TN 6

Recommendations and Future Work

Preliminary Development Plan

MELISSA ADAPTATION FOR SPACE, PHASE II

ESTEC/Contract Nº 20104/06/NL/CP

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ACRONYMS LIST

ALISSE	Advanced Life Support System Evaluation
ARES	Air Revitalization System
BLSS	Bioregenerative Life Support System
BPU	Biomass Pre-treatment Unit
BVAD	Baseline Values Assumption Document
BWTU	Black Water Treatment Unit
BVAD	NASA Baseline Values and Assumptions Document
COTS	Commercial Off The Shelf
EA	Empresarios Agrupados
ECLSS	Environmental Control and Life Support System
EELM	European ECLSS Lunar Module
ESM	Equivalent System Mass
EVA	Extra Vehicular Activity
FPU	Food Production Unit
GCR	Galactic Cosmic Rays
GWRU	Grey Water Recovery Unit
HPC	Higher Plants Compartment
ISPR	International Standard Payload Rack
ISS	International Space Station
ISRU	In Situ Resources Utilisation
LEO	Low Earth Orbit
LSS	Life Support System
MELiSSA	Micro Ecological Life Support System Alternative
MPP	MELiSSA Pilot Plant
mT	Metric Tones
P&ID	Process and Instrumentation Diagram
SMAC	Spacecraft Maximum Allowable Concentration
SPE	Solar Particles Events
TRL	Technology Readiness Level
UBP	Université Blair Pascal
UTU	Urine Treatment Unit

0. SCOPE

In the first part of this technical note a summary of the activity is presented. The second part compiles the recommendations for design improvements that have risen during the MELiSSA Adaptation for Space Phase 2 project, together with recommendations for further work and a preliminary development plan.

1. APPLICABLE AND REFERENCE DOCUMENTS

1.1 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

1.2 Reference Documents

[R1] Moon Base Scenario Definition and Life Support System Requirements, NTE-MEL2-TN-007, Issue 1.0, 11 Jan 2008. TN 1.

[R2] Summary of European Life Support System Technologies, NTE-MEL2-TN-009, Issue 1.0, 28 March 2008. TN 2.

[R3] Preliminary Life Support System Design, NTE-MEL2-TN-012, Issue 1.0, 05 Dec 2008. TN 3.

[R4] Life Support System Sizing, NTE-MEL2-TN-014, Issue 1.0, July 2009. TN 4.

[R5] Life Support System Recommended Design for a Demonstration in a Moon Base, NTE-MEL2-TN-015, Issue 1.0, 03 November 2009. TN 5.

[R6] BVAD. Advanced Life Support Baseline Values and Assumptions 2004. Hanford, Anthony J. Houston, August 2004.

2. SUMMARY

2.1 Baseline requirements

In [R1], the requirements for a European Life Support Lunar Module for a Moon base have been set. The requirements have been defined to baseline an scenario proposed by ESA at the beginning of the project. The scenario was based on the mission design that the space agencies were managing at that time (2006-2007). Briefly, it indicated that a Moon Base would be already installed and equipped with a basic ECLSS not based on regenerative technologies. The base would be permanently manned by a crew of 4, with a power source available of about 40 KW already in-place.

The purpose of the study is to perform the system design and sizing of an additional ECLSS based on recycling technologies for testing and technology validation purposes.

The performance requirements proposed by ESA implied to recycle 100% of the air, 90% of the water and provide the 5% of the food, in an initial configuration, increasing the food production up to a 40% in an expanded configuration. These performance requirements would be achieved integrating technologies being sponsored by ESA in the current time frame.

2.2 Review of ESA Life Support technologies

One of the objectives of the project was to collect information about the different systems being developed by ESA regarding Life Support. The technologies were selected from the current European developments in the area of Life Support which could be integrated together to cover the given performance requirements. In addition, quality control technologies were also considered, as for instance microbial contamination and gas trace detection. The technologies selected were:

- the MELiSSA compartments
- the Air Recovery System (ARES)
- the Gray Water Recovery System (GWRS)
- the Urine Treatment System (UTU),

and as quality control,

- MIDASS for microbial contamination measurement and
- ANITA for trace gases detection.

2.3 ALISSE

ALISSE is a metric promoted by ESA with the purpose of performing trade-offs between different life support technologies and configurations taking into account technical, safety, cost and strategic aspects. However, during the frame of the project, it was not possible to use at the full extent this metric since it is still under development and the calculation methods and tools were not available yet. Therefore, only a subset of the criteria was used to evaluate the technologies in this study and a general assessment was provided for the rest. The evaluation considered the following criteria [R3]:

- Efficiency: Need coverage ratio and transformation yield.
- Mass: Initial mass (time dependant mass, as for instance expendables, has not been considered)
- Energy: Peak Power (thermal and chemical energy as well as average power consumption not considered).

- Reliability: Some design recommendations performed.
- Risk to Human: Some design recommendations performed.
- Crew Time: Preliminary estimation figures given.

2.4 The EcosimPro Simulator

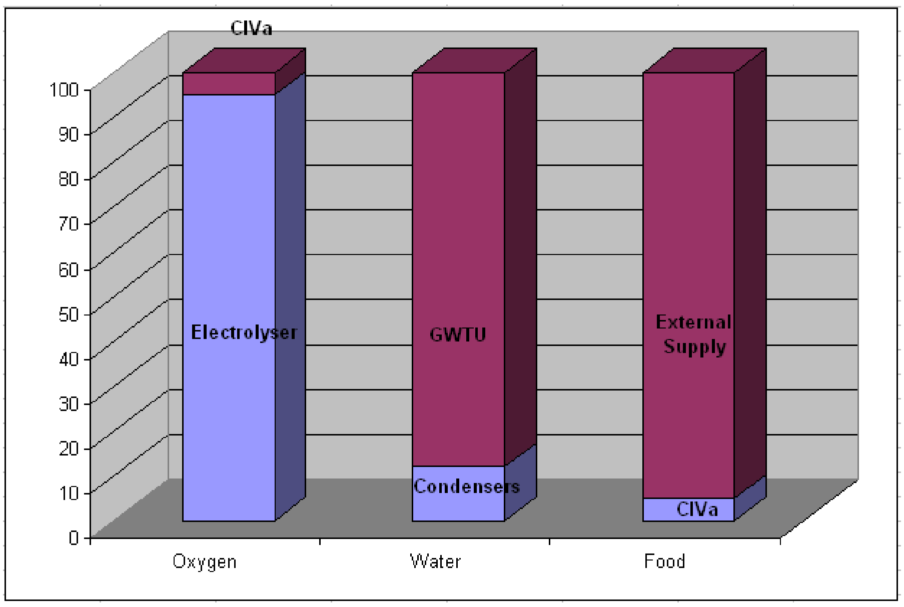


Figure 1 Oxygen, water and food production with the 5% configuration

The study required the development of a simulator in order to obtain the system performances (recycling efficiency, coverage ratio, etc.) and flow rates. The simulator was generated using the EcosimPro® process simulation software. The technologies were broken down into small components, modelled in EcosimPro® language and grouped into a library named ELSST (European Life Support System Technologies). Integrating the components from the library into different configurations allowed the generation and evaluation of different designs. The information to define the mathematical models for the components was provided by the UBP for the MELiSSA compartments, from EA for the ARES and the rest of technologies were modelled specifically for this study from the information provided by the MELiSSA partners and from bibliographical information. The mathematical models and assumptions are described in detail in [R2]. All components of the different technologies were modelled with enough detail to provide the mass balance at least at the C,H,O,N,S,P level. Stoichiometric equations, mass balance and gas / liquid equilibrium laws were used to generate the models, eventually permitting to obtain mass flows at the molecular level. The most complex design evaluated had more than 15,000 equations and took more than 17 seconds to be solved in a high end computer (Intel Duo processor). The EcosimPro® version used was 4.4.0.

The designs were analysed and modified cyclically, thus the process was recursive, as more knowledge was gained from the simulations, better understanding of the capabilities. The components efficiency as defined by the ALISSE criteria was calculated from the data provided by the simulator. Based on this evaluation and the feed-back from the iterations a design was proposed as the baseline for the study in [R3].

In Figure 1 there is a graphic of the quantities of oxygen, water and food in percentage produced by every major system with respect to total required (need coverage ratio). Values have been obtained from the simulation of the configuration to produce 5% of the food, while in Figure 3 there are the same values for the simulation of the extended configuration, able to produce the 40% of the food incorporating higher plants.

Parameter	Value
Food consumed (Kg/p/d) dry mass	0.617
Potable water consumed (Kg/p/d) 2.0 (Kg/p/d) of drink water 1.8 (Kg/p/d) of food water	3.85
Hygienic Water (Kg/p/d)	6.68
O2 consumed (Kg/p/d)	0.919
CO2 produced (Kg/p/d)	1.083
Fecal solid waste (Kg/p/d)	0.035
Fecal water (Kg/p/d)	0.098
Respiration and perspiration water (Kg/p/d)	2.199
Urine Water (Kg/p/d)	1.957

Table 1 Base line values used in the study. Obtained from BVAD and ECSS-E-30 (4A)

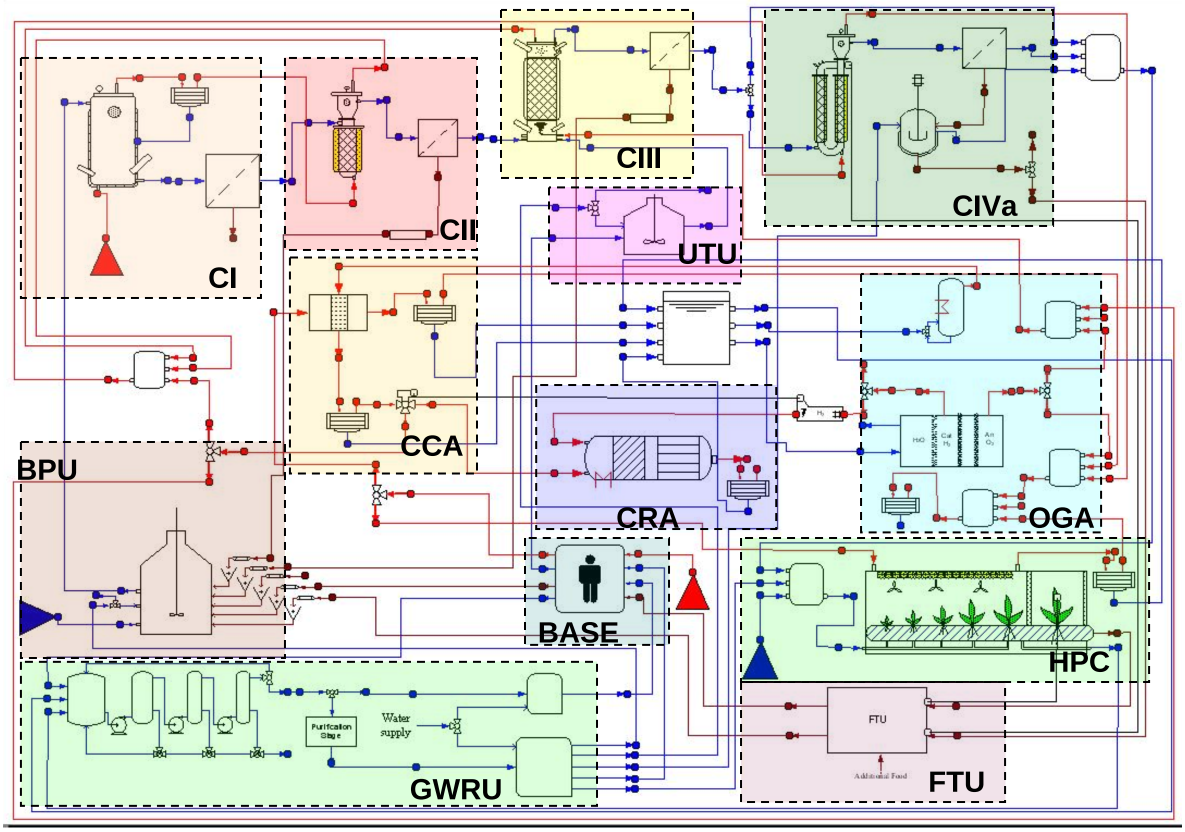


Figure 2 EcosimPro® model of the European Life Support System Design

Figure 2 is the schematic generated with EcosimPro® defining the configuration with higher plants (HPC). Colours and labels over the schematic have been added to indicate the location of the different subsystems.

Baseline values used for the simulation are indicated in Table 1. Some of these values are introduced as parameters into the simulation, while others, as for example the oxygen consumption by the crew, are results of the human metabolism model. It is already known that there is not a common agreement for these values. For example, in the study, laundry water was not considered, as a value would be very dependant on crew amenities. The total water consumption including hygiene and other grey water sources depend on the mission design and the comfort requirements of the crew. However, in order to limit the expansion of combinations, these values were considered fixed. Further work could include trade offs considering variations of these parameters, which can be easily introduced changing the parameters of the simulation.

2.5 System sizing

Once a system design was baselined, the study continued sizing the system in terms of mass, volume and power. From the P&ID of the MELiSSA compartments as designed for the MELiSSA Pilot Plant, it was possible to elaborate a list of the components that build up every compartment. From this list of devices, mass, power and volume was obtained using the commercial information. With the data about the flow rates obtained from the simulations and the resident times estimated for the reactors it was possible to size properly the tanks for the reactors. All these figures together allowed the calculation of the complete mass, volume and power of every subsystem [R4].

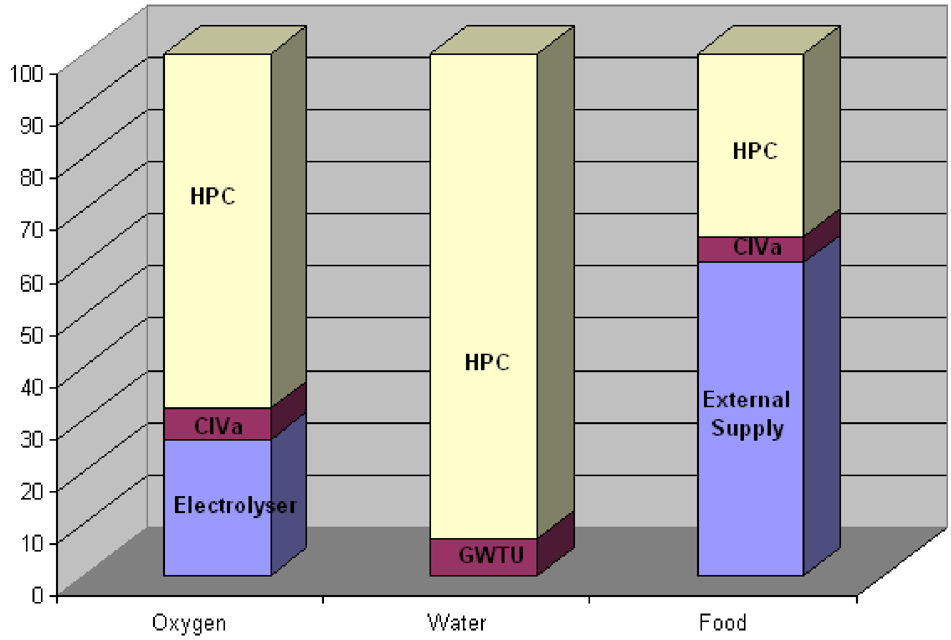


Figure 3 Oxygen, water and food production for the 40% configuration

2.6 Structure requirements

From the Lunar environmental requirements several architecture design factors were derived applicable to the containment structures. With these factors a trade-off was performed considering the effects to the structure shape, volume and materials.

- Mass: mass is mainly affected by the material and the volume of the structure.
- Volume: volume is constrained by the requirements of the system, the transportation and deployment in the Moon Base.
- Pressure: the shape will affect the performance of pressurisation systems.

- Gravity: the support on the Moon surface, surface transportation systems and stability will be affected by gravity. The shape and the materials will also be influenced by this factor.
- Radiation: radiation will constrain the materials used. Proper radiation shielding should be provided impacting to the total mass of the system.
- Temperature: proper temperature conditioning should be provided affecting also the shape and the materials of the structure.
- Micrometeorites impact: Again the shape and the materials of the structure should provide protection to micro-meteorites impacts.
- Lunar soil: lunar soil is mainly composed of a fine talk-like powder very abrasive. Proper protection during the EVA's ingress and egress should be considered.

The most important factor resulting from the structures trade-off is the materials used to build the structure of the module. As the complete system has a considerable mass and volume, even more if a higher plants extension is considered, the utilisation of inflatable structures is highly recommendable (see Table 2). Inflatable materials are a promising way of reducing dramatically the mass requirements while providing containment, radiation protection and pressurisation with reliable performances in a lunar environment. ESA is supporting the research and development in this area and further advance is expected in short. See [R5] for details.

Condition/structure	**Inflatable structure**	**Rigid structure**
Displacement	Fixed	Displacement available
Construction	Assembly process required	Already assembled
Transportation Weight	Low	High
Transportation Volume	Low	High
Air Leakage	High (porosity)	Low
Shape	w/o restrictions	Constrained by transportation
Maturity	Low	High

Table 2 Inflatable vs. rigid structure trade-off.

2.7 System Design

In order to perform a proper sizing of the system, a final design was proposed taking into account the interfaces with the Moon Base and additional technologies needed to operate the system. The schematic of the final design is presented in Figure 4.

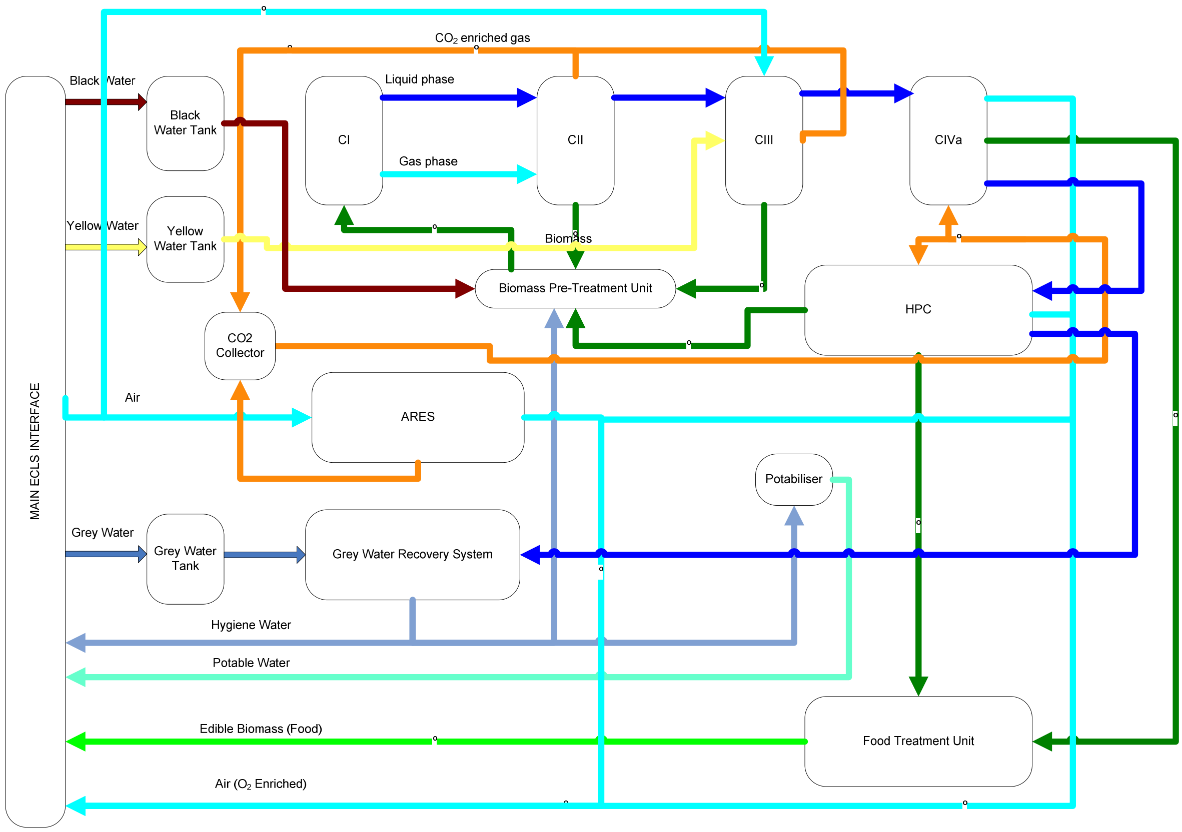


Figure 4 Final System Design.

The list of subsystems in the final design is the following:

- Biomass Pre-treatment Unit
- MELiSSA Compartment I
- MELiSSA Compartment II
- MELiSSA Compartment III
- MELiSSA Compartment CIVa
- Higher Plants Compartment
- Air Revitalisation System
- Grey Water Recovery System
- Food Treatment Unit
- Seed Germination Unit
- Common Equipment Rack

Finally, the distribution of the different subsystems into a well known structure as the ISPR rack, let to obtain a configuration of the system into a space module, similar to the Destiny in the ISS, the module was named EELM (European ECLSS Lunar Module), see Figure 5 and Figure 6. The different compartments have been drawn with a 3-D model tool as assemblies and distributed in the ISPR structures. These exercise provided the number of racks needed as well as the total volume of the system.

The dimensions of the current launcher design, which is currently being performed by NASA as part of the Constellation program, have been taken into account. Therefore, the characteristics of the ARES V rocket and the Altair Moon Lander have been used although other possibilities exist if ESA eventually develops their own Lunar Lander.

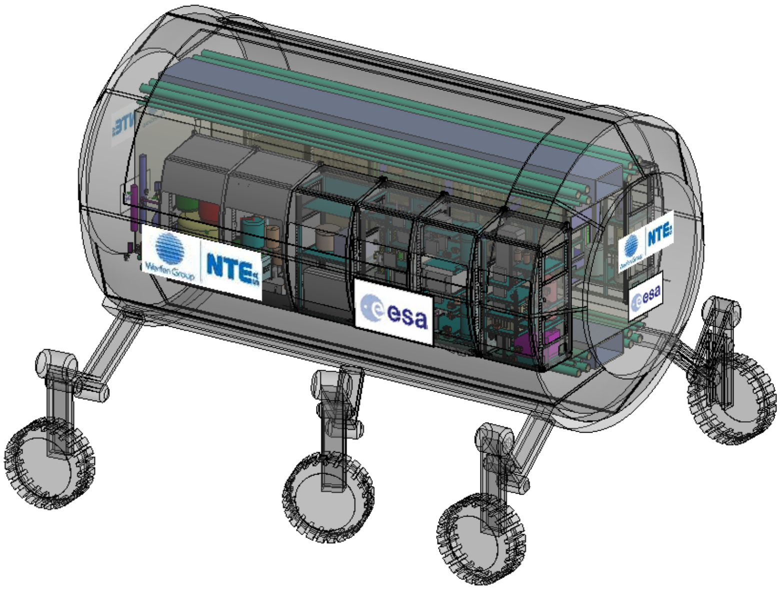


Figure 5 European ECLSS Lunar Module (EELM)

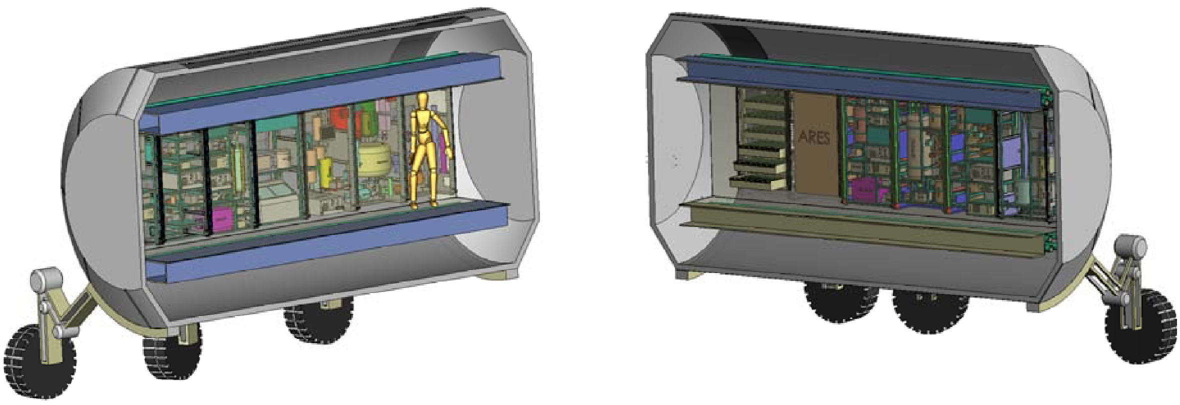


Figure 6 Racks distribution in the EELM

In [R5] the global system design was presented (Figure 4) taking into account the interfaces with the Moon Base as well as the inlet and outlet flow rates. To complete the design additional subsystems were outlined as the Seed Germination Unit or the Food Preparation Unit which are technologies still to be developed. In addition, a structural design was proposed in order to estimate the structural mass required also for the EELM. A system functional break-down was defined to perform an analysis of the different technologies and their status, a classification according to the estimated Technology Readiness Level was performed.

Figure 7 EELM with inflatable materials.

2.8 System mass and power

The final mass and power for the first phase with the requirements of providing 100% air closure, up to 90% water recycling and a 5% of the diet, i.e. without a higher plants structure, are in the following table:

System mass estimation (5% diet)	
System	**Mass (Kg)**
MELiSSA Equipment mass (w/o HPC)	1.157
Tanks mass	134
ARES mass	750
GWTU mass	386
Initial mass	270
Total estimated mass	**2.696**

Table 3 System mass to provide 100% air, 90% water and 5% of food

Total power estimation for the same configuration is indicated in the table below:

System peak power estimation (5% diet)	
System	**Power (W)**
MELiSSA (w/o HPC)	46,688
GWTU	6,289
ARES	2,200
Total	**55,177**

Table 4 Peak power estimation for 100% air, 90% water and 5% of food

Mass estimations are obtained from the evaluation of commercial hardware and from current MELiSSA Pilot Plant designs. Reliability and safety issues have not been taken into account, therefore redundancies or materials mandatory to be used in a space manned vehicle are not considered. In this first estimation, structures are also not considered since they will be incorporated in the sections below.

The peak power value is a bit over the 40 KW defined as a baseline requirement. Therefore, further improvement is required in this area. From one side, a detailed analysis of the estimations should be performed and then average power instead of peak power could be used, since the second is a very unlikely worst case situation. Other sources of improvement are the lighting systems, since two reactors are artificially illuminated. In that case, it is expected that the industry investments on the improvement of lighting devices would result in a major benefit for the power consumption of these reactors in short. A third factor that would improve power consumption is the sterilisation method. Currently using steam is the sterilisation process used for the start-up and cleaning of the reactors to maintain the axenicity. The contribution of the steam engine to the total power consumption of MELiSSA is considerable.

For the second phase to provide up to a 40% of the diet, in addition to the existing structures, a higher plants structure is needed. That means that the existing system needs to be dimensioned to process wastes generated by the higher plants as well as the water increase in the total system from the beginning.

System mass estimation (40% diet)	
System	**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 5 System mass to provide 100% air, 90% water and 40% of food

Mass of the HPC is estimated according to the current irrigation technology used in the MELiSSA Pilot Plant. This technology is based on hydroponics, the roots are always submerged in a rich-salt solution that is continuously circulated. The water flow is driven by gravity. Therefore, the water requirement of the system for the given 140 m^2 surface is very high (water and nutrient delivery system mass is estimated as more than 5 mT).
The power consumption as indicated in the table below considering artificial illumination would be prohibitive for the baseline requirements. However, the possibility of locating the higher plants structure in a permanent or semi-permanent illuminated lunar spots is a highly desirable improvement which would lead to huge power savings.

System peak power estimation (40% diet)	
System	**Power (W)**
MELiSSA (w/o HPC)	44,570
HPC	263,417
GWTU	6,791
ARES	1,100
Total	**315,878**

Table 6 Peak power estimation for 100% air, 90% water and 40% of food

The estimated surface obtained from the simulation calculations is about 140 m^2, which implies a considerable large structure. For this structure it is mandatory to consider inflatable materials to make the mission feasible. Rigid structures would imply a very high mass penalty and complicate the feasibility of the complete mission. However, if sunlight is planned to be used for the higher plants, the inflatable materials would need to be translucent (almost transparent) as an additional requirement, and this is being addressed very recently in ESA.

The composition of plants used to provide the fresh diet to the food is given in the figure below. This composition was provided by UBP since is the composition used in their simulations and the models of the plants are well known.

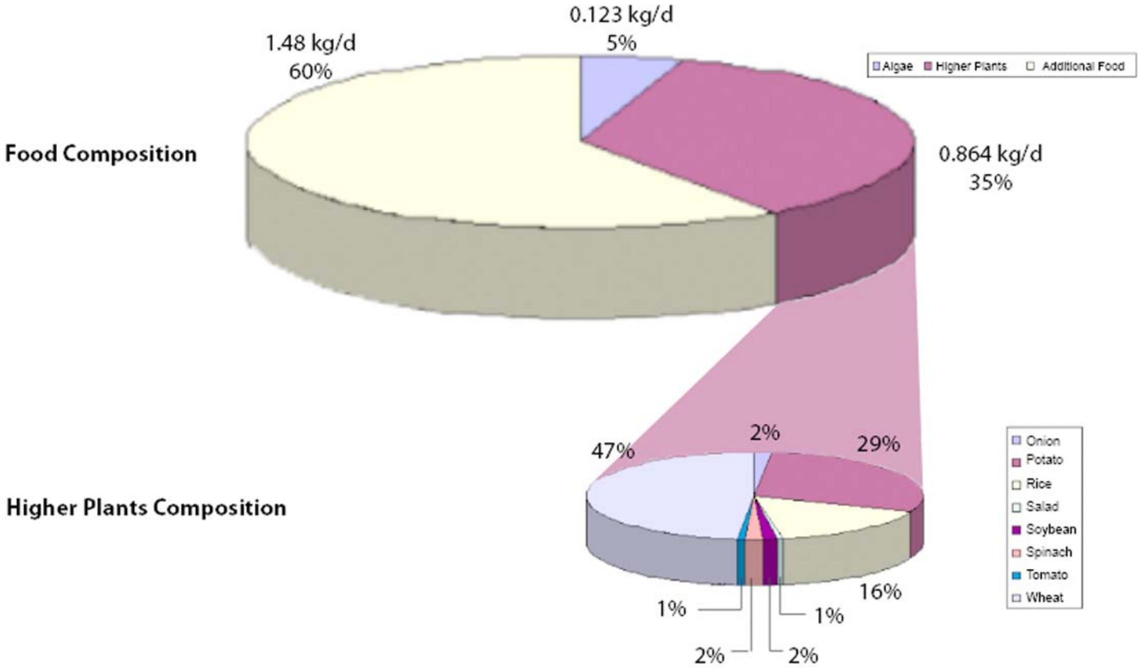


Table 7 Food composition including higher plants

In order to estimate the total launch mass and considering the architecture design factors defined above, a proposal of the structure to sustain the complete system was performed. This proposal is based on two approaches, the first is using rigid aluminium structures with proper radiation shielding, meteorite impact protection and pressurised volume. The shape selected is cylindrical, since it is well adapted to the transportation vehicles and maximises the utilisable space. Nevertheless, the cylindrical shape requires a support for stabilisation over the Moon surface. This support is also taken into account in the mass calculations. The second approach is using inflatable structures. The advantages are clear; less mass, however, although the perspectives are very promising this area needs still further development to be directly applicable.

The total transportation mass using rigid structures is around 40 mT shared by 5 different modules. Four modules would be dedicated to the higher (EELM-HPC) plants while the fifth (EELM) would be used to hold the rest of the subsystems.

The total transportation mass using inflatable structures is about 3,3 mT for the EELM (see Figure 7) and 14,9 mT for the EELM-HPC (see Figure 8). Details about structures mass calculation are provided in [R5].

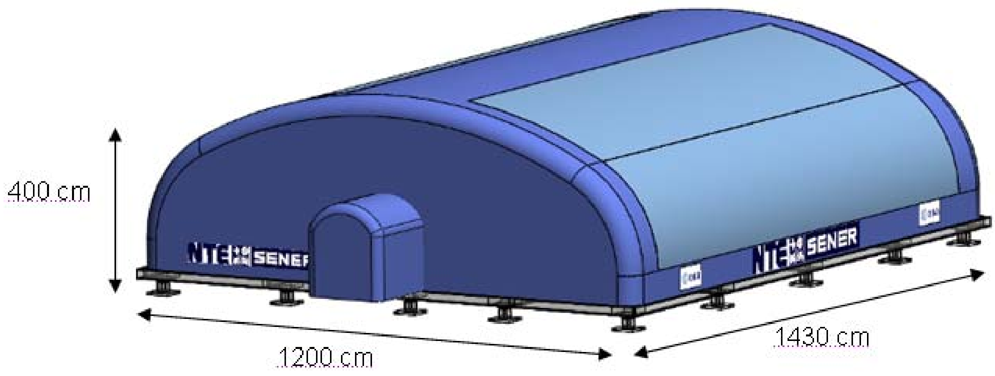


Figure 8 Higher Plants inflatable module.

2.9 Mission design

According to NASA, the ARES launcher will be able to deliver between 18 mT to 21 mT to the Moon surface.

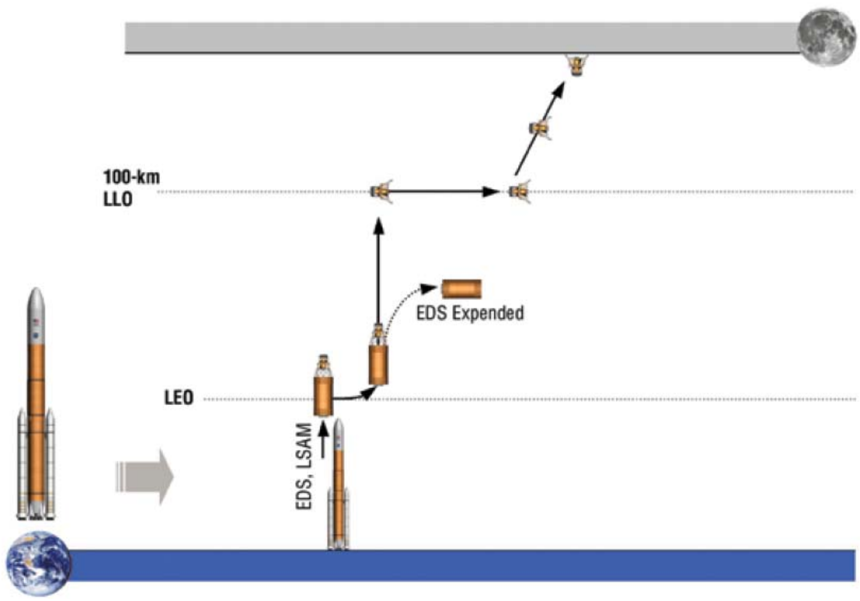


Figure 9 ARES launcher configuration (source: NASA)

ESA studies proposes the Ariane 5 with a single launch configuration able to deliver up to 4.1 mT to the Moon surface and a configuration with two Arian 5 launches able to provide 7.3 mT to the Moon surface.

The mission design taking the cargo launch capabilities and the transportation mass needed to start-up the system in the Moon base is presented considering only the inflatable option. In that case, a first launch of a small payload of about 3,4 mT would be needed to provided the 100% air and 90% water recycling and 5% of food production. The start-up of the system would need a long period if the system is transported inactive and reactors are started when in the Moon base. The start time can be estimated between 3 to 6 months according to the current colonisation requirements of the reactors.

After these 6 months, the second phase could be initiated with another transportation cargo of about 14,9 mT. Although this is a heavy launch, the transportation mass is inside current expected NASA transportation capabilities to the Moon surface. The start-up of the EELM-HPC would be shorter than for the EELM. The assembly would be a task involving considerable effort and crew time. However, after the assembly, activity could be initiated immediately if the seeds have been previously germinated in the Seed Germination Unit. Then, depending on the crop type the first harvesting can last several weeks.

2.10 Mission Mass

Considering the simulation results it is possible to perform the exercise of comparing the mass that needs to be transported if no recycling system is present in the base with the two proposed configurations, that is:

- Case 1: no recycling.
- Case 2: recycling 100% air and more than 90% of water and producing 5% of the diet (in dry mass)
- Case 3: recycling 100% air and more than 90% of water and producing 40% of the diet as an extension of the first configuration.

The results are not considering the cost of the transported mass but only compare the supplemental daily mass required by the crew in the three cases. Therefore it is not possible to determine precisely the break-out point only comparing these figures. The reason is clear; if for example a complete launch is saved every 6 months, it cannot be affirmed that the cost per kilo of the launch mass is lineal. The ESM uses the concept of the "location factors" as a factor to the total equivalent mass in order to compare cost of different transportation destinations. For instance, the factor for transporting 1 Kg from LEO to the Moon surface is 6,98 [R6]. Therefore, every Kilo that is saved it is not just a Kilo less to be transported. In any case, the exercise objective is to be able to have a summarised view of the performances of the different configurations.

Configuration	Performances	Initial Mass (Kg)	Daily Mass (Kg/p/d)
Case 1. Only a CO_2 adsorber and water recovery from condensation	0% oxygen production 25% of water recovery 0% food production	1000	9.92
Case 2. MELiSSA compartments w/o higher plants + GWRS + ARES + UTU	100% oxygen production 97% water recycling 5% food production	3400	2.73
Case 3. MELiSSA compartments with higher plants + GWRS + ARES + UTU	100% oxygen production 95% water recycling 40% food production	20000	5.3

Table 8 Estimated mission mass for the different configurations

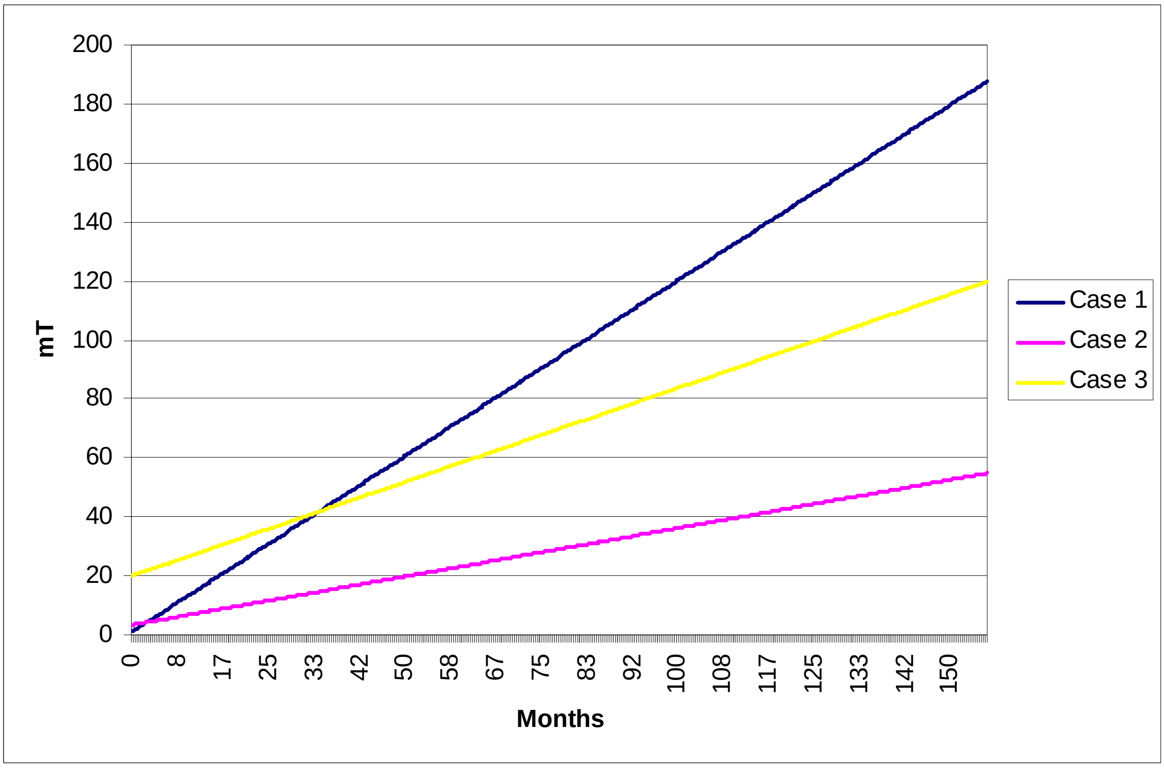


Figure 10 Estimated mission mass for the different configurations

One of the results that can be observed is that the supplemental mass required in Case 3 is higher than in Case 2. This is due to the increase of the total amount of water in the system while the performance of the water recycling decreases. With inclusion of the higher plants, the system circulates much more water than in the Case 2. In addition, the system is recycling the wastes of the higher plants in the MELiSSA Compartment I in order to recover the Carbon. This causes to lose some water in the purges after this treatment.

2.11 Technology Readiness

The study included also a break down of the implied technologies and a preliminary classification according to the Technology Readiness. From the classification it can be observed that most of the technologies are at a medium technology level, that is, demonstration technologies exist on ground but adaptation for space is still to be initiated. However, there is a considerable amount of technologies already present in the ISS that can be used and / or adapted to the proposed design.

3. CONCLUSIONS OF THE STUDY

This study has to be considered a preliminary approach to the complete system sizing. The results relay on a scenario definition fixed at the beginning of the project, which now has been redefined and probably will change in the near future. For example, the availability of water as a local resource in the Moon can change somehow the requirements for the ECLSS.

Although mass and power are estimations and the complete design is still very preliminary, the figures used have a traceable foundation. Mass and power measures have been obtained from existing commercial hardware used in the MELiSSA Pilot Plant. The simulator models come from literature and first principles equations, although most of the data have been provided by the MELiSSA partners. Calculations about rigid structures are based on current data from the NASA ESAS study (see [R5] for details) and inflatable structure performances come from the corresponding ESA working group. However, it has to be noted that although mass and power estimations are based on real data, reliability and safety requirements that would be imposed to any flight hardware have not been taken into account and will need to be addressed in the next phases.

It is expected that through the experimentation with the MELiSSA Pilot Plant it would be possible progressively define the confidence margins of the MELiSSA compartment models comparing the simulation data with real data, leading to a more realistic estimations. The simulator has been designed as a generic tool that can be adapted to new data, incorporate new components or modify the structure of the already existing ones. Thus, in the same way, it would be possible incorporate the progress in the other European technologies.

Only very preliminary conclusions can be obtained from the configurations trade-off. More precise quotation of the uncertainty margins is required to perform a detailed analysis. However, based on the mission mass estimation for the proposed configurations (Case 1: No recycling, Case 2: Water and air near 100% and 5% food production, and Case 3: Water and air near 100% and 40% food production), the following general conclusions can be obtained:

For Case 2 (5% food production) the study demonstrates that 76% of recycling can be achieved. This value could probably be improved by reconsidering the need of MELiSSA Compartments I and II for this design, since the additional food supply (95%) provides enough carbon to restore the quantity lost.

For Case 3 (40% food production with higher plants) the study demonstrates that the current state-of-the-art on higher plants does not authorise to reach satisfactory values.

In the following section several improvements classified per area are proposed. These recommendations of improvement come also from the conclusions of the study.

4. RECOMMENDED IMPROVEMENTS

4.1 Process Improvements

It has been verified that the recycling efficiency of the MELiSSA Compartment I affects the complete system. Although in case that the system is providing low diet percentages (40% or less) this is not a critical issue, if higher diet levels would be required in the future, the CI recycling efficiency becomes a determinant factor. Recycling efficiency of this compartment is in continuous improvement, in the beginning of the project it was estimated to be a 40% and currently is more than the 65%.

On the other hand, the Compartment I requires an elevated dilution rate for degrading higher plant wastes. An important improvement would be to use a technology to degrade these wastes using less water. A system called Fibber Degradation Unit is under development and would provide an increase of the efficiency of the complete system by reducing the total water requirement. However, attention must be given to the energy consumption of this system.

Another system that could be clearly improved is the Higher Plants compartment. Current irrigation technologies are huge water demanding. Other water irrigation systems would need to be studied more inline with the concept of “dessert approach”.

Selection of the crops to be cultivated in the HPC is also a factor of improvement. Depending on the crops the cultivation surface could be reduced. Although the current crop selection is based on the diet equilibrium with respect proteins, carbohydrates and lipids, energy supply (calories) could be also considered, deriving into a multidimensional criteria evaluation.

With respect to the process improvement, the progressive inclusion of dynamic behaviour in the simulations would permit to better predict and improve the initial system mass estimations.

4.2 Mass improvements

First contribution to the system mass is provided by the structures. However, this is a common space development issue not specific to ECLSS. Improvements in this area are expected from efforts performed in the architecture and launchers design working groups.

The second mass contribution is the initial water required considering current higher plants design in the MELiSSA Pilot Plant but this is also a proposal of process improvement.

Tanks mass is also considerable with the current flow rates and residence times. Here, process improvements will also improve the mass cost. Furthermore, residence times would need to be validated with real data since now they are only estimations. Finally, material composition of the tanks could also improve the total mass if for example composites or light weight materials are considered (now only stainless steel and polyethylene have been considered).

Another factor that would influence the mass estimations is the consideration of the reliability and safety margins required when the adaptation of the ground design to space hardware is performed. A detailed analysis of the design of the MPP designs, defining a preliminary adaptation to space for some of the technologies would start to give a first quantification of this factor.

In order to provide recommendations to mission design about when it is worth to set-up a regenerative life support system (break-out point) in graphs as Figure 10, ALISSE could help to define a way of calculating the cost of launch mass with respect to locally produced mass, in order to add this factor as another trade-off criteria.

4.3 Power improvement

First contribution to power consumption is from the Higher Plants compartment. For a surface of 140 m2, if the chamber is artificially lighted, the power consumption is huge. However, the power requirement would be drastically reduced if a permanent (or semi-permanent) illuminated spot is confirmed as a baseline parameter of the mission.

Second contribution to power consumption is the lighting devices of the phototrophic compartments. In this area it is expected that the investments that the industry are currently performing to design light devices with low power consumption would be adapted in the near future to phototrophic bioreactors.

Another device which is high power demanding is the steam generator. Steam is the current method used for sterilisation of the reactors when they are cleaned. The complete system requires to work in anexenic conditions. Alternative methods to steam sterilisation could be investigated (chemical, vacuum, temperature, UV, etc.).

In addition, it has to be noted that power consumption is calculated as peak power. Peak power represents the worst case, considering that all devices are working at the same time which is a very unlikely situation. A detailed study of the design of MELiSSA Pilot Plant reactors could produce more realistic data about devices utilisation, enabling the calculation of the average of peak power.

5. FUTURE WORK

The recommendation for the future work is to consider further development of the following tasks:

- Focus on the 5% food production configuration. Definition an optimal design for this configuration (perhaps reconsider the use of MELiSSA CI and CII).
- Improvement of the simulation incorporating the latest results and technologies. Definition of the uncertainties by comparing simulation results with real data obtained from experimentation with the MPP.
- Detailed analysis of MPP reactors design in order to define more precisely power consumption.
- Further utilisation of the ALISSE incorporating more knowledge according to the metric criteria.
- Start the estimation of crew time based on operations in the MELiSSA Pilot Plant.
- Perform further analysis on the transportation and logistic requirements for the system.
- Start the task of the reliability analysis definition for the MELiSSA reactors and the other technologies proposed as part of the ECLSS.
- Incorporate dynamic behaviour progressively in the simulations in order to increase the reliability of the estimations.

6. PRELIMINARY DEVELOPMENT PLAN

6.1 Technology Readiness Level

In order to define the preliminary development plan, the technology readiness level definition has been considered. The TRL definitions are presented briefly in Table 9.

TRL Level	Description	Value
TRL1	Basic principles observed and reported	Very Low “unique” Cost
TRL2	Technology concept and/or application formulated	Very Low “unique” Cost
TRL3	Analytical and experimental critical function and/or characteristic proof-of-concept	Low “unique” Cost
TRL4	Component and/or breadboard validation in laboratory environment	Low to Moderate “unique” Cost
TRL5	Component and/or breadboard validation in relevant environment	Moderate “unique” cost
TRL6	System/subsystem model or prototype demonstration in a relevant environment (ground or space)	Technology and demonstration specific

TRL7	System prototype demonstration in space environment	Technology and demonstration specific phase C/D demonstration system
TRL8	Actual system completed and “flight qualified” through test and demonstration (ground or space)	Mission specific; highest “unique” cost. Phase C/D for actual system.
TRL9	Actual system “flight proven” through successful mission operations	Mission specific; less than cost of TRL 8

Table 9 TRL Definition

In this document, the relation between TRL and the tasks plan will be implemented according to the next criteria:

- Adaptation to space corresponds to a range between TRL7 to TRL9 (phase C/D)
- Development corresponds to a range between TRL3 to TRL6 (phase B)

Adaptation means that the actual system already exists in ground or in space and its functionality and capacity has been demonstrated; the external characteristics and control (volume, materials, etc) should be updated or modified in order to get the final configuration required.

Development means that there is not hardware in ground or in space that satisfies the given performance requirements. However, there are assemblies or subassemblies that can be joined in order to obtain the hardware configuration required but still needs to be demonstrated and tested.

6.2 Task time estimation

The effort estimation has been performed considering the adaptation and development tasks at compartment level (system integration) and at subsystem level (subsystem integration). Also, to define the time estimation it has been taken into account the level of adaptation or development of each element. Tasks are classified as: design, manufacturing, prototype testing and the flight model elaboration. From the TRL classification performed in [R5] it can be noted that there are not technologies that require early investigation, but all of them at least exist as ground demonstration.

These tasks are described below:

Adaptation for design: The time covered by this concept is relatively low, as design adaptation implies only updates to the geometry and generic relations in the assembly. The estimated time could be around months (PHASE B).

Adaptation for manufacturing: This time is assigned to the manufacturing process as adaptation of previously elaborated parts, which means that the processes, installations and procedures are the same or similar to other parts mechanised before (PHASE B).

Adaptation for technology validation (engineering model): Test and procedures are similar for an assembly validation, which means that procedures and installations used in assemblies tested before can be applied. (PHASE C/D)

Adaptation for flight model (qualification model): In this adaptation the procedures, installations, processes, management and people would be the same or similar for the elaboration of the engineering model. (PHASE C/D)

Development for design: The time covered by this concept is relatively high, as design development a new solution should be proposed with its concept, analysis and pre-design process. The estimated time could be some years (PHASE A). In principle there are not technologies in this stage.

Development for manufacturing: This time is assigned to the new manufacturing process that needs a new development in order to get a new part or assembly; which means that the processes, installations and procedures can be different from other parts mechanised before. (PHASE A TO B)

Development for technology validation (engineering model): This development involves the test for new equipments and the conditions could be difficult to adapt from tests realised before. Test and procedures should be proposed and established before be accepted in any case (part or assembly), which means that procedures and installations used in assemblies tested before can not be applied. This development consists in the elaboration of new procedures, processes and installation analysis. New management and people with enough knowledge about the part or assembly which needs to be adapted are required in this new development (PHASE B TO C/D).

Development for flight model (qualification model): This development implies the adaptation of the procedures, installations and processes developed for the engineering model. Management and people involved would be the same or similar than for the elaboration of the engineering model (PHASE C/D).

6.3 Task Description

The following sections describe the tasks used in the planning of the Preliminary Development Plan. These Tasks were consecutive numbered and classified in Generic Task and Specific Task for some Compartments. In some cases the tasks applied in Compartments are the same described for other Compartments (Input buffer and common equipment, Biomass pretreatment unit, Food Process Unit, MELiSSA CII, MELiSSA CIII and MELiSSA CIVa), for this reason some Compartments with their respective Tasks are no mentioned below.

6.3.1 Generic Tasks

The tasks of the following list are applicable to almost all developments:

1.-Adaptation according with the inner substance. Task assigned for the tanks, buffers and reactors. It covers the design of specific materials, special elements as windows, sensors, etc. according with the storage substance, quality, safety and environmental conditions, volume required and logistics for manipulation during the launch, in space and during the landing process.

Figure 11 Example of inflatable tank

2.-Adaptation for the volume and geometry required. Task assigned to elements which already exist as prototypes in ground or as flight models but the volume and geometry must be modified or updated according to the required specifications. That means that the functionality and the performance with the assemblies or sub-assemblies has been tested and new tests must be conducted (following similar procedures of test) in order to verify the correct performance with the new element dimensions and/or geometry.

3.-Adaptation according with the inlet and/or outlet boundary conditions (temperature, pressure, etc). Task assigned to tanks, valves and pumps, and in general any conduction or flow device. It covers the design according with the temperature, pressure, density, pH, etc. of the flow matter.

4.-Adaptation of external devices (sensors, pipes, hoses, etc). Task assigned to elements that need external devices attached to them in order to have a performance control of these elements. The modifications of these elements should imply a change of material, geometry or volume.

Figure 12 Mechanical structure examples.

5.-Adaptation in case of low pressure losses and high reliability. This task refers to elements that depend of pressure property for their performance; the safety factor is taken into account as a test of reliability. A design and test could be conducted according to the established reliability requirements.

6.-Development of fixation to the Rack and transportation. Tasks assigned to assembled structures. The task consists in the design of fixations for three different stages: fixation during the launch, in the space and during the landing. This task covers also the design of the main logistics to manipulate elements inside the rack once the system starts the operations. The task is tightly related to task 13.

7.-Development of joints if multiple elements are required. Task assigned for elements that need to be joined in order to cover the volume or specific boundary condition (temperature, pressure, etc) required in the hardware. The joints between elements should be designed according to the space safety factor requirements.

8.-Development of thermal control. This task must be performed for elements that generate heat and this heat needs to be driven in some way inside or outside the module (recycled or ejected from the module). The design of coolers and heat exchangers include this task.

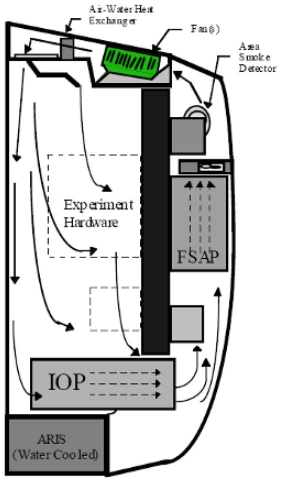


Figure 13 Thermal analysis example

9.-Development of disposal system for specific elements. This task covers the disposal of elements that should be trashed after accomplishing the effective life (filters, membranes, junctions, etc.). The task means design, manufacturing and logistic of external elements for the transformation and transportation of disposable materials.

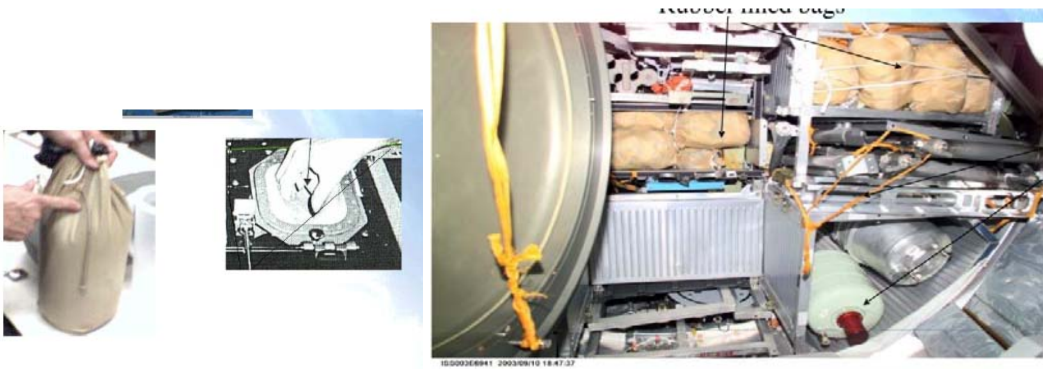


Figure 14 Examples of disposable elements

10.-Test and development of a prototype. Task assigned to elements that have not been tested as a complete assembly. Assemblies or subassemblies can have been tested in ground or in the space independently but still not as a complete configuration. This task applies to almost all developments in order to verify the technology, reliability, feasibility, safety, etc. previously to the space adaptation.

11.-Adaptation for specific maintenance. This task applies to all the elements and the time of design is in function of the complexity of elements, assembly and subassembly involved in the compartment.

12.-Manufacturing of the engineering model. In this task a flight-like model is manufactured and assembled according with the last modifications required from the prototype test and maintenance process analysis.

13.-Adaptation of the structure for the launch & and landing (vibration). This task applies to all compartments and it refers to fixation and adaptation systems applied to assemblies, subassemblies or separate elements inside the ISPR Rack during the launch and landing process.

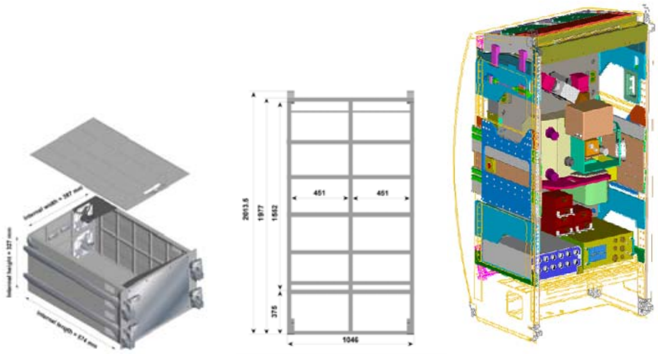


Figure 15 Fixation structures examples

14.-Adaptation to container links. This task refers to the redistribution required of the connection elements inside the structure due to mechanical interferences, protusions, etc.

15.-Development according with the power required for an acceptable performance. The power required in a reactor it will depend of the volume and elements needs to be in function in order to keep working the process in a reactor. That is the reason of importance of this task, that needs to be analyzed and development to assure that all the elements involved in the system works correctly and don't affect the performance in case if one of them fail.

6.3.2 Grew Water Recovery System

The Grey Water Recovery System consists of two main Units: An Urine Treatment Unit and the Grey Water Treatment Unit. The Compartment CIII will be adapted as Urine Treatment Unit.

a) Urine Treatment Unit (MELiSSA CIII adapted): The tasks assigned to Compartment III cover from internal process development until the elements adaptation. The elements to be developed are the nitrification Reactor, the aeration system, the filtration system and the ammonium control level system. On the other side, there are tasks that cover adaptation to external devices, in case of low pressure losses and an adaptation for a safety system for the complete unit.

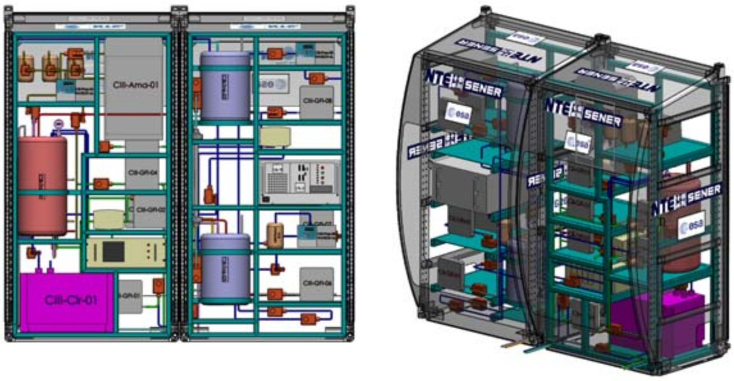


Figure 16 Urine Treatment Unit (adaptation of MELiSSA CIII)

b) Grey Water Recovery System (GWTU). The Task assigned to the GWTU are developments, these are:

16.-Development and test of electro-dialysis unit. Task assigned to the Grey Water Treatment Unit to verify the electro-dialysis performance. Adaptation of the technology to the space requirements.

17.-Development and test of ammonium absorption unit. Task assigned to the Grey Water Treatment Unit to verify the ammonium absorption performance. Adaptation of the technology to the space requirements.

18.-Adaptation of ammonium analyzer according with the parameters required. Task assigned to the Grey Water Treatment Unit to verify the ammonium absorption performance.

19.-Development and testing of biological filters. Task assigned to the Grey Water Treatment Unit to verify the biological filters performance in space.

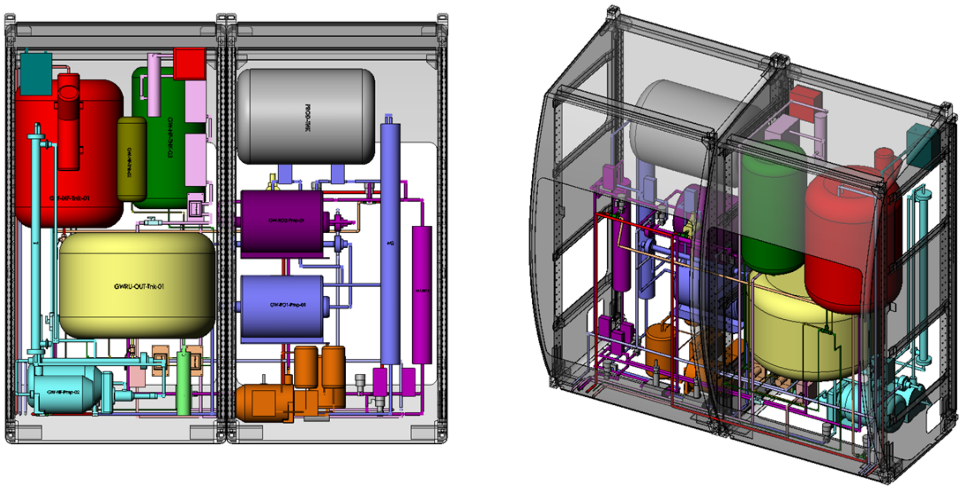


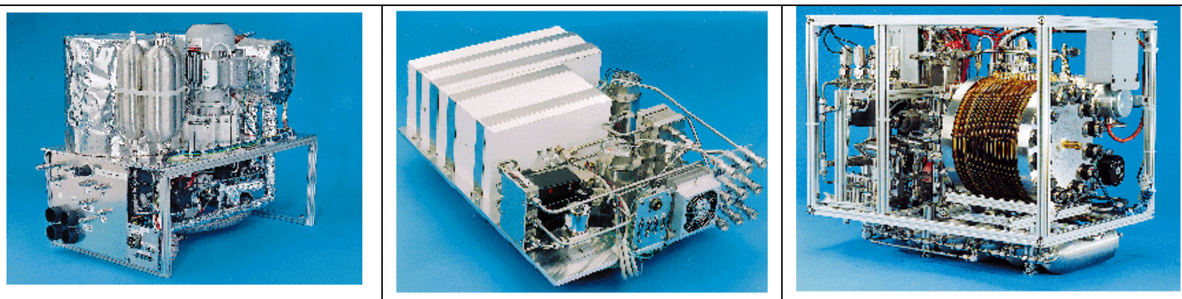
Figure 17 Grey Watery Recovery System

6.3.3 Air Recovery System

A bread board of the Air Revitalisation System (ARES) has been developed some years ago. ARES consist in three main systems: Carbon dioxide concentration (CCA), the Carbon dioxide processing (CPA) and The Oxygen Generation Assembly (OGA). These systems have been tested in the ground independently and in the next years will be tested as a complete assembly in the space.

The task pending for the ARES project is the fabrication of an engineering model and a flight model. This final task can be divided in different projects to be developed and adapted; from the power required until the fixation to the racks in order to avoid damage during the launch and landing process.

Figure 18 ARES Elegant Bread Board



a) b) c)

Figure 19 a) Carbon Dioxide Concentration Assembly, b) Carbon Dioxide Processing Assembly, c) Oxygen Generation Assembly.

6.3.4 Seed Germination Unit

The Seed Germination Unit can be developed from the adaptation of different technologies already existing either in ground or even in previous space missions.

20.-Adaptation for nutrients and liquid supplier system. This task is assigned to the Seed germination unit tray and consist in the adaptation of a system developed in others prototypes for different missions.

21.-Adaptation of new lighting technologies. This task is assigned to the Seed germination unit and Bioreactor compartments focusing to the lights required for the germination process and reactions respectively. The task will consider the adaptation of the most recent technologies in light devices from the industry.

22.-Adaptation with the control configuration required. The Control system element in the Seed Germination Unit must be adapted to a specific control according with the main boundary conditions (temperature, pressure, etc), and this task could be an adaptation of developments from previous missions.

23.-Development and adaptation for an irrigation system. The irrigation system is a key function in the Seed Germination Unit. This task will imply the development and adaptation of an optimum irrigation system in terms of the germination process and water consumption.

24.-Adaptation to supply nutrients and liquid system (volume required). In this task, the last techniques developed and tested for irrigation should be adapted according with the geometry and volume required for the specific space mission.

6.3.5 MELiSSA CI

MELiSSA CI already exists as a ground demonstration technology in the MPP. The tasks defined explicitly for the CI are the following:

25.-Adaptation according the inner substance for the Filters Unit. The filtration process should be adapted according with the substance driven. Different equipments that include filters have been tested in different missions.

26.-Adaptation according with the volume available. This task applies to the filters and gas flow controllers in order to update the actual geometry according with the space available in the ISPR rack and the distribution with the other elements. As the filtration process is well known compared with the rest of process, it is assumed that the geometry and volume can be adapted.

27.-Adaptation according with the inner gas. A gas analyzer development by NASA is in progress. In this case the gas analyzer would need to be adapted according with the types and quantities of gases that need to be measured/controlled.

28.-Adaptation to the tank or deposit to be controlled. The elements used as reference of measurement for the control process should be adapted to the tanks and buffers in order to guarantee a safe and reliable measurement (temperature sensors, pH meters, etc).

29.-Adaptation to the boundary conditions to be controlled. This task applies to the valves and pumps that are used as controllers inside the complete circuit system. The adaptation should be considered because some of them will apply for gas or liquid, it will be under different temperatures and pressures and substance to be driven will affect the lifetime of the valve or pump.

6.3.6 Higher Plants Compartment

In the HPC module there are tasks which have been already defined for the other developments, for example the task for the design of the tanks or the trays; on the other hand, there are specific tasks for this compartment that imply adaptation (trays or tanks conditions) or analysis, development and probably improvement according with the space requirements (materials, logistics, etc).

As an inflatable module the structure materials should be tested under space conditions and improvements should be applied. However, it is expected that benefits from general inflatable structures research will be directly applicable.

More specific is the logistics for the transportation and installation of all the elements for this compartment that must be developed for the launch and landing and operation process.

A brief description of the specific HPC tasks than need be conducted are indicated below:

30.- Adaptation for structure in the launch and the landing installation. The inflatable module that will conserve the HPC system should be designed and developed following some requirements of safety, volume, permeability, etc. Inside of these specific requirements the logistic and transportation are considered as relevant aspect. Firstly, the logistic in ground; that covers material test, mechanical properties, distribution and packaging process in the launcher. Secondly, there is the transportation and landing, deployment and accommodation over the Moon surface.

31.- Development of profile and support structure. A structure shaped by profiles and plates has been proposed as a first design for the interface between the inflatable structure and moon surface, the complete base structure should be tested in order to get a good weight/ performance relation.

32.- Adaptation of supports and lifters for the structure. Lifters and supports should be adapted in order to control the plane structure where the inflatable base will be placed (the landing surface will be irregular).

6.4 Preliminary Development Plan Description

The development plan is presented in the next pages. The schedule is organised as follows:

COMPARTMENT (yellow blocks): Corresponds to the identification of the main unit. The following compartments are identified:

- Input Buffers and common equipment
- Grey Water Recovery System
- Biomass pretreatment Unit
- ARES
- Seed Germination Unit
- MELiSSA CI
- Food Process Unit
- MELiSSA CII
- MELiSSA CIII
- MELiSSA CIVa
- Higher Plants Compartment

The Compartments are composed by the main elements that need to be developed or adapted according to specific requirements.

SUBYSTEM: The subsystems are the different elements that compose the assembly.

TASKS: Indicate the developments and adaptations required for each subsystem. There are generic tasks which apply to any subsystem and tasks that apply only to specific subsystems depending on the system if it is already developed and tested on ground and space.

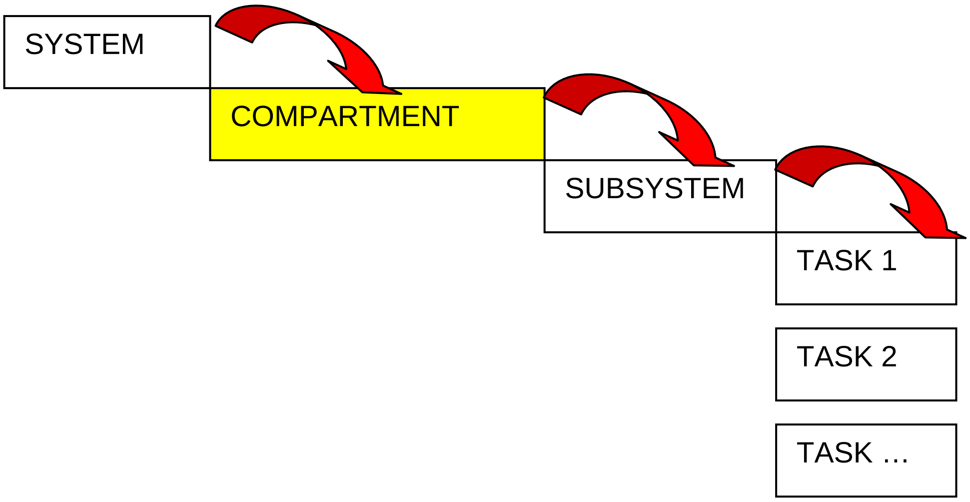


Figure 20 Development Plan description.

TASK NUMBER: this number identifies the task with the brief description of the task given in the section above.

QTY: Number of units required in the final assembly.

Time scale (1-2010 to 2-2019): Time estimated according to the kind of task applied to the specific subsystem. If the task is a Development or Adaptation (with 4 variations for both cases: design, manufacturing, validation test and final model. Each task is associate to the three main phases of the development process, phase A, phase B and phase C/D.

6.4.1 Phases Associated to the Development Plan

In the development plan the phases are associated to the tasks taking into account the level of development or experimentation of the subsystem, subassembly or assembly. The phase is assigned to phase B or C/D depending on the level of testing and development in ground or space. Phase B is assigned if the task consists in the technology adaptation or development on ground (prototype, breadboard). The phase C/D is assigned if the technology has enough maturity on ground and consists in the development of the qualification and flight model.

As the phases are showed per each task, subsystem and finally each compartment, a correlative rule was followed between them, this means, that the phases order was assigned with respect to each task (first phase B and after C/D), but some tasks can be back or forward the general phase if they are more advanced with respect to the others but can be started before (or need to be started after).

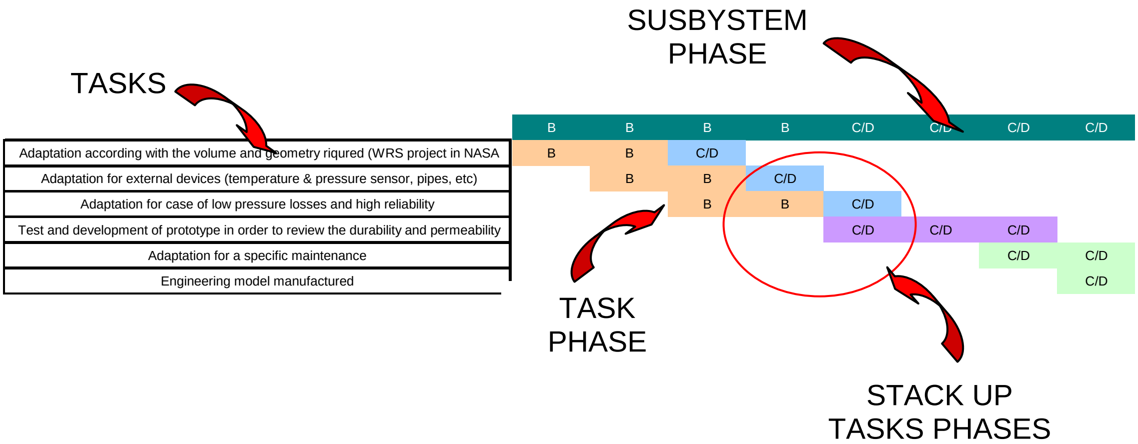


Figure 21 Subsystem and task phase definition.

In the same way, phases are indicated for compartment (blue row) and in general indicate the most early stage phase in the development of the different subsystems involved in the compartment.

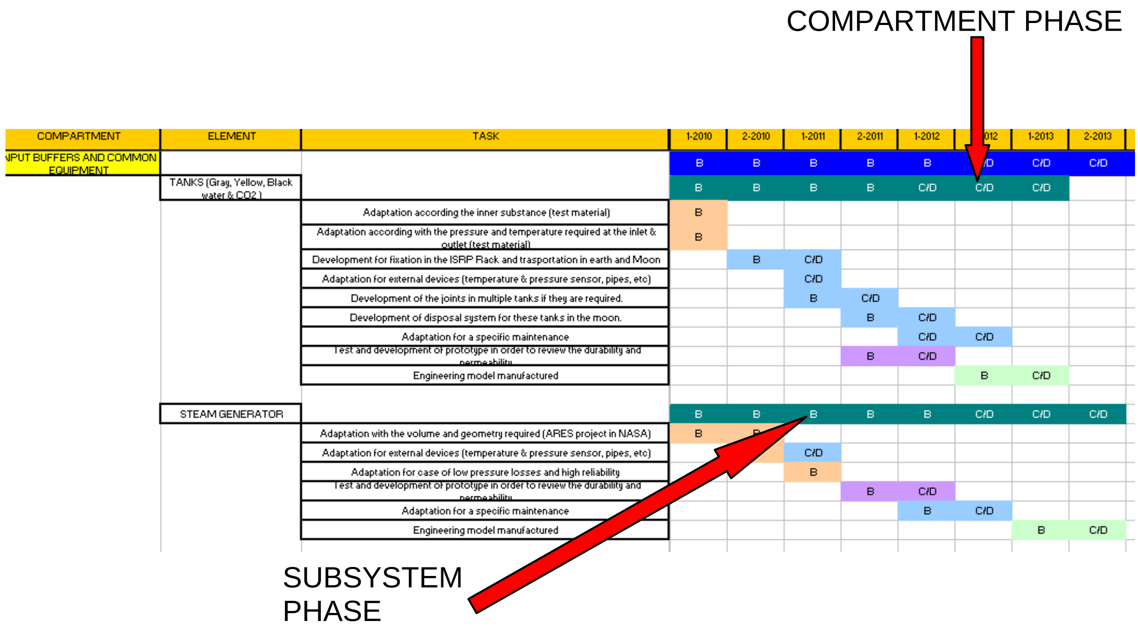


Figure 22 Compartment phase definition.

6.4.2 Development Team

The team proposed as the responsible to conduct the tasks should be composed by people with high expertise on many different areas. Following the profiles for the different specialities required by the team are indicated:

- **Chemist specialists**: People in charge of all chemistry processes involved in the different element phases (i.e. mass balance, reactions in the reactors, etc.). Also these specialists should contribute to the safety design and operations.
- **Biologists:** People in charge of design, development and verification of the technologies related to the higher plants cultivation, microbial cultures conditions. They will be responsible of the quality and safety control (microbial control in food, water and air). Also these specialists should contribute to the safety design and operations.
- **Nutritionists:** People responsible of the design and verification of the system according to the nutritional requirements.
- **Electrical and Electronics specialists:** People in charge for design, development and adaptation of all power and electronic devices. Test and verification of the performances should be also another responsibility for these specialists.
- **Materials specialists:** People in charge for the design, development and implementation of materials that comply with the performance requirements under the different and complex environments (radiation, chemical oxidation, etc)
- **Mechanical specialists:** People in charge of design, adaptation and manufacturing of all elements that gives shape to the complete module (ISPR racks, trays, etc). Also in charge of all installations or links between modules and racks (pipes, cables, air conducts, etc)
- **Thermal specialists:** People in charge of calculations and design for the power required and estimation of elements that will give the power to the system. Also the verification of the good performance and developments of the safety system in case of the system energy fails.

- **Integration Systems specialists:** People in charge of the engineering of the systems integrating the several subsystems.
- **Logistic and transportation specialist:** People in charge of all transportation processes and logistics on ground, during the launch, during the space transit and during the landing. Their responsibility covers protection, fixation manner, good performance and transportation from small elements, assemblies or subassemblies (valves, sensors, cameras, etc) until the big structures, complex assemblies or fragile elements (reactors, lights, etc)**.** Besides transportation, their responsibility covers the displacements and operations that should be done in order to spread and install all the module elements during the mission.
- **Space Safety specialists:** People in charge of to design and development of safety procedures for all the systems during all mission phases.
- **Space Operations specialists:** People in charge of development of procedures needed to operate the system during the different mission phases (in ground, deployment, utilisation and retirement).
- **Space project managers:** People in charge to make available all the resources to the specialists for the development of their tasks. In charge of take decisions according to the changes during the development of the project. Also in charge of verify the development of the project according to the time, schedule and cost estimated.

The quantity of these specialists will be variable and dependant on the maturity of the technology. In first instance chemist, biologist, mechanical and electrical specialists will have an important participation. However, as the planning proposed shows, some elements can be developed at the same time and thus; the quantity of these specialists will increase. The later phases will be more engineering and specialists in systems integration, mechanics and electronics will be the main components of the team.

6.4.3 Compartment phase definition

The next pages show the preliminary development plan divided in compartments with their respective subsystems and Tasks for each subsystem.

Input Buffers and common equipment Preliminary Development Plan

COMPARTMENT	ELEMENT	TASK	TASK NUMBER	QTY	1-2010	2-2010	1-2011	2-2011	1-2012	2-2012	1-2013	2-2013	1-2014	2-2014	1-2015	2-2015	1-2016
INPUT BUFFERS AND COMMON EQUIPMENT					B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
	TANKS (Gray, Yellow, Black water & CO2)			4	B	B	B	B	C/D	C/D	C/D	C/D					
		Adaptation according the inner substance (test material)	1		B												
		Adaptation according with the inlet and/or outlet boundary conditions	3		B												
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6			B	C/D										
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4				C/D										
		Development of the joints in multiple tanks if they are required.	7				B	C/D									
		Development of disposal system for specific elements	9					B	C/D								
		Test and development of a prototype	10					B	C/D	C/D	C/D						
		Adaptation for a specific maintenance	11						C/D	C/D	C/D						
		Manufacturing of the engineering model	12								C/D	C/D					
	STEAM GENERATOR			1	B	B	B	B	B	C/D	C/D	C/D					
		Adaptation with the volume and geometry required (ARES project in NASA)	2		B	B											
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	C/D										
		Adaptation for case of low pressure losses and high reliability	5				B										
		Test and development of a prototype	10					B	C/D	C/D							
		Adaptation for a specific maintenance	11						B	C/D	C/D						
		Manufacturing of the engineering model	12								C/D	C/D					
	CONDENSER			1	B	B	B	B	B	C/D	C/D	C/D					
		Adaptation according with the volume and geometry riqured (DAFT project in NASA and ARES)	2		B												
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	C/D										
		Adaptation for case of low pressure losses and high reliability	5				B	C/D									
		Test and development of a prototype	10						B	C/D	C/D						
		Adaptation for a specific maintenance	11						B	C/D	C/D						
		Manufacturing of the engineering model	12								C/D	C/D					
	COOLER			1	B	B	B	B	B	B	C/D	C/D	C/D				
		Adaptation according with the volume and geometry riquired (ARES project in NASA	2		B												
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	C/D										
		Adaptation for case of low pressure losses and high reliability	5				B	C/D									
		Development of thermal control	8					B	C/D								
		Test and development of a prototype	10						B	C/D	C/D						
		Adaptation for a specific maintenance	11							C/D	C/D						
		Manufacturing of the engineering model	12									C/D	C/D				
	ELECTRONICS & CONTROL						B	B	B	B	C/D	B	C/D	C/D			
	Devleopment and testing of prototype and engineering model									B	B	C/D	C/D	C/D	C/D	C/D	
	STRUCTURAL PERFORMANCE																
		Adaptation of the structure for the launch & and landing (vibration)	13											B	C/D	C/D	
		Adaptation to container links	14													B	C/D

Grey Water Recovery System Preliminary Development Plan

COMPARTMENT	ELEMENT	TASK	TASK NUMBER	QTY	1-2010	2-2010	1-2011	2-2011	1-2012	2-2012	1-2013	2-2013	1-2014	2-2014	1-2015	2-2015	1-2016	2-2016	1-2017	2-2017
GWRS					B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
	GREY WATER TREATMENT UNIT			1	B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D			
		Development and test of electro-dialysis unit.	16		B	B														
		Development and test of ammonium absorption unit	17		B	B														
		Adaptation of ammonium analyzer according with the parameters requiered.	18			B	B													
		Development and test of biological filters	19					B	C/D											
		Test and development of a prototype	10							B	C/D	C/D	C/D							
		Development for a specific maintenance	11									B	B	C/D	C/D					
		Manufacturing of the engineering model	12												C/D	C/D	C/D			
	ELECTRONICS & CONTROL							B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D			
	Devleopment and testing of prototype and engineering model												B	B	C/D	C/D	C/D	C/D	C/D	
	STRUCTURAL PERFORMANCE																			
		Adaptation of the structure for the launch & and landing (vibration)	13														B	C/D	C/D	
		Adaptation to container links	14																C/D	C/D

Biomass pretreatment Unit Preliminary Development Plan

COMPARTMENT	ELEMENT	TASK	TASK NUMBER	QTY	1-2010	2-2010	1-2011	2-2011	1-2012	2-2012	1-2013	2-2013	1-2014	2-2014	1-2015	2-2015	1-2016
BIOMASS PRETREATMENT UNIT					B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
	GRINDER			1	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D			
		Adaptation according with the volume and geomerty required (Prosoya, has been made a prototype for ALSSITB project)	2		B	B											
		Adaptation according with the inlet and/or outlet boundary conditions	3			B	B										
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6					B	C/D	C/D							
		Test and development of a prototype	10						B	C/D	C/D	C/D					
		Adaptation for a specific maintenance	11							C/D	C/D	C/D					
		Manufacturing of the engineering model	12									C/D	C/D	C/D			
	COOLER			1	B	B	B	B	B	B	C/D	C/D	C/D				
		Adaptation according with the volume and geometry riqured (ARES project in NASA	2		B												
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	C/D										
		Adaptation for case of low pressure losses and high reliability	5				B	C/D									
		Development of thermal control	8					B	C/D								
		Test and development of a prototype	10							B	C/D	C/D					
		Adaptation for a specific maintenance	11							C/D	C/D	C/D					
		Manufacturing of the engineering model	12									C/D	C/D				
	TANK			1	B	B	B	B	C/D	C/D	C/D	C/D					
		Adaptation according the inner substance (test material)	1		B												
		Adaptation according with the inlet and/or outlet boundary conditions	3		B												
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6			B	C/D										
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4				C/D										
		Development of the joints in multiple tanks if they are required.	7				B	C/D									
		Development of disposal system for specific elements	9					B	C/D								
		Test and development of a prototype	10					B	C/D	C/D	C/D						
		Adaptation for a specific maintenance	11						C/D	C/D	C/D						
		Manufacturing of the engineering model	12								C/D	C/D					
	ELECTRONICS & CONTROL									B	B	C/D	C/D	C/D			
	Devleopment and testing of prototype and engineering model													B	C/D	C/D	
	STRUCTURAL PERFORMANCE																
		Adaptation of the structure for the launch & and landing (vibration)	13										B	C/D	C/D		
		Adaptation to container links	14												C/D	C/D	C/D

ARES Preliminary Development Plan

COMPARTMENT	ELEMENT	TASK	TASK NUMBER	QTY	1-2010	2-2010	1-2011	2-2011	1-2012	2-2012	1-2013	2-2013	1-2014	2-2014	1-2015	2-2015	1-2016
ARES					B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
	CO2 CONCENTRATION (CCA)				B	B	B	C/D	C/D	C/D	C/D	C/D					
		Adaptation according with the volume and geometry riquired (ELEKTRON russian system)	2	1	B												
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	C/D										
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6				B	C/D									
		Adaptation for case of low pressure losses and high reliability	5				B	C/D	C/D								
		Test and development of a prototype	10					B	C/D	C/D							
		Adaptation for a specific maintenance	11						B	C/D	C/D						
		Manufacturing of the engineering model	12							C/D	C/D	C/D					
	OXIGEN GENERATION (OGA)			1	B	B	B	C/D	C/D	C/D	C/D	C/D					
		Adaptation according with the volume and geometry riquired (ARES project in NASA	2		B												
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	C/D										
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6				B	C/D									
		Adaptation for case of low pressure losses and high reliability	5				B	C/D	C/D								
		Test and development of a prototype	10					B	C/D	C/D							
		Adaptation for a specific maintenance	11						B	C/D	C/D						
		Manufacturing of the engineering model	12							C/D	C/D	C/D					
	CO2 REPROCESSING (CRA)			1	B	B	B	C/D	C/D	C/D	C/D	C/D					
		Adaptation according with the volume and geometry riquired (ARES project in NASA	2		B												
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	C/D										
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6				B	C/D									
		Adaptation for case of low pressure losses and high reliability	5				B	C/D	C/D								
		Test and development of a prototype	10					B	C/D	C/D							
		Adaptation for a specific maintenance	11						B	C/D	C/D						
		Manufacturing of the engineering model	12							C/D	C/D	C/D					
	ELECTRONICS & CONTROL									B	C/D	C/D	C/D				
	Devleopment and testing of prototype and engineering model											B	C/D	C/D			
	STRUCTURAL PERFORMANCE																
		Adaptation of the structure for the launch & and landing (vibration)	13										B	C/D	C/D		
		Adaptation to container links	14												C/D	C/D	C/D

Seed Germination Unit Preliminary Development Plan

COMPARTMENT	ELEMENT	TASK	TASK NUMBER	QTY	1-2010	2-2010	1-2011	2-2011	1-2012	2-2012	1-2013	2-2013	1-2014	2-2014	1-2015	2-2015	1-2016	2-2016	1-2017
SEED GERMINATION UNIT					B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
	TRAYS			6	B	B	B	B	C/D	C/D	C/D	C/D							
		Adaptation according with the volume and geomerty required.	2		B	B	C/D												
		Adaptation for nutrients and liquid supplier system (see the Astroculture root tray design for the CERES)	20			B	B	C/D											
		Test and development of a prototype	10					B	C/D	C/D									
		Adaptation for a specific maintenance	11							C/D	C/D								
		Manufacturing of the engineering model	12								C/D	C/D							
	LIGHT			6	B	B	B	B	C/D	C/D	C/D	C/D							
		Adaptation according with power and geometry required.	2		B	B	C/D												
		Adaptation of new lighting technologies	21			B	B	C/D											
		Test and development of a prototype	10					B	C/D	C/D									
		Adaptation for a specific maintenance	11							C/D	C/D								
		Manufacturing of the engineering model	12								C/D	C/D							
	CONTROL SYSTEM (Temperature, humidity, gas concentration, pressure control,			1	B	B	B	C/D	C/D	C/D	C/D								
		Adaptation with the control configuration required	22		B	B													
		Adaptation of the system developed (see ADVANCE ASTROCULTURE ADVASC)	22			B	B	C/D											
		Test and development of a prototype	10					C/D	C/D										
		Adaptation for a specific maintenance	11						C/D	C/D									
		Manufacturing of the engineering model	12							C/D	C/D								
	IRRIGATION/NUTRIENTS CONTROL			1	B	B	B	B	B	B	C/D	C/D	C/D	C/D					
		Development and adaptation for an irrigation system	23		B	B	B												
		Adaptation to supply nutrients and liquid system (see the Astroculture root tray design for the CERES)	24				B	C/D											
		Test and development of a prototype	10						B	C/D	C/D								
		Adaptation for a specific maintenance	11								C/D	C/D							
		Manufacturing of the engineering model	12										C/D	C/D					
	ELECTRONICS & CONTROL									B	B	C/D	C/D	C/D					
	Devleopment and testing of prototype and engineering model													B	C/D	C/D			
	STRUCTURAL PERFORMANCE																		
		Adaptation of the structure for the launch & and landing (vibration)	13												B	C/D	C/D		
		Adaptation to container links	14														C/D	C/D	C/D

MELiSSA CI Preliminary Development Plan

COMPARTMENT	ELEMENT	TASK	TASK NUMBER	QTY	1-2010	2-2010	1-2011	2-2011	1-2012	2-2012	1-2013	2-2013	1-2014	2-2014	1-2015	2-2015	1-2016	2-2016	1-2017	2-2017	1-2018	2-2018
MELISSA CI					B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
	TANKS			3	B	B	B	B	C/D	C/D	C/D	C/D										
		Adaptation according the inner substance (test material)	1		B																	
		Adaptation according with the inlet and/or outlet boundary conditions	3		B																	
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6			B	C/D															
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4				C/D															
		Development of the joints in multiple tanks if they are required.	7				B	C/D														
		Development of disposal system for specific elements	9					B	C/D													
		Test and development of a prototype	10					B	C/D	C/D	C/D											
		Adaptation for a specific maintenance	11						C/D	C/D	C/D											
		Manufacturing of the engineering model	12								C/D	C/D										
	FILTERS UNIT			1	B	B	B	B	C/D	C/D	C/D	C/D										
		Adaptation according the inner substance (gas or liquid, see WRS in NASA)	25		B	B	C/D															
		Adaptation according with the volume available (see WRS in NASA)	26			B	B	C/D	C/D													
		Adaptation according with the pressure and temperature required at the inlet & outlet (test material), see WRS in NASA	3				B	B	C/D													
		Test and development of a prototype	10						C/D	C/D												
		Adapattion for specific maintenance (see WRS in NASA)	11							C/D	C/D											
		Manufacturing of the engineering model	12								C/D	C/D										
	GAS FLOW CONTROLLERS/ GAS ANALYZER			2	B	B	B	B	C/D	C/D	C/D	C/D										
		Adaptation according the inner gas (WPA, PGBA, GAS ANALYZER SYSTEM, VOLATILE ORGANIC ANALIZER , ANITA in NASA)	27		B	B																
		Adaptation according with the inlet and/or outlet boundary conditions	3				B	C/D														
		Adaptation for the volume according with the space available in the ISRP	26					B	C/D													
		Test and development of a prototype	10						C/D	C/D												
		Adaptation for a specific maintenance	11							C/D	C/D											
		Manufacturing of the engineering model	12								C/D	C/D										
	HEAT EXCHANGER			2	B	B	B	B	B	B	C/D	C/D	C/D									
		Adaptation according with the volume and geometry riqured (ARES project in NASA	2		B																	
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	C/D															
		Adaptation for case of low pressure losses and high reliability	5				B	C/D														
		Development of thermal control	8					B	C/D													
		Test and development of a prototype	10						B	C/D	C/D											
		Adaptation for a specific maintenance	11								C/D	C/D										
		Manufacturing of the engineering model	12									C/D	C/D									
	CONDENSER			1	B	B	B	B	B	C/D	C/D	C/D										
		Adaptation according with the volume and geometry riqured (DAFT project in NASA and ARES)	2		B																	
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	C/D															
		Adaptation for case of low pressure losses and high reliability	5				B	C/D														
		Test and development of a prototype	10						B	C/D	C/D											
		Adaptation for a specific maintenance	11						B	C/D	C/D											
		Manufacturing of the engineering model	12								C/D	C/D										
	REACTORS			1	B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D			
		Adaptation according with the volume and geometry required (ARES or WRS projects in NASA	2		B	B	B	C/D														
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4				B	B	C/D	C/D												
		Adaptation for case of low pressure losses and high reliability	5						B	B	C/D											
		Development of thermal control	8								B	C/D										
		Development according with the power required for an acceptable performance	15								B	C/D	C/D									
		Test and development of a prototype	10									C/D	C/D	C/D	C/D							
		Adaptation for a specific maintenance	11												C/D	C/D	C/D					
		Manufacturing of the engineering model	12														C/D	C/D	C/D			
	PUMP			2	B	B	B	B	C/D	C/D	C/D	C/D	C/D									
		Adaptation according with the volume and geometry riqured (WRS project in NASA	2		B	B	C/D															
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	B	C/D														
		Adaptation for case of low pressure losses and high reliability	5				B	B	C/D													
		Test and development of a prototype	10						C/D	C/D	C/D											
		Adaptation for a specific maintenance	11								C/D	C/D										
		Manufacturing of the engineering model	12									C/D	C/D									
	LEVEL SENSOR/SWITCH			2	B	B	B	C/D	C/D	C/D	C/D	C/D										
		Adaptation according with the volume and geometry riqured (WRS project in NASA	2		B	B	C/D															
		Adaptation for case of low pressure losses and high reliability	5			B	B	C/D														
		Test and development of a prototype	10					C/D	C/D	C/D												
		Adaptation for a specific maintenance	11							C/D	C/D											
		Manufacturing of the engineering model	12								C/D	C/D										
	PhMETER			2	B	B	B	C/D	C/D	C/D	C/D											
		Adaptation to the tank or deposit to be controlled	28		B	B	C/D															
		Test and development of a prototype	10				B	C/D	C/D													
		Adaptation for a specific maintenance	11						C/D	C/D												
		Manufacturing of the engineering model	12							C/D	C/D											
	TEMPERATURE SENSOR			1	B	B	C/D	C/D	C/D	C/D	C/D											
		Adaptation to the tank or deposit to be controlled (see RdF temperature sensors)	28		B	B	C/D															
		Test and development of a prototype	10				C/D	C/D	C/D													
		Adaptation for a specific maintenance	11						C/D	C/D												
		Manufacturing of the engineering model	12							C/D	C/D											
	TURBIDITY SENSOR			1	B	B	B	C/D	C/D	C/D	C/D	C/D										
		Adaptation to the tank or deposit to be controlled (see BIOFILTER in NASA)	28		B	B	C/D															
		Adaptation to the liquid or gas required to controlled (see BIOFILTER in NASA)	28			B	B	C/D														
		Test and development of a prototype	10					C/D	C/D	C/D												
		Adaptation for a specific maintenance	11							C/D	C/D											
		Manufacturing of the engineering model	12								C/D	C/D										
	VALVES			2	B	B	C/D	C/D	C/D	C/D	C/D											
		Adaptation to the boundaries conditions to be controlled: temperature, pressure and driven substance (see x-valve from Parker Pneumatics and ARES in NASA)	29		B	B	C/D															
		Test and development of a prototype	10				C/D	C/D	C/D													
		Adaptation for a specific maintenance	11						C/D	C/D												
		Manufacturing of the engineering model	12							C/D	C/D											
	ELECTRONICS & CONTROL													B	B	C/D	C/D	C/D				
	Devleopment and testing of prototype and engineering model																	B	C/D	C/D		
	STRUCTURAL PERFORMANCE																					
		Adaptation of the structure for the launch & and landing (vibration)	13															B	C/D	C/D		
		Adaptation to container links	14																	C/D	C/D	C/D

Food Process Unit Preliminary Development Plan

COMPARTMENT	ELEMENT	TASK	TASK NUMBER	QTY	1-2010	2-2010	1-2011	2-2011	1-2012	2-2012	1-2013	2-2013	1-2014	2-2014	1-2015	2-2015	1-2016	2-2016	1-2017	2-2017	1-2018
FOOD PROCESS UNIT					B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
	GRINDER MILL			1	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D							
		Adaptation according with the volume and geomerty required (Prosoya, has been made a prototype for ALSSITB project)	2		B	B															
		Adaptation according with the inlet and/or outlet boundary conditions	3			B	B														
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6					B	C/D	C/D											
		Test and development of a prototype	10						B	C/D	C/D	C/D									
		Adaptation for a specific maintenance	11							C/D	C/D	C/D									
		Manufacturing of the engineering model	12									C/D	C/D	C/D							
	DRYER GENERATE POWDER			1	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D							
		Adaptation according with the volume and geomerty required (see CELLS projectin NASA)	2		B	B															
		Adaptation according with the inlet and/or outlet boundary conditions	3			B	B														
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6				B	C/D	C/D												
		Test and development of a prototype	10						B	C/D	C/D										
		Adaptation for a specific maintenance	11								C/D	C/D									
		Manufacturing of the engineering model	12									C/D	C/D	C/D							
	CENTRIFUGATION UNIT			1	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D								
		Adaptation according with the volume and geomerty required (see CENTRIFUGE ACOMODATION MODULE projectin NASA or SRA for ISS)	2		B	B															
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6			B	B	C/D													
		Test and development of a prototype	10					C/D	C/D	C/D											
		Adaptation for a specific maintenance	11							C/D	C/D										
		Manufacturing of the engineering model	12								C/D	C/D	C/D								
	FRIDGE			1	B	B	B	B	C/D	C/D	C/D	C/D									
		Adaptation according with the volume and geomerty required (see Kriogem-3M Roscomes or CGBA)	2		B	B															
		Adaptation according with the inlet and/or outlet boundary conditions	3			B	B														
		Adaptation for a fixation in the ISRP Rack and trasportation in earth and Moon	6				B	C/D	C/D												
		Test and development of a prototype	10						C/D	C/D	C/D										
		Adaptation for a specific maintenance	11							C/D	C/D										
		Manufacturing of the engineering model	12							C/D	C/D	C/D									
	VACUUM SEALER			1	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D								
		Development of a vacuum sealer of geometry and volume required from the commercial models, applying the vaccum technology used in the ISS experiements	2		B	B	C/D														
		Adaptation according with the inlet and/or outlet boundary conditions	3			B	C/D	C/D													
		Adaptation for a fixation in the ISRP Rack and trasportation in earth and Moon	6					B	C/D												
		Test and development of a prototype	10						C/D	C/D	C/D										
		Adaptation for a specific maintenance	11								C/D	C/D									
		Manufacturing of the engineering model	12									C/D	C/D								
	ELECTRONICS & CONTROL											B	B	C/D	C/D	C/D					
	Devleopment and testing of prototype and engineering model															B	C/D	C/D			
	STRUCTURAL PERFORMANCE																				
		Adaptation of the structure for the launch & and landing (vibration)	13														B	C/D	C/D		
		Adaptation to container links	14																C/D	C/D	C/D

MELiSSA CII Preliminary Development Plan

COMPARTMENT	ELEMENT	TASK	TASK NUMBER	QTY	1-2010	2-2010	1-2011	2-2011	1-2012	2-2012	1-2013	2-2013	1-2014	2-2014	1-2015	2-2015	1-2016	2-2016	1-2017	2-2017	1-2018	2-2018
MELiSSA CII					B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
	TANKS			1	B	B	B	B	C/D	C/D	C/D	C/D										
		Adaptation according the inner substance (test material)	1		B																	
		Adaptation according with the inlet and/or outlet boundary conditions	3		B																	
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6			B	C/D															
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4				C/D															
		Development of the joints in multiple tanks if they are required.	7				B	C/D														
		Development of disposal system for specific elements	9					B	C/D													
		Test and development of a prototype	10					B	C/D	C/D	C/D											
		Adaptation for a specific maintenance	11						C/D	C/D	C/D											
		Manufacturing of the engineering model	12								C/D	C/D										
	GAS PUMP			1	B	B	B	B	C/D	C/D	C/D	C/D	C/D									
		Adaptation according with the volume and geometry riqulred (ANITA project in NASA	2		B	B	C/D															
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	B	C/D														
		Adaptation for case of low pressure losses and high reliability	5				B	B	C/D													
		Test and development of a prototype	10						C/D	C/D	C/D											
		Adaptation for a specific maintenance	11								C/D	C/D										
		Manufacturing of the engineering model	12									C/D	C/D									
	LIQUID PUMP			4	B	B	B	B	C/D	C/D	C/D	C/D	C/D									
		Adaptation according with the volume and geometry riqured (Elektron O2, capillary flow experiment	2		B	B	C/D															
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	B	C/D														
		Adaptation for case of low pressure losses and high reliability	5				B	B	C/D													
		Test and development of a prototype	10						C/D	C/D	C/D											
		Adaptation for a specific maintenance	11								C/D	C/D										
		Manufacturing of the engineering model	12									C/D	C/D									
	GAS ANALYZER/ GAS FLOW CONTROLLER			1	B	B	B	B	C/D	C/D	C/D	C/D										
		Adaptation according the inner gas (WPA, PGBA, GAS ANALYZER SYSTEM, VOLATILE ORGANIC ANALIZER ANITA in NASA)	27		B	B																
		Adaptation according with the inlet and/or outlet boundary conditions	3				B	C/D														
		Adaptation for the volume according with the space available in the ISRP	26					B	C/D													
		Test and development of a prototype	10						C/D	C/D												
		Adaptation for a specific maintenance	11							C/D	C/D											
		Manufacturing of the engineering model	12								C/D	C/D										
	LIQUID FLOW CONTROLLER			2	B	B	B	B	C/D	C/D	C/D	C/D										
		Adaptation according with the volume and geometry riquired (see PFCS in ORU project for NASA	2		B	B																
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4				B	C/D														
		Adaptation for case of low pressure losses and high reliability	5					B	C/D													
		Test and development of a prototype	10						C/D	C/D												
		Adaptation for a specific maintenance	11							B	C/D											
		Manufacturing of the engineering model	12								C/D	C/D										
	HEAT EXCHANGER			1	B	B	B	B	B	B	C/D	C/D	C/D									
		Adaptation according with the volume and geometry riqured (ARES project in NASA	2		B																	
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	C/D															
		Adaptation for case of low pressure losses and high reliability	5				B	C/D														
		Development of thermal control	8					B	C/D													
		Test and development of a prototype	10						B	C/D	C/D											
		Adaptation for a specific maintenance	11								C/D	C/D										
		Manufacturing of the engineering model	12									C/D	C/D									
	VALVES			3	B	B	C/D	C/D	C/D	C/D	C/D											
		Adaptation to the boundary conditions to be controlled: temperature, pressure and driven substance (see x-valve from Parker Pneumatics and ARES in NASA)	29		B	B	C/D															
		Test and development of a prototype	10				C/D	C/D	C/D													
		Adaptation for a specific maintenance	11						C/D	C/D												
		Manufacturing of the engineering model	12							C/D	C/D											
	BIOMASS SENSOR			1	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D								
		Adaptation according with the volume and geometry riquired (commercial sensor)	2		B	B	C/D															
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	B	B	C/D													
		Test and development of a prototype	10						C/D	C/D	C/D											
		Adaptation for a specific maintenance	11								C/D	C/D										
		Manufacturing of the engineering model	12										C/D	C/D								
	BIOREACTOR			1	B	B	B	B	B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	
		Adaptation according the inner substance (test material)	1		B	B	B	C/D														
		Adaptation according with the volume and geometry riquired(See biotechnology facility in the ISS, actually there are some micro-bioreactors)	2				B	B	B	C/D												
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4								B	B	C/D									
		Adaptation for case of low pressure losses and high reliability	5									B	B	C/D								
		Development according with the power required for an acceptable performance	15									B	C/D	C/D								
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6										B	C/D	C/D							
		Test and development of a prototype	10											C/D	C/D	C/D	C/D					
		Adaptation for a specific maintenance	11														C/D	C/D	C/D			
		Manufacturing of the engineering model	12																C/D	C/D	C/D	
	LIGHTING SYSTEM			1	B	B	B	B	C/D	C/D	C/D	C/D										
		Adaptation according with power and geometry required.	2		B	B	C/D															
		Adaptation of new lighting technologies.	21			B	B	C/D														
		Test and development of a prototype	10					B	C/D	C/D												
		Adaptation for a specific maintenance	11							C/D	C/D											
		Manufacturing of the engineering model	12								C/D	C/D										
	ELECTRONICS & CONTROL													B	B	C/D	C/D	C/D				
	Devleopment and testing of prototype and engineering model																B	C/D	C/D	C/D		
	STRUCTURAL PERFORMANCE																					
		Adaptation of the structure for the launch & and landing (vibration)	13															B	C/D	C/D		
		Adaptation to container links	14																	C/D	C/D	C/D

MELiSSA CIII Preliminary Development Plan

COMPARTMENT	ELEMENT	TASK	TASK NUMBER	QTY	1-2010	2-2010	1-2011	2-2011	1-2012	2-2012	1-2013	2-2013	1-2014	2-2014	1-2015	2-2015	1-2016	2-2016	1-2017	2-2017	1-2018	2-2018	1-2019
MELISSA CIII					B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
	URINE TREATMENT UNIT			1	B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D								
		Adaptation according with the volume and geometry riqured	2		B	B	B	B	C/D														
		Adaptation for external devices (temperature & pressure sensors, pipes, etc)	4				B	B	C/D														
		Development of thermal control	8					B	B	C/D													
		Development and test of biological filters	19					B	B	C/D													
		Adaptation of ammonium analyzer according with the parameters requiered.	18						B	C/D	C/D												
		Adaptation for case of low pressure losses and high reliability	5						B	B	C/D												
		Test and development of a prototype	10								C/D	C/D	C/D										
		Adaptation for a specific maintenance	11									C/D	C/D	C/D									
		Manufacturing of the engineering model	12										C/D	C/D	C/D								
	TANK			2	B	B	B	B	C/D	C/D	C/D	C/D											
		Adaptation according the inner substance (test material)	1		B																		
		Adaptation according with the inlet and/or outlet boundary conditions	3		B																		
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6			B	C/D																
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4				C/D																
		Development of the joints in multiple tanks if they are required.	7				B	C/D															
		Development of disposal system for specific elements	9					B	C/D														
		Test and development of a prototype	10					B	C/D	C/D	C/D												
		Adaptation for a specific maintenance	11						C/D	C/D	C/D												
		Manufacturing of the engineering model	12								C/D	C/D											
	AMONIUM LIQUID ANALYZER			1	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D										
		Adaptation to the boundary conditions to be controlled: temperature , pressure, ect. (See Trace gas analyzer TGA in the ISS)	29		B	B	B	C/D	C/D														
		Test and development of a prototype	10						C/D	C/D	C/D												
		Adaptation for a specific maintenance	11								B	C/D											
		Manufacturing of the engineering model	12									C/D	C/D										
	BIOREACTOR			1	B	B	B	B	B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D		
		Adaptation according the inner substance (test material)	1		B	B	B	C/D															
		Adaptation according with the volume and geometry riqured(See biotechnology facility in the ISS, actually there are some micro-bioreactors)	2				B	B	B	C/D													
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4								B	B	C/D										
		Adaptation for case of low pressure losses and high reliability	5									B	B	C/D									
		Development according with the power required for an acceptable performance	15									B	C/D	C/D									
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6										B	C/D	C/D								
		Test and development of a prototype	10											C/D	C/D	C/D	C/D						
		Adaptation for a specific maintenance	11														C/D	C/D	C/D				
		Manufacturing of the engineering model	12																C/D	C/D	C/D		
	HEAT EXCHANGER			1	B	B	B	B	B	B	C/D	C/D	C/D										
		Adaptation according with the volume and geometry riqured (ARES project in NASA	2		B																		
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	C/D																
		Adaptation for case of low pressure losses and high reliability	5				B	C/D															
		Development of thermal control	8					B	C/D														
		Test and development of a prototype	10						B	C/D	C/D												
		Adaptation for a specific maintenance	11								C/D	C/D											
		Manufacturing of the engineering model	12									C/D	C/D										
	FLOW CONTROLLER			2	B	B	B	B	C/D	C/D	C/D	C/D											
		Adaptation according with the volume and geometry riqured (see PFCS in ORU project for NASA	2		B	B																	
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4				B	C/D															
		Adaptation for case of low pressure losses and high reliability	5					B	C/D														
		Test and development of a prototype	10						C/D	C/D													
		Adaptation for a specific maintenance	11							B	C/D												
		Manufacturing of the engineering model	12								C/D	C/D											
	GAS PUMP			2	B	B	B	B	C/D	C/D	C/D	C/D	C/D										
		Adaptation according with the volume and geometry riqured (ANITA project in NASA	2		B	B	C/D																
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	B	C/D															
		Adaptation for case of low pressure losses and high reliability	5				B	B	C/D														
		Test and development of a prototype	10						B	C/D	C/D												
		Adaptation for a specific maintenance	11								C/D	C/D											
		Manufacturing of the engineering model	12									C/D	C/D										
	GAS ANALYZER			1	B	B	B	B	C/D	C/D	C/D	C/D											
		Adaptation according the inner gas (WPA, PGBA, GAS ANALYZER SYSTEM, VOLATILE ORGANIC ANALIZER, ANITA in NASA)	27		B	B																	
		Adaptation according with the inlet and/or outlet boundary conditions	3				B	C/D															
		Adaptation for the volume according with the space available in the ISRP	26					B	C/D														
		Test and development of a prototype	10						C/D	C/D													
		Adaptation for a specific maintenance	11							C/D	C/D												
		Manufacturing of the engineering model	12								C/D	C/D											
	ELECTRONICS & CONTROL													B	B	C/D	C/D	C/D					
	Development and testing of prototype and engineering model																	B	C/D	C/D	C/D		
	STRUCTURAL PERFORMANCE																						
		Adaptation of the structure for the launch & and landing (vibration)	13																B	C/D	C/D		
		Adaptation to container links	14																		C/D	C/D	C/D

MELiSSA CIVa Preliminary Development Plan

COMPARTMENT	ELEMENT	TASK	TASK NUMBER	QTY	1-2010	2-2010	1-2011	2-2011	1-2012	2-2012	1-2013	2-2013	1-2014	2-2014	1-2015	2-2015	1-2016	2-2016	1-2017	2-2017	1-2018	2-2018	1-2019
MELiSSA CIVa.					B	B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
	BIOREACTOR			1	B	B	B	B	B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D		
		Adaptation according the inner substance (test material)	1		B	B	B	C/D															
		Adaptation according with the volume and geometry riquired(See biotechnology facility in the ISS, actually there are some micro-bioreactors)	2				B	B	B	C/D													
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4								B	B	C/D										
		Adaptation for case of low pressure losses and high reliability	5									B	B	C/D									
		Development according with the power required for an acceptable performance	15									B	C/D	C/D									
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6										B	C/D	C/D								
		Test and development of a prototype	10											C/D	C/D	C/D	C/D						
		Adaptation for a specific maintenance	11														C/D	C/D	C/D				
		Manufacturing of the engineering model	12																C/D	C/D	C/D		
	LIGHTING SYSTEM			1	B	B	B	B	C/D	C/D	C/D	C/D											
		Adaptation according with power and geometry required.	2		B	B	C/D																
		Adaptation of new lighting technologies	21			B	B	C/D															
		Test and development of a prototype	10					B	C/D	C/D													
		Adaptation for a specific maintenance	11							C/D	C/D												
		Manufacturing of the engineering model	12								C/D	C/D											
	BIOMASS SENSOR			1	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D									
		Adaptation according with the volume and geometry riquired (commercial sensor)	2		B	B	C/D																
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	B	B	C/D														
		Test and development of a prototype	10						C/D	C/D	C/D												
		Adaptation for a specific maintenance	11								C/D	C/D											
		Manufacturing of the engineering model	12										C/D	C/D									
	GAS PUMP			2	B	B	B	B	C/D	C/D	C/D	C/D	C/D										
		Adaptation according with the volume and geometry riquired (ANITA project in NASA	2		B	B	C/D																
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	B	C/D															
		Adaptation for case of low pressure losses and high reliability	5				B	B	C/D														
		Test and development of a prototype	10						C/D	C/D	C/D												
		Adaptation for a specific maintenance	11								C/D	C/D											
		Manufacturing of the engineering model	12									C/D	C/D										
	HEAT EXCHANGER			1	B	B	B	B	B	B	C/D	C/D	C/D										
		Adaptation according with the volume and geometry riqured (ARES project in NASA	2		B																		
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4			B	C/D																
		Adaptation for case of low pressure losses and high reliability	5				B	C/D															
		Development of thermal control	8					B	C/D														
		Test and development of a prototype	10						B	C/D	C/D												
		Adaptation for a specific maintenance	11								C/D	C/D											
		Manufacturing of the engineering model	12									C/D	C/D										
	GAS ANALYZER			1	B	B	B	B	C/D	C/D	C/D	C/D											
		Adaptation according the inner gas (WPA, PGBA, GAS ANALYZER SYSTEM, VOLATILE ORGANIC ANALIZER, ANITA in NASA)	27		B	B																	
		Adaptation according with the inlet and/or outlet boundary conditions	3				B	C/D															
		Adaptation for the volume according with the space available in the ISRP	26					B	C/D														
		Test and development of a prototype	10						C/D	C/D	C/D												
		Adaptation for a specific maintenance	11							C/D	C/D												
		Manufacturing of the engineering model	12								C/D	C/D											
	FLOW CONTROLLER			2	B	B	B	B	C/D	C/D	C/D	C/D											
		Adaptation according with the volume and geometry riquired (see PFCS in ORU project for NASA	2		B	B																	
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4				B	C/D															
		Adaptation for case of low pressure losses and high reliability	5					B	C/D														
		Test and development of a prototype	10						C/D	C/D	C/D												
		Adaptation for a specific maintenance	11							B	C/D												
		Manufacturing of the engineering model	12								C/D	C/D											
	ELECTRONICS & CONTROL													B	B	C/D	C/D	C/D					
	Devleopment and testing of prototype and engineering model																	B	C/D	C/D	C/D		
	STRUCTURAL PERFORMANCE																						
		Adaptation of the structure for the launch & and landing (vibration)	13																B	C/D	C/D		
		Adaptation to container links	14																		C/D	C/D	C/D

Higher Plants Compartment Preliminary Development Plan

COMPARTMENT	ELEMENT	TASK	TASK NUMBER	QTY	1-2010	2-2010	1-2011	2-2011	1-2012	2-2012	1-2013	2-2013	1-2014	2-2014	1-2015	2-2015	1-2016	2-2016	1-2017	2-2017	1-2018	2-2018	1-2019	2-2019
HPC					B	B	B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
	INFLATABLE MODULE			2	B	B	B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D						
		Development of an inflatable according with the volume and material requiered	2		B	B	B	C/D																
		Adaptation according with the inlet and/or outlet boundary conditions	3				B	B	B	C/D														
		Development of the joints in multiple tanks if they are required.	7						B	B	C/D													
		Adaptation for structure in the launch & the landing installation	30								B	C/D	C/D											
		Test and development of a prototype	10										C/D	C/D	C/D	C/D								
		Adaptation for a specific maintenance	11												C/D	C/D								
		Manufacturing of the engineering model	12													C/D	C/D	C/D						
	RIGID STRUCTURE			2	B	B	B	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D	C/D							
		Development of profile and support structure	31		B	B	C/D																	
		Adaptation of supports and lifters for the structure	32				B	B	C/D															
		Adaptation for structure in the launch & the landing installation	30						B	B	C/D													
		Test and development of a prototype	10								C/D	C/D	C/D	C/D										
		Adaptation for a specific maintenance	11										C/D	C/D	C/D									
		Manufacturing of the engineering model	12												C/D	C/D	C/D							
	AIR CONDUCTIONS			1	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D											
		Adaptation according with the volume and geometry required	2		B	B	C/D																	
		Adaptation for structure in the launch & the landing installation	30			B	B	C/D																
		Test and development of a prototype	10					C/D	C/D	C/D														
		Adaptation for a specific maintenance	11							C/D	C/D													
		Manufacturing of the engineering model	12									C/D	C/D											
	RECIRCULATIONS FANS			2	B	B	B	C/D	C/D	C/D	C/D	C/D	C/D											
		Adaptation according with the size and power requiered. (Commercial power adaptation)	2		B	B	C/D																	
		Adaptation for structure in the launch & the landing installation	30			B	B	C/D																
		Test and development of a prototype	10					C/D	C/D	C/D														
		Adaptation for a specific maintenance	11							B	C/D													
		Manufacturing of the engineering model	12									C/D	C/D											
	TANKS			2	B	B	B	B	C/D	C/D	C/D	C/D												
		Adaptation according the inner substance (test material)	1		B																			
		Adaptation according with the inlet and/or outlet boundary conditions	3		B																			
		Development for fixation in the ISRP Rack and trasportation in earth and Moon	6			B	C/D																	
		Adaptation for external devices (temperature & pressure sensor, pipes, etc)	4				C/D																	
		Development of the joints in multiple tanks if they are required.	7				B	C/D																
		Development of disposal system for specific elements	9					B	C/D															
		Test and development of a prototype	10					B	C/D	C/D	C/D													
		Adaptation for a specific maintenance	11						C/D	C/D	C/D													
		Manufacturing of the engineering model	12								C/D	C/D												
	TRAY			2	B	B	B	B	C/D	C/D	C/D	C/D												
		Adaptation according with the volume and geometry required.	2		B	B	C/D																	
		Adaptation for nutrients and liquid supplier system (see the Astroculture root tray design for the CERES)	20			B	B	C/D																
		Test and development of a prototype	10					B	C/D	C/D														
		Adaptation for a specific maintenance	11							C/D	C/D													
		Manufacturing of the engineering model	12								C/D	C/D												
	ELECTRONICS & CONTROL												B	B	C/D	C/D	C/D							
	Develoopment and testing of prototype and engineering model																B	C/D	C/D	C/D				
	STRUCTURAL PERFORMANCE																							
		Adaptation of the structure for the launch & and landing (vibration)	13																B	C/D	C/D			
		Adaptation to container links	14																		C/D	C/D	C/D	