TN 4

LIFE SUPPORT SYSTEM SIZING

MELISSA ADAPTATION FOR SPACE, PHASE II

ESTEC/Contract Nº 20104/06/NL/CP

APPROVAL LIST		
NAME	SIGNATURE	DATE
Prepared by: J. Duatis V. Guirado S. Podhajsky D. Moreno		01/07/2009 01/07/2009
Revised by: J. Duatis		17/07/2009
Approved by: E. Creus		20/07/09
Authorised by: J. Duatis		20/07/2009

DISTRIBUTION LIST

NAME	POSITION	COMPANY
Ch. Lasseur	TEC-MCT	ESTEC

CHANGE RECORD

AUTHOR	ISSUE	DATE	CHANGE
J. Duatis V. Guirado S. Podhajsky D. Moreno	Draft A	25 March 2009	Preliminary version
J. Duatis	1.0	01 July 2009	Updated figures 3-2 and 3-3 to include components as per comment #1. General remark about sizing of MELiSSA compartments added in 3.1.7.4 as per comment #2-6. Expanded principle of the UTU as per comment #9 Added ToC of figures and tables as per comment #10 Reviewed wording in general.

CONTENTS

ACRONYMS LIST

ARES	Air Revitalization System
BLSS	Bioregenerative Life Support System
BVAD	Baseline Values Assumption Document
BWTU	Black Water Treatment Unit
COTS	Commercial Off The Shelf
ECLSS	Environmental Control and Life Support System
EVA	Extra Vehicular Activity
FPU	Food Production Unit
GCR	Galactic Cosmic Rays
GWTU	Grey Water Treatment Unit
HPC	Higher Plants Compartment
ISPR	International Standard Payload Rack
ISRU	In Situ Resources Utilisation
LSS	Life Support System
MELiSSA	Micro Ecological Life Support System Alternative
MPP	MELiSSA Pilot Plant
PE	Polyethylene
SMAC	Spacecraft Maximum Allowable Concentration
SPE	Solar Particles Events
SS	Stainless steel
UTU	Urine Treatment Unit

Figures

Tables

1. SCOPE

This document defines the system sizing for the Life Support System design defined in TN3 [R1]. The two configurations, the 5% diet and the 40% diet will be considered as a staggered approach, that is, the design will consider first a configuration where the 5% of the diet is provided and in a second phase, the 40% of the diet will be provided due to the accommodation of a Higher Plants Compartment (Greenhouse).

For the configurations defined in TN3 [R1] information about the elements for each compartment (MELiSSA, ARES, GWRU, UTU) will be detailed, giving the estimated values for mass, power, volume and maintenance time.

In this technical note trade-offs about different configurations will be performed taking into account the moon scenario conditions defined in TN1 [R2].
- Geometry of the lunar module (gravity, pressure, transportation)
- Inflatable vs. rigid structures
- Materials for radiation protection

Specific considerations for each compartment and related technologies regarding the moon base scenario will be identified.

2. APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable Documents

[A1] Request for Quotation RFQ/3-11481/05/NL/CP – MELISSA Adaptation for Space - Phase 2, ref.: RES-PTM/CP/cp/2005.915, dated 16/11/05

[A2] Statement of Work MELiSSA Adaptation for Space – Phase 2, Ref. TEC/MCT/2005/3467/In.CL dated November 4th, 2005, Version 1 (Appendix 1 to RFQ/3-11481/05/NL/CP)

[A3] Special Conditions of Tender, Appendix 3 to RFQ/3-11481/05/NL/CP

[A4] ESA Fax Ref. RES-PTM/CP7cp/2006.226, dated 29/03/06

[A5] Minutes of Meeting ESA-NTE Clarification meeting on MELiSSA Adaptation for Space – Phase 2; no reference, dated 20/04/06

2.2 Reference Documents

[R1] Preliminary Life Support System Design, NTE-MEL2-TN-012, Issue 1.0, 05 Dec 2008

[R2] Moon Base Scenario Definition and Life Support System Requirements, NTE-MEL2-TN-007, Issue 1.0, 11 Jan 2008

[R3] Summary of European Life Support System Technologies, NTE-MEL2-TN-009, Issue 1.0, 28 March 2008

[R4] Engineering of the Waste Compartment. Design Report. N. Michel, J. Stuyck, F. Vand Vooren. 5/03/2007.

[R5] Preliminary Design of the Water Recycling System. TN 8. J. Mas. Issue 1.2. 22-Feb-2008.

[R6] Technical Specifications for the Re-design of the Compartment IVa Pilot Reactor. UAB.

[R7] Nitrfying Compartment Studies. Starting of the Nitrifying reactor. Issue 1.2. Perez, J. , Montesions J.L., Godia F., September 1996

[R8] Set-up of the Photosynthetic Pilot Reactor. TN 37.2. Issue 1.0. Vernerey. A., Albiol J., Godia F. April 1998.

[R9] Potential Designs for a Food Production Unit. E.G.O.N. Janssen, M.H. Stienstra, D. Wierinck , M. De Ridder, R. Kassel, J. Elvira. TN 2. Issue 1.1. 28 Feb 2005.

[R10] Higher Plant Chamber Prototype for the MELiSSA Pilot Plant: Detailed Design and Verification. Geofrey Watters, Alexandra Massot. Issue 1.0. 26 Sept 2006.

[R11] Photoheterotrophic Compartment Set-up. TN 37.6. Issue 1.0. Cabello, F., Albiol, J., Godia, F.

[R12] Advanced Life Support Baseline Values and Assumptions Document. Hanford, A.J. et al. (2004). JSC-47804, NASA CTSD-ADV-484A

[R13] ARES baseline design report, ARES-DOR-RP-001, Issue 5

[R14] MELiSSA Loop: First Estimate of Flow Rates and Concetrations through the Loop. Poughon L., Gros J.B. and Dussap C. G. ICES 2000.

[R15] NASA's Exploration Systems Architecture Study (ESAS). Section 1. Executive Summary. Final Report. November 2005.

[R16] Design of a Thermal and Micrometeorite Protection System for Unmanned Lunar Cargo Lander. Hernandez, Carlos A. et Al. The University of Texas, Austin, 1989.

[R17] Structural Design of a Lunar Habitat. Ruess, F. et Al. Institute for Structural Design, Univ. of Stuttgart. Journal of Aerospace Engineering, Vol. 19, No. 3, July 1, 2006.

3. INTRODUCTION

In previous technical notes, the requirements for an European Life Support module for a Moon base have been set [R2] and an EcosimPro library with the models of the MELiSSA loop, ARES, UTU and GWTU components has been created and described in [R3]. A preliminary design of a Life Support System has been defined in [R1] which will be the base for the preliminary system sizing performed in this document.

The preliminary design is based on MELiSSA for food production and waste recycling, ARES as a support for additional oxygen production and the Grey Water Recovery Unit plus the Urine Treatment Unit for water recovery. Two scenarios are defined, one with only the 5% of food production and a second which will reach up to the 40% of the diet of a crew of 4. With respect to the design, the main difference between the two scenarios is that the second will incorporate a Higher Plants Chamber, while the first with the Spirulina compartment (CIVa) it is enough to produce the 5% of the diet.

In the following sections, the sizing of the different technologies used in terms of mass, volume and power will be estimated. This information will be used in the next technical note (TN5) to define a preliminary system design

4. SIZING OF EUROPEAN LSS TECHNOLOGIES

4.1 MELiSSA

The library components used for the MELiSSA technologies are shown in Figure 1. The basic elements are Compartment I (CI), Compartment II (CII), Compartment III (CIII), Compartment IVa (CIVa), Higher Plants Chamber (HPC) and the Crew Compartment (CC).

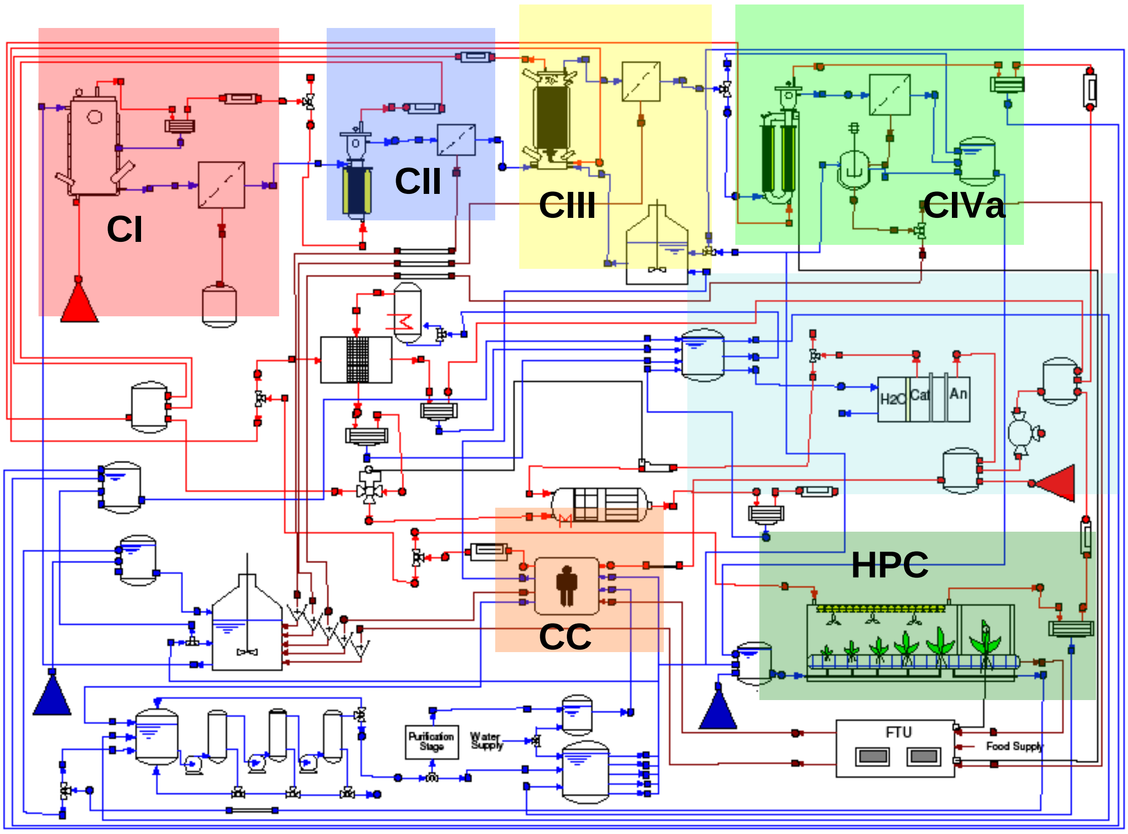


Figure 1 MELiSSA Technologies

To obtain the size in terms of mass, volume and power of the different MELiSSA compartments, the MELiSSA Pilot Plant designs have been selected as the base for the calculations. The list of components has been obtained from the TN generated for the compartments design and the mass, power and volume of each component has been obtained using the technical data available of the component or taking a similar component from which this data is already available. In the following sections the list of components is given for each compartment, indicating the reference from which the list of components has been taken, and the reference from which volume, mass and power has been obtained. Note that the volume and mass of tanks needed is added afterwards in sections 4 and 5 where global calculations are performed for the 5% food production and 40% food production configurations.

4.1.1 Compartment I Sizing

The list of components for the Compartment I is as follows:

Equipment	Description	Units	Power (W)	Volume (l)	Mass (kg)	Reference
3-way plug valve	Flow <1 l/h inlet pres.0.1-10 bar outlet pres.10 b	11	121	16.5	16.5	NTE-GWTU-TN-088_3.1; Swagelok
3-way plug valve	Flow <1 l/h inlet pres.0.1-10 bar outlet pres.10 b	3	33	4.5	4.5	NTE-GWTU-TN-088_3.1; Swagelok
3-way plug valve	Flow <1 l/h inlet pres.0.1-10 bar outlet pres.10 b	9	99	13.5	13.5	NTE-GWTU-TN-088_3.1; Swagelok
3-way plug valve	Flow <1 l/h inlet pres.0.1-10 bar outlet pres.10 b	4	44	6	6	NTE-GWTU-TN-088_3.1; Swagelok
Acid-Base pump	Flow < 0.5l/h	2	20	2.78	3	NTE-GWTU-TN-088_3.1; Watson Marlow
Biomass sensor	VIAMASS impedance spectroscopy	1	30	12	1.2	NTE VIAMASS sensor
Blender	0 - 250 rpm	1	150		2.5	NTE-GWTU-TN-088_3.1; Mervers
Blender	0 - 250 rpm	1	150		2.5	NTE-GWTU-TN-088_3.1; Mervers
Cooler	-40 to 30 Cº	1	380	53	37	M&C EC-30
Cooling and condensating element	-5°C to 50°C	1	500	30	13.6	NTE-GWTU-TN-088_3.1; ThermoCube
Effluent pump	Flow ca. 1 l/h	1	25	0.7	6	NTE-GWTU-TN-088_3.1; Watson Marlow
Gas Analyser	Multi-gas analyser	1	1500	37	75	MAIHAK MKAS 710 (no cabinet)
Gas compressor	60 psi vacuum/compressor pump	1	550	6.5	8.5	KNF N035
Gas flow controller	10-100 Nl/min	5	100	8	1	NTE-GWTU-TN-088_3.1; Gefran/Flowcor
Gas pump	21 Nl/min at 1.5 bar	1	120	8	10	KNF N920APE
Heater	5 - 40º (20-23 W per squared inch)	1	2200	0.517	10.8	GAUMER C2F3N13M2
Heater	5 - 40º (20-23 W per squared inch)	1	2200	0.517	10.8	GAUMER C2F3N13M2
Level sensor		2	5	0	0.2	NTE-GWTU-TN-088_3.1; Endress + Hauser
Level sensor		4	10	0	0.4	NTE-GWTU-TN-088_3.1; Endress + Hauser
Level sensor		1	2.5	0	0.1	NTE-GWTU-TN-088_3.1; Endress + Hauser
Level switch		1	2.5	0.12	0.1	NTE-GWTU-TN-088_3.1; Endress + Hauser
Level switch		2	5	0.24	0.2	NTE-GWTU-TN-088_3.1; Endress + Hauser
Level switch		1	2.5	0.12	0.1	NTE-GWTU-TN-088_3.1; Endress + Hauser
Liquid flow controller	0-72 l/d	1	10	9.9	0.3	NTE-GWTU-TN-088_3.1; Brooks
Nano filtration membrane		9	0	6.93	10.8	NTE-GWTU-TN-088_3.1; Exekia
Needle valve	Flow >1 l/h inlet pres.5-10 bar outlet pres.1 bar	5	50	2.5	3	NTE-GWTU-TN-088_3.1; Bronkhorst
pH meter	0-14	2	20	0.4	0.5	NTE-GWTU-TN-088_3.1; Elscolab
Powered 2-way valve	Inlet 0,1-2bar outlet 0,2bar	12	120	0	12	NTE-GWTU-TN-088_3.1; Eriks
Powered 2-way valve	Inlet 0,1-2bar outlet 0,2bar	5	50	0	5	NTE-GWTU-TN-088_3.1; Eriks
Powered 2-way valve	Inlet 0,1-2bar outlet 0,2bar	18	180	0	18	NTE-GWTU-TN-088_3.1; Eriks
Powered 2-way valve	Inlet 0,1-2bar outlet 0,2bar	18	180	0	18	NTE-GWTU-TN-088_3.1; Eriks
Pressure transmitter sensor	0-10 bar, acc < 10%	1	10	0.2	0.15	NTE-GWTU-TN-088_3.1; Endress + Hauser
Pressure transmitter sensor	-1-4 bar, acc<10%	1	0.48	0.25	0.25	NTE-GWTU-TN-088_3.1; Endress + Hauser
Pressure transmitter sensor	0-10 bar, acc < 10%	8	80	1.6	1.2	NTE-GWTU-TN-088_3.1; Endress + Hauser
Pressure transmitter sensor	0-10 bar, acc < 10%	2	20	0.4	0.3	NTE-GWTU-TN-088_3.1; Endress + Hauser
Pressure transmitter sensor	0-10 bar, acc < 10%	5	50	1	0.75	NTE-GWTU-TN-088_3.1; Endress + Hauser
Pressure valve	Inlet(-)0.1-0.5bar outlet 0,5bar	1	10	0	0.25	NTE-GWTU-TN-088_3.1; Ritec
Pressure valve	Inlet(-)0.1-0.5bar outlet 0,5bar	4	40	0	1	NTE-GWTU-TN-088_3.1; Ritec
Recirculation pump	Flow ca. 100 l/h	1	37	6.5	4.1	NTE-GWTU-TN-088_3.1; Masterflex

Equipment	Description	Units	Power (W)	Volume (l)	Mass (kg)	Reference
Recirculation pump	Flow ca. 100 l/h	1	37	6.5	4.1	NTE-GWTU-TN-088_3.1; Masterflex
Recirculation pump	Flow ca. 100 l/h	3	111	19.5	12.3	NTE-GWTU-TN-088_3.1; Masterflex
Recirculation pump	Flow ca. 100 l/h	3	111	19.5	12.3	NTE-GWTU-TN-088_3.1; Masterflex
Temperature sensor	0 - 50º	2	20	0	0.5	NTE-GWTU-TN-088_3.1; Prosensor
Temperature sensor	0 - 50º	1	10	0	0.25	NTE-GWTU-TN-088_3.1; Prosensor
Temperature sensor	0 - 50º	1	10	0	0.25	NTE-GWTU-TN-088_3.1; Prosensor
Temperature sensor	0 - 50º	2	20	0	0.5	NTE-GWTU-TN-088_3.1; Prosensor
Temperature sensor	0 - 50º	2	20	0	0.5	NTE-GWTU-TN-088_3.1; Prosensor
Turbidity Sensor	0 - 1000 NTU	1	30	1.1	4.5	Optek 156-AF56N
Vacuum pump	60 psi vacuum/compressor pump	1	550	6.5	8.5	KNF N035

Table 1Compartment I. List of components [R4]

Totals Compartment I	
Number of components	166
Power peak (W)	10025
Volume (l)	282
Mass (Kg)	342

Table 2. Compartment I Totals

4.1.2 Compartment II Sizing

The list of components for the Compartment II is as follows:

Equipment	Description	Units	Power(W)	Volume(l)	Mass (Kg)	Reference
Blender	0 - 250 rpm	1	150		2.5	NTE-GWTU-TN-088_3.1; Mervers
Control System	Control HW and graphical interface	1	190	15	5.5	NTE-GWTU-TN-088_3.1; Schneider
Cooler	-40 to 30 Cº	1	380	53	37	M&C EC-30
Effluent pump	Flow ca. 1 l/h	4	100	2.8	24	NTE-GWTU-TN-088_3.1; Watson Marlow
Effluent pump	Flow ca. 1 l/h	3	75	2.1	18	NTE-GWTU-TN-088_3.1; Watson Marlow
Gas Analyser	Multi-gas analyser	1	1500	37	75	MAIHAK MKAS 710 (no cabinet)
Gas flow controller	10-100 Nl/min	2	40	3.2	0.4	NTE-GWTU-TN-088_3.1; Gefran/Flowcor
Gas pump	21 Nl/min at 1.5 bar	1	120	8	10	KNF N920APE
Level switch		2	5	0.24	0.2	NTE-GWTU-TN-088_3.1; Endress + Hauser
Liquid flow controller	0-72 l/d	2	20	19.8	0.6	NTE-GWTU-TN-088_3.1; Brooks
pH meter	0-14	2	20	0.4	0.5	NTE-GWTU-TN-088_3.1; Elscolab
Powered 2-way valve	Inlet 0,1-2bar outlet 0,2bar	35	350	0	35	NTE-GWTU-TN-088_3.1; Eriks
Pressure transmitter sensor	0-10 bar, acc < 10%	2	20	0.4	0.3	NTE-GWTU-TN-088_3.1; Endress + Hauser
Pressure valve	Inlet(-)0.1-0.5bar outlet 0,5bar	1	10	0	0.25	NTE-GWTU-TN-088_3.1; Ritec
Reactor Lamps (m2 of illuminated surface)	4 KW per m2 of iluminated surface	1	4920	0.25	22.9	ASL Baseline Values and Assumptions- JSC 47804
Temperature sensor	0 - 50º	2	20	0	0.5	NTE-GWTU-TN-088_3.1; Prosensor
Turbidity Sensor	0 - 1000 NTU	2	60	2.2	9	Optek 156-AF56N

Table 3 Compartment II. List of components [R11]

Totals Compartment II	
Number of components	63
Power peak (W)	7980
Volume (l)	144
Mass (Kg)	242

Table 4. Compartment II Totals

4.1.3 Compartment III Sizing

The list of components for the Compartment III is as follows:

Equipment	Description	Units	Power(W)	Volume(l)	Mass	Reference
Gas pump	21 Nl/min at 1.5 bar	2	240	16	20	KNF N920APE
Pressure valve	Inlet(-)0.1-0.5bar outlet 0,5bar	1	10	0	0.25	NTE-GWTU-TN-088_3.1; Ritec
Control System	Control HW and graphical interface	1	190	15	5.5	NTE-GWTU-TN-088_3.1; Schneider
Powered 2-way valve	Inlet 0,1-2bar outlet 0,2bar	30	300	0	30	NTE-GWTU-TN-088_3.1; Eriks
Pressure transmitter sensor	0-10 bar, acc < 10%	1	10	0.2	0.15	NTE-GWTU-TN-088_3.1; Endress + Hauser
Level switch		2	5	0.24	0.2	NTE-GWTU-TN-088_3.1; Endress + Hauser
Effluent pump	Flow ca. 1 l/h	3	75	2.1	18	NTE-GWTU-TN-088_3.1; Watson Marlow
Gas Analyser	Multi-gas analyser	1	1500	37	75	MAIHAK MKAS 710 (no cabinet)
Heater	5 - 40º	1	500	30	13.6	
DO measurement	0- 10 mg O2/l	2	30	0	1	NTE-GWTU-TN-088_3.1; Elscolab
Acid-Base pump	Flow < 0.5l/h	2	20	2.78	3	NTE-GWTU-TN-088_3.1; Watson Marlow
pH meter	0-14	2	20	0.4	0.5	NTE-GWTU-TN-088_3.1; Elscolab
Cooler	-40 to 30 Cº	1	400	1.8	20	
Blender	0 - 250 rpm	1	150		2.5	NTE-GWTU-TN-088_3.1; Mervers
Temperature sensor	0 - 50º	2	20	0	0.5	NTE-GWTU-TN-088_3.1; Prosensor
Gas flow controller	10-100 Nl/min	2	40	3.2	0.4	NTE-GWTU-TN-088_3.1; Gefran/Flowcor
Amonium analyser	0.2 - 12 mg/L NH4+-N	1	100	49.28	10	NTE-GWTU-TN-088_3.1; AMTAX-Compact

Table 5 Compartment III. List of components [R7]

Totals Compartment III	
Number of components	56
Power peak (W)	5320
Volume (l)	191
Mass (Kg)	216

Table 6. Compartment III Totals

4.1.4 Compartment CIVa Sizing

The list of components for the Compartment CIVa is as follows:

Equipment	Description	Units	Power(W)	Volume(l)	Mass (Kg)	Reference
Acid-Base pump	Flow < 0.5l/h	2	20	2.78	3	NTE-GWTU-TN-088_3.1; Watson Marlow
Amonium analyser	0.2 - 12 mg/L NH4+-N	1	100	49.28	10	NTE-GWTU-TN-088_3.1; AMTAX-Compact
Biomass sensor	VIAMASS impedance spectroscopy	1	30	12	1.2	NTE VIAMASS sensor
Blender	0 - 250 rpm	1	150		2.5	NTE-GWTU-TN-088_3.1; Mervers
Control System	Control HW and graphical interface	1	190	15	5.5	NTE-GWTU-TN-088_3.1; Schneider
Cooler	-40 to 30 Cº	1	380	53	37	M&C EC-30
DO measurement	0- 10 mg O2/l	2	30	0	1	NTE-GWTU-TN-088_3.1; Elscolab
Effluent pump	Flow ca. 1 l/h	3	75	2.1	18	NTE-GWTU-TN-088_3.1; Watson Marlow
Gas Analyser	Multi-gas analyser	1	1500	37	75	MAIHAK MKAS 710 (no cabinet)
Gas flow controller	10-100 Nl/min	2	40	3.2	0.4	NTE-GWTU-TN-088_3.1; Gefran/Flowcor
Gas pump	21 Nl/min at 1.5 bar	2	240	16	20	KNF N920APE
Heater	5 - 40º (20-23 W per squared inch)	1	2200	0.517	10.8	GAUMER C2F3N13M2
Level switch		2	5	0.24	0.2	NTE-GWTU-TN-088_3.1; Endress + Hauser
pH meter	0-14	2	20	0.4	0.5	NTE-GWTU-TN-088_3.1; Elscolab
Powered 2-way valve	Inlet 0,1-2bar outlet 0,2bar	30	300	0	30	NTE-GWTU-TN-088_3.1; Eriks
Pressure transmitter sensor	0-10 bar, acc < 10%	1	10	0.2	0.15	NTE-GWTU-TN-088_3.1; Endress + Hauser
Pressure valve	Inlet(-)0.1-0.5bar outlet 0,5bar	1	10	0	0.25	NTE-GWTU-TN-088_3.1; Ritec
Temperature sensor	0 - 50º	2	20	0	0.5	NTE-GWTU-TN-088_3.1; Prosensor

Table 7 Compartment IVa. List of components [R6], [R8]

Totals Compartment IVa	
Number of components	60
Power peak (W)	12785
Volume (l)	164
Mass (Kg)	242

Table 8. Compartment IVa Totals

4.1.5 Common equipment

Following equipment it supposed to be reused by all the compartments:

Equipment	Description	Units	Power(W)	Volume(l)	Mass	Reference
3-way plug valve	Flow <1 l/h inlet pres.0.1-10 bar outlet pres.10 b	7	77	10.5	10.5	NTE-GWTU-TN-088_3.1; Swagelok
Cooling and condensating element	-5°C to 50°C	1	500	30	13.6	NTE-GWTU-TN-088_3.1; ThermoCube
Steam generator	1 BHP - 34.5 LB/HR - 33500 BTU/HR	1	10000	324	90	LG10 Electro-Steam

Table 9 List of components reused

Totals Common	
Number of components	9
Power peak (W)	10577
Volume (l)	364.5
Mass (Kg)	114

Table 10. Common Components Totals

4.1.6 HPC Compartment

For the HPC compartment, the data from study performed in [R9] is used. There, a design of a greenhouse named Food Production Unit (FPU) based on ground technologies, and with a trade-off of different architectures is performed. The study proposes three different configurations, based on an inflatable structure, a rigid structure and a ISS module based structure. The mass, power and volume of each solution is calculated. Also ESM values are obtained. The following table briefs the figures obtained in this study:

		Mass	Volume	Power	Cooling	Crew time
SS#	Subsystem	kg	m^3	kW	kW	h/p-k
1	Irrigation system	1572	0.00	0.00	0.00	3.00
2	Light system	171	0.00	130.26	130.26	0.00
3	Water and nutrient delivery	5158	0.00	2.55	2.55	0.00
4	Climate control system	1693	0.00	2.88	2.88	2.00
5	Waste Management	52	0.00	1.42	1.42	0.00
6	Crop and seed preservation	592	0.00	3.07	3.07	0.00
7	Crop handling	270	0.00	2.00	2.00	3.00
8	Plant support structure	2154	0.00	0.00	0.00	0.00
9.1	External structure (Inflatable FPU)	2922	147.66	0.00	0.00	4.96
9.2	External Structure (Rigid FPU)	2899	147.66	0.00	0.00	4.77
9.3	External Strucutre (ISS Module)	3920	147.66	0.00	0.00	4.77

Table 11. Mass, volume and power for a FPU from [R9]

In that study, one of the FPU designs is for a Mars base scenario, providing 40% of diet to a crew of 6. Main differences of the Moon with respect to the Mars scenario are the reduced radiation, the presence of dust storms, the increased gravity and the composition of the soil. On the other hand, depending on the landing zones, in the Moon there is the possibility of using Sun light, but with the problem of proper shielding for radiation and for micro-meteorite impacts. Also, cultivation area will be reduced if requirements are for a crew of 4.

The use of a transparent structure with possibility of filtering Sun light and even with the possibility of shadowing completely the light to simulate the night cycles would be very useful in reducing the amount of power required. The Sun light in a permanent (or almost permanent) illuminated zone of the Moon will be a precious resource to be taken into account. The transparent material would need to feature special characteristics, and be resistant enough, but it is clearly an affordable option. Power requirements in [R9] are based on led illumination. This is an interesting technology since permits to reduce considerably the power consumption in case that artificial lighting is needed. We will use two options when considering power consumption of the HPC, one with the proposed artificial lighting using a mixing of MHL and Sodium Lamps, and another using sunlight. Obviously the latter option will have structural design implications which will be analysed in TN5.

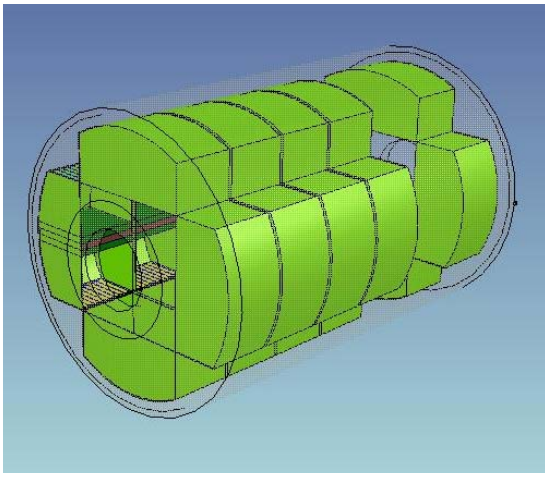


Figure 2. Columbus based growth chambers.

Surface used in simulations of TN3 [R1], is detailed in the following table:

Crop	Variable in Ecosim	Value (m^2)
Onion	Higher_Plants_Chamber_1.A[onion]	5.82
Potato	Higher_Plants_Chamber_1.A[potato]	37.66
Rice	Higher_Plants_Chamber_1.A[rice]	40.076
Lettuce	Higher_Plants_Chamber_1.A[salad]	15.22
Soybean	Higher_Plants_Chamber_1.A[soybean]	1.028
Spinach	Higher_Plants_Chamber_1.A[spinach]	12.074
Tomato	Higher_Plants_Chamber_1.A[tomato]	5.999
Wheat	Higher_Plants_Chamber_1.A[wheat]	14.60
TOTAL	Higher_Plants_Chamber_1.A_total	**132.50**

Table 12. Crop selection and surface from TN3

This lead to a total surface of 132.5 m^2 which is quite similar to the used in the FPU study (about 145 m^2). The difference is mainly because of the crop selection, more optimised in terms of nutrition since it is for a crew of 6. The crop in Table 12 used for the current study is based on the work performed by Poughon in [R14], for these crops growth models are available.

	Total surface [m²]	Weekly harvest [m²]	Edible biomass [kg / m²]	Crop [kg]
Wheat	76,5	6,3	1.2	7,56
Soybean	11,7	0,9	1,8	2,49(*)
French beans	31,7	2,6	0,94	3,75(*)
Garden cress	25,0	3,5	1,2	4,20

(*) Considering an average surface factor of 0.65

Table 13. Crop selection from [R9]

Volume of the facility is considered high enough to allow the crew access. The preliminary design will be based on cylindrical modules with only one layer to maximise light profitability. Taking as a base the ISS Destiny module (cylinder with 8,4 m length by 4,3 m diameter) it is needed to use 4 modules to reach around 145 m².

Label	Equipment	Description	Units	Power(W)	Volume(l)	Mass	Reference
HPC-Ctl	Control System	Control HW and graphical interface	1	190	15	5.5	NTE-GWTU-TN-088_3.1; Schneider
HPC-Dom	DO measurement	0- 10 mg O2/l	2	30	0	1	NTE-GWTU-TN-088_3.1; Elscolab
HPC-Dsf	Disinfection system UV/O3	16 mj/cm2 20 gpm (76L) 4.5m3/h	1	40	7.2	5.5	UVDynamics 8.40 E
HPC-Ecm	EC measurement	0- 110 mS/cm	2	30	0	0.8	NTE-GWTU-TN-088_3.1; Elscolab
HPC-Fan	Fan	1500 L/s air recirculation	3	120	5.1	4.8	ACI slimline VBL4/3
HPC-IR	Infra-red and Paramagnetic Analyser (CO2, O2)	CO2 0-500 ppm, O2 0-5%	1	70	40	10	YOKOGAWA IR200
HPC-LFl	Liquid flow controller	0-72 l/d	4	40	39.6	1.2	NTE-GWTU-TN-088_3.1; Brooks
HPC-Lgs	Light intensity sensor LI-190SL	Quantum Sensors calibrated for artificial	5	0	0.05	0.14	http://www.licor.com/
HPC-Lmp	Lamps HPS-MH including ballast per m2	4.5 lamps/m2	145	261000	90.625	720.65	ASL Baseline Values and Assumptions-JSC 47804
HPC-pHm	pH meter	0-14	2	20	0.4	0.5	NTE-GWTU-TN-088_3.1; Elscolab
HPC-Pmp	Effluent pump	Flow ca. 1 l/h	5	125	3.5	30	NTE-GWTU-TN-088_3.1; Watson Marlow
HPC-Pmp	Acid-Base pump	Flow < 0.5l/h	2	20	2.78	3	NTE-GWTU-TN-088_3.1; Watson Marlow
HPC-Pmp	Recirculation pump	Flow ca. 100 l/h	1	37	6.5	4.1	NTE-GWTU-TN-088_3.1; Masterflex
HPC-T	Temperature sensor	0 - 50º	9	90	0	2.25	NTE-GWTU-TN-088_3.1; Prosensor
HPC-Vlv	Level sensor		2	5	0	0.2	NTE-GWTU-TN-088_3.1; Endress + Hauser
HPC-Vlv	Powered 2-way valve	Inlet 0,1-2bar outlet 0,2bar	10	100	0	10	NTE-GWTU-TN-088_3.1; Eriks

Table 14. List of equipment in the HPC, from [R10]

For the mass calculation of the HPC, it is more important to account for the mass of the structures to support the different subsystems than the devices that they contain due to the big volumes involved. Therefore, the values of mass obtained in [R14] are used, these values are detailed per subsystem and contain the structures and devices (see table Table 11. Mass, volume and power for a FPU from [R9]). However, mass for the external structure is still not calculated, to calculate this mass it is necessary to define the layout of the module where the greenhouse will be contained.
However, as the artificial lighting system selected is based on the HPC design in the MPP (see 4.1.7.2), the power values are calculated using the figures from the devices and lighting power of this MPP design. This figure can be refined when defining the final layout.

Totals HPC	
Power peak (KW) (artificial lighting system + auxiliary equipment)	261
Volume (l)	220
Mass (Kg) (from R14 without structure)	11,662

Table 15. HPC Totals

4.1.7 General Assumptions

4.1.7.1 Bioreactor lighting

In Compartment II and IVa power is driven by the lighting system. Taking as a reference the Pilot Plant model in [R6] we can see that the MPP model of 77l of volume has a lighting system consuming 7KW for an illuminated surface of 1.42 m^2. It is clear that this figure can be improved by a detailed study of lighting systems, current system is based on halogen lamps which are not very efficient as most of the power is transformed into heat. However we will assume this factor since it is an experimental value. Therefore 7KW / 1.42 m^2 = 4.92 KW per m^2 of illuminated surface.

4.1.7.2 Higher Plants Chamber lighting

For the HPC in [R9] several lighting options are studied for space implementation. From the different options an average can be estimated for lighting power consumption of around 4 KW/ m^2. Also in [R11] for the MELiSSA Pilot Plant HPC a mixing of HPS and MH lamps is recommended with a total power consumption of 5.5 KW per 5 m^2 or 1.1 KW/m^2. On the other hand, in [R12] it is indicated as NASA baseline value for a higher plants chamber an average of 4.5 lamps x 400 W per squared meter, which results on 1.8 KW/m^2 , quite near to the MPP HPC. Hence we will use the 1.8 KW per cultivated m^2 as the factor for evaluation.

4.1.7.3 Biomass treatment

For CII it is assumed that biomass is not consumed by humans, so no special treatment is performed. On the other hand, biomass of CIVa is processed by a solid liquid separation system. For mass, volume and power it is assumed that is equivalent to a centrifuge an values from a COTS system are also taken. Other food treatment processes as drying or boiling are not considered at this stage.

4.1.7.4 Compartment devices

All valves have been considered automated valves, considering that there is power consumption.

Although lists of components for every compartment have been taken from MELiSSA Pilot Plant implementations, and this implementations are sized for one person, the number of devices can be extrapolated to be the same for a crew of four. The parts that depend on crew size will be calculated in the following sections, where the flow rates and bioreactors volume are dimensioned for the required crew number. Therefore the illuminated surface of the bioreactors, the size of the tanks and thus the resulting mass is calculated accordingly.

In this study piping is not considered although will affect considerably to the mass figures. However piping depends on the materials and the final geometric distribution of the design and therefore, at this stage it is difficult to perform a good estimation.

4.1.7.5 Structures mass

Also, support and enclosure structures are not taken into account in this section. In the following sections, the distribution of MELiSSA compartments into structures will be performed and mass derived from these structures accounted for.

4.1.8 Power consumption

Power consumption assumes that some equipment is reused by all compartments. For example an sterilisation unit used to maintain axenic conditions it is supposed to be reused by all compartments. The same for example for a condenser to recover water at the compartment gas outputs.

Total power consumption is outlined in the following table:

Element	Peak power (W)
Compartment I	10,025
Compartment II	7,980
Compartment III	5,320
Compartment IVa	12,785
Common equipment	10,577
Total (without HPC)	**46,688**
HPC (including artificial lighting)	263,417
Total (including HPC)	**310,105**

Table 16. MELiSSA compartments peak power

From the table above it can be noted that the compartments with lighting system (CII, CVIa and HPC) are the more power demanding.

4.1.9 Mass

Mass calculation is highly dependant on the materials for the different tanks. Size of tanks will be defined in the sections below taking into account the residence times and flow rates estimated for the system.

Total mass without accounting for the tanks is stated in the following table:

Element	Mass (Kg)
Compartment I	343
Compartment II	242
Compartment III	216
Compartment IVa	242
Common equipment	114
Total (without HPC)	**1,157**
HPC	11,662
Total (with HPC)	**12,819**

Table 17. MELiSSA compartments mass.

4.2 ARES

Air REvitalisation System (ARES) is a system to remove CO2 from the atmosphere and recover the oxygen by using a Sabatier reactor to generate water and methane and afterwards a electrolyser to recover the oxygen from this water.

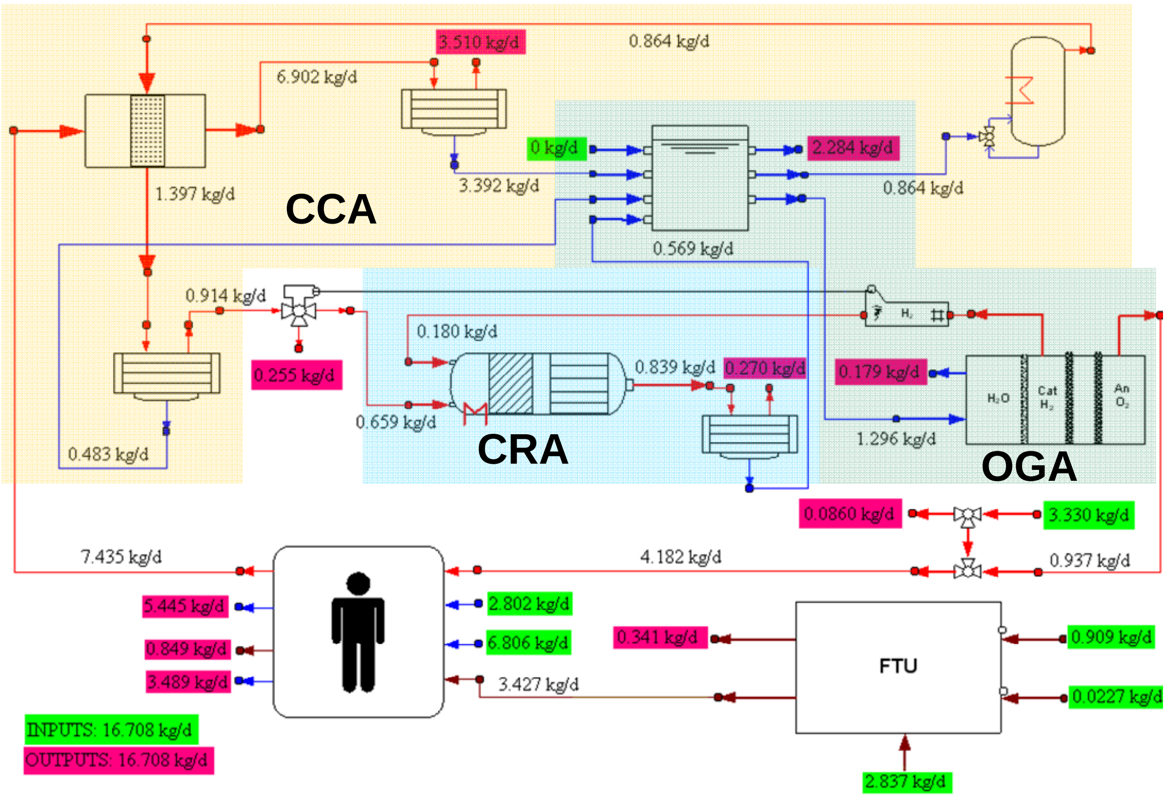


Figure 3. ARES technologies

The main components of ARES are the Carbon dioxide Concentration Assembly (CCA), the Carbon dioxide Reduction Assembly (CRA) and the Oxygen Generation Assembly (OGA).

The CCA contains an Adsorber-Desorber component, which separates the CO_2 from the atmosphere. The evaporator (E_CAA) is producing water vapor for the desorption process and two condensers after each of the components recuperates water from the gas streams.

The CRA contains the Sabatier reactor, which receives the CO_2 directly from the CCA.

Totals ARES	
Number of components	
Power peak (W)	3300
Volume (l)	ISPR rack
Mass (Kg)	750

Table 18. Mass, volume and power for ARES.

4.3 UTU

The Urine Treatment Unit subsystem principle is based on the biological conversion by nitrification of the urea present in the urine into nitrates. In nominal conditions, the urine is decomposed into urea, acid uric and creatinine, thus urea can be processed by the microbial bacteria of the nitrification bioreactor. In order to optimise the nitrification process it is important to dilute the urine to maintain low electro- conductivity (EC) values. Urine dilution is attained by mixing it with clean water coming from outside the system (for instance hygiene water processed by the GWTU or humidity condensate). Then, the resulting liquid is processed in the nitrification bioreactor (MELiSSA CIII).

4.4 GWTU

The Grey Water Treatment Unit (GWTU) collects grey water (from showers, laundry, sinks, etc) and humidity condensate and applies a filtration process to obtain water with hygiene quality. A part of this hygiene water is sent to a purification stage to obtain water with potable quality. Via the Liquid Collector and Distributor the obtained water from the different purification stages are distributed according to their needs.

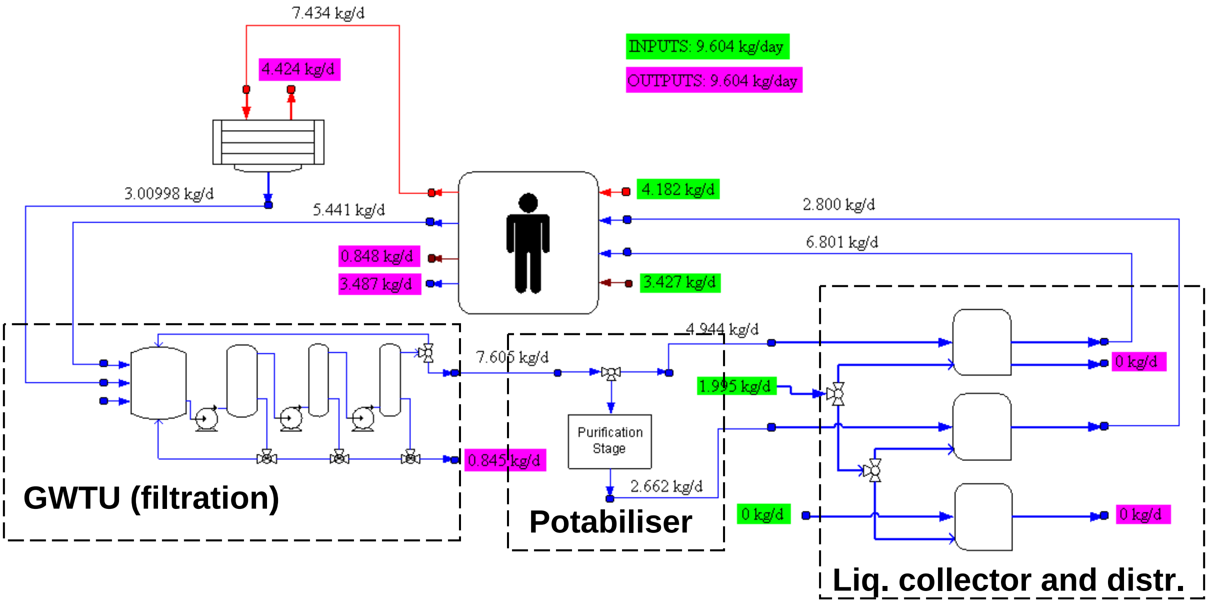


Figure 4. GWTU technologies

Mass, power and volume for the Water Recovery System is obtained from [R8] for a system with an input flow of ca. 80 litters/day and reproduced in the tables below:

	Mass Kg	Volume (l)	Power consumption (W)
Membranes	16,80	14,46	0,00
Pumps	162,30	40,90	5.311,00
Valves	40,11	TBD	249,00
Sensors, actuators & Hx	58,92	105,23	1.040,92
Tanks & filters	250,02	688,78	0,00
Piping	79,22	127,40	0,00
Control System	5,50	15,00	190,00
Total	612,87	991,76	6.790,92

Table 19. Mass, volume and power for GWRU.

The GWTU is quite efficient in recovering water from the grey water generated by the crew. It can be seen that there is a high power demand by the pumps. This high power demand is because of the high pressure required in the reverse osmosis filtration unit. However, with only the GWTU it is possible to recover the 90% of water if the UTU is used along with the filtration and potabilisation unit. Furthermore, if it is used in conjunction with MELiSSA, other sources of water can come from the condensation units of the different compartments and the HPC, reaching a near 90% water of total loop closure [R5].

5. CONFIGURATION A. 5% FOOD PRODUCTION

5.1 Volumes estimation

Bioreactor	Volumetric flow (l/d)	Residence time (days)	Volume (liters) rounded	Increased Volume (+20% and rounded)
CI	8	10	80	100
CII	6	0.8	5	10
CIII	34	0.4	14	20
CIVa	34	2.4	80	100
UTU (dilution tank)	28			40

Table 20. Tanks volume, 5% food production.

Residence times have been taken from [R14].

Note that volumes calculated have been increased in a approximately 20% to take into account the gas and some contingency, therefore a margin factor of 1.2 is applied.

Service tanks used to store potable water, hygienic water, enriched air, and foot treatment to ensure a rated delivery to the crew are not considered in this study.

Storage tanks used to store wastes resulting from water treatment and wastes treatment are also not considered.

5.2 Mass estimation

In order to provide the total mass of the compartments (not including structures and piping) it is necessary to estimate the mass of the tanks. This mass is mainly driven by the volume and construction material of the tanks for the different compartments. To estimate the volume of the tanks we need the flow rates and the residence times. At this stage it is difficult to perform a precise calculation since there is a high uncertainty on the residence times and therefore, the volumes calculated can be very different. In addition, materials will be of major importance, since it is very different in mass a tank build completely of stainless steel or partially build of Polyethylene (PE). To give a preliminary idea, average volumes will be taken and only phototrophic compartments are considered partially made of PE since they need to be transparent:

Tanks mass estimation

Bioreactor	Volume (liters)	Material	Mass (Kg)
CI	100	Stainless steel	76
CII	10	PE (70%) Ss(30%)	6
CIII	20	Stainless steel	22
CIVa	100	PE (70%) Ss(30%)	41
UTU (dissolver tank)	40	PE (70%) Ss(30%)	16
Total	**270**		**134**

Table 21. Tanks mass estimation, 5% food production.

Ss: Stainless steel, PE: Polyethylene

Also through the volumes estimation it is possible to obtain the initial mass of the system, simplifying it is possible to consider that all volumes are initially filled with water, this gives a total initial mass of **270 Kg**.

Finally in the following table mass for the 5% configuration is given. Note that this mass does not include structural housing and elements nor piping.

Total mass estimation	
Mass	**Mass (Kg)**
MELiSSA Equipment mass (w/o HPC)	1,157
Tanks mass	134
ARES mass	750
GWTU mass (w/o CIII)	386
Initial mass	270
Total estimated mass	**2,696**

Table 22. Total mass estimation, 5% food production.

5.3 Power estimation

Power estimation is calculated accounting for the power of the different systems used in the configuration that is:

System	Power (W)
MELiSSA (w/o HPC)	46,688
GWTU	6,289
ARES	2,200
Total	**55,177**

Table 23. Total power estimation, 5% food production.

This is a little bit far from the requirement of 40 KW but for sure this figure can be improved using space qualified hardware by a factor of near the 50%. For instance, if instead of using a commercial gas analyser we use flight hardware, the power consumption could be reduced in 5KW and the mass in 30 Kg, taking as a base the ANITA gas analyser configuration [R1]. Also, other light sources for phototrophic compartments could be used. In [R14] there is a trade-off of different light technologies and as a conclusion the LED technology is selected as the better balanced in performance and power consumption.

6. CONFIGURATION B. 40% FOOD PRODUCTION

6.1 Volumes estimation

Volumes have been calculated in the same way as for the 5% food production configuration. The difference comes from the fact that volumetric flows are different.

Bioreactor	Volumetric flow (l/d)	Residence time (days)	Volume (liters)	Increased Volume (+20% and rounded)
CI	70	10	700	840
CII	60	0.8	48	60
CIII	88	0.4	35	50
CIVa	88	2.4	211	260
UTU (dissolver tank)	28			40

Table 24. Tanks volume estimation, 40% food production.

Flow to the CIVa can be also reduced depending on the nutrients demand to produce the 5% of food. This could lead to a reduction of the total volume.

6.2 Mass estimation

Tanks mass estimation			
Bioreactor	**Volume (liters)**	**Material**	**Mass (Kg)**
CI	840	Stainless steel	351
CII	60	PE (70%) Ss(30%)	25
CIII	50	Stainless steel	36
CIVa	260	PE (70%) Ss(30%)	106
UTU (dissolver tank)	40	PE (70%) Ss(30%)	12
Total	**1250**		**530**

Table 25. Tanks mass estimation, 40% food production.

Ss: Stainless steel, PE: Polyethylene

Total mass estimation	
Mass	**Mass (Kg)**
MELiSSA Equipment mass (w/o HPC)	1,157
HPC mass (145 m2)	11,662
Tanks mass	530
ARES mass	750
GWTU mass (w/o CIII)	386
Initial mass	1,250
Total estimated mass	**15,735**

Table 26. Total mass estimation, 40% food production.

6.3 Power estimation

Power estimation is calculated accounting for the power of the different systems used in the configuration, but ARES is reduced a 50% since the HPC supplies more than half of the oxygen demand.

System	Power (W)
MELiSSA (w/o HPC)	44,570
HPC	263,417
GWTU	6,791
ARES	1,100
Total	**315,878**

Note that ARES power is quite lower than for the 5% configuration, this is due to the fact that more than the 60% of oxygen will be provided by the HPC, therefore a "small" ARES will be needed, with lower power consumption. The power figure has been obtained from the simulation.

The resulting power consumption is clearly far from the requirement of 40 KW. However, the possibility of using sunlight would reduce considerably the power requirement. Also space adaptation of several technologies from which up to know power consumption has been obtained from the counterpart ground versions, will decrease power consumption.

7. ARQUITECTURES TRADE-OFF

The Moon habitat structure proposed is constrained by the Moon environment and the process to make a safety construction feasible in a hazardous environment. As a first evaluation the main characteristics to be taking in account for comparison between habitats (cylinder structure, semi-circular or anchor structure and inflated structure) are: the mass, volume, pressure, gravity, radiation, temperature, lunar dust and micrometeorites.

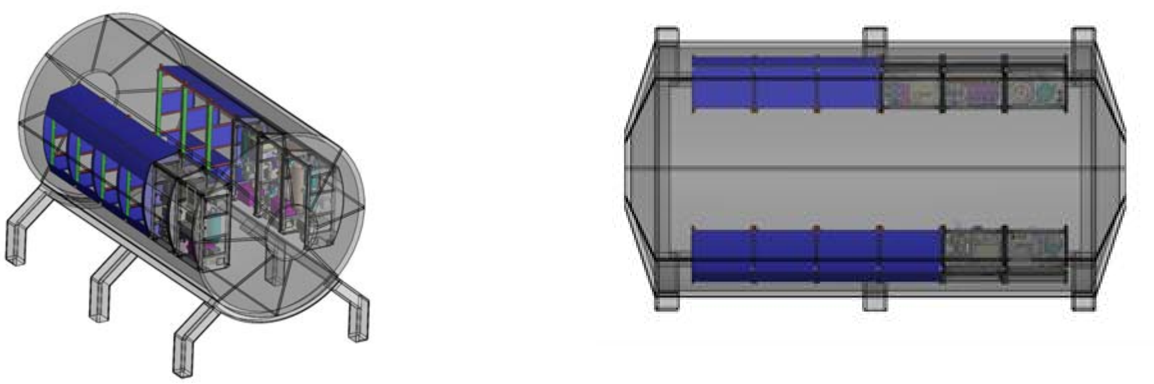


Figure 5 Cylindrical shape

A brief description of these parameters is shown below:

7.1 Mass

The mass of the structure will be defined by the shape and the materials, in first instance a metallic structure with the shape of a space module is taken into account and inside this classification two types can be identified: the semi-circular (or 3 anchor structure) and the complete cylinder. Other options as inflatable structures could also be considered having the advantage of the low mass for transportation, however there are some points which need further development, as for example the pressure and the stability in the moon surface, to consider this last option feasible.

7.2 Volume

The cylinder shape offer a major volume structure compared to the 3-anchor structure. Regarding the space disposition, in the 3-anchor structure it is more complex to install standard racks than in the cylindrical. However, the volume occupied in the launch increase considerably with the cylinder shape.

7.3 Pressure

According to the Moon pressure environment and the ECLSS requirements, the compartments must be located within a pressurized enclosure and the structure elements will also have to maintain internally an equilibrium pressure. Therefore the entire system will have to feature pressure relieve valves / venting where necessary to equalize pressure as well as the means to restore pressure in compensation for gas leakage. According with these conditions both structures (the anchor and the cylinder) are adequate for this condition.

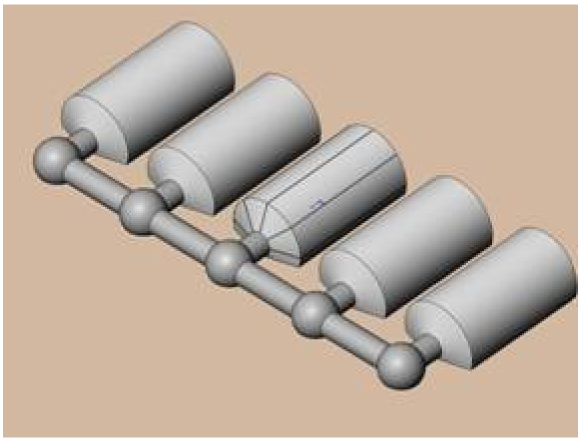


Figure 6 3-Anchor shape

7.4 Gravity

The gravity of the moon is one sixth of that on Earth. It may have an impact on the dynamics of the gas, liquid and solid loops and needs to be considered in the phase separation, notably gas/liquid. Pressure relieve valves/ venting and pumps can be used in order to save this condition.

About the structural shape, the anchor geometry can be considered with the best performance taking into account that there are little or no bending moments introduced in the structure and tension or compression is much more efficient and is and advantage for this type of structures.. The cylinder shape will result inefficient because the loads will be transferred to the foundation and will appear bending moments. However, NASA recent designs [R15] include in the module a transportation system equipped with articulated arms and wheels that could prevent these moments and the requirement for a completely flat terrain. In addition, this articulated arms could permit an inclined configuration of the module to take more advantage of the sunlight.

7.5 Radiation

The lunar surface is exposed to two major natural radiation sources: solar particles events (SPE), which include solar wind and solar flares, and galactic cosmic rays (GCR). This ionizing radiation is a potential thread for both, biological systems present in the lunar base, including crew, and also electronic equipment.

The deleterious effects of ionizing radiation on biological systems are a function of the dosage and the exposure time. Over the lunar surface GCR deliver a relatively constant radiation of approximately 30 rem/year. High-energy protons produced during solar flare events can deliver hundreds of rem in few hours. In terrestrial conditions the maximum permissible whole-body radiation dose rate for an individual is determined at 5 rem/year .

A multilayered insulation is proposed, which consist of several layers of thermal protection material separated by layers of a low conductivity and impact protection material. The layers of aluminized Mylar provide redundant thermal insulation while the Dacron mesh of low thermal conductivity reduces conductive heat transfer.

7.6 Temperature

The lunar environment is characterized by temperatures ranging from -171 to +111 degrees Celsius (-276 to +232 degrees Fahrenheit). Thermal radiation protective materials should be highly reflective, durable, and stable in the vacuum and the ultraviolet environment of space. Alternative materials for thermal protection considered by the design team are aluminized Kapton, Mylar, and Tedlar films. These films are secured to the surface of the micrometeorite protection structure also.

7.7 Lunar dust

The lunar surface is covered by a fine talc-like powder, which is abrasive and tends to adhere to the objects with which it comes into contact.

Stabilizing lunar soil for landing pads, transportation arteries, and building sites can be achieved with on-site material and available heat sources. The proposed use of chemical stabilizers and emulsions, which may include both importing of materials and an ecologically damaging effect on the lunar environment, must be critically researched.

Focused sunlight, microwave, plasma, or other heat sources can form a magma-ceramic crust to arrest unstable lunar dust. Spacecraft landing pads, vehicular traffic roads, pedestrian walkways, and all other surfaces needed for construction sites can be stabilized with a heat source, by on-spot fusion of the top layers. The sintering process can be implemented by an automatic vehicle roving over the surface with a preset, time-fusion-depth program.

Lunar dust can become a problem if is introduced inside the pressurised volumes. It is envisaged that the ECLSS module will interface with an already existing pressurised compartment and outside interaction will be always under-pressure, therefore no filtration of lunar dust can be expected. In addition, EVAs which can be the more probable source of dust filtrations can be designed to maintain the EVA suits out of the enclosed volume which will minimise leaks and also dust filtration. Nevertheless, provision for vacuum cleaners should be performed in the module to evacuate possible dust accumulations.

7.8 Micrometeorites

The surface Moon has periodic impacts by micrometeorites with velocities averaging 20 kilometres per second (12.5 miles per second). In order to take advantage of the sun light for the HPC module, habitats covered by windows can be used; however the material windows must be accomplished with radiation, thermal and micrometeorites requirements.

The material recommended is composed by an outer skin of thermally protective Kapton followed by layers of aluminized Mylar which are separated by layers of a Dacron mesh. Micrometeorite protection is provided by the Dacron mesh layers and the aluminized Mylar layers. Multilayered micrometeorite protection has the same effect as using many closely spaced micrometeorite bumpers.

7.9 Trade-off results

As structure for the habitat according with the considerations and characteristics described above the cylinder structure equipped with an articulated transportation system is selected as the best option instead of the 3-anchor shape and inflatable structure. Besides the experience with the cylindrical structures is higher (as for the International Space Station) and the possibility to perform different configurations is possible (windows, complete closed structure, connections between habitats, etc). However, there are several considerations which require more exhaustive studies such as: transportation, construction process (including elements and construction tools), evacuation of heat produced by the tools during construction (no air convection in vacuum), surface base location (the habitat should be placed in an almost flat surface), etc.

As part of the NASA Constellation program, NASA is working on the design of a Lunar launcher and a Lunar Lander vehicles. The launcher, named Ares V, can be defined as a cargo configuration vehicle which could carry up to 45 Tones to the surface of the moon [R15] . The initial design of the ECLSS module will be based on the possibilities of the Ares V rocket. This rocket is able to place a Lunar Lander module (named Altair) which can be equipped with a module instead of a crew exploration vehicle. The descent stage can carry approximately 14 Tones to the Moon surface. The approximate size of the module will be 4.5 m height by 7.5 m length.

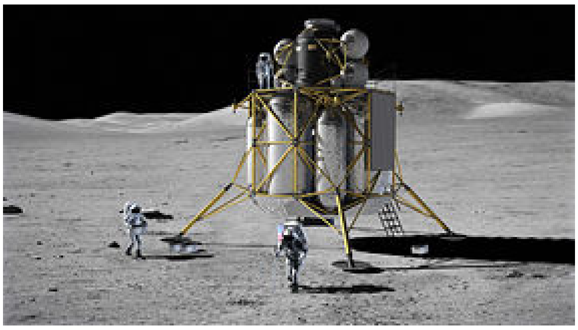


Figure 7 Altair Lunar Lander (source: NASA)

The selected distribution of the elements inside the module will be based on the well known ISPR rack. Although it is not the best option in terms of space, is a first step to distribute the volumes and different elements inside the module. The ISPR rack has been thought to be operated in microgravity, and therefore can be placed at any side of the module, however in hypo-gravity only the walls will be suitable to be equipped with racks. The design should also consider maintenance issues, to allow the crew to move a rack inside the module for a possible replacement or maintenance intervention. The top (ceiling) and down (floor) parts of the module will be used for servicing conductions (air, liquids, solids, etc.). The Greenhouse could feature a transparent cover to allow the plants to be provided with direct sunlight.

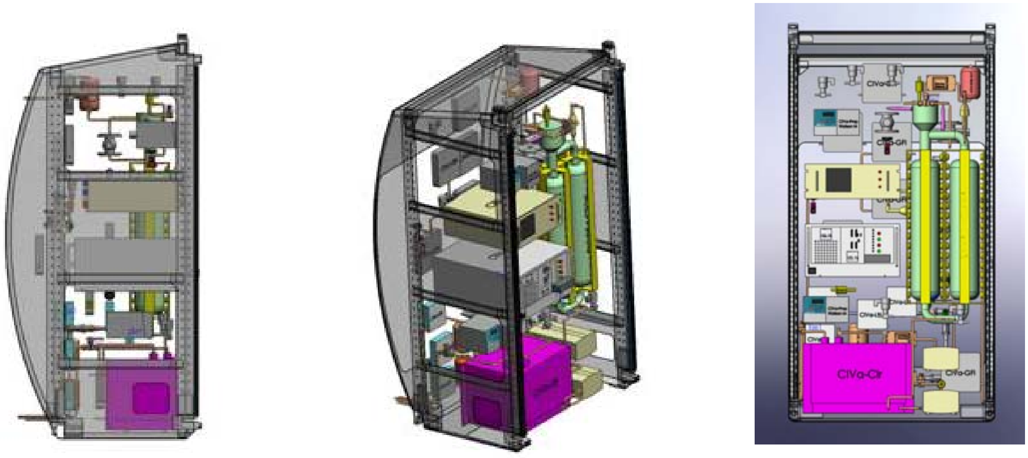


Figure 8 MELiSSA CIVa Compartment assembled in an ISPR Rack.

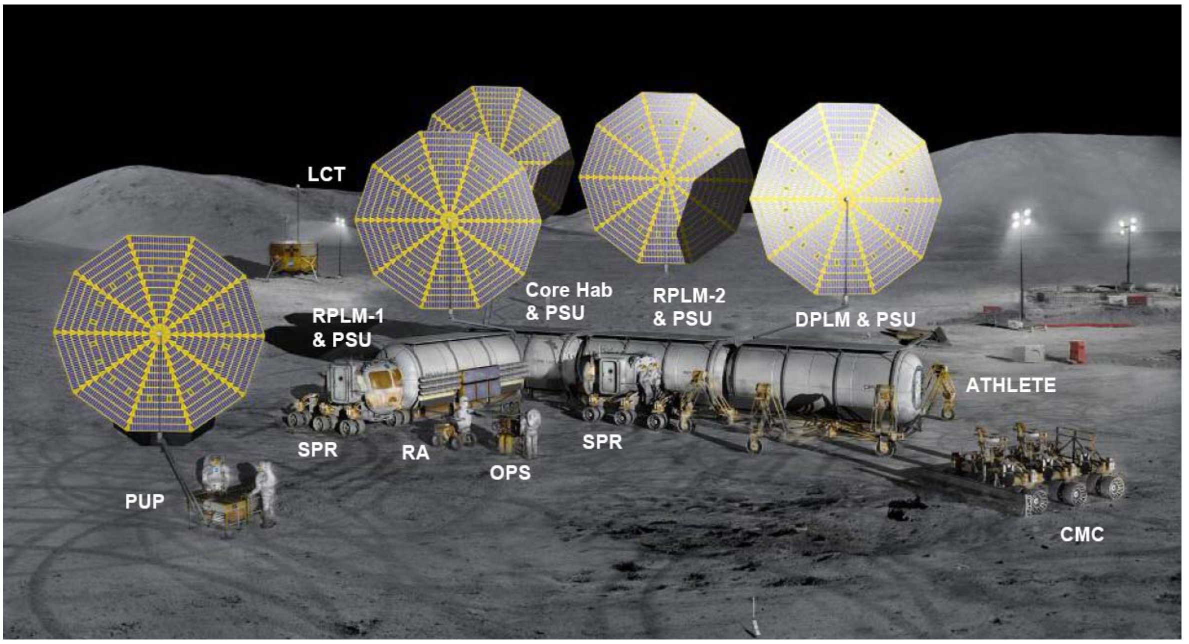


Figure 9. Artist impression of a Lunar Outpost (source: NASA)

8. CONCLUSIONS

A preliminary estimation of a Life Support System mass and power consumption has been performed, based on already existing ground technologies. The table below outline the mass and power required for each configuration studied:

5% Food Production	
Mass (Kg)	2,696
Power (W)	55,177
40% Food Production	
Mass (Kg)	15,735
Power (W)	315,878

A preliminary definition of the structures needed to support the both configurations can be performed based on the Destiny ISS module, which is 8,4 m length and 4,3 m width. In principle it can be advanced (details to be provided in TN5) that all MELiSSA compartment, GWRU and ARES can fit in one module, and the HPC will be divided into 4 more. So adding this mass to the previous table the results are:

5% Food Production	
Mass (mT) with structures (rounded)	6.7
Power (KW) (rounded)	55.0
40% Food Production	
Mass (mT) with structures (rounded)	35.0
Power (KW)	316.0

The power consumption is calculated using artificial lighting, in case that the sunlight is used in the Greenhouse, the power can be reduced in 263 KW, which leads to a total power consumption of approximately 55 KW near to the initial requirement (40 KW). This calculation is also based on peak power, which is worst case, probably average consumption is quite less.

As the project requirements define a staggered approach, it is likely that the ECLSS will be assembled progressively so mass will be distributed in several cargos and transported to the Moon spread in time.

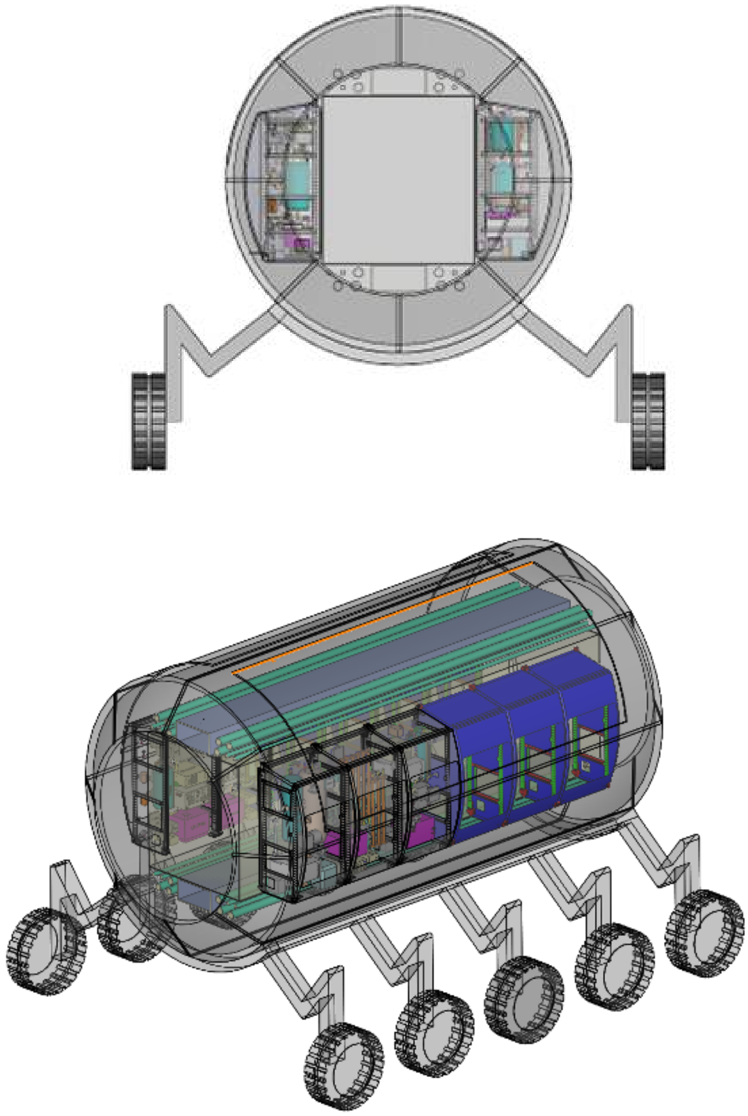


Figure 10 European ECLSS Lunar Module Concept transparent view.

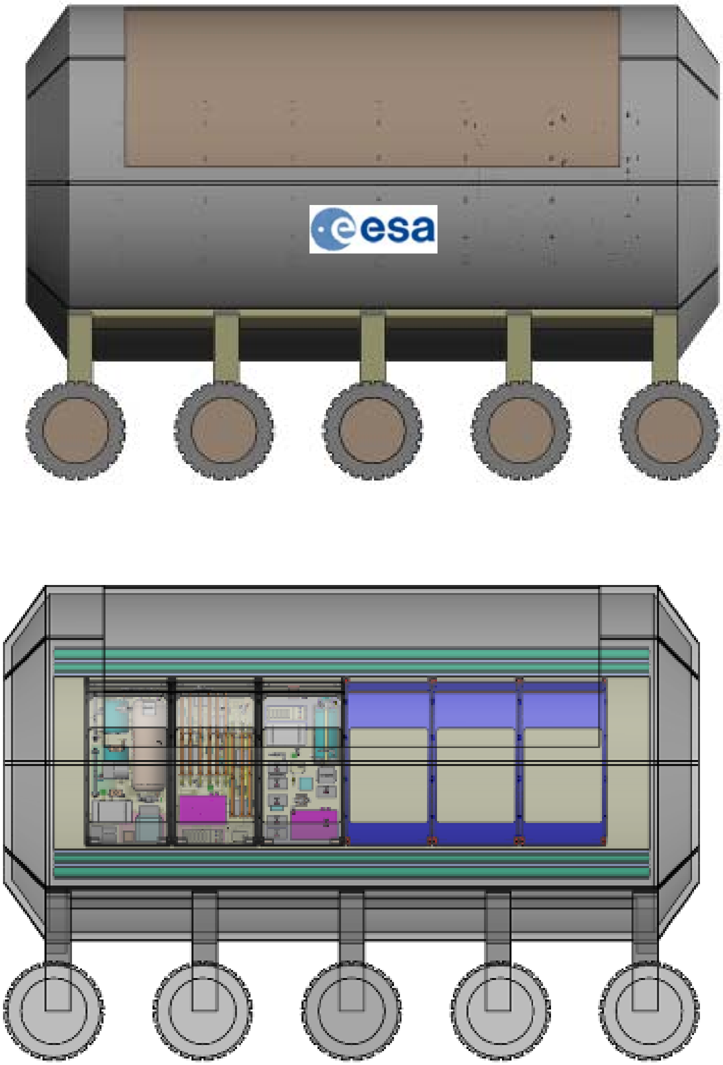


Figure 11. European ECLSS Lunar Module Concept lateral view.

Taking into account the mass calculated for both configurations it is possible to perform a trade-off considering the total mass consumed per crew (food, water and air) in the presence of the 5% food production configuration, 40% production configuration or no recycling at all. The problem in the 40% configuration is the required initial mass as well as the additional mass, since the volume of water is very high. In that case, as the loses of the GWRU are near the 10% the resupply of water is high.

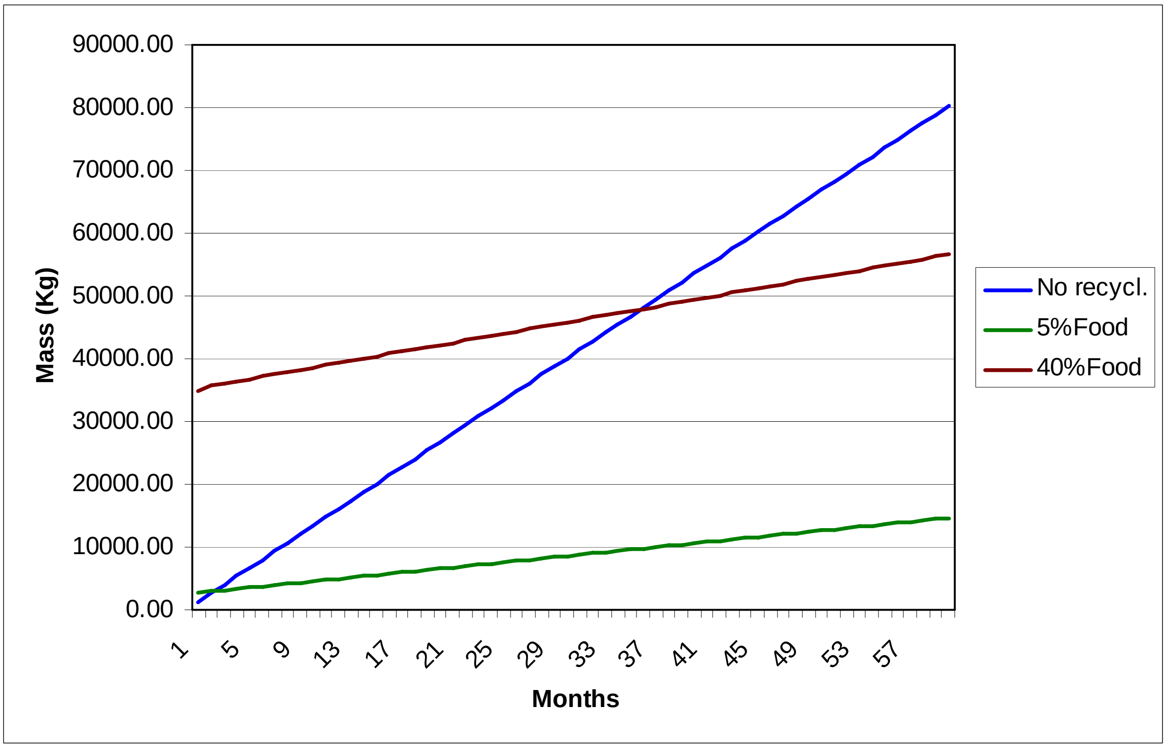
Mass Resupply		
Total Mass No recycling	44.58	Kg/man/d
Total Mass 5% Food	6.73	Kg/man/d
Total Mass 40% Food	12.00	Kg/man/d

Table 27 Mass resupply for each configuration.

Initial Mass		
Initial Mass No recycling	0	Kg
Initial Mass 5% Food	6700	Kg
Initial Mass 40% Food	35000	Kg

Table 28 initial mass for each configuration.

In the resulting graph can be observed that the 40 % configuration is clearly affordable for a continuous manned outpost. In that case, after 36 month the system will start to save mass transportation from earth.



The 35 Tones for the Greenhouse come from the structure module, which for 4 modules is around 20 Tones. The calculated mass for the equipment and internal structures for the 145 m2 of surface is around 15 Tones.

Obviously this is a preliminary study and the figures must be considered also preliminary. As the design of the different MELiSSA compartments change and the recycling performances increase (especially for the Waste Compartment or CI) the initial mass can be reduced. Also, for the mass, volume and power calculation, ground based equipment has been selected, for space equivalent hardware a reduction of near the 50% can be expected. However, the highest amount of mass will come from the external structures needed to hold the complete system, which in that case have been taken from already existing flight hardware.

Another major reduction, in this case in power, will be the possibility of using sunlight for the greenhouse, easily achievable if the base is located in a nearly permanent illuminated zone.