CAB

CAB call for ideas themes

	Responsibility
Written by	
CAB team	Author
Verified by	
M. Lamantea	Checker
Approved	
Cesare Lobascio	Study Manager
Documentation Manager	
Elena Vaccari	

The validations evidences are kept through the documentation management system.

CHANGE RECORDS

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1. INTRODUCTION

This document is issued in the frame of the CAB project to identify the themes to be subjected to a call-for-idea process, aiming at obtaining from additional Italian actors (industry and academia) the most valuable contributions for each identified research development need.

The document will support the activity foreseen in the frame of the WP 4000 "Call for proposal and valutazione proposte" as per AD 2.1-1 and AD 2.1-2.

The terms of participation to the call for idea are reported in section 5.

2. LIST OF DOCUMENTS

2.1 Applicable documents

AD 2.1-1 DC-MED-2005-028, "Controllo Ambientale Biorigenerativo (CAB) - Capitolato tecnico", rev. A, 22-09-2005

AD 2.1-2 SGI-AAS-I-PRO-0029, "Controllo ambientale biorigenerativo (CAB) – Proposta tecnico gestionale", issue 1, volume I, Nov. 2005

AD 2.1-3 SD-SY-AI-0010, "CAB preliminary functional specification", is.1, Mar. 16, 2007

2.2 Reference documents

RD 2.2-1 CAB website, http://www.fobiotech.org/cab

RD 2.2-2 "Workshop on bioregenerative environmental control – State of art and trends – Working groups report – WG #1: System and architecture", Dec. 19, 2006

RD 2.2-3 "Workshop on bioregenerative environmental control – State of art and trends – Working groups report – WG #2: Regenerative technologies", Dec. 19, 2006

RD 2.2-4 "Workshop on bioregenerative environmental control – State of art and trends – Working groups report – WG #3: Biological elements", Dec. 19, 2006

RD 2.2-5 "Workshop on bioregenerative environmental control – State of art and trends – Working groups report – WG #4: Demonstrators", Dec. 19, 2006

RD 2.2-6 SD-RP-AI-0488, "CAB workshop report", is.1, Dec. 21, 2006

RD 2.2-7 SD-TN-AI-1053, "CAB functional architecture", is.1, Mar. 16, 2007

RD 2.2-8 SD-TN-AI-1054, "State of art for the CAB items", is.1, Mar. 16, 2007

RD 2.2-9 "Life support and habitability manual", ESA PSS-03-406, issue 1, Aug. 1991

RD 2.2-10 HUMEX: A Study on the Survivability and Adaptation of Humans to Long-Duration Exploratory Missions, ESA SP-1264

RD 2.2-11 REGLISSE: Review of European ground Laboratories and Infrastructures for Sciences and Support Exploration, ESA Internal study

RD 2.2-12 "Atmosphere quality standards in manned space vehicles", ESA PSS-03-401, issue 1, June 1992

RD 2.2-13 Minute of the RDR of CAB written by B. Negri at ASI Rome, Mar. 22, 2007

2.3 Related Web Sites Links

LK 2.3-1 ASI Piano Triennale di Attività
http://www.asi.it/html/ita/news/PTA%202006-2008%20approvato%20delibera%2017-2006.pdf

LK 2.3-2 ESA Advanced Life Support
http://ecls.esa.int/ecls/?p=

LK 2.3-3 NASA Bioastronautics Roadmap
http://bioastroroadmap.nasa.gov/User/discipline.jsp?filterDisciplines=15

LK 2.3-4 NASA Ames Research Center, Advanced Life Support
http://www.nasa.gov/centers/ames/research/technology-onepagers/advanced-life-support.html

LK 2.3-5 NASA Jet Propulsion Laboratory, Advanced Environmental Monitoring and Control
http://aemc.jpl.nasa.gov/

3. GENERALITIES ON THE PROJECT

The Bioregenerative Life Support program CAB (Controllo Ambientale Biorigenerativo) is a key element of the Italian Space Agency (ASI) Medicine & Biotechnology scientific program, set forth in the ASI Activity Plan 2006-2008.

3.1 CAB project team

The prime contractor of the CAB project is:

- Alcatel Alenia Space - Italia (AAS-I)

with the following main partners:

- The Department of Agricultural Engineering and Territorial Agronomy (DIAAT) of the University of Naples Federico II, and
- The Department of Plant Biology and Centre of Excellence CEBIOVEM of the University of Turin

Further partners will join the team on the basis of the "call for idea" competition presented in this document in order to cover specific topics of interest for the CAB project as identified in paragraph 3.5.

3.2 CAB project elements

During the design and integration of the International Space Station, Italian space industries have developed a strong background and competences in Environment Control and Life Support Systems. In particular, Alcatel Alenia Space – Italia (AAS-I) has become a major actor in the design, procurement and integration of the ECLSS of six ISS modules. Several studies and technological developments in advanced life support components and the definition of new exploration architectures and habitat concepts are on-going, also with the support of academia and research centres.
In this framework, the Italian Space Agency is launching the Bioregenerative Environmental Control Project, CAB (Controllo Ambientale Biorigenerativo).

The overall CAB objective is to define and prepare the technological, scientific and demonstration elements needed to setup a Bioregenerative Life Support System (BLSS), allowing the regeneration of resources and the production of food for life support in long duration missions. The project includes:

(1) Higher plants as basic elements for food and oxygen production, CO2 regeneration and water purification via the photosynthetic and leaf transpiration processes
(2) Biological & physico-chemical systems for environmental control, monitoring, power & data distribution, etc.

Particularly, the sectors of concern will be:

1. Food production, particularly using higher plants, and food management
2. Air regeneration, in terms of production of O2, removal of CO2 and trace gases
3. Water regeneration in terms of urine and gray water processing and potable water management
4. Solid waste processing

5. Thermal-hygrometric control
6. Resources allocation and storage

The main objective in CAB is to develop a regenerative system, promoting self-sufficiency and minimizing the need of resources for long lasting missions. This shall be achieved throughout the maximization of its cycle closure and regeneration using higher plants and other autotrophic organisms, the design and setup of an integrated monitoring and adaptive control system and a better understanding of problems related to buffering of the regenerated resources.

Analytical methods and tools shall be developed for the regenerative system. Mission, functional resource balance and stability analyses will aid in architectural and technological choices, while the definition and application of metrics at system and lower levels shall allow trade-offs with respect to mission scenarios and scientific-technical monitoring.

Space environment compatibility issues shall be resolved. Research efforts should focus on reduced gravity issues with plants and multi-phase systems, ionizing radiation susceptibility of living organisms (plants, bacteria), low pressure operations and possible psychological benefits of the greenhouse system (availability of fresh food, environment similar to earth) for the crew in isolation.
Finally, technology transfer and spin-offs shall be pursued via a quick identification of possible alternative fields of application for the developed technologies. Project promotion using scientific publications, education programs, web site, media, etc. should also be planned.

3.3 CAB project phases

The CAB project is based in two main and subsequent stages:

- Preparatory stage
- Applicative stage

The preparatory stage of the CAB programme is currently on-going, aiming at defining the major CAB elements to be developed in the following applicative stage. This preparatory stage will last about 12 months, subdivided in three main phases, as described below.

CAB – Phase 1
The first phase of the study has been devoted to the definition of the system functional requirements and preliminary architecture. For this purpose a workshop has been organized inviting representatives of the major European and Extra-European projects of both biological and physico-chemical systems. This has contributed to define the technological and scientific state-of-the-art, to identify the main development lines to be pursued in CAB, to exploit the technical and scientific achievements of the researchers and identify what already available off the shelf. The driving idea has been to realize a project that would be synergic and complementary with previous and current programs, in order to maximize the CAB benefits.
Based on the workshop results, the "Call for Ideas" themes proposed in this document have been issued, aimed at obtaining from additional Italian actors (industry and academia) the most valuable contributions for each identified research development need.
In this phase also the Scientific and Technical Committee (STC) has been named, with the duty to participate to the selection of the scientific and technological elements of interest for the CAB project and (in the following phases) to evaluate and integrate in the CAB project the responses to the issued call for ideas.

CAB – Phase 2
In the second phase of the project, the scientific-technical committee (STC), elected during Phase 1, shall evaluate the answers to the "Call for Ideas" and new qualified partners shall be selected for joining the CAB team and working on the project scientific-technical needs. The most interesting elements shall be integrated in a PDR preliminary architecture and the functional requirements, defined in the first phase, shall be completed and integrated with a set of preliminary technical requirements.

CAB – Phase 3
During the CAB third phase, the team shall hone and finalize the system architecture and requirements. The development plan for the subsequent technological demonstration shall be proposed, highlighting critical elements, risks and possible alternatives.
Finally, the industrial and scientific structure proposed for the subsequent applicative part of the project will be defined.

Once approved by ASI, the CAB applicative stage will be started according to the activity and the plan agreed with ASI at the end of the previous preparatory phase. This second stage is tentatively scheduled on a 3 yr + 3yr time.

3.4 CAB schedule

The schedule of the preparatory stage of the CAB project as currently set is shown in Figure 3-1 and will last 12 months starting from October 2006 when the kick-off of the activities has occurred.

As already stated in 3.3, once approved by ASI, the CAB applicative stage will be started according to the activity and the plan agreed with ASI at the end of the previous preparatory phase. This second stage is tentatively scheduled on a 3yr + 3yr time-frame.

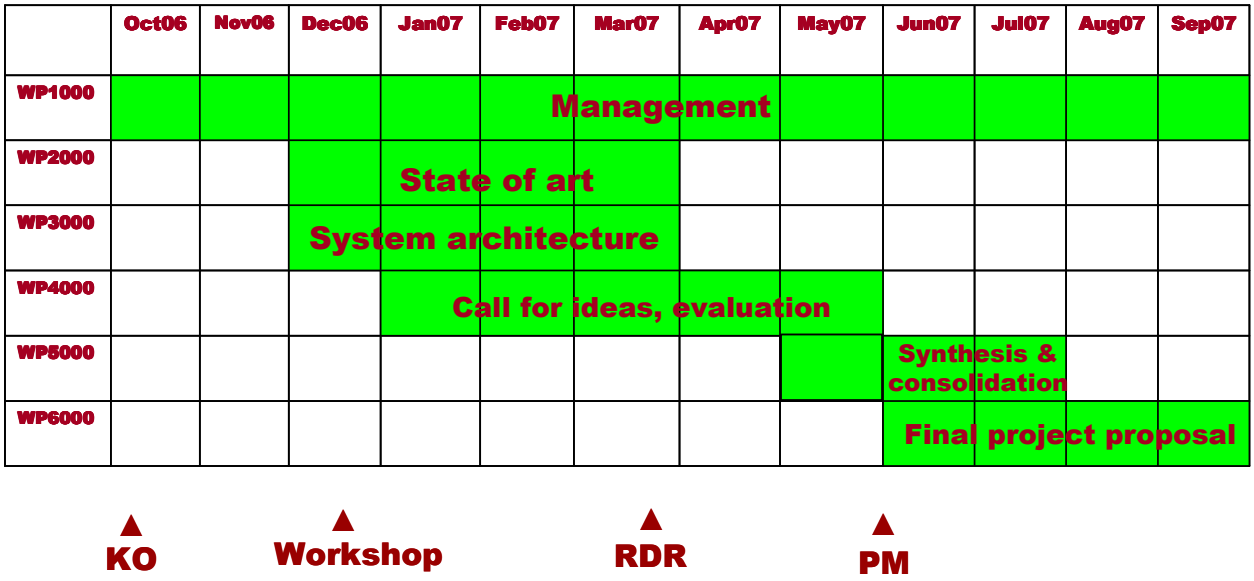

Figure 3-1: CAB project preparatory stage schedule

3.5 CAB Work Breakdown Structure

The CAB work breakdown structure (WBS) is shown in Figure 3-2. The details of the WBS for the part related to the "scientific and technological elements" are reported in Figure 3-3.
The WBS shows how the project is organised, listing the main topics addressed in the project. All the items for which a call for idea is issued are identified in the WBS (yellow boxes). All the other items are in charge of AAS-I, DIAAT of UniNA and DPB of Uni To.

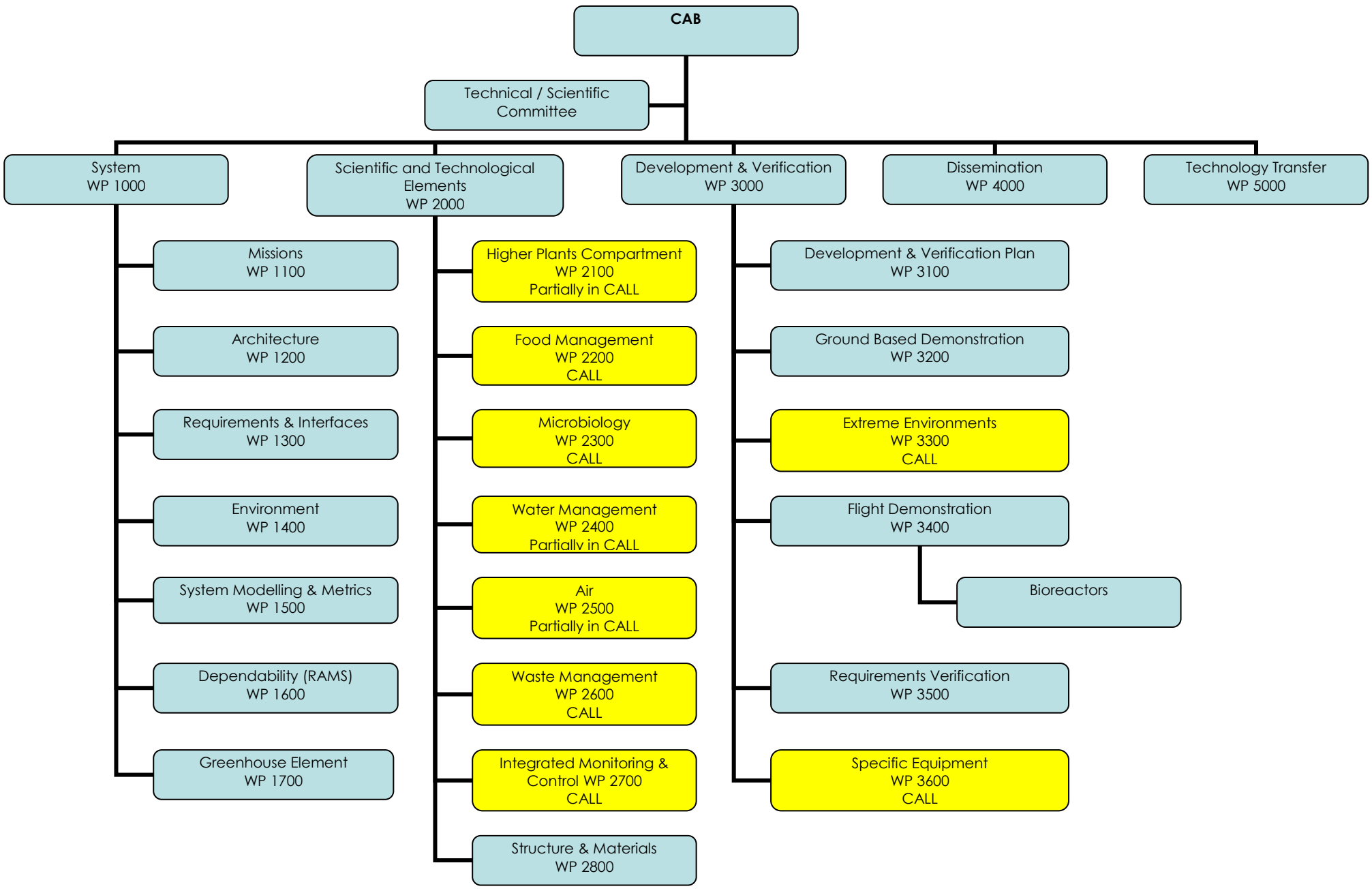

Figure 3-2: CAB general WBS

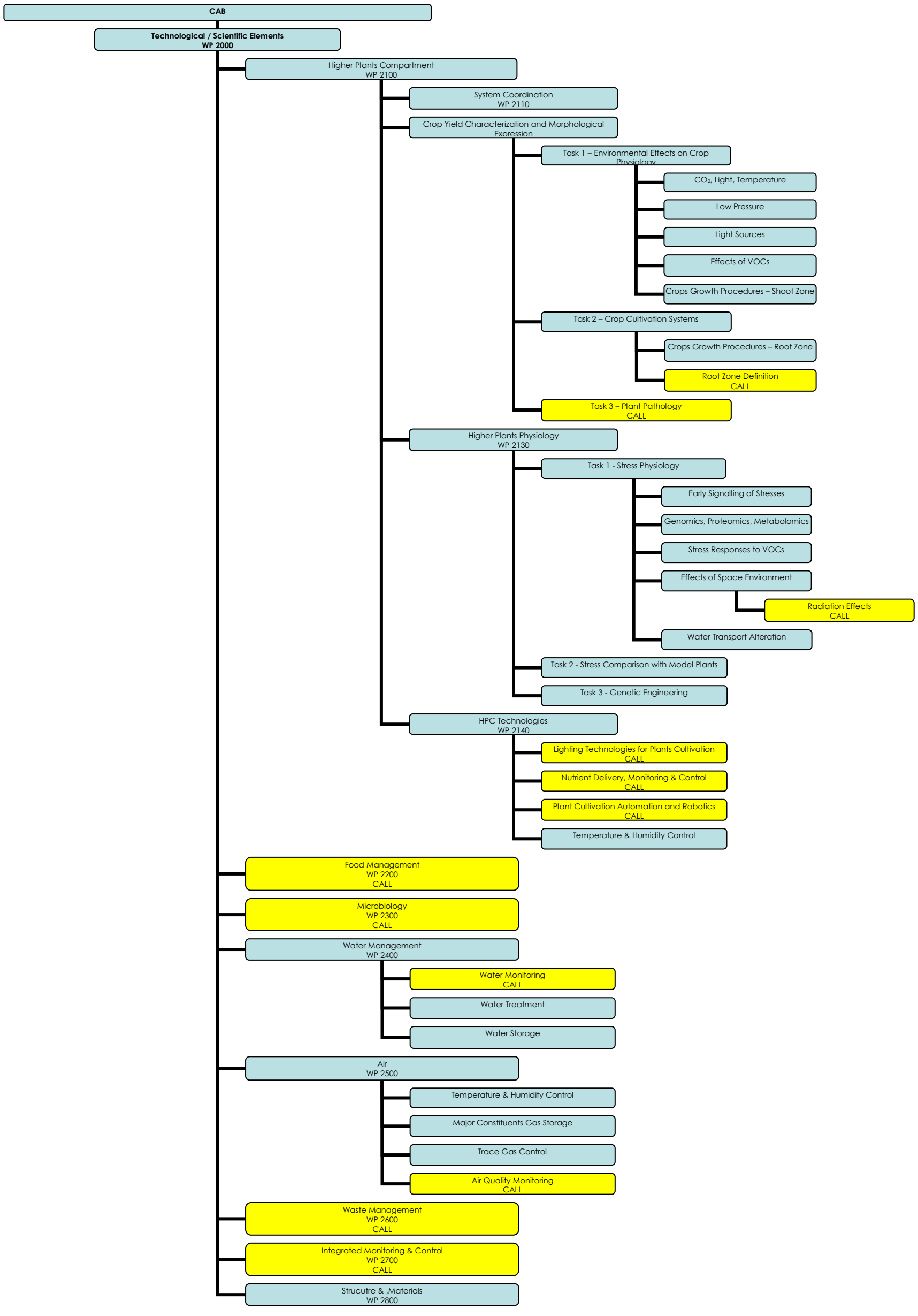

Figure 3-3: CAB WBS of the "scientific and technological elements" WP

3.6 Role of the calls for idea in the CAB project

The CAB team (see paragraph 3.1) intends to collect - by means of the calls proposed within this document (as part of the phase 2 of the programme, see paragraph 3.3) - new qualified partners that, thanks to their competence and their proposals, can provide an innovative product and complete the CAB team in specified fields of interest for the project.

After the evaluation of the proposals, the selected partners will be integrated in the CAB team to concur in the activities planned in the phase 3 of the preparatory phase of the project (see paragraph 3.3).

An involvement of four months is therefore foreseen for these new partners in order to contribute in the finalisation of the project to be presented to ASI. The activity will be aimed:

- at consolidating architecture and requirements of the CAB system,
- at identifying the development plan, the cost and the activities proposed for the following applicative stage.

Once the applicative stage will be approved by ASI, the partners will be involved in it as settled in the development plan and in the related work packages.

3.7 CAB preliminary architecture description

The mission of the CAB system is to support crew life in space missions providing fresh food, oxygen, potable water, hygiene water and removing CO_2. This shall be done by means of biological systems for resources regeneration, coupled with physical-chemical technologies. In particular, the system shall include, as basic element for food production, the higher plants. Since previous breakeven analyses show that bio-regenerative systems become convenient for mission longer than years, the CAB system shall be designed for planetary missions, i.e. for gravity environment.

The CAB system is intended to be part of a planetary human base.

The CAB system shall be designed as a human-tended system. Its environment shall be optimized for the growth of the biological systems, allowing at the same time crew accessibility.

The crew quarters and laboratories are supposed to be in separate, dedicated modules. Therefore, the galley, the kitchen or the system for food preparation, storage and consumption, the toilet and the crew hygienic facilities are not included in the CAB architecture. For the same reason, the CAB project is supposed not to include its own systems for power generation, communication and heat load removal (radiators).

To guarantee the CAB system performances a number of elements shall be included in the architecture. The primary structure shall have proper interfaces with the other modules of the base, the power plant, the external thermal control and the data transmission. The CAB preliminary functional architecture is shown in Figure 3-4.

The system will include all the subsystems directly involved in the resources bio-regeneration, i.e. the water recovery and management, the waste management, the food processing and monitoring and

the higher plants growth facility. The possibility of implementing an algae growth facility has been taken into account in the preliminary architecture. Furthermore the system shall comprise the nutrient delivery system for the biological elements and the environmental control of both the cabin and the biological facilities.

Growing and taking care of crops will require a number of hours per day for the crew members. The presence of a robotic and automation system in the greenhouse, thus reducing the biological facility needs for human presence, could result in a significant increase of astronauts' time for scientific experiments. A robotic system has then been considered in the preliminary architecture, and will be subject of trade off studies in the following phases of the project.

Finally, the system will comprise thermal control, avionic, monitoring and storage systems.

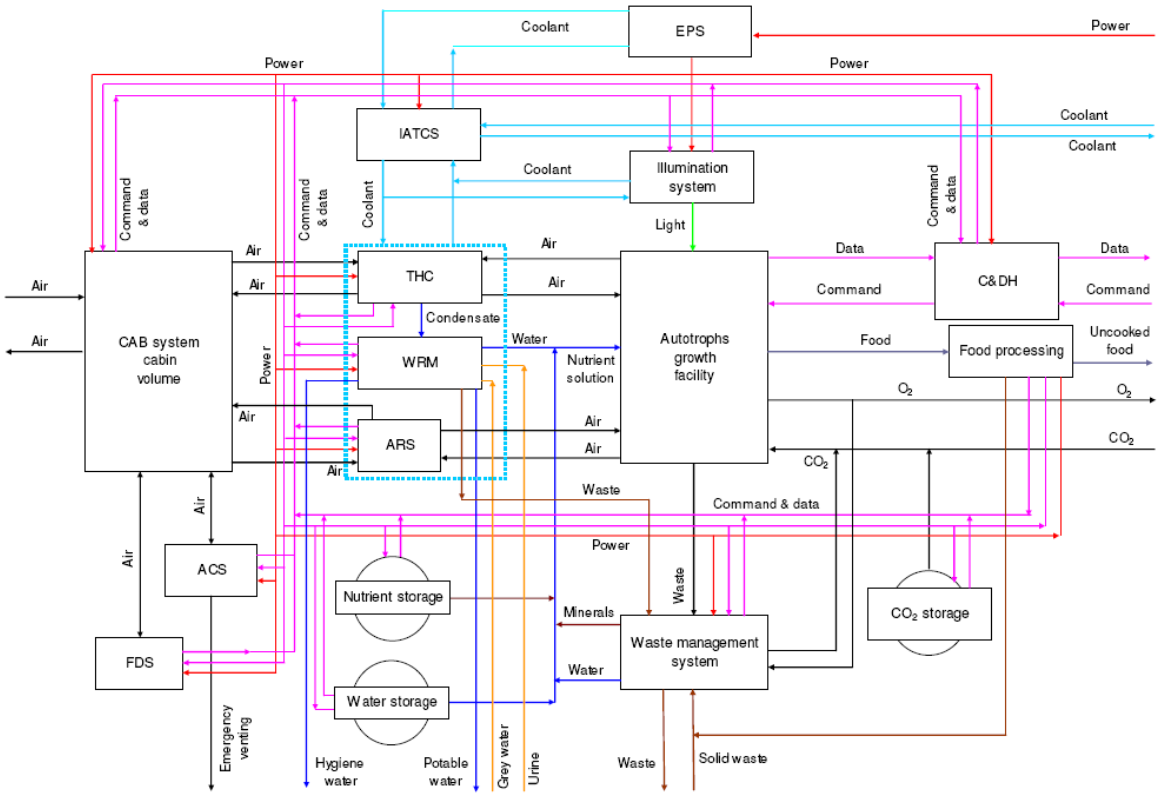

Figure 3-4: CAB Preliminary Functional Architecture

4. CALLS IDENTIFICATION AND DESCRIPTION

The CAB team (see paragraph 3.1) intends to collect - by means of the calls proposed within this section - new qualified partners that, thanks to their competence and to the quality of their proposals, can provide an innovative product and complete the CAB team in specific fields of interest for the project.
The issued calls are identified in Table 4-1. Following subsections describe each call.

Call reference number	Call title	For details see paragraph:
1.1	Defining the root-zone environment and improving root adaptation to the "space" environment.	4.1
1.2	Plant Pathology: higher plants microbiological risk and pest control	4.1
2.1	Radiation effects on plants	4.2
3.1	Lighting technologies for plants cultivation	4.3
3.2	Nutrient delivery, monitoring and control	4.3
3.3	Plants cultivation automation and robotics	4.3
4.1	Space food and diet	4.4
5.1	Microbiology aspects for complex biological systems	4.5
6.1	Water monitoring	4.6
7.1	Air quality monitoring	4.7
8.1	Waste management	4.8
9.1	Integrated monitoring	4.9
10.1	Demonstration of CAB technologies in extreme environments	4.10
11.1	Expression of interest for specific CAB equipment	4.11

Table 4-1: List of the CAB calls

4.1 WP 1 – Crop characterisation and yield optimisation

Under the coordination of the DIAAT of UniNa and in the frame of an activity aimed at characterising the effect of single and combined environmental factors (i.e. atmosphere composition and pressure, light intensity, ethylene…) on plant growth, physiology and productivity (biomass production, harvest index, gas exchanges), the following calls are issued for proposals from qualified teams.

Call 1.1 **Defining the root-zone environment and improving root adaptation to the "space" environment.**

Root/substrate interactions in soilless systems, such as those that must be necessarily used on planetary bases, can substantially affect plant growth and biomass production. Knowing the complex interactions between plants, solid and liquid phases at the root zone is therefore pivotal to define optimal conditions for this peculiar environment. Experienced horticulturists and crop physiologists should focus on water and nutrient delivery concepts, including the effects of different ratios of NH_4:NO_3 in hydroponic systems, and the use of nutrient-loaded zeolite growing media that would only require addition of water to sustain crop growth.

Technical issues that should be also addressed may also include aspects related to 1) sterilization and the recycling of growing medium; 2) removal of potentially toxic root exudates; 3) investigating possible problems associated to hypoxia; 4) analyzing root-to-shoot communications with respect to different root-zone environments; 5) production of mineral forms of nutrients specifically designed for plant growth in the space environment. Mathematical models directed to the predictive control of nutrient uptake should also be developed.

CALL 1.2 **Plant Pathology: higher plants microbiological risk and pest control**

Plant growth in space will undergo to microbial exposure and contamination. The microbiological risk, microbial mitigation and control technologies should be studied with respect to specific interactions with the space environment. This call is addressed to microbiologists and plant pathologists interested in investigating the effect of Space factors on the mechanisms of phytopathology and the principles of plant disease control. Mathematical models directed to the predictive control of plant disease in Space should also be developed.

4.2 WP 2 – Effects of space environment on plants

Under the coordination of the DPB of UniTo and in the frame of an activity aimed at characterising the effect of the space environment on the plants, the following call is issued for proposals from qualified teams.

Call 2.1 **Radiation effects on plants.**
Outside the earth, living organisms are subject to the severe ionizing radiation environment from GCR and SPE. The call is intended for studies and testing on ionizing radiation effects on plants and ensuing plant responses, along their complete life cycle (from seed to seed through mature plant).

A support in the definition of appropriate shielding countermeasures shall be provided.
Support to the definition of potential synergistic effects with all the other environmental parameters of the CAB mission shall be provided (microgravity, electromagnetic field, etc.)

4.3 WP 3 – Higher plants cultivation technologies

Under the coordination of AAS-I and in the frame of an activity aimed at promoting the development of key technologies for the management of higher plants cultivation systems aimed at maximising the plant yield and minimising the crew involvement and the resources utilisation, the following calls are issued for proposals from qualified teams.

Call 3.1 **Lighting technologies for plants cultivation**

Light is fundamental to higher plants to perform photosynthesis. Plant growth chambers illumination can be artificial, natural or hybrid. Trade offs have to be performed in order to choose whether to use electric light sources (e.g., high-pressure sodium, microwave sulphur lamps, LEDs, …) or solar light collection and distribution (by mean of solar collectors and optic fibres), in order to determine the best candidate(s) for a plant cultivation chamber (space application). Furthermore, technological development of innovative plants illumination systems has to be carried out.
The activity in the frame of this call shall also address the system for the monitoring of the light intensity and frequency (PAR).

CAB is seeking partners to join the team that will help in performing the above mentioned trade studies and will develop the technological systems for the illumination of the higher plants growth facility. This call is addressed to non space companies or researchers having an expertise in light production systems that are interested in improving the current state of the art, developing innovative systems for plants illumination. The applicant shall report about the current state of art and research trends, both in terrestrial and space applications and provide innovative ideas in the lighting technologies field to be implemented within the CAB project in order to maximise the overall electrical efficiency of the lighting system.

Call 3.2 **Nutrient delivery, monitoring and control**

The nutrient solution supply system is of paramount importance for plant cultivation in a closed soilless growing system based on resources regeneration like CAB is. Proper technologies shall be proposed and developed to monitor the status of the circulating nutrient solution and control all its constituents (pH, needed minerals, oxygen, water content, etc) inside the requested ranges in order to guarantee the wellbeing of the cultivated plants and maximise its yield. The effect of accumulation, saturation, overconcentration, deposition and of the root exudates shall be investigated. In this respect, also the microbial and the particulate control of the solution shall be ensured.
A survey of current state of art and trends of the irrigation systems and its main components in analogous projects both in terrestrial and space applications shall be done and the suitable CAB irrigation system shall be designed to be integrated in the CAB project (hydroponic, aeroponic, proper matrices, etc.).

The flow rates and the quality of the water supplied from the water recovery system of the CAB element shall also be identified and concurred with AAS-I. The system shall include the sizing of the storage of the needed resources to support the entire CAB mission.
The system shall cope with typical space requirements related to mass, volume, crew time and power consumption minimisation.

The call is open to non space companies or researchers having an expertise in water solutions circulation, monitoring and control mainly in the filed of the irrigation systems that are interested in improving the current state of the art, developing innovative systems for plants nutrients delivery system. The applicant shall provide innovative ideas to be implemented within the CAB project and shall join to the CAB team to harmonise the proposed system and technologies in the Cab architecture.

Call 3.3 **Plants cultivation automation and robotics**

Growing and taking care of crops will require a number of hours per day for the crew members. The presence of a robotic and automation system in the greenhouse, thus reducing the biological facility needs for human presence, could result in a significant increase of astronauts' time for scientific experiments. The increase in system mass, power need and complexity could then be counterbalanced by saving man-time and reducing astronauts' cultivation expertise requirements. System level trade offs have to be performed in this respect.

CAB is seeking partners to join the team that will help in performing the above mentioned trade studies and focusing on the greenhouse robotic system. The applicant shall report about the current state of art and research trends, both in terrestrial and space applications and provide innovative ideas in the cultivation automation field to be possibly implemented within the CAB project.

4.4 WP 4 – Food management

The entire WP #4 will be managed via the following call by a qualified specialists' team in strict relation with AAS-I and DIAAT of UniNa.

Call 4.1 **Space food and diet**

Plant biomass produced from controlled environments can have different biochemical characteristics than biomass from field settings. Research focused on determining what changes in the environment are important for improving the quality of harvested food and to enhance its nutritional value is planned within the CAB project. Because of the constraints of the project, the higher plants cultivation shall be focused on a very limited number of species able to provide as much as possible a complete and variable diet. In this context and within this call, motivated food scientists shall define a complete astronauts' diet based mainly on the on board cultivated higher plants, but also on additional nutritional sources such as algae, micro-organisms, fungi, and identify needed supplemental intakes. Palatability and variability of the food is to be cared with due considerations with astronauts' isolation conditions and specific activities. The call shall include a side to side activity with the CAB horticulturists to select the cultivated species, also in due consideration of aspects such as the edible/non-edible biomass ratio, to define cultivation protocols and to ensure the quality and suitability of the edible part of the cultivated plants. Possible anti-nutritional factors and synergic factors in food assimilation shall be identified and controlled.
Development of novel technologies for minimal food processing should also be considered.

CAB is seeking partners to join the team that will help in developing the program. The partner will be charged of the work package about food, in strict relation with Alcatel Alenia Space Italia and the Department of Agricultural Engineering and Agronomy (DIAAT) of the University of Napoli. The applicant shall report about the current state of art and research trends, both in terrestrial and space applications and provide innovative ideas in the food, diet and nutrition field to be implemented within the CAB project.
The food industry is invited to issue ideas and proposals.

Specific topics will include (but not be limited to):

- Food characterization wrt to space cultivation environment
- Basic food processing (i.e. not including preparation and cooking)
- Food safety and quality control and monitoring
- Astronauts' diet definition

4.5 WP 5 – Microbiology

The entire WP #5 will be managed via the following call by a qualified specialists' team in strict relation with AAS-I, DIAAT of UniNa and DPB of UniTo.

Call 5.1 **Microbiology aspects for complex biological systems**

The CAB project includes several biological systems (controlled bioreactors, plants and humans) in relation to each other and in a closed environment. In this respect, the microbiological control appears of paramount importance for both the survivability and reliability of the entire system.

Within this call, proper systems, methodologies and protocols for monitoring, mitigation and control of microbial contamination of air, water, surface and closed compartments shall be managed comprising the development of proper prophylaxis plans and monitoring and disinfection systems. Biofilm formation shall be studied and controlled. Automatic systems shall be promoted to minimise the man-power in the process.

State of art and trends in both terrestrial and space industry shall be prepared in the frame on the activity.

Experts of hygiene, sanitation and disinfection are invited to issue ideas and proposals on the subject focusing on possible innovative aspects. For the purpose of this call, the emphasis shall be placed on the higher plants compartment, on the CAB cabin and on their interactions with bioreactors and human compartments. Bioreactors development and management are considered as mostly covered by parallel studies (e.g. MELISSA).

4.6 WP 6 – Water management

Under the coordination of AAS-I and in the frame of a work package dedicated to the water production and distribution to the different utilities, the following call is issued for proposals from qualified teams.

Call 6.1 **Water monitoring**

Water quality monitoring is a prerequisite for maintaining a safe place habitat water supply. The function of the water quality monitoring subsystem is to ensure that the standards in potable, wash and hygiene water and in water supply for plants nutrients solution make up are continuously met. The water monitoring system shall ensure water quality monitoring, during and after water recycling processes and before water distribution to the facilities for consumption. Amongst the other, monitoring of TOC, $NH_4^+, NO_3^-, NO_2^-, PO_4^{3-}, SO_4^{--}$, urea, hormones and antibiotics is required. Proper on line and off line techniques shall be proposed for further development. Attention to micro and nano-technologies shall be paid.

4.7 WP 7 – Air management

Under the coordination of AAS-I and in the frame of a work package dedicated to the air management in all the CAB compartments, the following call is issued for proposals from qualified teams. The air management in the CAB project will be basically performed exploiting the higher plant compartment able to regenerate the atmosphere composition removing excess CO_2 to produce O_2. Air management of both the cabin volume and the growth chambers for the biological systems shall be addressed in the work package.

Call 7.1 **Air quality monitoring**

Atmospheric composition monitoring subsystem must monitor CAB atmosphere both in the cabin and in the higher plant growth facilities to check the air quality in each compartment and address the operations of the control system in order to maintain adequate levels of major gas compounds concentration and to limit trace contaminants below acceptable thresholds. Air quality monitoring shall be performed before, during and after CAB recycling processes.

In particular, for the air quality control in the higher plant growth facility, sensors and biosensors able to detect ppb quantities of VOC will be of paramount importance for early detection studies in stress perception. Among VOCs, particular evidence shall be given to the development of innovative techniques for ethylene detection and quantification.

This call is intended for a technological development of a monitoring system for major constituents and trace gases, including ethylene and other VOCs of interest for plant cultivation. Owing to light weight, specific responses, low energy requirement and durability, attention towards micro and nanocomponents is required in the frame of this call.

The call is open to biosensor developers and nanotechnology-oriented institutions.

4.8 WP 8 – Waste management

The entire WP #8 will be managed via the following call by a qualified specialists' team in strict relation with AAS-I, DIAAT of UniNa and DPB of UniTo.

Call 8.1 **Waste management**

Waste recycling is fundamental in regenerative systems, in order to maximize the cycle closure loop. Waste has to be collected, fractionated, stabilized and processed for recycling. Particular attention should be posed to recycling of so far non-addressed products (wipes, clothes, etc.). Both physical-chemical and biological waste treatment have to be considered. Furthermore the waste that cannot be regenerated must be stabilized and stored in order to prevent unpleasant or harmful consequences to humans and equipment. For this reason waste in storage tanks shall be monitored continuously to prevent its degradation.

Because of the major parallel activities of MELISSA in this field, it is not expected to perform dedicated technological developments, at least in the first years of the CAB project.
CAB is thus seeking competent partners to join the team that will help in developing the program, in due consideration of the activities part of the MELISSA program. The partner will be charged of the work package about waste management, in strict relation with the major CAB team members, i.e. Alcatel Alenia Space Italia, the Department of Agricultural Engineering and Agronomy (DIAAT) of the University of Napoli and the Department of Plant Biology and Centre of Excellence CEBIOVEM of the University of Torino.
The call includes also a side to side activity with the CAB horticulturists to select the cultivated species considering aspects such as the composition of the non-edible biomass of the cultivated plants in order to ensure their compatibility with the waste management system.

Specific topics will include (but not be limited to):

- Waste biological treatment – link and interface with MELISSA activities
- Waste P/C treatment, incl. Stabilization, Compaction & Storage, especially for what concerns the non-edible part of higher plants
- Waste safe storage
- Waste monitoring
- Approaches to reducing the amount of produced wastes
- Recycling of so far non-addressed products (wipes, clothes, personal hygiene, food packaging, etc.)

The applicant shall report about the current state of art and research trends, both in terrestrial and space applications and provide innovative ideas in the waste management field to be implemented within the CAB project.

4.9 WP 9 – Integrated monitoring and control

The entire WP #9 will be managed via the following call by a qualified specialists' team in strict relation with AAS-I, DIAAT of UniNa and DPB of UniTo.

Call 9.1 **Integrated monitoring and control**

With the aim of exploiting the advancements in micro-technologies, virtual reality etc., the call is intended for development of an integrated environmental monitoring and control system for the CAB project, comprising (but not limited to):

- Constellation of micro-sensors of gas, humidity, temperature, noise, bio-contamination, radiation, illumination, plant health status, hardware health status etc., based on silicon micro-technologies (porous silicon, thin film, etc.) or other technologies
- Constellation of microswitches, switches, actuators and mechanisms for the selection of the operating points of the active items
- Advanced control techniques
- Signal transmission on fibre optics and wireless means
- Utilization of virtual and augmented reality tools for design, simulation and control.
- Data elaboration and commands issue, control laws and definition of the feedbacks for the control of the CAB system
- Stability of the control system
- Modulation of the system parameters for the optimisation of the performances
- Management of anomalies and failures
- Management of off-nominal conditions
- Management of redundancies
- Caution and warning
- Failure detection and isolation
- Maintenance planning
- Interfacing with the crew

Scope of such an integrated "multi-tasking" system is to guarantee optimum crew and system health, safety and productivity, and improve availability and sustainability of the CAB system.

The activity shall first define a comprehensive strategic plan, delineating the main lines of development. In this framework, the most urgent monitoring and control needs shall be identified and the most attractive enabling technologies defined, with due considerations of the state of the art and metric tools. For each items of the integrated system, detailed requirements and development plans shall be defined.

4.10 WP 10 – Demonstration in extreme environments

In the frame of the activities needed for the development and verification of the CAB system, a work package dedicated to the possible exploitation of Earth extreme environment is set. This work package will be entirely managed with the following call.

Call 10.1 **Demonstration of CAB technologies in extreme environments**
Selected technologies within the CAB project will follow the proper demonstration and verification campaign to test their performances and lifetime. This could benefit of terrestrial extreme environments similar, for some of their characteristics, to the moon or Mars. Examples include very cold, very hot, remote and high altitude locations.

While it is not expected such a major effort on this aspect in the first years of the CAB project, we are seeking partner(s) with proven competence in this field, with the objective to set-up future campaigns in a cost-effective fashion.

4.11 Expression of interest for specific CAB equipment

In the frame of the activities to procure all the items to equip the CAB system demonstrator(s), the program intends to involve possible partners interested in proposing hardware needed inside the CAB project as per following call.

Call 11.1 **Expression of interest for specific CAB equipment**
Non-space industry and academia institutions interested in the participation to the CAB project for the inclusion in the CAB demonstrators of commercial or custom-made equipment are invited to submit proposals or ideas.

The following equipment is of interest for the CAB project:

- Plants production equipment
- Plants nutrients dosing system
- Nutrient solution monitoring and control for closed soilless growing systems (considering the combination of sensor technology and expert system technology)
- Greenhouse environment control and automation
- Food processing equipment
- Food storage equipment
- Modelling software
- Innovative light systems for optimal plant growth
- Trace gas detection systems
- Trace gas removal filters Adaptation of commercial gas sensors
- Modelling software
- Condensing heat exchangers
- Commercial gas sensors
- Trash compactors
- Waste incinerator

Co-funding of any proposed R&D is requested in this case.

5. PROSPECTIVE PARTNERS, APPLICATION AND TERMS

5.1 Motivation

Manned planetary exploration missions will be a fascinating challenge and endeavour in the next decades. It is recognised that this kind of missions will be feasible only if supported by bioregenerative control systems. The development of these systems will further have valuable spin-offs on terrestrial applications.
ASI, with the participation of AAS-I as prime contractor, intends to develop an Italian long term project for the development of a bioregenerative system (CAB). The CAB project will ultimately realise a closed environment that will maximise the recycling to provide food, water and air.
This program will not attempt to duplicate existing efforts on international levels (MELISSA). Instead the aim is to propose a complementary programme that will ensure an integrated European approach and that will cover the main scientific and technological issues on the subject.

In this context, the CAB consortium is seeking for partners of clear competence and with innovating ideas to be captured and promoted in the CAB project; a number of basic and focused expertises are needed to build a solid, operative and self standing programme in the scheduled time.

Question that should be answered in the frame of each call is: **what would it be your idea, innovative contribution and preliminary development plan if you were given the opportunity to join the CAB project?**
The main aim of this call for ideas is to identify new, creative ideas (but feasible in the timeframe of the programme and in coherence with its intents) to shape the CAB programme final proposal to ASI. All the ideas shall be compatible with the time-frame of the CAB programme as reported in paragraph 3.4.
The submission of an idea will give the opportunity to actively participate in the shaping of the CAB complete team.

5.2 General characteristics of prospective partners

A partner or a team of partners (with the identification of the team leader and coordinator) can answer to the proposed calls.

The following requisites shall be met by applicants:

- Nationality: Italian. Collaborations outside Italy are welcome but will not be eligible for funding
- Institution legally recognised in Italy
- Registered office in Italy
- Demonstrated competence in the field of interest of the call: publications, patents
- Sound scientific or technological background
- For private enterprises: economical warranties

The following will be considered as welcome in the evaluation of the applicant team:

- Participation in international collaborations, partnerships and projects related to the answered call.
- Role in national and international associations.

- Experience in space activities.

5.3 Announcement and publication

The set of the call for ideas issued in the frame of the CAB project are published in the CAB website:

http://www.fobiotech.org/cab

Please forward this call for ideas to any other colleague who might be interested.

5.4 Deadline

The deadline for the submission of ideas is:

Wednesday 2nd of May 2007.

However, participants are encouraged to submit their own response as soon as possible.

5.5 Application form

The response to this call for ideas should not exceed **10 pages**.
It shall include as a minimum:

- The reference number and call of the call for which the answer is submitted.
- A short description of the applicant team / team member background, past or current major related projects and publications (max 1 page per team member)
- A long-term perspective of the kind of activity envisaged in relation to the specific topics addressed in the call and how it can be exploited inside the CAB project and which are its excellences. This part can include a vision beyond what is technologically feasible today.
- A brief proposal of the steps to be taken in the next 2- 3 years in order to work towards fulfilling the aforementioned long-term perspective. This should include, but not be limited to, preparatory ground-based research as well as the use of specific demonstrators (extreme environment, ISS, etc.). Also possibilities for transnational co-operation should be indicated.
- Possible synergies with terrestrial applications and spin-offs.
- Name, contact information (phone, fax, e-mail) and affiliation (university, institute....) must be included in the reply, in line with the constraints listed in paragraph 5.2.

Ideas should preferably be submitted electronically, using the form reported in Figure 5-1 and Figure 5-2 and available for download on [RD 2.2-1], as an attachment to the following e-mail address:

CAB@aleniaspazio.it

If electronic submission is not possible the Form can be faxed to the following number:

+39 011 7180 239
Attn. of Cesare Lobascio, Matteo Lamantea, Sergio Palumberi

Indication of the call reference number shall be added in the transmission letter subject, both in case of e-mail and fax transmission.

An e-mail of receipt will be sent to each team coordinator.

5.6 Notification of interest

A notification of interest with the indication of the call reference number and title and of the team coordinator is appreciated by:

Monday 16th of April 2007

preferably at the e-mail address listed in section 5.5.

5.7 Information

Any information and detail can be requested to:

Cesare.Lobascio@aleniaspazio.it
Matteo.Lamantea@aleniaspazio.it
Sergio.Palumberi-sofiter@supportoesterno.aleniaspazio.it

5.8 Evaluation process of the ideas

The ideas submitted will be analysed by a Scientific and Technical Committee (STC) named for this scope during the phase 1 of the CAB project (see paragraph 3.3). The STC comprises members of the CAB project, of ASI and of international universities.

The results of the STC will be indisputable and will be made on the basis of the compliance with the set requirements and schedule, soundness of the proponents' background in the field of interest, originality and innovation of the idea, cost, compatibility and homogeneity with the CAB programme.

Based on the number of submitted calls, the evaluation process will be performed in about one month (tentatively **by end of May**). The teams that have proposed the selected ideas will be convened in a meeting tentatively in the **month of June**.

5.9 Expected activities for selected teams

The selected new partners are requested to participate to the phase 3 of the preparatory stage of the project (see 3.3). An involvement of four months is therefore planned for these new partners in order to contribute in the finalisation of the project to be presented to ASI. The activity will be aimed:

- at consolidating architecture and requirements of the CAB system to be considered as reference for the following applicative stage,

- at identifying the development plan, the cost and the activities proposed for the following applicative stage.

5.10 Perspectives

Once the applicative stage will be approved by ASI, the partners will be involved in it as defined in the development plan and in the related work packages prepared during the phase 3 of the preparatory stage (see 3.3).

5.11 Refund

Limited funding is available for the current preparatory stage of the CAB project.
A reimbursement of the demonstrated expenses can be provided for the activities foreseen in section 5.9.

CALL FOR IDEAS - Applicants Response Form

Due date for submission May 2nd, 2007

CALL TITLE:

Call Reference Number:

Proposer Information

Name, First Name; Title(s):
Affiliation (University, Company, Institute):
Position Held:
Address:
Telephone Number:
Fax Number:
Email Address:

How did you hear about the call for ideas?

Direct Email ☐

Forwarded Email ☐

Other: _____

Keywords describing your idea:

Co-Proposer(s) Information (if Applicable)

Name, First Name; Title(s):
Affiliation (University, Company, Institute):
Position Held:
Address:
Telephone Number:
Fax Number:
Email Address:

Figure 5-1 - CAB Call for Idea Response Form (a)

Proposer(s) Participation in Previous Relevant Studies Related to the Selected Call (Compile for each Proposer)

Name of the Study:

Short Description:

Why is the study related to the selected call:

Role:

Publications:

Patents (if Applicable):

Description and Scientific Justification of the Investigation Idea:

Indication of the Technology Readiness Level (if Applicable):

Areas of Synergy of the Idea with Terrestrial Applications or Experiences from other Terrestrial Applications Related to the Idea:

Most relevant literature references:

Figure 5-2 - CAB Call for Idea Response Form (b)

6. ABBREVIATIONS AND ACRONYMS

AAS-I	Alcatel Alenia Space - Italia
AD	Applicable Document
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
CAB	Controllo Ambientale Biorigenerativo (Bioregenerative environmental control)
CELSS	Closed (Controlled) Ecological Life Support System
DN	Direct Negotiation
DIAAT	Department of Agricultural Engineering and Territorial Agronomy (University of Naples Federico II)
DPB	Department of Plant Biology and centre of excellence CEBIOVEM (University of Turin)
EM	Equivalent Mass
ESA	European Space Agency
ESM	Equivalent System Mass
GCR	Galactic Cosmic Rays
GF	Growth Facility
ISRU	In Situ Resources Utilisation
ISS	International Space Station
MELISSA	Micro Ecological LIfe Support System Alternative
NASA	National Aeronautics and Space Administration
NDS	Nutrient Delivery System
PAR	Photosynthetically Active Radiation
P/C	Physico-Chemical
PPB	Parts per Billion
PPF	Photosynthetic Photon Flux
RD	Reference Document
RDR	Requirement and preliminary Development Review
SPE	Solar Particle Event
STC	Scientific and Technical Committee
TG	Trace Gas
TRL	Technology Readiness Level
UniNa	University of Naples
UniTo	University of Turin
VOC	Volatile Organic Compound
WBS	Work Breakdown Structure
WG	Working Group
WM	Waste Management
WP	Work Package

END OF DOCUMENT