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EDEN ISS

Exploitation Strategy

prepared for

WP 7.2 Exploitation

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Executive Summary

This document presents the exploitation strategy and objectives of the EDEN ISS project. The objectives are to ensure that the technology developed by the project activities contributes to European technological advances and economic growth. The strategy for achieving this is to market the technology in the form of greenhouse modules (GHM) to a broad range of potential users or user groups, for whom it would present an improvement in their living conditions or make their existence possible. These groups are broadly classified as terrestrial and space applications.

This exploitation strategy, based on market analyses, should be viewed as part of a broader, coordinated outreach strategy. In the short term, focused dissemination activities will promote the advantages of GHMs and encourage further development projects. Outreach activities have already been initiated as part of DLR's School Lab mission, which will substantially support future efforts. In the longer term, building on the results of a field trial at the Neumayer III research station in Antarctica, focused efforts will be made to advance the technology for terrestrial and for space applications. In addition, opportunities of demonstrating the technology on board the International Space Station in the form of payload facilities will be aggressively pursued.

Exploitation activities will be performed for the project as a whole, supplemented by the activities of the consortium partners, who may separately exploit their subsystem technologies as part of their business plans. Three Innovation Workshops will be held near the end of the project to ensure maximum exposure of the results and knowledge transfer to potential developers.

Consortium Partners

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Acronyms

Acronym	Explanation
AIAA	American Institute of Aeronautics and Astronautics
CEA	Controlled Environmental Agriculture
CSA	Canadian Space Agency
CFI	Call for Ideas
C-Min	ESA Council Meeting at Minister Level
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V.
DLR-RY	DLR Institute of Space Systems
ECLSS	Environmental Control and Life Support System
EDEN	Evolution and Design of Environmentally-Closed Nutrition-Sources
EMCS	European Modular Cultivation System
EREP	European Robotic Exploration Programme
ESA	European Space Agency
EU	European Union
FCU	Food Complement Unit
FEG	Future Exploration Greenhouse
GER	Global Exploration Roadmap
GHM	Greenhouse Module
IAA	Institute of Aeronautics and Astronautics
ISECG	Intl. Space Exploration Coordination Group
ISS	International Space Station
ISPR	International Standard Payload Rack
JAXA	Japan Aerospace Exploration Agency
LEO	low Earth orbit
NASA	National Aeronautics and Space Administration
Roscosmos	Russian Space Agency
TRL	Technology Readiness Level

1 Objectives of the EDEN ISS Exploitation Strategy

The EDEN ISS project represents first and foremost an investment by the European Union in the future technological capability of Europe, as a motor for economic growth. The underlying technologies being developed for the EDEN ISS project, defined here as Controlled Environmental Agriculture (CEA) technologies, can potentially make a significant contribution to improved plant cultivation and hence food production in areas and situations where conventional food production is inadequate. As such, an exploitation plan is a key instrument to assure that these technologies being developed for the EDEN ISS project are exploited where possible to provide an adequate return on the initial investment.

Many CEA technologies offer a meaningful improvement over conventional agricultural techniques. For example, sub system and specific technical solutions needed in EDEN ISS can increase reliability and harvests of conventional greenhouse systems that currently cover vast areas of land world-wide. Examples include lighting supplement, pathogen control, nutrient delivery control and quality control via the environment.

The greatest benefits of CEA lie in those areas of agriculture where conventional agriculture is currently unable to generate a worthwhile harvest, i.e. in extreme environments. The ultimate extreme environment is that prevailing in space; hence, one central objective of the EDEN project is the creation of systems and facilities capable of producing food for astronaut consumption during long-duration space exploration missions. However, at system level, the production of food cannot be considered in isolation: long-term human presence in space will require the development of bio-regenerative life support systems (BLSS). The integration of such systems into manned habitats decreases the resupply requirements by generating human resources by means of biological processes. The EDEN ISS project aims to validate selected subsystems and key technologies up to a TRL of 6 according to the standards described in the Technology Readiness Levels Handbook for Space Applications of the European Space Agency (ESA)[RD1]. Therefore the project will demonstrate operational capability of key technologies in an environment with some characteristics relevant to space. For this purpose a dedicated test campaign will be executed at the Neumayer Station III in Antarctica where a deployed mobile test facility will be operated by an isolated overwintering crew. This operational deployment will also form the basis for preparatory research for a future plant production system on board the ISS.

It will be recalled that the main objectives of EDEN ISS are as shown in Table 1-1.

Table 1: Objectives of the EDEN ISS project

Objective 1	**Manufacturing a space analogue mobile test facility** to provide representative mass flows and proper test environments for plant cultivation technologies as an essential on-ground preparatory activity for future space exploration.
Objective 2	Integration and test of key elements for plant cultivation in 1) an **ISPR-like system** (International Standard Payload Rack) for future test on–board ISS and 2) a **Future Exploration Greenhouse (FEG)** to prepare for closed-loop bio-regenerative life support systems.
Objective 3	**Adaption, integration, fine-tuning and demonstration of key technologies** and their functionality in respective laboratory environments and (under highly isolated conditions) in an Antarctic environment.
Objective 4	Development and demonstration of **operation techniques and processes for higher plant cultivation to achieve reliable** and safe production of high-quality food.
Objective 5	Study of **microbial behavior and countermeasures** in plant-based closed ecosystems and their impacts on isolated crews.
Objective 6	Actively **advancing knowledge related to human spaceflight and transformation of research results into terrestrial applications**, by actively leveraging synergies between space and non-space consortium partners.

The objectives of this exploitation plan naturally build on, and must be harmonized with, the objectives of the project. For the purposes of this initial draft issue it is assumed that all project objectives will be achieved. Some modification of exploitation goals may be necessary for the final issue.

At the same time, it is clear that whereas technical objectives can be identified and verified quantitatively, exploitation objectives are qualitative in nature and subject to unpredictable external circumstances which impact success. A TRL of 6 should be achieved, but this level of technological maturity is still inadequate to assure commercial success. The transition from prototype to operational products in a market environment is also a sensitive issue, and hence a comprehensive product development strategy is essential. Forces affecting the successful exploitation of the EDEN ISS project in terms of future market share of operational facilities include changing institutional technology investment policies, climate changes, spin-off products, availability of alternative technologies, geopolitical considerations, to name only a few. In addition, the diverse nature of the EDEN ISS consortium members could result in a range of subsystem-related objectives being pursued independently. Of course, rigorous near-term exploitation efforts will be made to ensure broader awareness of the EDEN ISS project, and to encourage further development and applications; these activities are covered in the Dissemination Plan, Document No. D 7.10. [AD1]

Exploitation objectives can be broadly grouped under the following:

- identify exploitation markets and target groups,
- demonstrate the added value of the project and promote further research,
- develop facilities which fulfil institutional and/or commercial market demand,
- create and provide a service,
- promote standardisation activities.

A central exploitation objective is the continued development of EDEN ISS technology leading to operational facilities. To this end, a clear understanding of key performance characteristics and their suitability of satisfying potential market demand is necessary. At this time, a particular product cannot be defined; rather, a range of core products has been conceived, representative of the cultivation technology most appropriate for each market segment. An extensive market study of terrestrial applications has been carried out, which provides a firm basis for future development strategies.

Product development for space applications follows a somewhat different path. Since human space exploration programmes and missions are primarily governmental in nature, system performance requirements, and the associated technology development priorities are largely dictated by space agencies, for European programmes by the European Space Agency (ESA). Space systems are exposed to extreme environmental conditions (zero gravity, vacuum, radiation) which substantially influence the design. In addition, product assurance and safety requirements play a key role in the design and development philosophy. The resulting space-qualified hardware is so specialised in performance, configuration and operation that it is much more expensive than comparable commercial products. However, by first developing and refining the EDEN ISS technology for ground-based projects, key technologies can be verified and subsequently incorporated into a mission-dedicated system.

2 Product Development Strategy Plan

2.1 Overall Strategy

Figure 1 presents an overview of the potential markets for EDEN ISS technology and products.

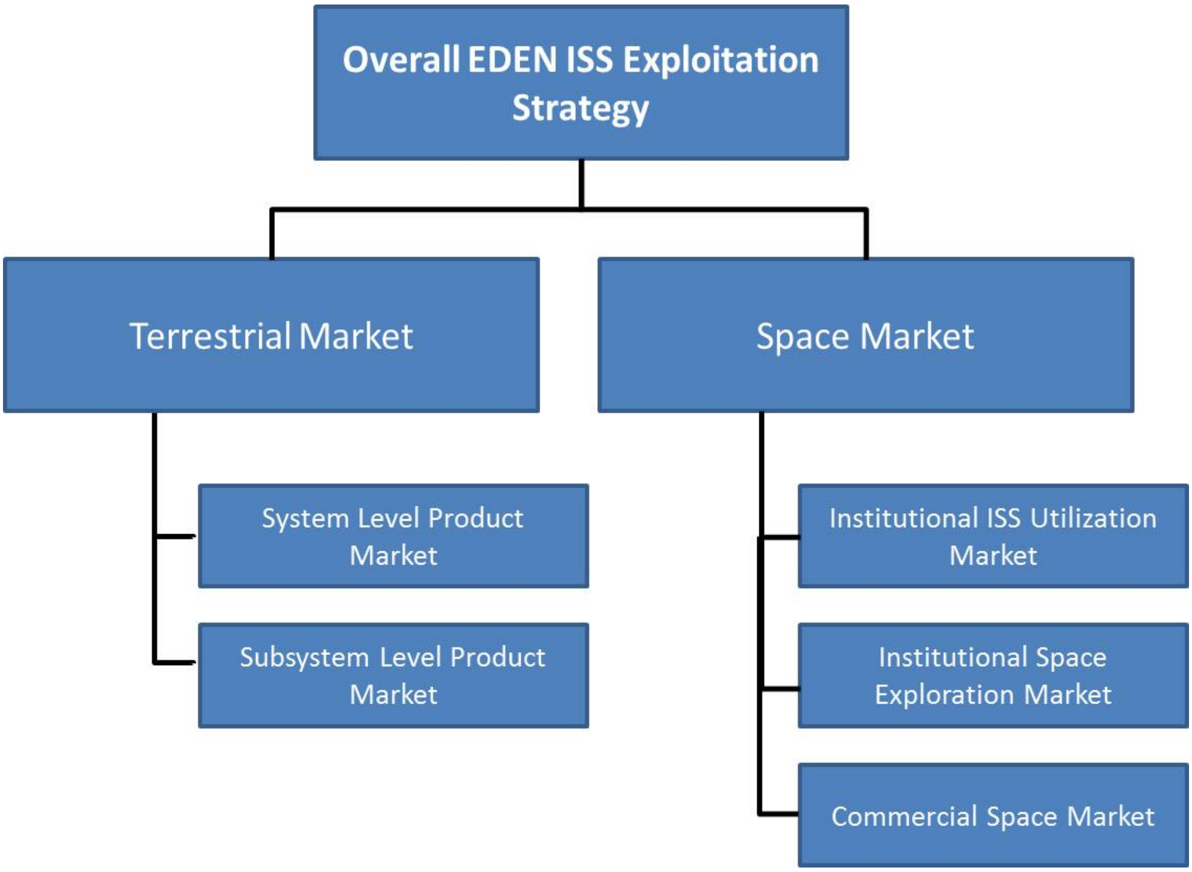

Figure 1: Overview of Exploitation Markets

From the figure it can be seen that the overall market potentially accessible to the EDEN ISS technology is made up of terrestrial markets and space markets. These markets are quite different to each other. Terrestrial market segments can be identified with demand for EDEN system facilities as well as subsystems, potential customers can be institutional and commercial, even end consumers. The space market is characterised at this time essentially by potential institutional demand for advanced, integrated system facilities, designed to meet specific performance requirements. This demand is in turn dependent on political commitment to a long-term space exploration programme. In time, a commercial space market can be envisioned, as part of commercial space transportation activities supporting institutional space exploration missions. Synergy between terrestrial and space applications should be pursued as far as possible to optimise technology advances and reduce costs.

3 Terrestrial Market

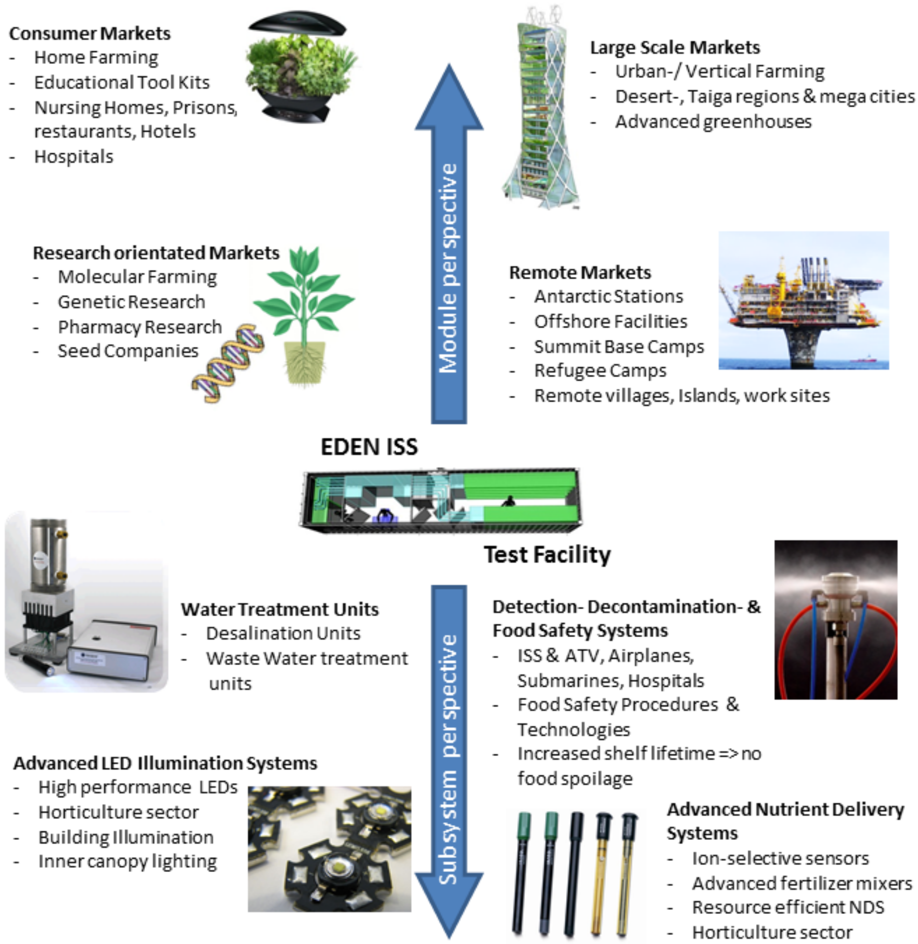

Figure 2: Overview of Terrestrial Market Segments

Beginning with the EDEN ISS test facility as presently conceived, a number of potential markets can be identified at subsystem as well as system level, as summarised in Figure 2.

At subsystem level, the following markets have been identified as potential targets for application of EDEN subsystems and assembles:

- **Water Treatment Units,** including desalination units as well as waste water treatment units
- **Air Management systems**, including VOC filtration, temperature and humidity control, water recovery and filtration to minimise the consumption, enhance component selection and qualification for severe environments.
- **Advanced LED Illumination Systems,** including high performance LEDs, horticulture sector applications, building Illumination and inner-canopy lighting
- **Detection, Decontamination & Food Safety Systems**, including food being transported and stored on spacecraft such as ISS & ATV, on board aircraft, submarines, in hospitals. These technologies will also improve food safety procedures; increased shelf lifetime will potentially reduce food spoilage.
- **Advanced Nutrient Delivery Systems**, including ion-selective sensors, advanced fertilizer mix-ers, resource-efficient NDS, applications in the horticulture sector.

At system level, markets can be identified with socio-economic applications. Examples are:

- **Research-oriented Markets,** including molecular farming, systems genetic research, pharmacy research, seed companies
- **Remote Markets,** including Antarctic stations**,** offshore facilities, summit base camps, refugee camps, remote villages, islands, work sites
- **Consumer Markets,** covering home farming, educational tool kits, hospitals and nursing homes, prisons, speciality restaurants, hotels
- **Large Scale Markets,** which could include urban/vertical farming, cultivation of desert and taiga regions, construction of mega cities, and advanced greenhouses

3.1 Product Marketing on System Level

3.1.1 Market Survey

A key element of executing this project is the assurance that the investment is justified. To that end, five principal terrestrial market segments have been identified for analysis and future consideration:

- Micro-scale commercial market
- Small-scale remote market
- Medium-scale specialised market
- Large-scale vertical farming market
- Medium-scale research-oriented market

In addition, a preliminary market survey has been performed for EDEN ISS space exploration applications. This market can be compared to the small-scale remote market identified above, with the difference that long-duration, highly-reliable operation under space conditions will be required.

Micro-Scale Commercial Market

This market segment is initially foreseen for consumers with highly specialised requirements, and focused on high-income groups with profiles favouring eco-friendly and sustainable technologies. Additional important aspects within this market segment include educational issues (e.g. deployment of greenhouse modules (GHM) as educational school kits), as well as providing personal psychological well-being benefits (e.g. in hospitals and nursing homes, etc.), both of which the product has to fulfil. The associated GHM product/market is characterised by:

  - Small home appliance-sized machine,
  - Small producible quantities, e.g. herbs or leaf vegetables,
  - High requirements on design and automation, including sensitivity to quality and safety issues
  - Price sensitivity is high within this segment.

Small-Scale Remote Market

This market segment includes all inhabited remote sites and the different needs of people living and working at those locations. This market segment combines extreme isolated worksites, for example research stations at Antarctica, isolated communities on islands and in mountain valleys, in addition to crews on research vessels, cruise liners, off-shore installations and military camps and isolated mines. The focus within this group is on the provision of fresh food (fruit and vegetables with short storability levels) that are expensive to resupply at a sufficient rate. The associated GHM product/market is characterised by:

  - Mobile 20-40 foot container structure housing the GHM,
  - Withstands harsh environments (marine climate, low temperatures, etc.),
  - Medium producible quantities, focused on fresh, leaf plants (e.g. lettuces, radish, tomatoes) that have low storability levels,

- Sensitivity to the quality and safety issues, and even more to nutritional quality.
- Highly integrated production system with sufficient system redundancy,
- Price sensitivity is relative low within this segment.

Medium-Scale Specialized Market

This market segment covers special functions that can be provided within customized GHMs. By deploying functional units, the GHM can be used for certain waste water treatments as well as for desalination purposes. A special function could be, for example, GHM deployment within refugee camps as emergency food production units. In this scenario, the modified GHM could produce certain types of functional food plants with high levels of proteins or vitamins to promote the health of the camp inhabitants.

The potential customers are seen within local communities or for waste management companies. For desalination purposes, certain desert countries are possible candidates. The refugee application is aimed at institutional customers e.g. countries (France, Germany), NGOs, and the United Nations. The associated GHM product/market is characterised by:

- Lightweight, deployable GHM system,
- Commercial-of-the-shelf components to minimise cost,
- High producible quantities of single functional crops (e.g. for food or waste/water treatment purposes),
- Using hybrid illumination system (natural sun light in combination with artificial LED systems),
- Price sensitivity is relatively low within this segment.

Large-Scale Vertical Farming Market

This segment targets large scale markets where the envisioned concept produces high quantities of different crops for large numbers of customers. Basically, three sub segments were evaluated: Desert/ Taiga regions and mega cities. Spanning all three areas, traditional agriculture is to some extent dependent on the use of extensive machinery. The concept foresees a semi-automated plant cultivation infrastructure within a skyscraper, with all pre- and post-processing procedures accommodated. DLR performed a special Concurrent Engineering (CE) study for the Vertical Farm concept. The associated GHM product/market is characterised by:

- Transformation of the GHM module principle into a building concept (typically skyscrapers, vertical farming technologies),
- High output of edible biomass such as vegetables and/or fruit (several tons per month are envisaged) the whole year round,
- Optimized production procedures, but with a personnel around 60 employees per vertical farm unit,
- Usage of pure artificial light source or hybrid systems,
- Price sensitivity is very high within this segment

Medium-Scale Research Orientated Market

This market segment deals with general research-orientated issues of the GHM concept, as well as initial small production concepts of high-value plants and/or products. The GHM would be modified to form a highly adjustable growth environment for special functional plants (e.g. Chinese medicinal plants) or genetically modified plants (e.g. molecular farming). The GHM would provide a wide set of adjustable environmental parameters (RH, T, p, nutrient composition), while ensuring a high level of safety with respect to contamination or outbreak. Potential customers are to be found within biological domains of research institutes/universities, pharmaceutical companies, and seed companies. High-value biological compounds (e.g. vaccines) can be produced in these modules. The associated GHM product/market is characterised by:

- Retention of the modular structure of the GHM concept but with the use of certified components only,
- Allocation of precise growth environments for medicinal and/or genetically modified plants,
- Adherence to high safety requirements for the system (in particular, redundancy),
- Low output of edible biomass, but of extremely high quality (vaccines, high value macro molecules, etc.),
- Price sensitivity is low within this segment.

3.1.2 Development Strategy

As mentioned above, a comprehensive product development strategy is needed to achieve penetration of the markets potentially accessible to the large GHM product spectrum. A core product with the highest probable success rate is being investigated first, followed by diversification into other potential markets. This choice was governed to some extent by the need to pick a product and market that still fits within current research objectives of the DLR institute. There is a high affinity related to current DLR research activities, which facilitates easier transformation of the latest research results into the GHM project.

In this way synergies can best be realised between DLR's Technology Marketing (TM) department and the DLR Institute of Space Systems (DLR-RY) in Bremen. The decision was made to investigate the Small Scale Remote Market, which includes the most complementary work domains and allows the development of a first 'functional demonstrator'. The justification for this approach is as follows:

DLR is working on a project for an in-space GHM, with the aim of establishing a greenhouse for astronauts and scientists on space exploration missions, for example to the Moon and Mars. [AD 2] A natural inclination of the project developers would be to find such markets on Earth which are similar to the environment of Mars. Polar Research Stations provide the living and working conditions which are similar to the conditions faced by astronauts and scientists in outer space i.e. no logistics connection to the outside world for up to 6 months. Fresh food is a critical commodity at these remote locations, in terms of diet needs and logistic costs. An on-site GHM would consequently reduce the station's resupply costs. It is also important to keep the scientists physically and mentally healthy and in good spirits, in order to ensure quality research work. The scientific community agrees strongly with these issues and some innovative projects are already running at Scott Amundsen Research Station (United States), Jang Bogo and King Sejong Stations (South Korea) and Showa Station (Japan) related to growing fresh fruit and vegetables.

Research stations in Antarctic and the Arctic provide a permanent research base to various nations. The scientific crew stays in these stations every year in harsh living and working conditions with limited resources and limited supply of fresh food. In year-round stations, which also operate in winter, crew becomes isolated from the rest of the world for typically 6-9 months. Supply of food and other commodities is not frequent at many research stations due to sea ice and logistic issues. In this scenario, working crews do not get a sufficient supply of fresh food. The GHM concept can potentially remedy this shortcoming by providing a consistent supplement of fresh food in harsh weather conditions, and avoid logistic issues of resupply.

The basic design (GHM as a mobile module) for remote sites can be seen as a nucleus of the overall envisioned market idea. For this, a detailed questionnaire has been conducted among crews living in isolated areas. The research being carried out at DLR-RY complements this market analysis. The reasons for this decision are presented below:

- A first customer (AWI) is already within the research network as beta tester,

- The envisioned GHM enables a representative test environment for the different CEA technologies (hence enabling optimisation of the subsystems and GHM performance output),
- Market participants are governmental and research orientated, which impose lower market barriers than end consumer markets,
- Research stations are often extremely isolated and have special needs for fresh food since resupply typically occurs at a maximum of twice a year,
- The isolated crew is better motivated (through the resulting psychological well-being benefit) to operate the module as necessary.

The other four markets are natural spin-off possibilities for a future product diversification plan. A conceptual product development plan for future projects is shown in Figure 3. In order to penetrate and exploit these other markets, proper product development phases need to be performed. The core concept (deployment of CEA technologies in a highly integrated plant production system) needs to be transformed from a mobile module concept into, for example, a solid built-up structure (like the example vertical farming), a deployable light-weight/low cost GHM for refugee camps or a small household appliance (e.g. home farming). These examples highlight the high degree of variability of this concept.

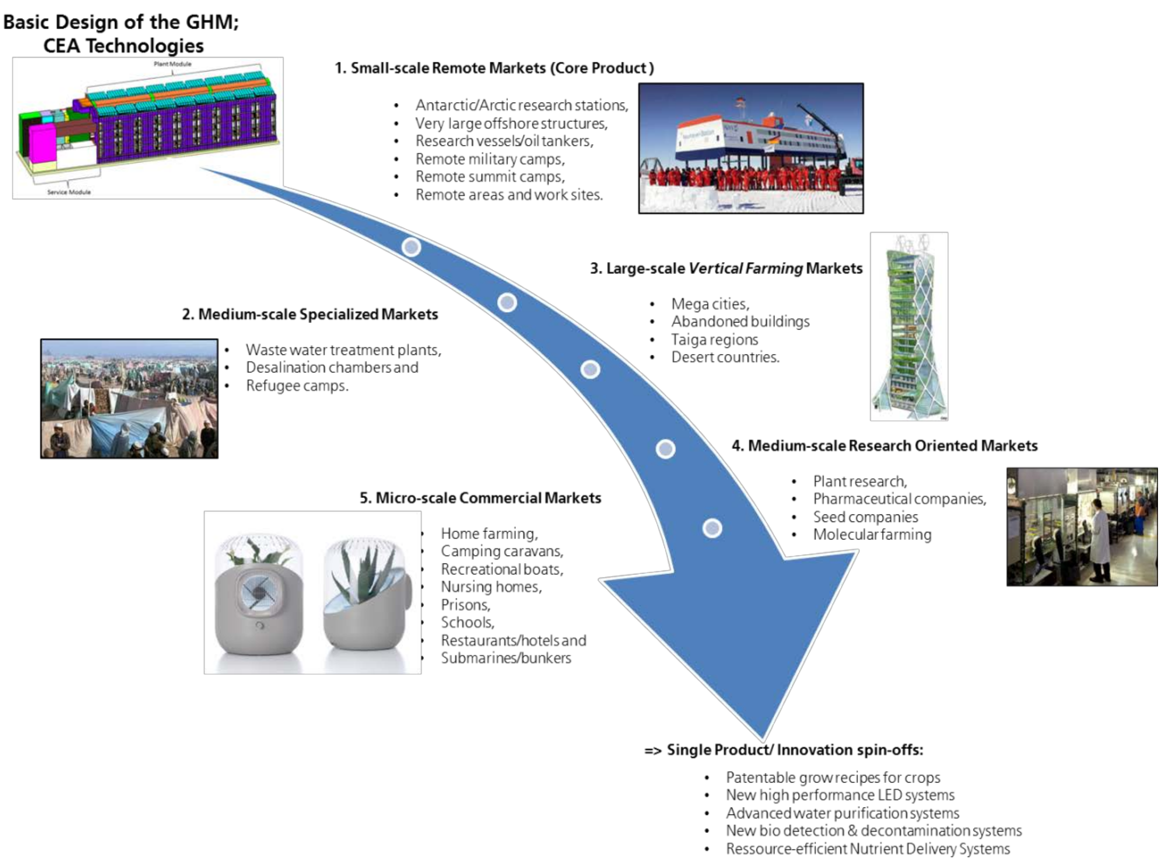

Figure 3: Development of basic GHM design from core product to potential spin-offs

3.2 Product Marketing on Subsystem Level

The outlined product development strategy allows for multiple single spin-offs, such as patentable growth recipes of specific crops (right mix of nutrients in combination with specified illumination parameters) in order to achieve higher outputs, or particularly desired tastes or functional substances. Other examples are the development of high-performance LED systems for conventional horticulture processes, the development of advanced nutrient delivery systems, innovative bio-detection and decontamination systems can be possible single spin-offs within this endeavour.

Not all the EDEN ISS consortium partners will be able to exploit technology developments to the same extent. However, improvements in food quality, safety and processing can be expected. Possible examples include:

- advances in sensory analysis for controlled environment activities and space life science research;
- plant growth protocols for bioactive, flavour and palatability enhancement, in particular to individual crop species;
- patentable nutrient growth solution recipes;
- a patentable organic-based algae inhibitory growth medium;
- light recipes for optimal plant growth.

Subsystem marketing activities will form part of the consortium's outreach effort, and will be reported on the outreach web site.

4 Space Applications

Acquisition strategies in institutional space programmes need to be based on a sound understanding of space agencies' goals and funding levels. In the case of extended human space exploration, it is generally accepted that the programme costs are too high to be borne by one country alone, and that a broad international partnership will be needed to enable the costs to be shared and hence to provide the necessary long-term commitment.

European human spaceflight activities are carried out only by the European Space Agency, acting on resolutions and approved funding from its Member States. This field is currently dominated by ESA's participation in the International Space Station (ISS) programme. This programme represents a major commitment to research activities in low Earth orbit (LEO), one element of which is the preparation for future space exploration missions. The ISS offers excellent flight opportunities for demonstrations of EDEN ISS technologies under representative operating conditions.

The long-term partnership formed and sustained by the ISS partner agencies (NASA, ESA, CSA, JAXA and Roscosmos) is frequently cited as the best model on which to base future plans for human space exploration activities. The United States is implementing a human space exploration programme with the goal of exploring Mars. At this time, NASA is developing two key spaceflight systems on which to build future international exploration missions – the Space Launch System (SLS) together with the Orion crew transportation vehicle. ESA is cooperating with NASA by providing the European Service Module (ESM) for Orion. The ESM will provide the crew with power, water and other life support consumables during all phases of the mission until it is separated shortly before the crew module re-enters the atmosphere.

In 2006, 12 space agencies with common space exploration interests formed the International Space Exploration Coordination Group (ISECG), and continue to meet regularly to exchange ideas and information in an informal forum. In the course of their discussions, the Group has released two versions of a Global Exploration Roadmap (GER)[RD2], a document intended to present possible exploration goals and strategies where the partners find common interests. In the interest of promoting a free exchange of ideas, the Global Exploration Roadmap does not represent any commitment by the participating space agencies.

Figure 4 presents the Global Exploration Roadmap in its current form. Although still an early stage of discussion, the roadmap reflects a common long-range human exploration strategy that begins with the ISS and expands human presence into the solar system, leading to human missions on the surface of Mars. It focuses on the first steps in implementing this strategy: utilizing the ISS, continuing to expand the synergies between human and robotic missions, and pursuing discovery-driven missions in the lunar vicinity that evolve capabilities and techniques needed to go further. By taking these first steps, missions into deep space and the Mars system would be enabled in a sustainable manner.

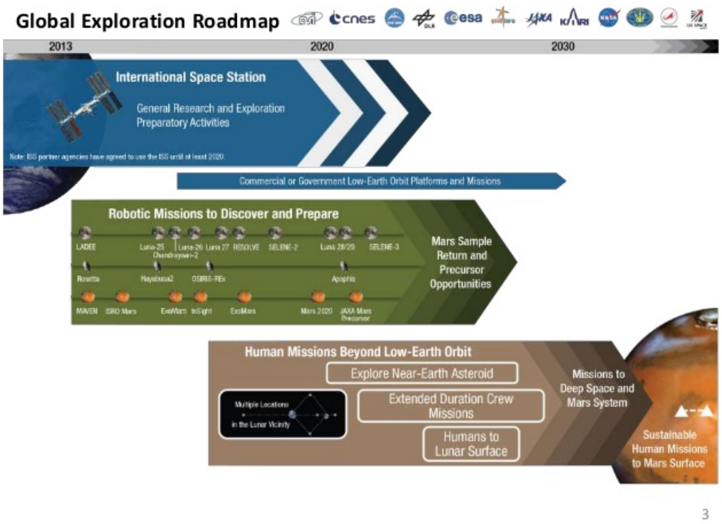

Figure 4: Global Exploration Roadmap

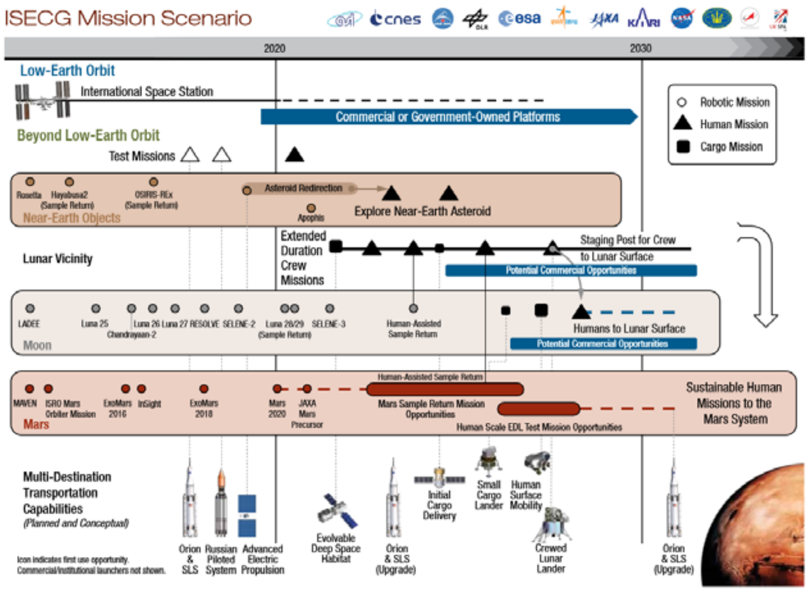

Figure 5: ISECG Mission Scenario

Building on the GER, the partner Agencies have released an exploration Mission Scenario, shown here as Figure 5. The Mission Scenario reflects a coordinated international effort to advance common goals and objectives while enabling interested agencies to pursue their priorities and prepare for critical contributions to Mars missions. All nations will not necessarily participate in every element or mission depicted in this roadmap. Sustainable human exploration missions to Mars will be possible if multiple agencies contribute capabilities and expertise. In addition, long-term sustainability may also be enhanced through availability of commercial services and use of public-private partnerships.

Using planned and conceptual capabilities, the ISECG Mission Scenario identifies a set of missions in the lunar vicinity and on the lunar surface that advance readiness for human Mars missions after 2030. Extended duration crew missions in the lunar vicinity and missions to an easily accessible asteroid will enable discoveries and allow demonstration of the transportation, habitation, robotic servicing and other key systems on which long-duration missions into deep space must rely. Human missions to the lunar surface will allow critical demonstrations of planetary exploration capabilities and techniques, while pursuing the highest priority lunar science objectives.

This mission scenario promotes the integration of robotic and human missions for achieving common objectives and developing concepts for increased human-robotic partnership. The ISECG Mission Scenario serves as a reference for agencies by informing studies and other exploration preparatory activities.

In January 2014, representatives from 30 countries met in Washington, DC. for the fourth International Space Exploration Forum (ISEF), to continue the dialogue at political level initiated by the European Commission and ESA and most recently held in Italy in November 2011 on the progress in advancing the exploration and utilization of space and on the resulting benefits to humankind.

ESA activities are determined at the highest level by a series of Council Meetings at Ministerial Level (C-Min). The next such meeting is currently planned for the end of 2016. In preparation for this meeting, ESA has prepared a Space Exploration Strategy [RD3] and a Draft Long Term Plan (LTP)[RD4] containing the decisions expected at the next C-Min.

In the LTP three areas have been identified as possibly opening new possibilities for Agency's programmes:

- a global endeavour for space exploration,
- cheaper access to space and
- security and defence.

With regard to a global endeavour for space exploration, the ESA LTP says the following:

> A political decision of international partners to cooperate in realising the next common step of a global endeavour for space exploration, in line with the

Global Exploration Roadmap and with the outcome of the January 2014 ISEF meeting in the U.S., may generate opportunities for ESA on future cooperation with international partners. ESA's Space Exploration Strategy identifies potential focus areas for ESA in such a global endeavour and preparation activities that are necessary to ensure attractive roles for ESA.

Considering the evolution of the international scenario and independently of a major political decision as outlined above, decisions may be expected to relate to the optimum use of ISS up to 2024/2028, the preparation and implementation of the post-ISS LEO exploitation scenario, the first EREP post-ExoMars mission to Mars and the participation in an international Mars Sample Return campaign, and the participation in the robotic and human exploration of the Moon.

Also, further international cooperation may lead to decisions on participation to asteroid and lander missions, possibly followed at a later stage by sample returns from Europa and/or Ganymede, in preparation of further in-situ resource exploitation.

Finally, considering the perspectives created for ESA by the development of the service module for the NASA Orion crew transportation vehicle, to play a sustained role in human transportation may require decisions concerning the continuation of cooperation with the US on the development of capabilities for human transportation.

Further, the LTP contains proposals for decision roadmaps for exploration-related activities:

Short-term (2015-2017)

Prepare and decide on activities for securing the European role in human exploration building on the ATV and Ariane 5 heritage and on related developments currently ongoing

Medium-term (2018-2020)

Implement human exploration activities, including technology demonstrators and future transportation elements, as decided in the short-term period

Long Term (2021-2024)

Building upon the successful implementation of the ExoMars missions and developments in the context of ESA's lunar exploration activities, participate in an international Exploration Programme targeting missions to Moon and Mars including international Moon and Mars Sample Return missions and human exploration missions to cis-lunar space and Mars. Focus…………

- for human exploration on the development of critical transportation and technology elements, leveraging on ESA's lunar exploration activities, ISS technology demonstrators, all the European ISS programme elements' heritage as well as synergies with the post-2020 LEO exploitation scenario

The Long Term Plan also contains preliminary cost plans for the optional programmes to be decided in the timeframes identified above. For the group of programmes forming the future human spaceflight and exploration activities ESA is proposing a funding envelope from 2015 to 2024 of about €3.2

billion. The Human Exploration Preparation Phase 1 programme would account for just over €1 billion.

The proposed cost plan is shown in Figure 6 below. The Human Exploration Preparation Phase 1 programme cost profile up to 2024 is shown at lower right in the chart.

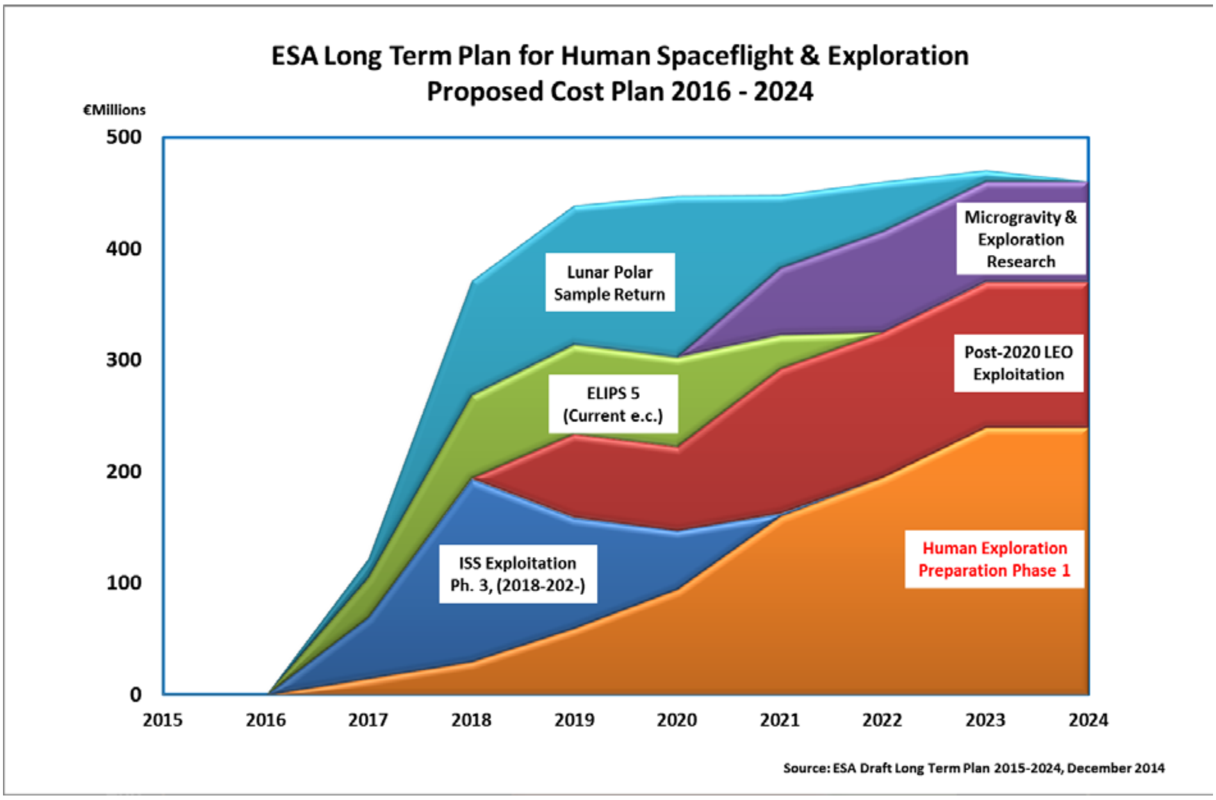

Figure 6: ESA Cost Plan for Human Spaceflight & Exploration 2016-2024

This information provides the basis for marketing EDEN ISS technology to ESA, firstly as a technology demonstration on the ISS and subsequently as an integrated element of a European space exploration strategy. However, it must be noted that this proposal by ESA must first be discussed by the Member States in preparation for a decision at the 2016 C-Min.

In March 2015 ESA published a Call for Ideas (CFI) on Space Exploration [RD5]. The Consortium sent a Letter of Interest to ESA in response to the CFI and was represented at a workshop in April. Further contact with ESA and with National Space Agencies is planned, at which the status and potential of the EDEN ISS concept will be promoted.

In parallel to the operation of the GHM at the Neumayer Station III, further development of an experiment growth module for operation as a payload on the International Space Station will be pursued. To achieve this objective, a focused acquisition strategy will be formulated and implemented at the national and at the European level. The acquisition activities will begin with coordinated design efforts in W.P. 6.2 to produce a credible payload configuration. The payload will consist of an integrated package accommodated in an International Standard Payload Rack (ISPR), which is the usual form of ac-

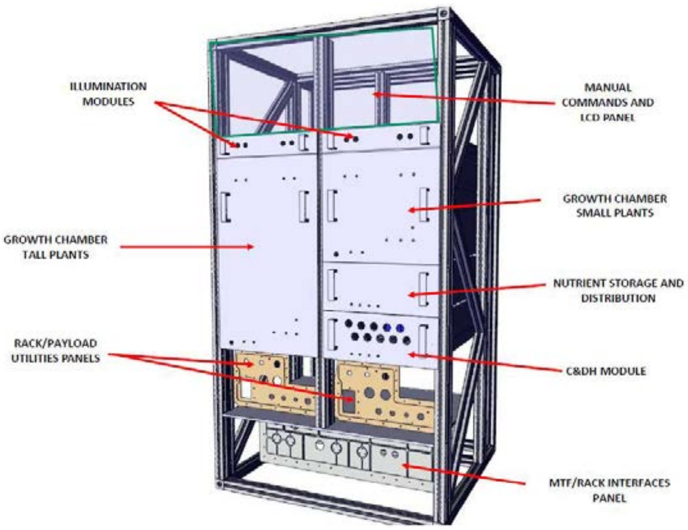

Figure 7: Preliminary ISPR Configuration

commodation for internal payloads in the ISS. Figure 7 shows the preliminary ISPR configuration.

At the same time, discussions will be opened with ESA and national space agencies to inform them of the technology advances achieved by the project, and the importance of demonstrating the greenhouse concept under space conditions, on board the ISS. The goal is to have the EDEN ISS payload accepted in the ELIPS programme, which will provide continued funding and a flight opportunity.

5 Exploitation Activities of the Consortium Partners

The EDEN ISS Consortium is made up of 13 partners, representing leading academic institutions and industrial companies. Coordinated by DLR-RY, the consortium will aggressively promulgate information about the EDEN ISS project to stakeholders and potential developers. Each of these partners contributes key elements of the overall project, but at the same time need to consider their individual business plans and/or research strategies. For terrestrial applications, commercialisation of the respective technologies will be a principal objective.

In total, the Exploitation Plan includes the activities of each partner.

5.1 Conference Plan – Terrestrial

19-23 July 2015	International Symposium on High Technology for Environment Engineering, Energy-Saving and Crop Management in Greenhouse Systems, (Greensys 2015), Évora, Portugal
May 2016:	5th Agrospace Conference May 2016, Sperlonga, Italy
22 May 2016:	VIII International Symposium on Light in Horticulture,
20 August 2017:	Greensys 2017, Beijing, PR China
May 2018:	6th Agrospace Conference, Sperlonga, Italy

5.2 Conference Plan – Space

Aug/Sept 2015	AIAA Space 2015, Pasadena, CA.
October 2015:	IAC 2015, Jerusalem
24-26 May 2016:	IAA Conference on Human Space Exploration, Moscow
July 2016:	46th International Conference on Environmental Systems (ICES), Vienna, Austria
September 2016A:	IAA Space 2016, Long Beach, CA
October 2016:	IAC 2016
July 2017:	47th ICES
September 2017:	AIAA Space 2017
October 2017:	IAC 2017
September 2018A:	IAA Space 2018
July 2018:	48th ICES
October 2018:	IAC 2018

5.3 Trade Fairs and Other Events:

September 2015:	DLR Open Day, Cologne
May 2016:	International Luftfahrt Ausstellung (ILA), Berlin
June 2017:	Le Bourget Airshow, Paris
May 2018:	ILA, Berlin
June 2019:	Le Bourget Airshow, Paris

5.4 Innovation Workshops

Three stimulus-led Innovation Workshops will be held in October/November 2018. The venues will most likely be in Germany, Italy and the Netherlands. These events will represent the peak of the terrestrial exploitation efforts.

The overall goal is to transfer the knowledge generated by the project to support new products and promote SME's and business ideas. Influential decision makers such as technical people, management, financial experts will be invited to ensure a broad range of comments. Brainstorming approaches supported by structured discussion frameworks will be employed to generate ideas and subsequent evaluation.

Workshop Concept

The Innovation Workshops will follow a common framework, designed to produce an optimum result.

- Goals and objectives will be agreed upfront with stakeholders

The overall goals and objectives will be discussed prior to the Workshops with stakeholders and other participants, and a list of key focus areas or topic areas for the workshop will be prepared. These key focus areas will help define specifically what the brainstorming topics with the participants will be.

- Innovation challenges and opportunities will be presented to set the context

Building on the results and insights gathered by the project, stakeholders will present short overviews of the business needs related to the innovation challenges, and the kinds of ideas they are looking for from the session. This will help set the background context for the technical experts at the session.

- A well-defined agenda and participant guide will be prepared

The agenda will clearly mark out sections for opportunity identification (brainstorming), opportunity categorization (hearing sales pitches for each idea and combining related ideas), and opportunity prioritization (voting).

- Participants will be encouraged to build upon each other's ideas

Once the participants have identified opportunity ideas, they will be able to review the ideas from others and add comments as appropriate. This helps them build upon each other's ideas and can help to strengthen the overall value proposition around the ideas or help raise additional questions for consideration.

- The sales pitches for each idea will be heard

Since ideas are submitted by everyone simultaneously, it's important to review them in order and listen to the sales pitches from the people who submitted them. This gives the full audience an overview of the ideas before moving to the voting stage.

- A well-defined set of voting criteria will be used

A well-defined set of criteria helps to ensure that voting results can be used to properly evaluate ideas based upon business or economic benefits, and ease of implementation. Ideally there will be an equal number of criteria for each of these vectors so that innovation ideas and opportunities can be plotted on a cost/benefit matrix or similar analysis tool such as a project prioritization matrix.

- Measurement of success will be defined

Three key areas will be tracked to measure the success of the workshops: the quality of the workshop session, the quality of the facilitators themselves, and the business opportunities achieved as a result of the session. This can be achieved by participant satisfaction surveys at the conclusion of the workshop and also by rigorous follow-up to monitor the success of ideas designated for further analysis and eventual implementation.

6 References

6.1 Applicable Documents

1. Dissemination Plan, Document No. D 7.10
2. "Abstract & Summary Report" ESA-GSTP, GHM for Space, 4000101818/10/NL/GLC

6.2 Reference Documents

1. ESA Technology Readiness Levels Handbook for Space applications.

Available at: https://artes.esa.int/sites/default/files/TRL_Handbook.pdf

2. Global Exploration Roadmap

   Available at: http://www.globalspaceexploration.org/wordpress/wp-content/uploads/2013/10/GER_2013.pdf

3 Space Exploration Strategy

   Available at: http://esamultimedia.esa.int/multimedia/publications/ESA_Space_Exploration_Strategy/

4. Draft ESA Long Term Plan 2015-2024, ESA/C92014)101, Rev1, 12 December 2014

5. ESA Call for Ideas for Space Exploration.

   Available at: http://esamultimedia.esa.int/docs/hso/ESA_CFI__Space_Exploration_as_a_Driver_for_Growth_and_Competitiveness.pdf