.0000	0.0000
Daily Mass Flow per crew, kg/CM-d	0.0115	0.0000	0.0000	3.8158	0.1230	0.6969	0.0000	3.8158
Total Daily Mass Flow, kg/d	0.0690	0.0000	0.0000	22.8948	0.7380	4.1817	0.0000	22.8948
Total Mass per mission, kg	**41.4000**	**0.0000**	**0.0000**	**13736.8590**	**442.8000**	**2508.9999**	**0.0000**	**13736.8590**

Figure 7.3 Primary Mass Balance Sheet of the SWMS (Part 3)

Overall Mass Balance of SWMS (Cont'd)					
Equipment					
Stream Name	Dried Solid Waste	Wet Solid Waste	Recovered Water	Vent	
Stream No.	FSW20	FSW21	FSW22	FSW23	
From:	Solid Waste Proc	Solid Waste Proc	Solid Waste Proc	Wet Trash Storage	
To:	Dry Waste Storag	Wet Waste Storag	WMS/Storage Ta	TBD	
Air, kg/CM-d					
H_2O Mass, kg/CM-d	0.0000	0.0000	1.0451	TBD	
Solids, kg/CM-d	0.7963	0.0000	0.0000	TBD	
Daily Mass Flow per crew, kg/CM-d	0.7963	0.0000	1.0451	TBD	
Total Daily Mass Flow, kg/d	4.1434	0.0000	4.2537	TBD	
Total Mass per mission, kg	2486.0131	**0.0000**	2552.2268	TBD	

Figure 7.4 Primary Mass Balance Sheet of the SWMS (Part 4)

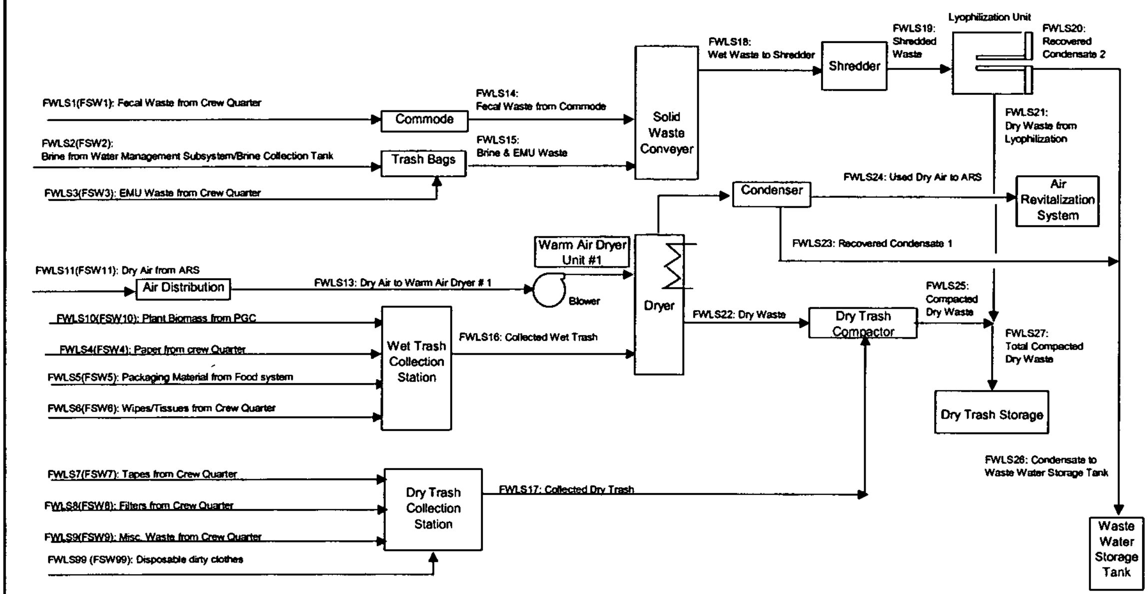
Overall Mass Balance of SWMS	Contingent Waste Storage								
Equipment									
Stream Name	Used MAG due Contingent EVA	Waste due contingent clothing	Fecal (contingency)	Collected Wet Solid Waste (Contingency)	Total collected Wet Solid Waste w/ clothing (Contingency)	Plant Mass (Contingency)	Brine+EMU (Contingency)	Total Brine&EMU due Contingency	Total Waste Storage due contingency
Stream No.	FSW1								
From:	EVA (contingent)	HA							
To:	Waste storage	Waste Storage							
Air, kg/CM-d									
H_2O Mass, kg/CM-d									
Solids, kg/CM-d									
Daily Mass Flow per crew, kg/CM-d	0.7230	0.4860	0.1230	0.6969	na	na	na		
Total Daily Mass Flow, kg/d	1.4460	2.9160	0.7380	4.1817	na	0.0000	3.4774	na	na
Total Mass per mission, kg	**14.4600**	**29.1600**	**7.3800**	**41.8167**	**70.9767**	**0.0000**	**34.7740**	**49.2340**	**127.5907**
			0.0232		0.2028	0.0000		0.0821	0.3081

Figure 7.5 Primary Mass Balance Sheet of the SWMS (Part 5)

Figures 8 and 9, showing the individual block flow diagram and mass balance sheet of the selected waste treatment option, are used as an example for further explanation of how the primary mass balance sheet works with the secondary mass balance sheet.

The mass balance sheet shown in Figure 9 of the selected SWMS technology performs the mass balance and calculates the processing rates to be handled by the different equipment used by this technology. The processing rates were transferred to the specific equipment's sizing worksheets for equipment sizing.

The recovered wastewater requiring further treatment is returned to the designated column in the SWMS primary mass balance sheet and transferred to the WMS for programmatic distribution through the Integration and Overall Mass Balance Module.



Block Flow Diagram for the Combination Technology (Warm Air Drying + Lyophilization + Storage)

Figure 8. Secondary Block Flow Diagram of the SWMS (Storage+WAD+Lyophilization)

WAD + Lyophilization + Storage								
Equipment								
Stream Name	Fecal Waste	Brine	EMU Waste	Paper	Packaging Material	Wipes/Tissues	Tapes	Filters
Stream No.	FWLS1	FWLS2	FWLS3	FWLS4	FWLS5	FWLS6	FWLS7	FWLS8
From:	Crew Quarter	WMS/Brine Tank	Crew Quarter	Crew Quarter	Food Subsystem	Crew Quarter	Crew Quarter	Crew Quarter
To:	Commode	Trash Bags	Trash Bags	Wet Trash Collector	Wet Trash Collector	Wet Trash Collector	Dry Trash Collector	Dry Trash Collector
Air Mass, kg/CM-d								
H_2O Mass, kg/CM-d	0.0910	0.2394	0.5500	0.0288	0.0000	0.1358	0.0000	0.0000
Solids, kg/CM-d	0.0320	0.0590	0.1730	0.0407	0.3266	0.0582	0.0410	0.0543
Daily Mass Flow per crew, kg/CM-d	0.1230	0.2984	0.7230	0.0695	0.3266	0.1940	0.0410	0.0543
Total Daily Mass Flow, kg/d	0.7380	1.7904	1.6870	0.4172	1.9595	1.1640	0.2460	0.3260
Total Mass per mission, kg	**442.8000**	**1074.2400**	**1012.2000**	**250.3188**	**1175.6931**	**698.4000**	**147.6000**	**195.5880**
Total Volume per mission as applicable, m^3								

Figure 9.1 Secondary Mass Balance Sheet of the SWMS (Storage+WAD+Lyophiliztion) (Part 1)

WAD + Lyophilization + Storage (Cont'd)								
Equipment								
Stream Name	Misc. Waste	Plant Biomass	Dirty Clothes	Clean Dry Air	Clean Dry Air	Fecal Waste	Brine & EMU Waste	Combined Trash
Stream No.	FWLS9	FWLS10	FWLS99	FWLS11	FWLS13	FWLS14	FWLS15	FWLS14&15
From:	Crew Quarter	Plant Growth Chamber	HA	Air Revitalization System	Air Revitalization System	Commode	Trash Bags	Commode&Trash Bags
To:	Dry Trash Collector	Wet Trash Collector	Disposable	Total Air Blower	Dryer # 1 Air Blower	Solid Waste Conveyer	Solid Waste Conveyer	Solid Waste Conveyer
Air Mass, kg/CM-d				3.8158	3.8158			
H_2O Mass, kg/CM-d	0.0000	0.0000	0.0000			0.0910	0.7894	0.8804
Solids, kg/CM-d	0.0115	0.0000	0.0000	0.0000	0.0000	0.0320	0.2320	0.2640
Daily Mass Flow per crew, kg/CM-d	0.0115	0.0000	0.0000	3.8158	3.8158	0.1230	1.0214	1.1444
Total Daily Mass Flow, kg/d	0.0690	0.0000	0.0000	22.8948	22.8948	0.7380	3.4774	4.2154
Total Mass per mission, kg	**41.4000**	**0.0000**	**0.0000**	**13736.8590**	**13736.8590**	**442.8000**	**2086.4400**	2529.2400
Total Volume per mission as applicable, m^3								
								12/6/01 JY

Figure 9.2 Secondary Mass Balance Sheet of the SWMS (Storage+WAD+Lyophiliztion) (Part 2)

WAD + Lyophilization + Storage (Cont'd)								
Equipment								
Stream Name	Collected Wet Trash	Collected Dry Trash	Fecal, Urine, EMU Waste	Shredded Waste	Recovered Condensate 2	Dry Waste from Lyophilization	Dry Waste	Waste to be compacted
Stream No.	FWLS16	FWLS17	FWLS18	FWLS19	FWLS20	FWLS21	FWLS22	FWLS17&22
From:	Wet Trash Collector	Dry trash Collector	Solid Waste Conveyer	Shredder	Lyophilization Unit	Lyophilization Unit	Dryer Unit #1	DTC, DU#1
To:	Dryer # 1	Compactor	Shredder	Lyophilization Unit	Waste Water Storage	Dry Trash Storage	Compactor	Total Compactor
Air Mass, kg/CM-d								
H_2O Mass, kg/CM-d	0.1647	0.0000	0.8804	0.8804	0.8804	0.0000	0.0000	0.0000
Solids, kg/CM-d	0.4255	0.1068	0.2640	0.2640	0.0000	0.2640	0.4255	0.5323
Daily Mass Flow per crew, kg/CM-d	0.5901	0.1068	1.1444	1.1444	0.8804	0.2640	0.4255	0.5323
Total Daily Mass Flow, kg/d	3.5407	0.6410	4.2154	4.2154	3.2657	0.9497	2.5527	3.1937
Total Mass per mission, kg	2124.4119	384.5880	**2529.2400**	**2529.2400**	**1959.4400**	569.8000	**1531.6251**	1916.2131
Total Volume per mission as applicable, m^3						2.8490		
								12/6/01 JY
			Lyophilization Water flow, kg/day:	1.9861				

Figure 9.3 Secondary Mass Balance Sheet of the SWMS (Storage+WAD+Lyophiliztion) (Part 3)

WAD + Lyophilization + Storage (Cont'd)					
Equipment					
Stream Name	Condensate 1	Used Dry Air	Compacted Dry Wastes	Overall Condensate	Total Dry Waste
Stream No.	FWLS23	FWLS24	FWLS25	FWLS26	FWLS27
From:	Dryer Unit #1	Dryer Unit #1	Dry Trash Compactor	FWLS20& FWLS23	Compactor & Lyophilization
To:	Waste Water Storage	Air Revitalization System	Dry Trash Storage	Waste Water Storage	Dry Waste Storage
Air Mass, kg/CM-d		3.8158			
H_2O Mass, kg/CM-d	0.1647		0.0000	1.0451	0.0000
Solids, kg/CM-d	0.0000	0.0000	0.5323	0.0000	0.7963
Daily Mass Flow per crew, kg/CM-d	0.1647	3.8158	0.5323	1.0451	0.7963
Total Daily Mass Flow, kg/d	0.9880	22.8948	3.1937	4.2537	4.1434
Total Mass per mission, kg	**592.7868**	**13736.8590**	1916.2131	2552.2268	2486.0131
Total Volume per mission as applicable, m^3			4.7905		7.6395

Figure 9.4 Secondary Mass Balance Sheet of the SWMS (Storage+WAD+Lyophiliztion) (Part 4)

Water Management Subsystem (WMS) (Ref. 41)

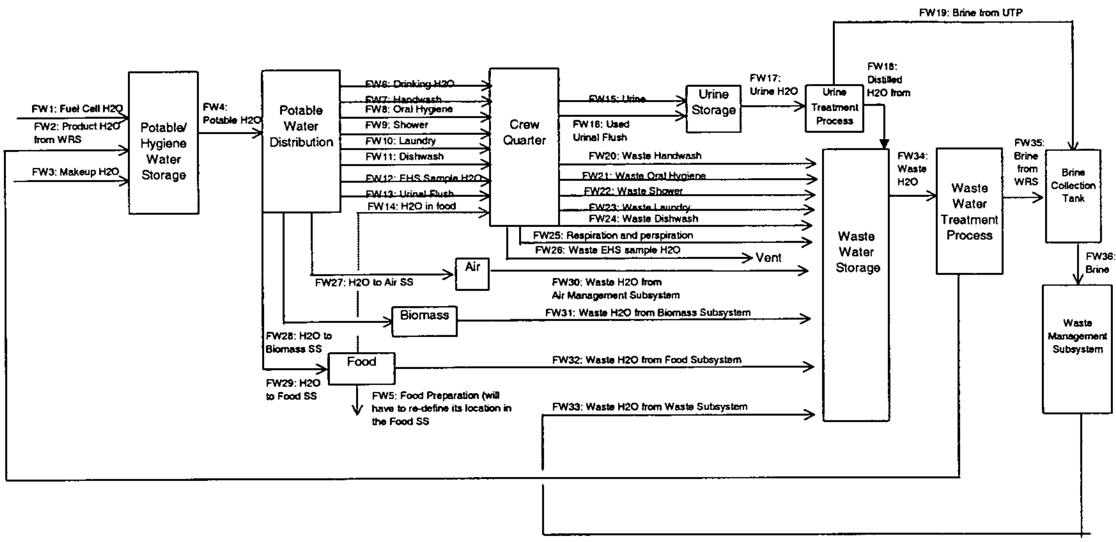
The Water Management Subsystem includes three water recovery technologies for the closed loop system and the storage option for a short mission open loop system. The WRS technologies are the International Space Station (ISS) Water Recovery Subsystem (WRS), the Bioregenerative Water Recovery Subsystem (BWRS), and the Vapor Phase Catalytic Ammonia Removal (VPCAR) Subsystem.

The block flow diagram and mass balance sheet of the primary WMS are shown in Figures 10 and 11, respectively.

Figure 10 shows the relationship between the WMS internal subsystems including the potable/hygiene water storage, potable water distribution, water treatment process, etc., and its relationship with the other ALS subsystems, including the AMS, Biomass, Food, SWMS, etc., directly and indirectly.

The WMS adopts the same format used in the development of the AMS BFD. The inlet and outlet streams of each WMS internal subsystem and ALS subsystem are clearly defined and labeled with stream numbers.

The mass balance sheet was developed in conjunction with the WMS primary block flow diagram. Stream properties, such as mass flow rates of stream components for a certain stream (e.g. FW1), are included in stream "FW1" column of the mass balance sheet. The mass balance sheet also shows the source block and destination block that the stream is flowing from and to inside the BFD.



Block Flow Diagram of the Water Management Subsystem

Figure 10. Primary (Overall) Block Flow Diagram of the WMS

Mass Balance for Water Management Subsystem								
	Closed Loop System							
Equipment			**Makeup H_2O Tank**	**Potable H_2O Tank**				
Stream Name	Fuel Cell H2O	WRS Product H2(	Makeup H2O	Total Potable req'	Food Prep	Drinking H2O	Hand/Face wash	Oral Hygiene
Stream No.	FW1	FW2	FW3	FW4	FW5	FW6	FW7	FW8
From:	FC H2O	WRS Product H2(	Makeup H2O	Potable H2O Stor	Potable H2O Dist	Potable Dist	Potable Dist	Potable Dist
To:	Potable H2O Stor	Potable H2O Stor	Potable H2O Stor	Potable H2O Dist	Food Subsystem	Crew Quarter (?)	Crew Quarter (?)	Crew Quarter (?)
H_2O Mass, kg/CM-d	0	25.8342	-0.7987	25.0355		2.0000	4.0820	0.3630
Solids, kg/CM-d	0	0.0000	0.0000	0.0000				
Daily Mass Flow per crew, kg/CM-d	0	25.8342	-0.7987	25.0355		2.0000	4.0820	0.3630
Total Daily Mass Flow, kg/d	0	155.0053	-4.7924	150.2129		12.0000	24.4920	2.1780
Total Mass per mission, kg	**0**	**93,003.1868**	**-2,875.4280**	**90,127.7588**		**7,200.0000**	**14,695.2000**	**1,306.8000**

Figure 11.1 Primary (Overall) Mass Balance Sheet of the WMS (Part 1)

Mass Balance for Water Management Subsystem								
	Closed Loop System							
Equipment								**Urinal**
Stream Name	Shower	Laundry	Dishwash	EHS Sample H2O	Urinal Flush	Potable H2O for E	H2O in Food	Urine
Stream No.	FW9	FW10	FW11	FW12	FW13		FW14	FW15
From:	Potable Dist	Potable Dist	Potable Dist	Potable Dist	Potable Dist	Potable Dist	Food Subsystem	Crew Quarter
To:	Crew Quarter (?)	Crew Quarter (?)	Crew Quarter (?)	Crew Quarter (?)	Crew Quarter (?)	EVA	Crew member ?	Urine Storage
H_2O Mass, kg/CM-d	2.7220	12.5000	0.0000	0.0000	0.4940	0.6348		1.5010
Solids, kg/CM-d								0.0590
Daily Mass Flow per crew, kg/CM-d	2.7220	12.5000	0.0000	0.0000	0.4940	0.6348		1.5600
Total Daily Mass Flow, kg/d	16.3320	75.0000	0.0000	0.0000	2.9640	5.0089		9.3600
Total Mass per mission, kg	**9,799.2000**	**45,000.0000**	**0.0000**	**0.0000**	**1,778.4000**	**3,005.3333**		**5,616.0000**
						***** check		

Figure 11.2 Primary (Overall) Mass Balance Sheet of the WMS (Part 2)

Mass Balance for Water Management Subsystem								
	Closed Loop System							
Equipment		**Urine Treatmnt Proc**		**Brine Tank for UTP**				
Stream Name	Used Urinal Flush	Urine Water	Distillate from UT	UTP Brine	Waste HW	Waste Oral	Waste Shower	Waste Laundry
Stream No.	FW16	FW17	FW18	FW19	FW20	FW21	FW22	FW23
From:	Crew Quarter	Urine Storage	Urine Treatment F	UTP	Crew Quarter	Crew Quarter	Crew Quarter	Crew Quarter
To:	Urine Storage	Urine Treatment	WW Storage	Brine Store	WW Storage	WW Storage	WW Storage	WW Storage
H_2O Mass, kg/CM-d	0.4940	1.9950	1.7556	0.2394	4.0820	0.3630	2.7220	12.5000
Solids, kg/CM-d		0.0590	0.0000	0.0590				
Daily Mass Flow per crew, kg/CM-d	0.4940	2.0540	1.7556	0.2984	4.0820	0.3630	2.7220	12.5000
Total Daily Mass Flow, kg/d	2.9640	12.3240	10.5336	1.7904	24.4920	2.1780	16.3320	75.0000
Total Mass per mission, kg	**1,778.4000**	**7,394.4000**	**6,320.1600**	**1,074.2400**	**14,695.2000**	**1,306.8000**	**9,799.2000**	**45,000.0000**

Figure 11.3 Primary (Overall) Mass Balance Sheet of the WMS (Part 3)

Mass Balance for Water Management Subsystem								
	Closed Loop System							
Equipment								
Stream Name	Waste DW	Resp & Persp	Waste EHS SW	H2O for OGS	H2O for Plt Growt	Potable H2O to F	AMS Waste H2O	Biomass WW
Stream No.	FW24	FW25	FW26	FW27	FW28	FW29	FW30	FW31
From:	Crew Quarter	Crew Quarter	Crew Quarter	Potab H2O Dist	Potab H2O Dist	Pot H2O Dist	Air SS	Biomass SS
To:	WW Storage	WW Storage	WW Storage	Air subsystem	Biomass SS	Food SS	WW Storage	WW Storage
H_2O Mass, kg/CM-d	0.0000	2.2770	0.0000	0.0000	0.0000	2.0397	0.0000	0.0000
Solids, kg/CM-d		0.0180		0.0000	0.0000			0.0000
Daily Mass Flow per crew, kg/CM-d	0.0000	2.2950	0.0000	0.0000	0.0000	2.0397	0.0000	0.0000
Total Daily Mass Flow, kg/d	0.0000	13.7700	0.0000	0.0000	0.0000	12.2380	0.0000	0.0000
Total Mass per mission, kg	**0.0000**	**8,262.0000**	**0.0000**	**0.0000**	**0.0000**	**7,342.8254**	**0.0000**	**0.0000**

Figure 11.4 Primary (Overall) Mass Balance Sheet of the WMS (Part 4)

Mass Balance for Water Management Subsystem								
Equipment				Waste H_2O Stor. Tk		WMS Brine/cake to Waste	Product H_2O Tank	
Stream Name	Waste H2O from	WW from Waste	Waste H2O from	Waste H2O Total	Brine from WRS	Brine/Cake	Product H_2O Tank	
Stream No.	FW32	FW33		FW34	FW35	FW36		
From:	Food SS	Waste SS	EVA	WW Storage	WTP	Brine Tank/AES	WRS	
To:	WW Storage	WW Storage	WW Storage	WRS	Brine Storage	Waste SS	Product H_2O Tank	
H_2O Mass, kg/CM-d	0.794	1.0451	0.2956	25.8342	0.2394	0.2394	25.8342	
Solids, kg/CM-d			0.0000	0.0180	0.0590	0.0590	0.0000	
Daily Mass Flow per crew, kg/CM-d	0.794	1.0451	0.2956	25.8522	0.2984	0.2984	25.8342	
Total Daily Mass Flow, kg/d	4.764	6.2704	1.7733	155.1133	1.7904	1.7904	155.0053	
Total Mass per mission, kg	**2,858.4**	**3,762.2268**	**1,064.0000**	**93,067.9868**	**1,074.2400**	**1,074.2400**	**93,003.1868**	
			check later 5/21/03 jy					

Figure 11.5 Primary (Overall) Mass Balance Sheet of the WMS (Part 5)

Mass Balance for Water Management Subsystem								
Equipment								
Stream Name	Waste H2O from F	**Potable H2O sto**	**Waste H2O from**	**Potable H2O for**	**Actual additional**	**Potable H2O for**	**Total Potable H2**	**Hygiene H2O for**
Stream No.	FW32							
From:	Food SS							
To:	WW Storage							
H_2O Mass, kg/CM-d		2.1467	0.7600					
Solids, kg/CM-d		0.0000	0.0000					
Daily Mass Flow per crew, kg/CM-d		2.1467	0.7600					
Total Daily Mass Flow, kg/d		4.2933	1.5200			24.2380		45.9660
Total Mass per mission, kg		**3005.3333**	**1064.0000**	**49.6000**	**42.9333**	**242.3804**	**285.3137573**	**459.66**
		Need to size stora	Need to size storage tank					

Figure 11.6 Primary (Overall) Mass Balance Sheet of the WMS (Part 6)

Mass Balance for Water Management Subsystem						
	Open Loop System w/ Contingency or Makeup&Contingency for Closed System					
Equipment						
Stream Name	Potable Water Re	Hygiene Water Re	Urine and U. flush	Hygiene Waste W	Potable Water w/	Hygiene H2O w/ C
Stream No.						
From:	Potable Water Tk	Hygiene H2O Tk (	Urine Tk (OL)	Hyg. Waste Tk		
To:						
H_2O Mass, kg/CM-d	-0.7987	0.0000	0.0000	0.0000		
Solids, kg/CM-d	0.0000	0.0000	0.0000	0.0000		
Daily Mass Flow per crew, kg/CM-d	-0.7987	0.0000	0.0000	0.0000		
Total Daily Mass Flow, kg/d	-4.7924	0.0000	0.0000	0.0000		
Total Mass per mission, kg	**-2,875.4280**	**0.0000**	**0.0000**	**0.0000**	**-2,590.1143**	**459.6600**

Figure 11.7 Primary (Overall) Mass Balance Sheet of the WMS (Part 7)

The mass balance sheet shown in Figure 11 summarizes the wastewater streams generated by and potable water required by the crewmembers. These numbers are input by the ALSSAT user through the User Interface Module. It also summarizes the wastewater generated by the other ALS subsystems and external interfaces, as well as the potable water required by the other ALS subsystems and external interfaces. The flow rates are transferred to this balance sheet through the Integration and Overall Mass Balance Module by integrating all of the ALS subsystems together.

The wastewater streams are further transferred into the mass balance sheet of the selected Water Recovery Subsystem for calculating the potable water recovered. The ISS WRS is used for this case study. Its BFD and mass balance sheet are shown in Figures 12 and 13, respectively. The amount of potable water recovered depends on the water recovery efficiency set for the WRS selected. The potable water stream is returned to the primary mass balance sheet for makeup water calculation.

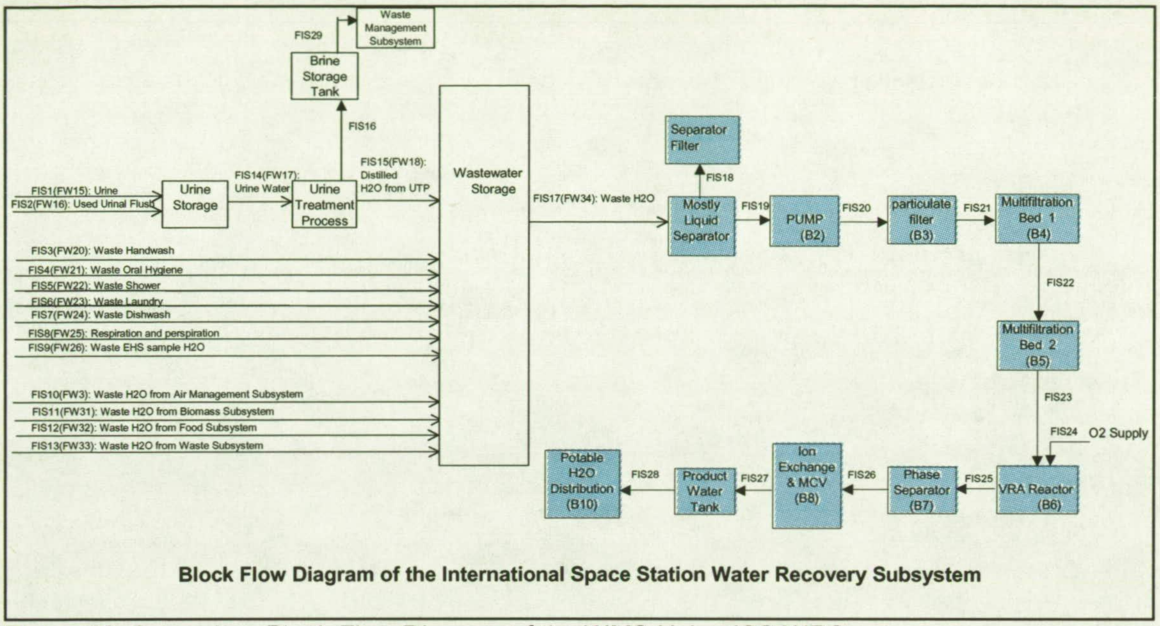


Figure 12. Secondary Block Flow Diagram of the WMS Using ISS WRS

The makeup water included in the mass balance sheet of the primary WMS is calculated based on the balance of the total amount of potable water recovered from the WRS with the potable water required by crew members plus potable water required by the other ALS Subsystems' activities.

Detailed assumptions for the WMS mass balance calculations are included in the ALSSAT model (Ref. 5).

It is worth mentioning that, after the overall mass balance integration of all the ALS subsystems and external interfaces, the makeup water stream in the WMS mass balance sheet shows the water deficiency or excess situation. For the water deficiency case, an additional storage tank with water to be brought up the space was sized; for the water excess case, the amount of excess water will be displayed as a negative value in the integration summary sheet to show the user that excess water exists in the case study.

ISS WRS Mass Balance Summary								
Equipment to be sized								
Stream Name	Urine	Urinal Flush	Waste Hand/face	Waste Oral	Shower H2O	Laundry H2O	Dishwash	Respiration and P
Stream No.	FIS1	FIS2	FIS3	FIS4	FIS5	FIS6	FIS7	FIS8
From:	Crew Quarter	Crew Quarter	Crew Quarter	Crew Quarter	Crew Quarter	Crew Quarter	Crew Quarter	Crew Quarter
To:	Urine Storage Tar	Urine Storage Tar	Waste Hygiene Ta	Waste Hygiene Ta	Waste Hygiene St	Waste Hygiene St	Waste Hygiene St	Waste Hygiene S
Description								
H_2O Mass, kg/CM-d	1.5010	0.4940	4.0820	0.3630	2.7220	12.5000	0.0000	2.2770
Solids, kg/CM-d	0.0590	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0180
chemicals, kg/CM-d	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total mass per crew, kg/CM-d	1.5600	0.4940	4.0820	0.3630	2.7220	12.5000	0.0000	2.2950
Daily mass flow, kg/d	**9.3600**	**2.9640**	**24.4920**	**2.1780**	**16.3320**	**75.0000**	**0.0000**	**13.7700**

Figure 13.1 Secondary Mass Balance Sheet of the WMS Using ISS WRS (Part 1)

ISS WRS Mass Balance Summary								
Equipment to be sized								
Stream Name	Animal Resp&Per	EHS Sample Wat	Waste Water from	Waste H_2O From	Waste H_2O From	Waste H_2O From	Waste H_2O From	Waste Water fron
Stream No.	FIS?	FIS9		FIS10	FIS11	FIS12	FIS13	
From:		Crew Quarter	EMU	Air Management	Biomass Subsyste	Food Managemer	Waste Manageme	EVA
To:	Waste Hygiene St	Waste Hygiene St	Waste Water Stor	Waste Hygiene St	Waste Hygiene St	Waste Hygiene St	Waste Hygiene St	Waste H2O Stora
Description								
H_2O Mass, kg/CM-d	0.0000	0.0000	0.2956	0.0000	0.0000	0.7940	1.0451	0.2956
Solids, kg/CM-d	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
chemicals, kg/CM-d	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total mass per crew, kg/CM-d	0.0000	0.0000	0.2956	0.0000	0.0000	0.7940	1.0451	0.2956
Daily mass flow, kg/d	**0.0000**	**0.0000**	**1.7733**	**0.0000**	**0.0000**	**4.7640**	**6.2704**	**1.7733**
			Note: Values of stream L passed from "Mass Balance for WMS." 7/10/03 JY.					

Figure 13.2 Secondary Mass Balance Sheet of the WMS Using ISS WRS (Part 2)

ISS WRS Mass Balance Summary								
Equipment to be sized	VCD				Brine Storage	Waste H2O Sto		
Stream Name	Urine Water	H_2SO_4, Oxone	Urine pretreated n	Distilled H2O from	Brine Stream	Waste Water	Liquid Waste Wat	Liquid Waste Wat
Stream No.	FIS14			FIS15	FIS16	FIS17	FIS19	FIS20
From:	Urine Storage	Chemical Storage	Urine Pretreat uni	VCD	VCD	Waste H2O Sto	MLS	Pump
To:	Urine Treatment F	VCD Urine Pretre:	VCD	Waste Hygiene St	Brine Storage	MLS	Pump	Particulate Filter
Description								
H_2O Mass, kg/CM-d	1.9950	0.0000	1.9950	1.7556	0.2394	25.8342	25.8342	25.8342
Solids, kg/CM-d	0.0590	0.0000	0.0590	0.0000	0.0590	0.0180	0.0180	0.0180
chemicals, kg/CM-d	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total mass per crew, kg/CM-d	2.0540	0.0000	2.0540	1.7556	0.2984	25.8522	25.8522	25.8522
Daily mass flow, kg/d	**12.3240**	**0.0000**	**12.3240**	**10.5336**	**1.7904**	**155.1133**	**155.1133**	**155.1133**

Figure 13.3. Secondary Mass Balance Sheet of the WMS Using ISS WRS (Part 3)

ISS WRS Mass Balance Summary								
Equipment to be sized	Multifiltration Beds		VRA Reactor		Ion-Exchange Be	MCV	Potable H2O Sto	Waste Stream
Stream Name	Liq Waste Water		Product from Multi		Semi-Product H2(	Polished Product	Product H2O	Brine
Stream No.	FIS21	FIS22	FIS23	FIS25	FIS26	FIS27	FIS28	FIS29
From:	Particulate Filter	MF#1	MF#2	VRA	Phase Separator	IX & MCV	Potable H2O Sto	Brine
To:	Multifiltration#1	MF#2	VRA	Phase Separator	IX & MCV	Potable H2O Sto	H2O Distribution	Waste Manageme
Description								
H_2O Mass, kg/CM-d	25.8342	25.8342	25.8342	25.8342	25.8342	25.8342	25.8342	0.2394
Solids, kg/CM-d	0.0180	0.0014	0.0001	0.0001	0.0009	0.0000	0.0000	0.0590
chemicals, kg/CM-d	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total mass per crew, kg/CM-d	25.8522	25.8356	25.8343	25.8343	25.8351	25.8342	25.8342	0.2984
Daily mass flow, kg/d	**155.1133**	**155.0138**	**155.0061**	**155.0061**	**155.0107**	**155.0053**	**155.0053**	**1.7904**

Figure 13.4 Secondary Mass Balance Sheet of the WMS Using ISS WRS (Part 4)

An option for treating laundry wastewater separately from other wastewater streams by the Reverse Osmosis (RO) treatment process was implemented. The RO treatment process is accessible when the Biological Water Recovery Subsystem (BWRS) is the water recovery technology of choice. Previous treatment processes were accomplished by sending the laundry wastewater into the total feed tank of the bioreactor. The block flow diagram and mass balance sheet of the BWRS were modified to handle the impact of this inclusion.

Wastewater and urine for the open loop system will be stored and brought back to the surface, as denoted in the FY02 version. Should it be decided to dump the wastewater and urine overboard for the open loop system, the wastewater and urine storage will be zeroed out. This issue will be discussed and revised in the FY04 ALSSAT release.

Extravehicular Activities (EVA)

The block flow diagram and mass balance sheet of the EVA external interface were also developed (Ref. 4, 5).

The EVA interface also allows user to select the option of carrying an inflatable airlock for emergency EVA on the Transit Vehicle. Note that the current design of the Mars Transit Vehicle does not include an airlock.

After the user enters the data prompted by ALSSAT for the EVA interface, consumables like air and water needed for the EVA will be calculated. For a closed loop system, the recovered cooling water will be sent to the WMS for further purification.

The user can select the airlock recycle pump option for minimizing air loss due to EVA for long missions as well as short missions.

For long mission durations on the Martian surface, the user can select the option of generating EVA O_2 by the OGA in space instead of transporting O_2.

Used Maximum Absorbency Garments (MAG) will be sent to the Waste Management Subsystem for storage or treatment in recovering the water if the closed loop is selected.

The amount of food for EVA contingent purposes was calculated based upon the Shuttle Training Menu and is listed as a separate contingent contribution in ALSSAT's summary of results.

Detailed assumptions, BFD, and the mass balance sheet can be found in Reference 5.

Human Accommodations (HA) Interface (Ref. 5)

The BFD and mass balance sheet for the HA interface were implemented.

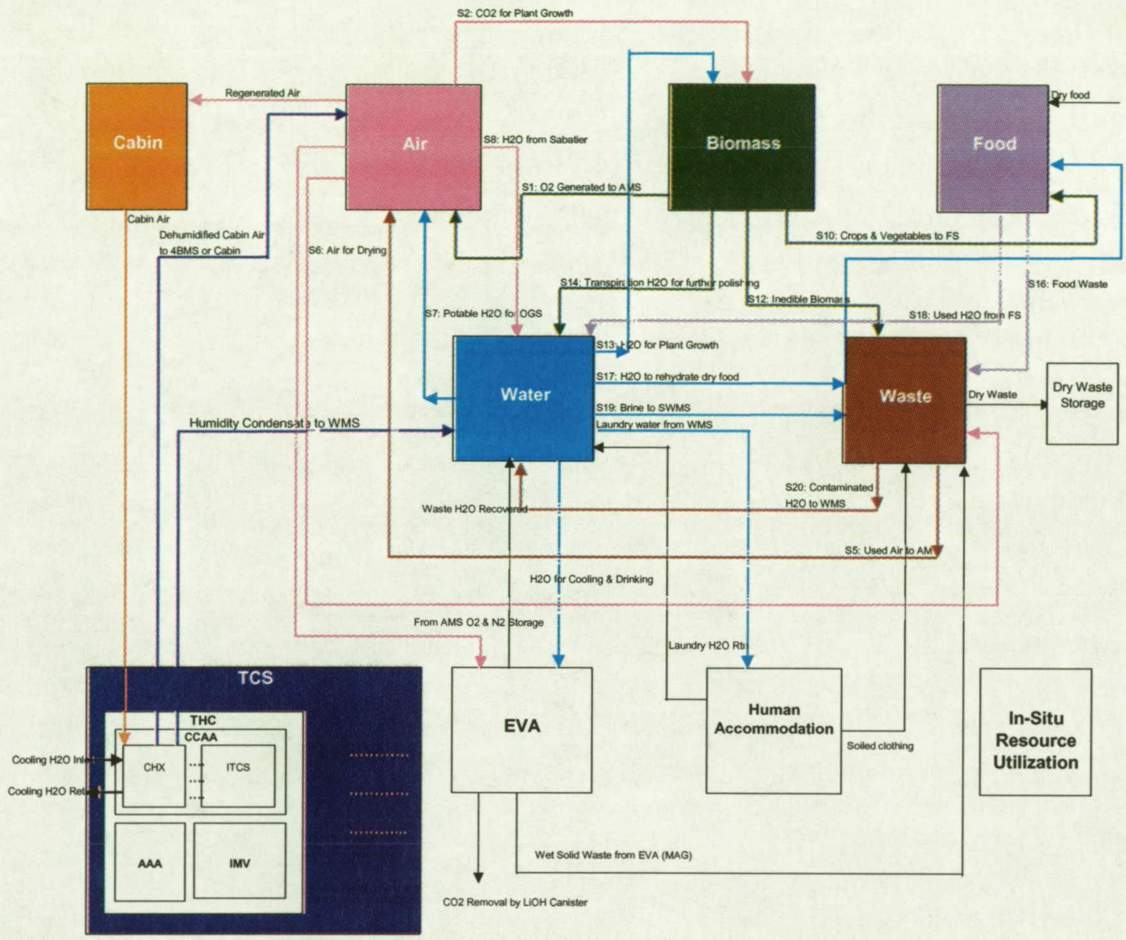
The interface between the HA and the ALS subsystems are the disposable dirty laundry to the waste management subsystem and laundry water to/from the Water Management Subsystem (WMS) if a laundry machine is used. The clothes used by the crew are tracked as disposable clothes or reusable clothes.

Washer and dryer mass and volume values were scaled in accordance with the crew size and water consumption rate if the use of a laundry machine is selected for the mission.

Detailed assumptions, BFD, and the mass balance sheet of the HA can be found in Reference 5.

Overall Mass Balance (Ref. 4, 5)

A block flow diagram (ALSSAT BFD) for the overall mass balance module that relates the six ALS subsystems and the external interfaces applicable to the ECLSS was developed and shown in Figure 14. An overall mass balance sheet that integrates the ALS subsystems and the external interfaces in conjunction with the ALSSAT BFD was also developed with embedded detailed assumptions, comments, and references for better traceability. A flowsheet of the overall mass balance was developed in the matrix form to show the relationship between the six ALS subsystems, including the AMS, Biomass, FMS, TCS, SWMS, WMS, and the three external interfaces, including the EVA, HA, and the In-Situ Resource Utilization (ISRU) interfaces.



Block Flow Diagram for the Overall Mass Balance of ALSSAT

Figure 14. Overall Block Flow Diagram of the ALS Subsystems and External Interfaces

Equivalent System Mass (ESM) Calculation Worksheet (Ref. 50 and 51)

The Equivalent System Mass (ESM) Calculation worksheet for calculating ESM Non-Crew Time (NCT) or ESM (NCT) and ESM with Crew Time (ESM (CT)) for the six ALS subsystems and the External Interfaces applicable to the ECLSS was developed.

Cost factors for the volume, power, cooling, and crew time based on the different environments were collected from References 50 and 51 and summarized in the ESM calculation worksheet shown in Table 1. The cost factors are made transparent to the user, so that they can be updated easily when the values are changed in the future.

The ESM worksheet was designed to track the subsystem mass, volume, power, cooling, resupply mass, and resupply volume of the hardware units in routine operation and to track the subsystem mass and volume for the redundant hardware units .

Cost Factors for ESM Calculations (Ref. 10)					
		Infrastructure Cost Factors			
Option	Mission/Vehicle	Volume, kg/m^3	Power, kg/kW	Thermal, kg/kW	Crewtime, kg/CM-hour
1	ISS	66.7	476	348.9	0.49
2	Mars Transit Vehicle	9.16	237	60	1.14
3	Mars Surface Habitat Vehicle	9.16	228	146	1.25
4	Mars Ascent/Descent Vehicle	66.7	237	146	6.01
5	Earth Return Vehicle	9.16	237	60	1.14

Table 1. Cost Factors for calculating the ESM of the Volume, Power, Cooling, and Crewtime

Equivalent System Mass Calculation										
Subsystem Abbreviation	**Equipment Mass, kg**	**Resupply Mass, kg**	**Bkup Equip Mass, kg**	**Equipment Volume, m^3**	**Resupply Volume, m^3**	**Bkup Equip Volume, m3**	**Power, Watts**	**Thermal (Cooling), Watts**	**Crew Time, MMH/Duration**	**ESM (equip. vol.), kg**
Air	4,976.86	2,697.63		6.31	2.43		5,386.70	5,386.70	4.63	57.81
ACS	**119.40**	**0.00**	**0.00**	**0.26**	**0.00**	**0.00**	**70.50**	**70.50**	**0.00**	**2.35**
APC	119.40	0.00	0.00	0.26	0.00	0.00	70.50	70.50	0.00	2.35
ARS	**972.27**	**113.03**	**0.00**	**3.08**	**0.47**	**0.00**	**5,314.72**	**5,314.72**	**4.53**	**28.17**
CO2Rem	173.20	0.00	0.00	0.40	0.00	0.00	516.00	516.00	4.53	3.67
CO2Red	96.91	0.00	0.00	0.17	0.00	0.00	95.26	95.26	0.00	1.57
O2Gen	345.82	81.01	0.00	1.97	0.00	0.00	3,959.24	3,959.24	0.00	18.07
TCCS	85.62	32.03	0.00	0.17	0.47	0.00	243.73	243.73	0.00	1.57
ACMA (MCA)	54.30	0.00	0.00	0.09	0.00	0.00	103.50	103.50	0.00	0.82
SDS	35.11	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.38
ACO2R	181.30	0.00	0.00	0.23	0.00	0.00	397.00	397.00	0.00	2.08
Biomass	501.64	0.00		4.86	0.00		5,085.94	5,085.94	0.00	44.54
Food	0	0	0	0	0	0	960	960	0	0
Thermal	359.0894	31.3333	0.0000	1.0475	0.1260	0.0000	1406.9250	1406.9250	3.3333	9.5947
Waste	451.80	0.00	0.00	9.13	0.00	0.00	1,364.57	1,364.57	160.00	83.64
Water	1,329.46	3,516.89	0.00	5.01	0.00	0.00	1,982.57	1,982.57	0.00	45.93
ESM Total for E	**7,618.85**	**6,245.86**	**0.00**	**26.37**	**2.56**	**0.00**	**16,186.71**	**16,186.71**	**167.97**	**241.51**

Figure 15.1 ESM Calculation Worksheet for the six ALS Subsystems (Part 1)

Equivalent System Mass Calculation									
Subsystem Abbreviation	ESM (resupply vol.),kg	ESM(bkup equip vol.),kg	ESM (power), kg	ESM (cooling), kg	ESM(NCT), kg	ESM(NCT w/ bkup),kg	ESM (Crewtime), kg	ESM(NCT& CT, no bkup), kg	ESM(NCT& CT, w/ bkup), kg
Air	22.27		1,228.17	786.46	9,769.20	9,769.20	5.79	9,774.99	9,774.99
ACS	**0.00**	**0.00**	**16.07**	**10.29**	**148.11**	**148.11**	**0.00**	**148.11**	**148.11**
APC	0.00	0.00	16.07	10.29	148.11	148.11	0.00	148.11	148.11
ARS	**4.33**	**0.00**	**1,211.76**	**775.95**	**3,105.51**	**3,105.51**	**5.67**	**3,111.18**	**3,111.18**
CO2Rem	0.00	0.00	117.65	75.34	369.86	369.86	5.67	375.52	375.52
CO2Red	0.00	0.00	21.72	13.91	134.11	134.11	0.00	134.11	134.11
O2Gen	0.00	0.00	902.71	578.05	1925.66	1925.66	0.00	1925.66	1925.66
TCCS	4.33	0.00	55.57	35.58	214.70	214.70	0.00	214.70	214.70
ACMA (MCA)	0.00	0.00	23.60	15.11	93.83	93.83	0.00	93.83	93.83
SDS	0.00	0.00	0.00	0.00	35.49	35.49	0.00	35.49	35.49
ACO2R	0.00	0.00	90.52	57.96	331.86	331.86	0.00	331.86	331.86
Biomass	0.00		1,159.60	742.55	2,448.32	2,448.32	0.00	2,448.32	2,448.32
Food	0	0	218.88	140.16	359.04	359.04	0	359.04	359.04
Thermal	1.1542	0.0000	320.7789	205.4110	927.3616	927.3616	4.1667	931.5283	931.5283
Waste	0.00	0.00	311.12	199.23	1,045.78	1,045.78	200.00	1,245.78	1,245.78
Water	0.00	0.00	452.03	289.45	5,633.76	5,633.76	0.00	5,633.76	5,633.76
ESM Total for I	**23.42**	**0.00**	**3,690.57**	**2,363.26**	**20,183.47**	**20,183.47**	**209.96**	**20,393.43**	**20,393.43**

Figure 15.2 ESM Calculation Worksheet for the six ALS Subsystems (Part 2)

In order to simplify ALSSAT's input and calculation processes, the user is allowed to select a simple mission, such as ISS, or single vehicle (e.g. Mars Transit Vehicle) instead of missions that includes more than one vehicle, such as the Dual Lander.

Figure 15 shows part of the ESM calculation results for the six ALS subsystems from one sample case study. Detailed assumptions and calculation results for the six ALS subsystems and the External Interfaces, including contingency, can be found in Reference 5.

Contingency and Redundancy

The contingency option for regenerative subsystem was included. Inclusion of redundant hardware units as user-specified options within the six Advanced Life Support internal subsystems was also completed.

The mass balance worksheets, sizing worksheets, and the ESM calculation worksheet, impacted by the inclusion of the contingency and redundancy options for the six Advanced Life Support (ALS) Subsystems and two External Interfaces, were updated and integrated.

The results of additional ECLSS mass, volume, and power requirements due to the inclusion of contingency for mission scenarios were calculated separately from those of the routine operation.

User Interface Module

The interface forms for each of the six ALS External Interfaces, namely, EVA, HA, ISRU, Integrated Control, Power, and Radiation Protection, were implemented. The Visual Basic (VB) program code of ALSSAT was upgraded to allow ALSSAT to accept default values for the

External Interfaces, obtained from the 2002 Baseline Values and Assumptions Document (BVAD) (Ref. 48).

Modifications to the ALSSAT program and user interfaces were performed, resulting in an increased ease of data entry and program maintenance.

The user interface module has been significantly improved by the inclusion of redundant and contingent considerations. The individual interface forms were modified to contain user input prompts for all equipment that may benefit from redundant units. Contingent considerations are addressed at the beginning of data entry. The user is given an option to input contingent items in the first interface form. If this option is chosen, a program "flag" causes each remaining form to display a contingent data entry box in all applicable areas. A default of 10 days has been assumed for contingency purposes.

The VB program code enables the tool to read data from and write data to an independent text file. It reactivated ALSSAT's ability to provide four mission scenarios studies for up to four separate missions.

Results Presentation Enhancement

The addition of all user-specified input data to ALSSAT's multiple-mission Comparison Page was completed. This is beneficial to the user in that it displays the input values used to generate results listed Contingency results are captured within their own area on the worksheet, enabling the user to quickly determine the contingent impacts upon mission scenarios. The addition of contingency options permits an ALSSAT user to analyze a total of eight different mission scenarios, complete with the specific input data used to generate each scenario.

Results obtained from the External Interface calculations appear on ALSSAT's Comparison Page, which has been divided between the ALS subsystems and the two External Interface categories mentioned, namely, the detailed EVA and HA results.

ALSSAT's original graphical comparison suite, consisting of mass, power, and volume values for multiple missions and depicting only Non-Crew-Time (NCT) ESM values, was completed by the inclusion of an ESM (NCT+CT) display. Additionally, the Comparison Page was expanded to include results representing scenario values inclusive and exclusive of contingency options. These improvements to the Comparison Page have been translated graphically.

A Direct Input/Output worksheet was created within the ALSSAT to allow the user to immediately obtain results for a single mission when changes are made to the original input for one single mission scenario. This is done by entering the change through the Main Module and is independent of the user interface forms. The original scenario results will remain unchanged in the Comparison Page once the VB program has been executed.

ALSSAT'S APPLICATIONS IN TRADE STUDIES

Several trade studies were conducted using ALSSAT during FY03. They are: 1. Mars Transit Vehicle (MTV) with and without airlock for emergency EVA (Ref. 42); 2. CO_2 and Moisture Removal Subsystem (CMRS) for open loop system (Ref. 44); 3. Generation of EVA O_2 by OGA or transportation of EVA O2 to the space (Ref. 45).

The results of the first trade study are presented in this paper.

Study 1. Mars Transit Vehicle (MTV) with and without airlock for emergency EVA

For the Mars missions, the top priority is to reduce the consumption of resources such as air and water due to the high cost of transporting them. The Mars Transit Vehicle and the Descent/Ascent Vehicle are not currently designed to be equipped with an airlock. If an emergency EVA is required for any reason, the lack of an airlock will cause a significant amount of air loss for a vehicle dependent upon cabin volume alone.

A vehicle equipped with an airlock will add additional launch mass and volume to the vehicle, thus increasing the overall ESM of the vehicle. ALSSAT was used to perform the feasibility study of adding an airlock to the vehicle. This study calculated the breakeven point between the airlock mass and the additional launch mass caused by bringing additional O_2 and N_2 high pressure storage tanks needed to compensate for the total air loss that occurs when performing EVA without an airlock.

In order to minimize the total launch mass and volume of the vehicle, an inflatable airlock (Ref. 43) was used for the study.

In order to simplify the trade study, it was assumed that there was no recycle pump for contingent EVAs with an airlock for the MTV. Case studies were also performed for the DAV with an airlock versus the DAV with both airlock and recycle pump. The recovery efficiency of the recycle pump was assumed to be 90%.

The volumes of the MTV and DAV were assumed to be 97.7 m^3 (Ref. 49) and 25.5 m^3 (Ref. 48), respectively. A total cabin pressure of 62 kilopascals and cabin temperature of 22 degree Celsius (Ref. 49) were used for the calculation of both the MTV and DAV case studies.

This study also assumed that the DAV and MTV were made of rigid shells. It was assumed that two crewmembers would conduct an EVA and that the remaining crewmembers would support routine activities, thereby consuming no extra oxygen.

More detailed assumptions, calculations, and result summaries in tabular formats, can be found in Reference 42.

i. MTV w/ and w/o Airlock

The results for the mass, volume, and ESM comparison plotted are shown in Figures 16, 17, and 18, respectively.

Figure 16 shows that the breakeven point for the MTV with and without airlock is one EVA, while Figure 17 shows a breakeven point of five EVAs if the ECLSS volume is used to compare the impact of adding an airlock. Figure 18, using the ECLSS ESM to compare the results, confirms a breakeven point of approximately one EVA.

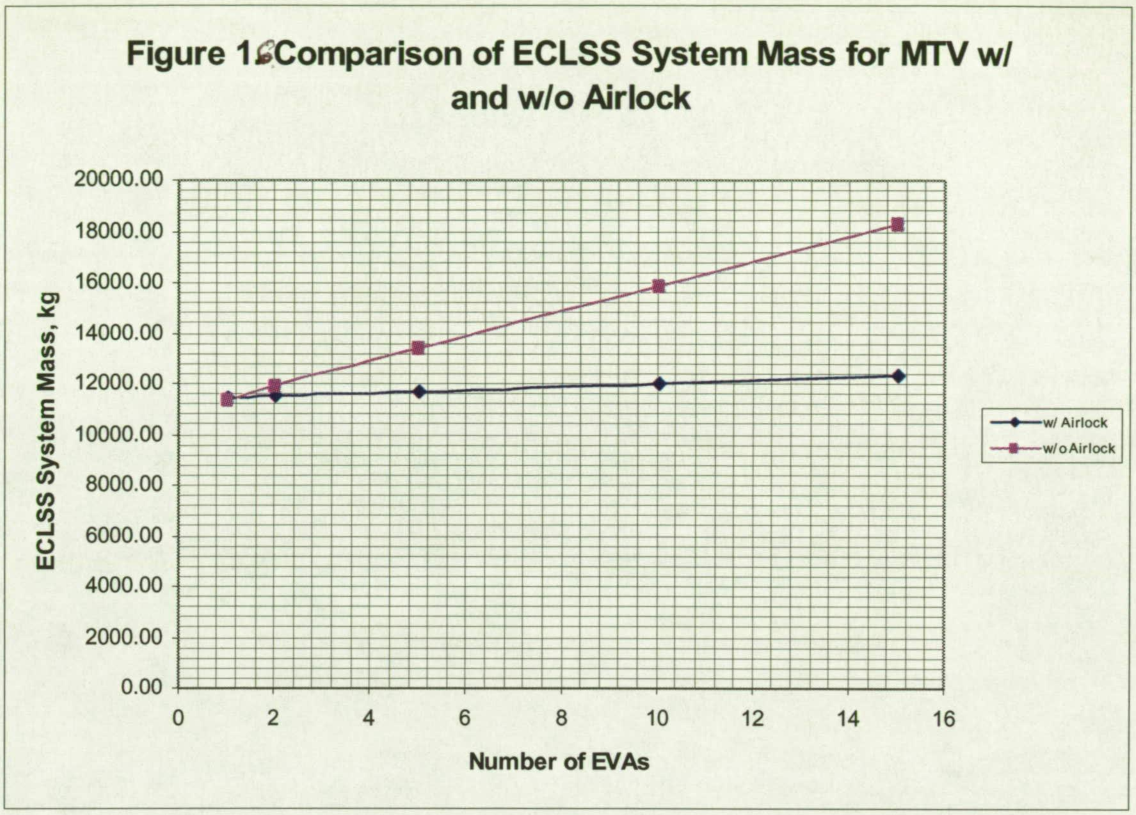


Figure 16. Comparison of ECLSS Masses for MTV w/ and W/O Airlock for Emergency EVA

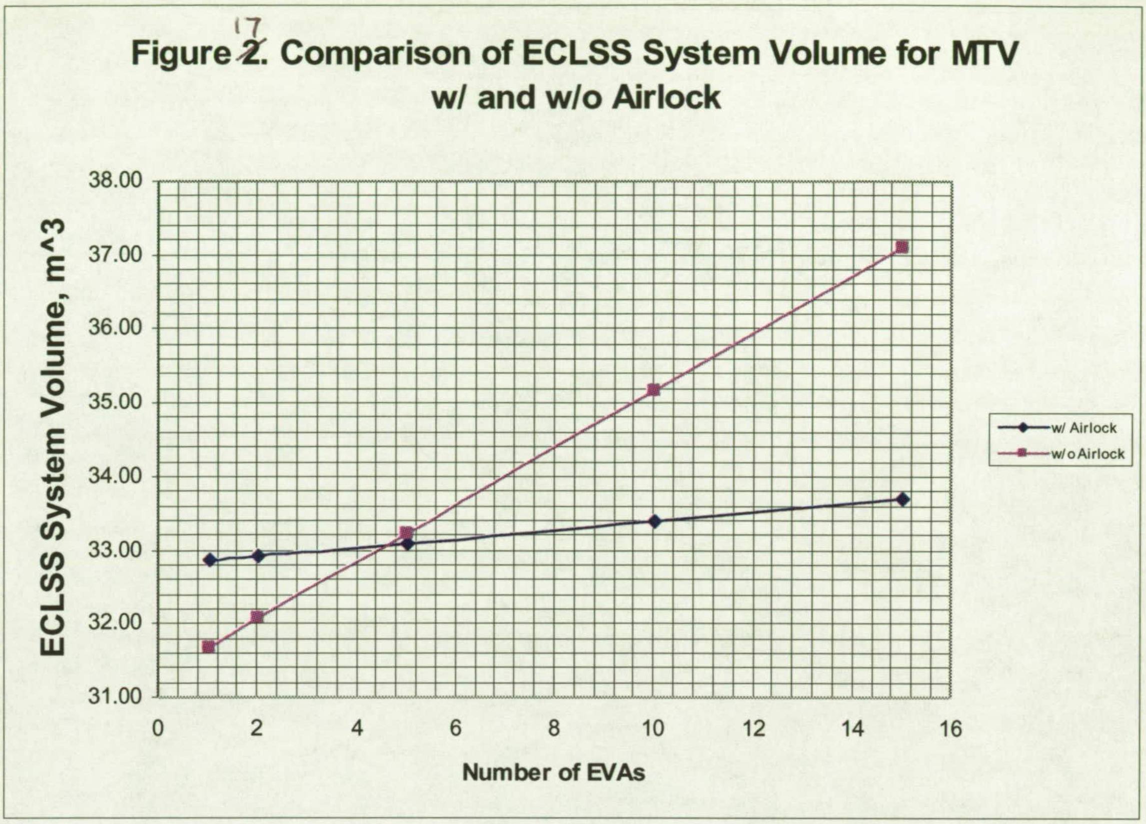


Figure 17. Comparison of ECLSS Volumes for MTV w/ and W/O Airlock for Emergency EVA

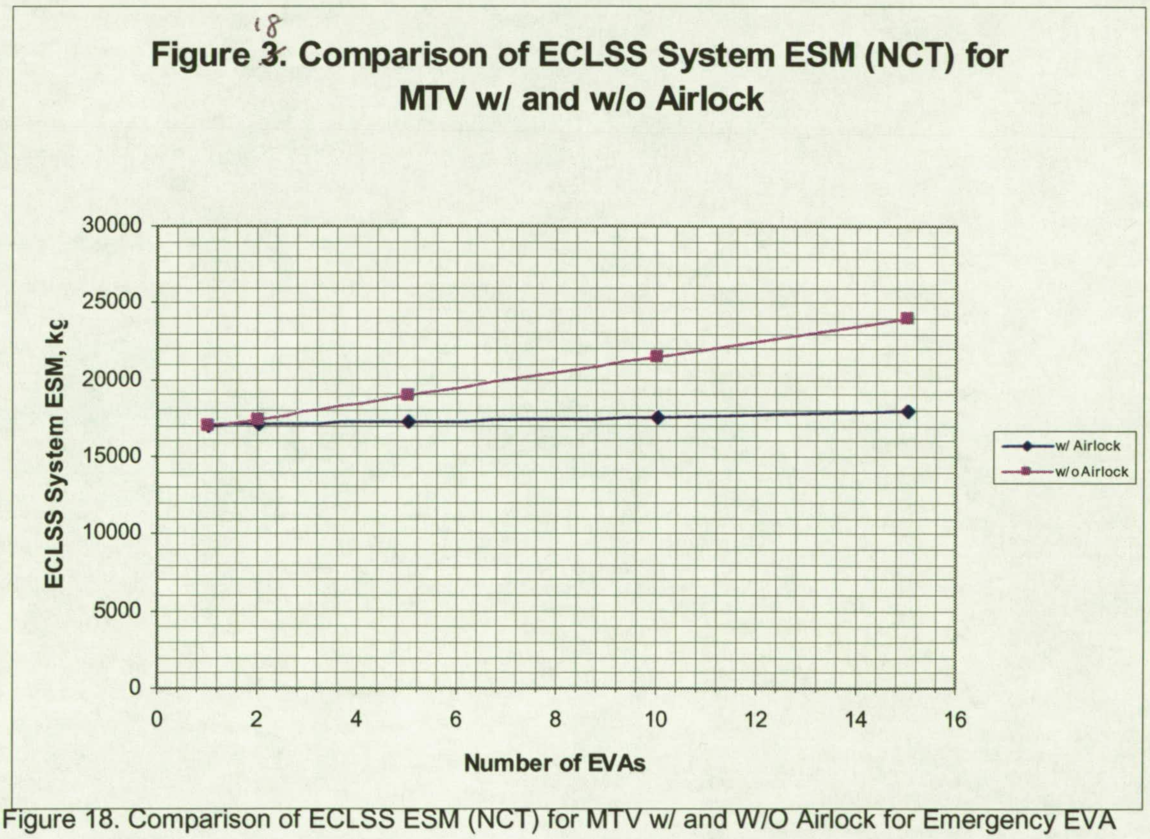


Figure 18. Comparison of ECLSS ESM (NCT) for MTV w/ and W/O Airlock for Emergency EVA

ii. DAV w/ and w/o Airlock

The study on the DAV with an airlock was expanded to include a recycle pump in order to determine the impact of the recycle pump.

Figure 19 compares the ECLSS mass for the three case studies and shows that the breakeven point for the DAV with an airlock (no recycle pump) and without an airlock is 5.5 EVAs, while the breakeven point for the DAV with an airlock (including pump) and without an airlock is four EVAs.

Figure 20 compares the ECLSS volume for the three cases and shows that the breakeven point for the DAV with airlock is 22 EVAs and the breakeven point for the DAV with an airlock (including pump) is 19 EVAs.

Figure 21 compares the ECLSS ESM for the three cases and shows that the breakeven point for the DAV with an airlock is six EVAs and the breakeven point for the DAV with an airlock and pump is eight EVAs.

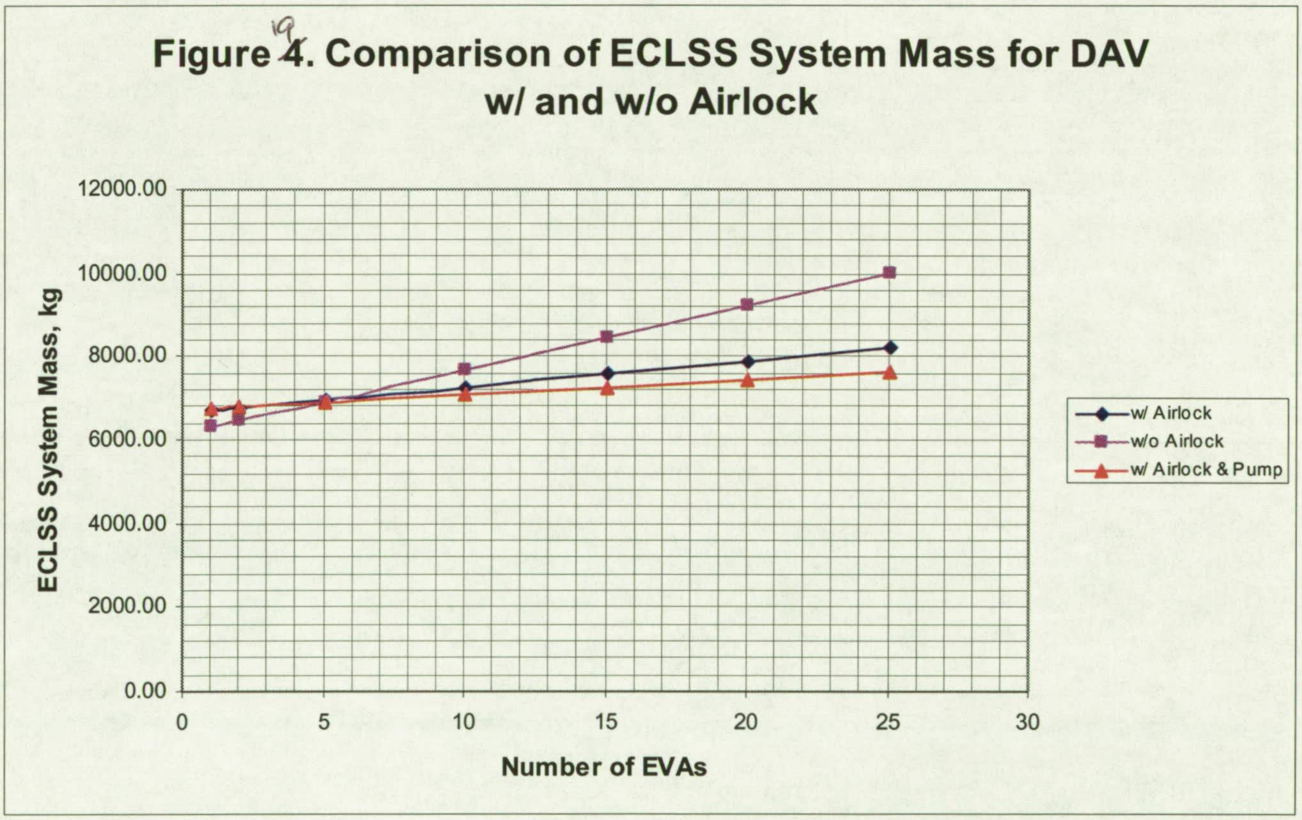


Figure 19. Comparison of ECLSS Masses for DAV w/ and w/o Airlock for Emergency EVA

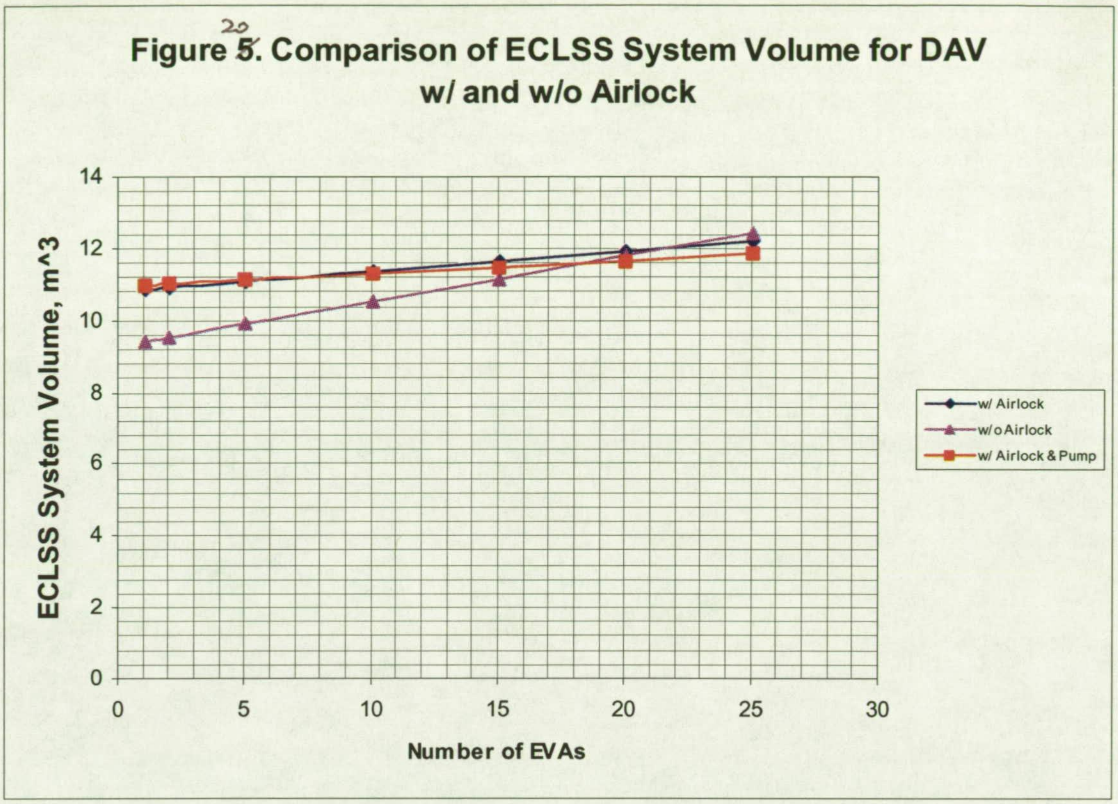


Figure 20. Comparison of ECLSS Volumes for DAV w/ and w/o Airlock for Emergency EVA

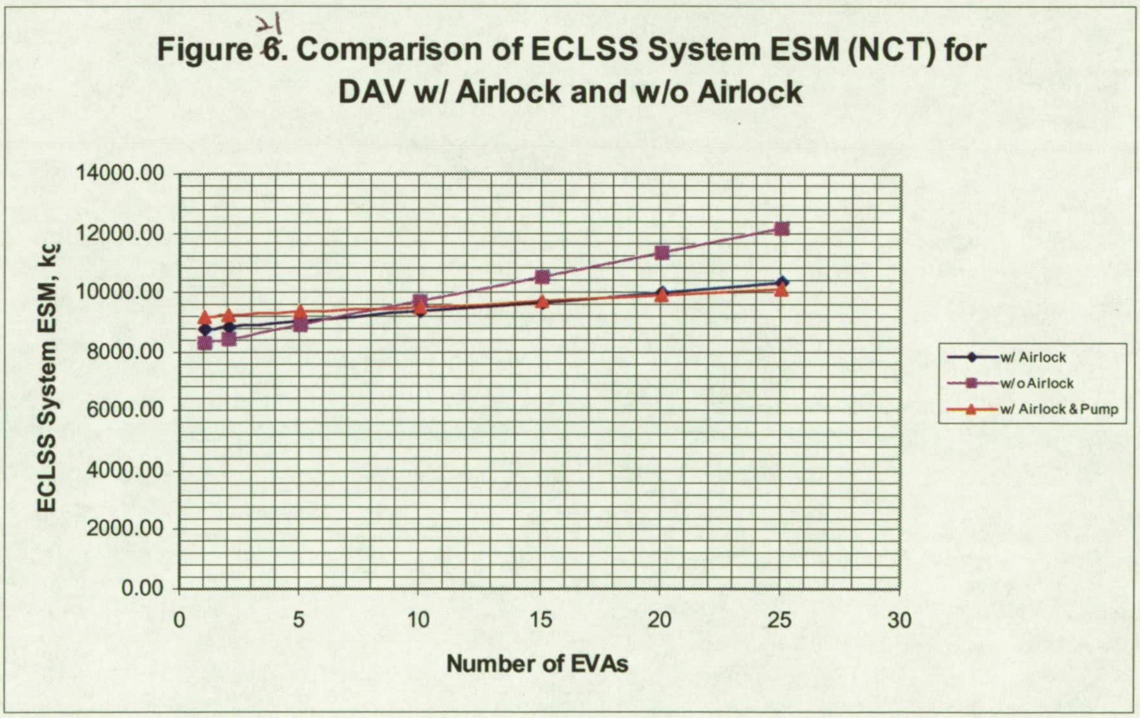


Figure 21. Comparison of ECLSS ESM (NCT) for DAV w/ and w/o Airlock for Emergency EVA

iii. Trade Study Summary

This study concluded that the larger the cabin volume of the vehicle, the fewer the number of EVAs required to pay off the extra mass caused by carrying the airlock to space.

For an MTV mission, inclusion of an inflatable airlock is justified, considering that the breakeven point is one EVA for a round-trip mission of 360 days. A normal mission duration is 180 days.

For a DAV mission, inclusion of an inflatable airlock may not be necessary, based on the current assumption of a cabin volume of 25.5 m^3. As Figure 21 shows, the breakeven point for the DAV with an airlock (no recycle pump) and without an airlock is six EVAs, while the breakeven point for DAV with an airlock (including recycle pump) and without an airlock is eight EVAs. The DAV's normal mission duration is seven days, while its maximum mission duration is 30 days.

Although the recycle pump can reduce the air loss in order to reduce the ECLSS launch mass and volume, the power consumption by the recycle pump makes it unfavorable for short duration missions.

This study also shows that the ESM system is quite helpful in decision-making for feasibility studies. It is difficult to determine the proper direction based on the calculation results of the three fundamental measurements, i.e. the mass, volume, and power, especially when these three measurements are moving in different directions. For instance, using the recycle pump increases the power consumption, while the ECLSS mass and volume are reduced by the pump's inclusion. Without the ESM system, it would be difficult to decide at what point to use the recycle pump with an airlock.

CONCLUSIONS

ALSSAT has been upgraded into a well-developed sizing analysis tool for the ALS technology trade studies since its publication in ICES 2001. ALSSAT has been constantly upgraded to include more technology selections for the ALS subsystems, to improve its calculation accuracies, to update the subsystems with more current sizing data, and to increase its flexibility in performing trade studies. It has been expanded to include the Food Management Subsystem, Waste Management Subsystem, Thermal Control Subsystem, the EVA and Human Accommodations, and the ESM calculation.

The Overall Mass Balance worksheet was implemented to integrate the ALS subsystems and the external interfaces. The integration allows the user to determine the impact of the overall result if the user wants to compare the different options or technologies used by a certain regenerative subsystem.

The user can perform parametric studies by changing a single parameter in the Main Module and to view the instantaneous change of the result in the Direct Input/Output worksheet. The user can also run multiple case studies by entering the inputs and storing them in separate files. The data files can be reloaded to run up to four cases at the same time to view the impact of selecting different technology/options by displaying the results in the graphical format. The addition of contingency options allows the user to view of the four cases with and without contingency, bringing the total case comparison capability up to eight cases.

ALSSAT demonstrated its capability in performing trade studies easily and efficiently, as illustrated by the inclusion of the airlock trade study evaluation results. It has been used to calculate the FY02 and FY03 Metrics reported to NASA Headquarter in Washington DC.

ACKNOWLEDGMENTS

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

4BMS: 4 Bed Molecular Sieve

AAA: Avionics Air Assembly

ACMA: Atmosphere Composition Monitoring Assembly

ACO2R: Airlock CO_2 Removal Unit

ACS: Atmosphere Control System

AMC: Atmospheric Microbial Control

APC: Atmospheric Pressure Control

ATCO: Ambient Temperature Catalytic Oxidizer

ALS: Advanced Life Support

ALSSAT: Advanced Life Support Sizing Analysis Tool

ARS: Air Revitalization System

BFD: Block Flow Diagram

Biomass: Biomass Subsystem

BNC: Baseline Nominal Capacity

BPC: Biomass Production Chamber

BVAD: Baseline Values and Assumptions Document

BWRS: Bioregenerative Water Recovery System

CDRS: Carbon Dioxide Removal Subsystem

CMRS: Carbon Dioxide and Moisture Removal Subsystem

CCAA:Common Cabin Air assembly

CO_2: Carbon Dioxide

CO2Red: CO_2 Reduction

CO2Rem: CO_2 Removal
CRS: CO_2 Reduction System

CT: Crew Time

CTSD: CREW AND THERMAL SYSTEMS DIVISION

DAV: Descent/Ascent Vehicle

ECLS: Environmental Control and Life Support

ECLSS: Environmental Control and Life Support System

EMU: Extravehicular Mobilitiy Unit

EVA: EXTRAVEHICULAR ACTIVITIES

EDC: Electrochemical Depolarized Concentrator CO_2 Removal System

ESDM: Environmental Control and Life Support System Design Model

ESM: Equivalent System Mass

FAn: Stream number n in the Air Management Subsystem

FDS: Fire Detection and Suppression

FFn: Stream n of the BFD and mass balance of the Food Subsystem

FISn: Stream n of the individual BFD and mass balance of the WMS using ISS WRS

FMS: FOOD MANAGEMENT SUBSYSTEM

Food: Food Management Subsystem

FSWn: Stream Number n in the overall BFD and mass balance sheet of the Solid Waste Management Subsystem

FWLSn: Stream No. n of the individual BFD and mass balance of the SWMS using WAD+Lyophilization+Storage

FWn: Stream Number n of the Primary BFD and Mass Balance of the Water Management Subsystem

FY02: FISCAL YEAR 2002

FY03: FISCAL YEAR 2003

H_2: HYDROGEN

HA: HUMAN ACCOMMODATIONS

ICES: International Conference on Environmental Systems

IMV: Intermodule Ventilation

ISS: International Space Station

ISS WRS: International Space Station Water Recovery System

ITCS: Internal Thermal Control Subsystem

JSC: Johnson Space Center

LiOH: Lithium Hydroxide

MAG: Maximum Absorbency Garment

MCA: Major Constituent Assembly

MVP: Mass, Volume, and Power

MTV: Mars Transit Vehicle

N_2: Nitrogen

NASA: National Aeronautics and Space Administration

NCT: Non-Crew-Time

O_2: Oxygen

O2Gen: Oxygen Generation

OGS: Oxygen Generation Subsystem

SAVD: Solid Amine Vacuum Desorption

SDS: Sample Delivery System

SFSPE: Static Feed SPE

SPE: Solid Polymer Water Electrolysis

SWPS: Solid Waste Processing System

TCCS: Gaseous Trace Contaminant Control Subsystem

TCS: Thermal Control Subsystem

THC: Temperature & Humidity Control

VB: Visual Basic

VIPeR: Vehicle Integrated Performances and Resources

Vpcar: Vapor Phase Catalytic Ammonia Removal Process

WAD: Warm Air Drying

WMS: WATER MANAGEMENT SUBSYSTEM

WRS: Water Recovery system, Water Reclamation system