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MOON BASE HABITABILITY ASPECTS

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ABSTRACT

Looking at the overall space scene of recent years, a general interest appears evident in supporting manned space activities according to a general, organic plan. The consolidation of the human presence in Low Earth Orbit, in fact, is a challenge to explore further the human capability to live and work for prolonged periods on another planet.
This goal seems to be pursued with the growing conviction that a long term program, aimed at the expansion of human presence beyond LEO, has to be implemented.
Like the other spacefaring countries, Europe is supporting a series of dedicated studies, looking at the possibility of developing an autonomous **European Space Infrastructure** to sustain future manned missions, like **Moon Bases** and **Mars Missions.**
The return to the Moon will require a systematic exploration for the selection of the best site to establish a lunar outpost. In the following phases, the Moon Base will grow according to the selected scenario to include laboratories, production plants, additional habitat capabilities, power production facilities, etc., and it could be regarded as a staging base for more distant space travel.
In this paper, the main habitat requirements for a Moon Base are identified and analysed. Various issues and technologies related to the local environment in which human beings will operate must be considered so as to choose from among different scenarios and to identify possible design solutions. Moreover, the mission characteristics play an important role in the basic sizing of the habitat, that depends heavily on the crew size and length of stay according to the different phases of the enterprise.
Considerations about the influence of human aspects on the habitat design are also drawn, and the requirements to ensure maximum crew safety are outlined. The main habitat features are then described, according to a multistep Moon Base design approach.
The **Environment Control and Life Support System (ECLSS)** is also regarded as an essential subsystem for any manned space system, and it will require a growing level of self-sufficiency with the development of the Moon Base's needs. A modular design of the ECLSS is proposed to adapt it for either variable capacities or different evolutionary stages.

1 INTRODUCTION

Since the time of the Apollo program, the interest in exploring our solar system further and, eventually, in experiencing life in space hawe been two of the challenges of the advanced research [1].
All the spacefaring countries are involved in programs dealing with the possibility to establish permanent presence of man in Low Earth Orbit first and on the surface of other planets later.
Europe is looking to develop an autonomous European manned facility in Low Earth Orbit to be supported by a fully autonomous European in-orbit infrastructure, that will be used also as a staging base for future space missions, like Moon Bases and Mars Missions.
In particular, the ESA Long Term Project Office is supporting the definition studies of a dedicated program, **EMSI (European Manned Space Infrastructure)**, to develop an autonomous European manned facility in Low Earth Orbit.
The proposed scenario foresees the implementation of the European Space Station in a man-tended mode first, and as a permanently manned facility some years later [2].
According to today's perspective of economical practicability and international cooperation, possible scenarios for Lunar Colonization are considered as they match a coherent global plan for manned space activities in the first half of the 21st Century [3].
The return to the Moon will require systematic exploration and the establishment of permanent outposts at locations of interest, primarily for a variety of scientific studies.
In the evolution phase, the outposts on the Moon will evolve according to the different characteristics of the possible scenarios: scientific, commercial or planetary colonization.

2 MOON MANNED BASE DESIGN APPROACH

A Moon Base project is a complex study that has to satisfy different needs, from the completely different environmental compatibility to the high transportation expenses [4].
Any design approach conceived to define the basic characteristics and requirements of a Moon Base supporting manned surface operations should introduce a high level of self-sufficiency.
The high cost of space transportation, in fact, impacts on crew rotation and resupply operations.
Various issues and technologies related to the environment in which human beings will operate must be considered to choose among possible scenarios and to maximize the potential of the selected one.
At the beginning of the Moon Base construction, it is possible to foresee that a sort of outpost will be established on the Moon surface. During the development phases, it will be necessary to carry heavier components, laboratories, optical instruments, chemical facilities, etc., according to the selected scenario. It seems likely that inflatable structures will be employed to build wide domes that will probably have to fit with the preceding habitats.

3 MOON BASE HABITAT MAIN CONSTRAINTS

When dealing with the definition of habitat design concepts for living on the Moon, it is possible to identify three basic sets of requirements that drive the process at high level [4,5].
The first one derives the needs and characteristics of the system as imposed by the environment in which it will operate, and by the nature of the operations foreseen by the selected scenario.
The second one dictates the basic sizing of the habitat, depending substantially upon the mission itself, crew size and length of stay according to the different phases of the enterprise.
The third one considers the human impacts on facility design, that is one of the major drivings for the main characteristics identification of the internal layout of the habitat.
It is apparent that all these requirements will influence in turn the dimensioning of the various elements of the system.

3.1 Impact due to Environmental Characteristics

The environmental conditions that are unique to the Moon and require attention and investigation to ensure human survival are: vacuum, radiation, temperature gradient, reduced gravity level and surface characteristics.

- **Vacuum** - The lack of atmosphere pressure on the Moon dictates the requirement that all manned volumes on the lunar surface be artificially pressurized.
- **Radiation** - Radiation protection is one of the major issues that has to be considered when placing human habitats outside the Earth's atmosphere. As far as the Moon Base habitat is concerned, the most widely proposed method for radiation protection is to use in-situ materials, i.e. lunar regolith.

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- **Temperature Gradient** - It is widely known that the Moon surface temperature may vary from more than 110° C during the day to less than -170° C at the end of the lunar night, which is approximately a 280° C sun-shade fluctuation. These temperature extremes may cause many problems to human habitats if a thermal barrier is not provided; problems such as expansion and contraction of the structure and very heating and cooling loads for air systems. The regolith that is used for radiation protection can also act as a thermal barrier for the module.
- **Gravity Level** - The presence of a certain gravity level (1/6 g) on the Moon surface heavily affects the main configuration characteristics of the habitat.
- **Surface Conditions** - Since the Moon has an extremely dusty surface, measures must be taken to prevent dust contamination of the interior of habitats. An airlock has to be foreseen from the beginning, to dress/undress the EVA suits, to depressurize the module before an EVA, and to prevent dust from entering the habitat. External operations like launch and landing of space vehicles, robotic digging, mining of minerals, etc., will raise a lot of dust, and appropriate dust removal systems and shielding must be provided.

3.2 Impact due to Mission Characteristics

Planned activities at a manned lunar base can be categorized as supporting one or more of three possible objectives [6,7]: scientific research; exploitation of lunar resources for use in building a space infrastructure; or attainment of self-sufficiency in the lunar environment as a first step in planetary exploration and colonization (see Table 1).

OBJECTIVES		SCENARIO
Scientific Research **Lunar Sciences** **Space Observation**	⟶	**Scientific**
Moon Resources Exploitation * **strucural materials (Fe, Al, Ti)** * **fuel (O_2, He_3)** * **life support (O_2)** * **photovoltaic materials (Si)** **Tourism**	⟶	**Commercial**
Self-maintaining Capability Development **Outpost for Solar System Exploration**	⟶	**Pioneeristic**

Table 1 - Moon Mission Scenarios

The process of constructing the scenario clearly demonstrates that later phases are critically dependent on technologies, systems, and elements developed during the early phases. The cost and the complexity of the Moon Base, as well as the structure of the Space Transportation System required to support it, in fact, are functions of the chosen long-term strategy.

- **Scientific Scenario** - A Moon Base developed according to a scientific scenario will probably require habitat capabilities located in different sites on the lunar surface to investigate the Moon and its environment and to set up scientific instrumentation in proper locations (also on the lunar far-side and at the lunar poles).
  The lunar base will have to provide logistical and supporting capability to expand knowledge of lunar geology, geophysics, environmental science, and resource potential rapidly through wide-ranging field investigations, sampling, and placement of instrumentation.
  A centralized laboratory will probably be set up, with satellite laboratories dedicated to specific activities.
  It may be foreseen that habitability functions will be more demanding for the central base than for the supporting laboratories, in which the greater part of the activities will be likely performed by robotic tools.
- **Commercial Scenario** - If the Moon Base evolves according to a commercial scenario, the greater part of the equipment transported from Earth with the first launches will serve to realize pilot plants to check the feasibility of lunar resource exploitation.
  Within this frame, in the early phase of the scenario, the habitat will probably be a sort of outpost, a place where a minimum group of astronauts will oversee the assembly work performed by robots.
  Once the possibility to produce materials from lunar soil has been verified, the Moon Base will grow to include larger production facilities [8].
  According to the available technology and to the consequent need to enlarge the human presence at the Base, the habitat's characteristics will change, to ensure basic habitability features.
- **Pioneeristic Scenario** - Completely different characteristics may be envisioned for habitability solutions if a pioneeristic scenario is pursued for the creation of a Moon Base. A self-sufficient lunar base is, in fact, a long-term objective that creates new challenges in planning and development.
  In the near term, emplacement of habitats on the Moon surface involves known technology. The initial concept for a lunar habitat module might be, in fact, a sort of extension of the design experience acquired with the space station.
  A different perspective is required to plan systems that can utilize lunar materials and energy sources to produce a self-sufficient base. The habitability solutions will probably be focused on the ultimate goal to construct a structure that is able to satisfy the human need "to feel at home".
  It is possible to foresee that, with the growth of the Moon Base, the habitat design will tend to answer a continuously increasing demand for privacy. Independent units will be realized and the common zones will be dedicated to leisure activities. Laboratory capabilities and materials production plants will likely satisfy the local requirements.
- **Mission Length** - Mission length is determined by factors such as destination and planned operations, which affect the design of the facilities in the form of crew habitation volumes and comfort level. It is evident that the requirements of the crew increase as the mission increases. In Table 2 some possible data referring to different mission durations are compared [5].

3.3 Human Impacts on Facility Design

At a high level of considerations, two main human factors have to be considered when designing habitats for a Moon Base: locomotion and safety.

- **Locomotion** - The accommodation of human locomotion becomes very important for the design of living volumes in a lunar gravity environment. In a partial gravity environment, in fact, human walking and running gaits, posture, and the level of traction change. Walking in a 0.16 g environment requires less muscular energy than in a 1 g environment, and the critical speed at which walking shifts to running becomes lower [9,10].

Duration	Short < 2 weeks	Medium < 6 months	Long > 6 months
Description			
* Crew Size	9	9	9
* Work Shift	3 of 3 crew	Earth like	Earth like
* Crew Quarters	shared	private	private
* Personal Storage	yes	yes	yes
* Dressing Space	shared	shared	private
Volumes [m^3]			
* Sleeping	0.7	2.5	2.5
* Personal Storage	0.3	0.3	2.5
* Stand-up	-	-	3.0
* Total	3.0 (*)	25.2 (**)	72.0 (**)

(*) for crews of 3 (with shifts)
(**) for crews of 9 (without shifts)

Table 2 - Crew Requirements vs. Mission Duration

Analogously, running and jumping are favoured in a reduced gravity level, because the low apparent weight of the astronaut reduces the vertical force component of traction producing movement.

Human posture in lunar gravity also differs from posture in the Earth gravity environment. In lunar gravity, as the speed is increased, the forward body inclination gets progressively larger.

With a reduction of gravity, a human experiences a reduction in the friction between himself/herself and the surface on the ground. This can become a serious hazard because astronauts cannot rapidly change position to avoid moving or falling objects or gain a surer foothold or handhold while in a precarious position.

Human locomotion in lunar gravity strongly affects the design of manned facilities on the Moon, playing an important role in the design of corridors, floor surfaces, ceiling heights, staircases and chairs.

- **Safety** - Crew safety is one of the most important issues to be considered in the design of any manned facility to be located in an isolated environment.
  As far as a Moon Base is concerned, the presence of a dual egress to allow crew escape in emergency situations and radiation protection is mandatory.

4 MOON BASE HABITAT KEY REQUIREMENTS

Some basic requirements have to be considered in the design of a Moon Base:

- **Provision of Resources** - During the first missions, resource modules will supply the Moon habitat resources needs. As far as power production is concerned, it is possible to foresee that during the first growth phases, the Moon Base will be powered by solar cells.
  With the increase of power demand during the evolution of the Moon Base, alternative solutions could be considered, like nuclear power system or solar dynamics.
- **Psychological Aspects** - The Moon habitat internal architecture must guarantee the highest level of psychological and physiological comfort and well-being of the crew.
  A very important factor is the capability to allow a good view of the external landscape. Another important consideration is related to the feeling of confinement, typical of living and working in a closed environment. The different modules that will form the Moon Base could be disposed according to a triangular or square configuration, reducing the impression of living in a tunnel [4].
- **Environmental Control and Life Support** - An important requirement is the problem of interfacing with the natural environment, made of dust, micrometeoroids and various kinds of radiation, large temperature gradients, and with the induced (by the crew presence inside the Base) environment, that is, noise, vibration and contamination [11].
  As far as the external environment is concerned, the utility of covering the Base with lunar regolith becomes evident.
  The temperature of the habitat should be maintained at a given level and be selected by the crew. The air filtration system should remove dust and other particles from the air. The freshness of the air should be maintained within specific tolerances, and the air should be well circulated throughout the habitats and connected assemblies.
  The life support system should be a closed loop system that converts waste and carbon dioxide into usable consumables. The waste and carbon dioxide could be used, in fact, for growing plants, and hence provide food and oxygen for the crew.
- **Safety** - A mandatory condition for a Moon Base is to provide protection against radiation and micrometeoroids. As already said, the possibility to utilize lunar regolith to cover to Moon Base structure seems to be the best solution.
  A safe haven must be part of the habitat. A dual egress capability has to be foreseen. During the Moon Base evolution it is likely that first-aid tracked shelters will be placed at different sites and distances from the Base along the exploration paths covered by crew members in EVA [12].
- **Interfaces** - The habitat will have to interface with other elements that will be employed in the construction of the Moon Base. In particular, it will be necessary to have a perfect interface between it and the airlock.
- **Physical Constraints** - During the first robotic phase, different automatic equipments and tools will have to be transported on the Moon surface to prepare the Moon Base site.
  For the first manned flight, the launch system will have to transport, as a minimum, one habitation module, a thruster stage, and a landing craft. With the growth of the Moon Base, it is possible to foresee that larger launch capabilities will be required.
- **Moon Base Growth/Reconfiguration** - It seems, from a preliminary analysis, that the Moon Base will initially grow by adding pressurized, independent modules, connected in a triangular or square overall configuration. A longitudinal internal arrangement presents a lot of advantages w.r.t. a transversal arrangement.
  A further evolution of the Base could make use of an inflatable dome structure that could be connected with the initial Moon Base unit.
- **Mission Needs** - This set of requirements essentially concerns the crew size and their accommodation and functional allocation, that is, provision of facilities to the crew.
  As far as the crew size is concerned, this will be deeply influenced by the level of robotized functions w.r.t. directly manned ones.
  The accommodation volume of the first crew members will probably be the landing craft module itself. This may have the capability to host 4 people on the lunar surface for about one week. The outpost will grow into a more complex structure that will host a greater number of people, and that will include an inflatable habitat, connecting tunnels, thermal radiators, solar panels, roads to the landing pad, a lunar oxygen pilot plant with a dedicated solar power system.
- **Operational Constraints** - This set of criteria is related to the process of servicing and maintenance of configurational options, that is, servicing cycles, operations of preparation to EVA and of EVA termination, accessibility of interfaces to be maintained/serviced, availability of stowage containers, etc..
- **Assembly** - The following points will have to be considered for the assembly of the Moon Base:
  * transportation of automatic equipment during the robotic phase
  * transportation and assembly sequence during the initial buildup phase
  * transportation and assembly sequence during growth phases
  * logistic support and traffic schedule.

  It is foreseeable that the transportation system will have to enhance its capability to satisfy the needs of a developing lunar infrastructure better.
- **International Cooperation** - An international cooperation approach seems to be the most feasible way to plan for this type of very demanding mission. A national autonomy will have to be maintained in any case, and the Moon Base could be composed of common zones and private sectors dedicated to national projects.
- **Availability** - This aspect refers to the availability of the different technologies considered to solve habitability requirements on the Moon surface.
  In case cylindrical modules are used, the technology required is already known. As far as the inflatable structures is concerned, it is necessary to develop the present knowledge further.
  Another field related to the habitat preparation is the robotic technology that has to be improved and tested before facing the hard lunar environment.
  As previously stated, also the transportation system will have to answer a continuously increasing demand to carry heavier payloads.
- **Commonality** - Due to the phasing approach that will be used to build the Moon Base, and in case an international cooperation philosophy supports the overall project, it becomes mandatory to adopt the highest possible degree of commonality among the different elements of the Moon Base infrastructure.
- **Cost** - This complex factor can be further subdivided into various aspects, like development costs, production costs, assembly costs, and operational costs, shared internationally.
- **Moon Base as a Step of the EMSI Scenario Evolution** - The EMSI Scenario has been conceived to support future long duration manned space missions. From this perspective, the Moon Base has a value by itself, as the first surface structure in which men can live and work out of their native planet.
  Moreover, the Moon Base can be regarded as a stepping stone in solar system exploration and colonization, acting as a staging base for interplanetary flights to Mars and for future Mars missions.

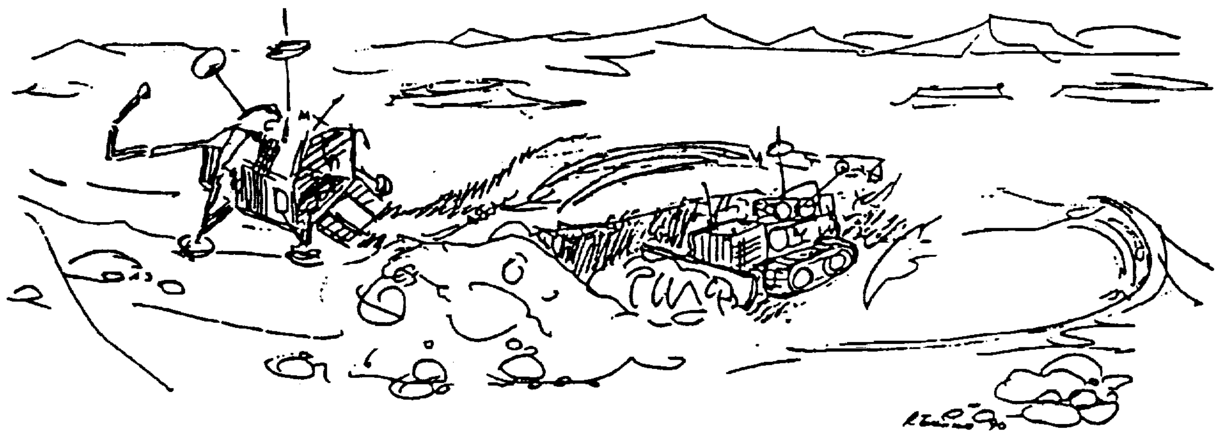

Fig. 1 - Moon Base Precursor Robotic Phase

5 MOON BASE CONSTRUCTION PHASING

The most realistic strategy to build a Moon Base seems to be a multistep approach, with a gradual growth of the human settlement [4].

5.1 Robotic Exploration

In the initial robotic phase, scientific and technical data will be gathered and collected to prepare the successive manned phases.
The attention is focused on the understanding of the environmental conditions and on the selection of candidate landing sites (Fig.1).

5.2 First Manned Missions

As already stated, the first lunar habitat could be the lunar lander itself that, with the Orbital Transfer Vehicle (OTV), an aerobrake system, and a crew or a cargo module, constitutes the lunar spacecraft [13].
The aerobrake system is necessary when part of the lunar vehicle has to return to LEO.
This mission would serve to check the Moon Base possible sites already identified during the precursor robotic phase, and to choose and prepare the place where the first habitation module will be landed.

5.3 Outpost

After the Moon Base site has been selected, it will be time to start the construction of the Moon Base outpost.
Figure 2 illustrates the concept of what can be called the first Moon Base manned phase. Once the site has been prepared by robotic means, the first Moon Base habitation module will be landed on the lunar surface and will be settled into the arranged pit. At this point the habitation module will be only partially protected by the lunar regolith, and robotic and human labour will be required to cover the upper half of the module. The following functional areas have to be allocated in the Moon Base outpost:

* Crew Quarters
* Crew Health Care Compartment (CHCC)
* Exercise and Recreation Area
* Personal Hygiene and Body Waste Management Areas
* Galley
* Data Management and Communication Facility
* Repair and Working Area
* EVA Suits Storage Area
* Safe Haven

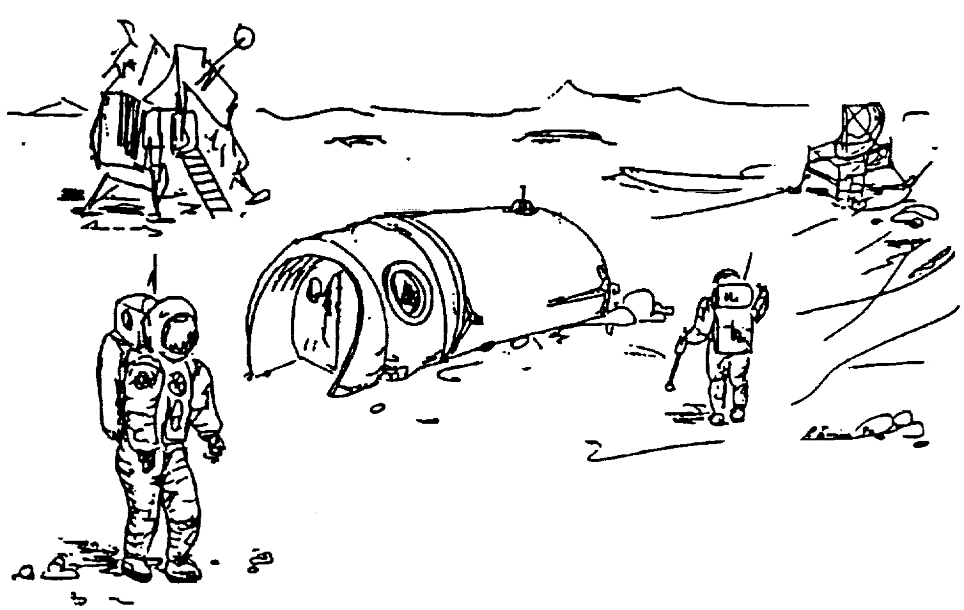

Fig. 2 - First Moon Base Manned Phase

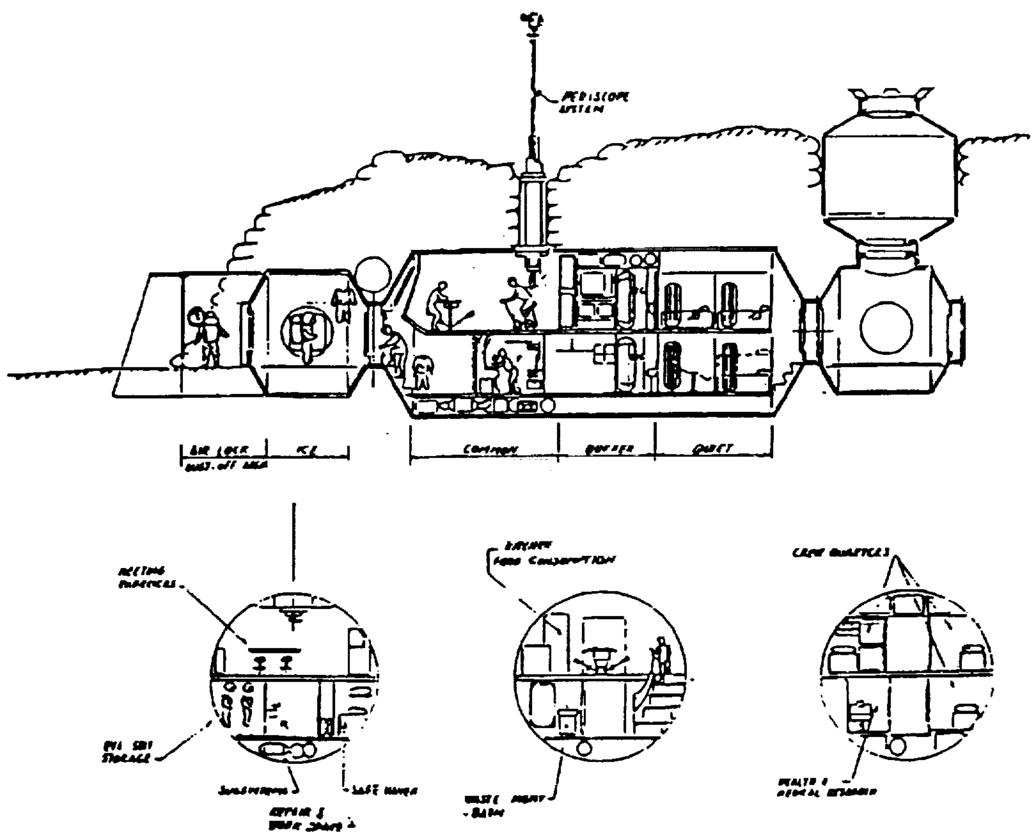

Fig. 3 - Habitation Module Internal Layout

Figure 3 shows the possible internal layout of the habitation module. It is connected with an Interconnecting Element (ICE) that is preceded by a sort of shed for the gross dust removal. The ICE acts as an airlock, in which crew members can get ready to transit from intravehicular activities (IVA) to extravehicular activities (EVA) and vice versa. The airlock can accommodate two people at one time, and store two or three suits. Other suits are stored in the wardrobe in the first part of the habitation module.
The internal configuration of the habitation module is composed of two floors. A staircase of a few steps (the height of each step can be bigger in 1/6 g than in a 1 g environment) connects the two floors.
Three main areas, the common zone, the buffer zone, and the quiet zone, can be identified.
In the lower part of the common zone, the EVA suits storage room, the repair and working area, and the safe haven are located. The upper part of the common zone includes the meeting and exercise area. A periscope system is foreseen to allow external view when the habitation module is covered by lunar regolith.
The first floor of the buffer zone contains the waste management system and one bathroom. A staircase of a few steps allows access to the second floor, where the galley and the food consumption table are located. Another bathroom is foreseen for redundancy and suitability in proximity of the crew quarters.

The crew quarters are located in the quiet zone. They can host four crew members on the second floor and other two on the first floor. Two additional bunk beds are foreseen for visiting crew. The lower part of the quiet zone also houses the health maintenance facility.
Another Interconnecting Element allows the passage to another pressurized module, that will be added to the first habitation module during the Moon Base growth. Stacked in a vertical array, another interconnecting element provides a second egress capability for emergencies and other operational needs. It could also provide support for a viewing cupola and/or docking capability for external pressurized elements (pressurized rovers, first-aid shelters, etc.).

5.4 Moon Base Evolution

The Moon Base will grow according to a multistep process. Different phases may be envisioned, but the general idea is that, anyhow, additional elements will be added to compose an increasingly evolved structure.
In the so-called second evolutionary phase (Fig.4, page 6), other pressurized modules will be connected to the first one according to a triangle or square configuration. These pressurized modules will be configured as crew quarters, laboratories, working stations, research centers, etc., according to the needs of the selected scenario. Additional power and communication systems, and surface transport capabilities are also part of the scenario at this point.
During the third growing phase (Fig.5, page 6), the Moon Base will evolve to include other pressurized modules that will host a larger number of crew members and facilities. Different viewing points will have to be provided.
The selected scenario will deeply influence the overall structure evolution with the addition of laboratories, plant facilities, research centers, observatories, exploration outposts. Connecting tunnels will be built to link some of these elements.
Automatic means will prepare roads to the landing path and surface transportation rovers will increase the mobility range. Shelters will be built to protect robotic means and rovers from radiation and micrometeoroid bombardment.
The larger power demand will probably require the construction of a nuclear power plant in addition to the already existing solar power systems. This plant will have to be located at a safe distance from the manned facilities and, anyhow, additional radiation control and protection will have to be provided.
Habitat heat rejection systems and thermal radiators will have to be adapted to the hard lunar environment. The thermal control of the Lunar Base is, in fact, difficult due to the extreme environment on the Moon. Problems with the atmosphere, the lunar soil, and micrometeoroids must be accounted for before an extended human presence can be realized.

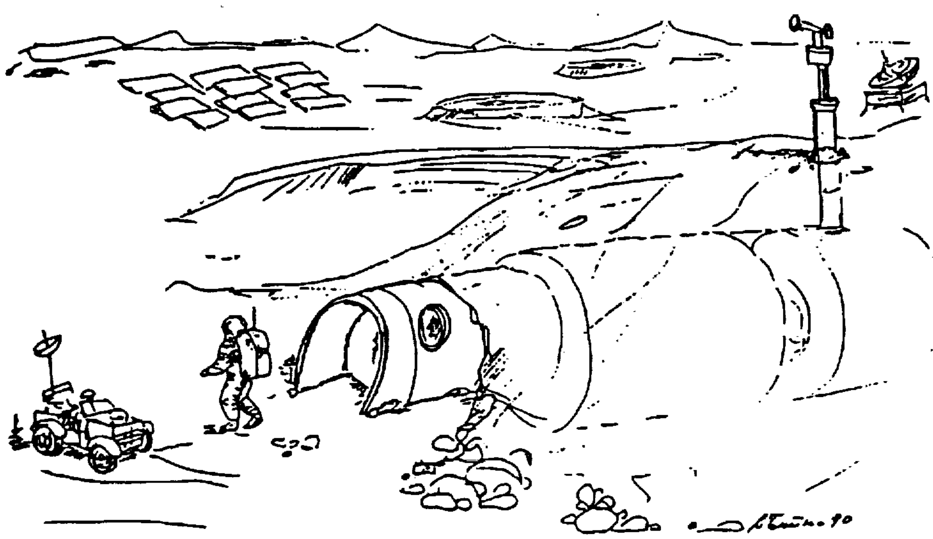

Fig. 4 - Second Moon Base Manned Phase

A fourth growing phase of the Moon Base may be envisioned, during which a fundamental evolutionary leap in the Moon architecture could occur (Fig.6, page 7).

The habitat architecture could evolve from the use of convectional modules, on built and brought from Earth, to completely new structures, realized also with lunar materials. This evolution would allow a real breakthrough in volume availability and habitability concepts to be used on the Moon.

Several solutions have been explored and preliminary comparisons of habitat options have been considered in different studies [14].
The concepts that seem more likely to be utilized are:

* Inflatable Structures - habitable pressurized volumes realized via deployment of previously prepared and folded structures
* Moon Material Based Structures - habitats realized utilizing lunar materials such as concrete, and/or peculiar lunar structures, like lava tubes, as shelters.

5.5 Need of Enlarged Crew at Moon Base

Once a commitment is made to lunar development, the Moon Base could grow into a network of lunar bases and eventually evolve into a self-sufficient lunar colony. Through the evolution phases, in fact, the Moon Base has achieved a complex architecture, assuring sustained life and work for several people. It is possible to foresee that this Base will constitute the first seed of a real lunar colony, whose evolution is oriented to an autonomous, permanent human presence on the Moon.
At this point, the concept itself of "Habitation Module" as a structure where people can live and work protected from the harsh external environment will change its meaning.
The development of an indigenous lunar architecture, and maybe of a "Moon Colony Town-planning" will be likely to occur [15]. In this case, it will no longer be necessary to squeeze together different functional areas as it is in a conventional habitation module. The separation between living quarters, free-time areas, exercise and medical facilities will offer a pleasant living environment to people who have chosen to live on the Moon.

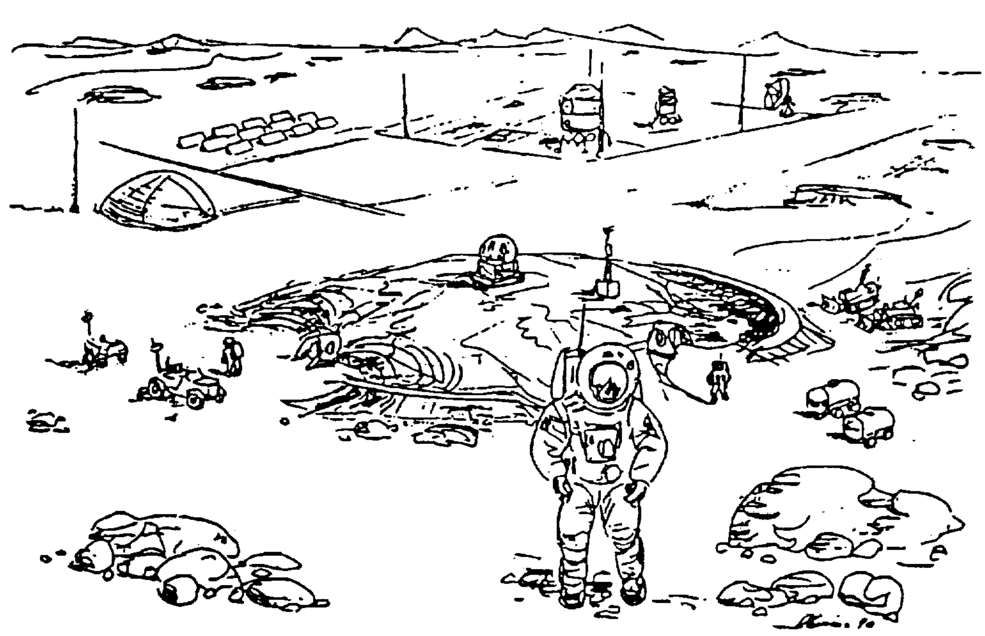

Fig. 5 - Third Moon Base Manned Phase

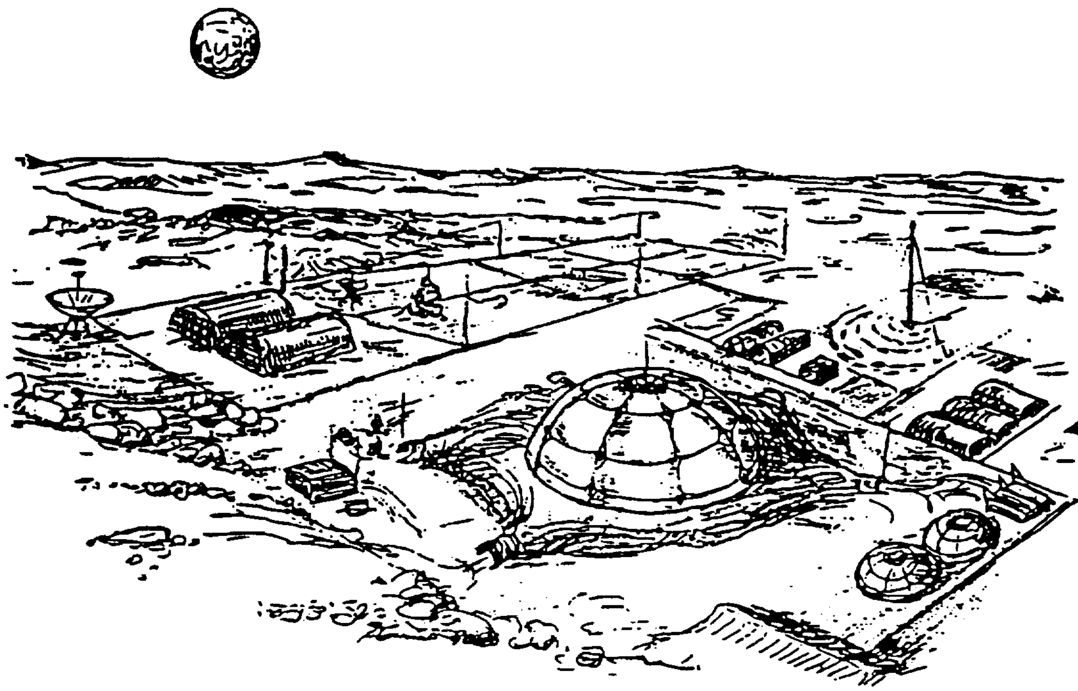

Fig. 6 - Fourth Moon Base Manned Phase

5.6 Moon Base Assembly Alternative Strategy

A possible alternative strategy to assembling the different modules making up a Moon Base is the MALEO Project (Modular Assembly in Low Earth Orbit) [16].
According to this strategy, the modular Lunar Base components are brought up to Low Earth Orbit by a heavy lift launch vehicle, and assembled there to form the complete lunar Base. Modular propulsion systems are then used to transport the MALEO lunar Base, complete and intact, to the lunar surface. Modular, erectable, deployable, inflatable and indigenous architectures for the evolution of the lunar Base could be experimented and developed while the crew live in the MALEO structure. The main purpose of this approach is to initiate and sustain early lunar Base buildup safely. The architectural drivers for this strategy are the dust free and less harsh radiation environment of Low Earth Orbit which permits safer manned EVA and the utilization of a space station infrastructure.

6 ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM

Long duration space missions are possible only with advanced subsystem design providing a high degree of self-sufficiency. The system supply needs of those missions is a very sensitive parameter for verification of the feasibility and performance.
The required self-sufficiency of the Environmental Control and Life Support System (ECLSS) for a manned Moon Base has to consider the different operational phases for the habitat development. The different functions that the ECLSS has to handle are [17]:

* atmosphere management
* water management
* food management
* waste management

In the first settlement phase, the ECLSS will be based on technology development for space stations in LEO, with a relatively low degree of self-sufficiency. A modular design of the ECLSS is required to adapt this subsystem on variable capacities and different evolutionary stages.

With the evolution of the Moon Base, a Controlled Ecological Life Support System (CELSS) will be developed to include:

* plants facilities
* waste processing facilities
* back-up physico-chemical ECLS subsystem for atmosphere and water management
* storage for dehydrated and frozen food as back-up and buffers
* resource storage

The different optimum environmental conditions for crew habitability and plants growth will force the establishment two clearly separated areas of the habitation complex.
Problems of internal contamination, due to the presence of people inside the module, to the systems and experiments, and to visiting crew, will have to be carefully considered [11,18]. The general purpose of equipment related to contamination control is the monitoring of air and internal conditions, detection of contaminants (gases, fluids or particles) and provision of means for decontamination of air and interior by specific equipment. Contamination control should not be designed to provide the crew with environmental conditions as clean as possible, but as healthy as possible.

The life support of the crew in the Moon Base will be performed by a redundant system: the CELSS is the nominal system providing self-sufficiency of the complex by closed loops of oxygen, water and food supply; the more conventional ECLSS represents the backup solution to be used in emergency cases, during maintenance work on the CELSS or during initial phase of Base build-up. The back-up system is a conventional system that does not have any impact on the overall configuration of the Base. In relation to that, the evolutionary CELSS will have significant impacts on the overall configuration.
An evolutionary development and growth of the manned complex by addition of dedicated modules for implementation of CELSS technologies can be executed easily because of the back-up ECLSS using state-of-the-art technology.
Plants represent a central point of future biological environmental control and life support systems for the number of regeneration functions provided.

7 CONCLUSIONS

From a broad point of view, the future European programs are characterized by the interest in assessing human presence in Low Earth Orbit and beyond.

This is a huge, multifacetted enterprise that implies an extraordinary commitment and sustained resource allocation, in order to implement the necessary strategy whatever the chosen mission model will be.

Moreover, as stated above, this sort of evolution for manned space activities seems currently to be a major focus of attention also for other spacefaring nations outside Europe.

This consideration leads automatically to speculate that, at least when Moon and/or Mars activities are considered, a cooperative approach seems to be not only the auspicious way but also the more practical possibility, especially on the basis of economical analysis.

The human settlement and, eventually, the colonization of other worlds, is the ultimate goal that puts man in a central, unique position. A substantial part of the effort will have to be dedicated to the assessment and solution of the man-related problems. All these aspects will assume a dimension well beyond the present capabilities, because of the "very far from Earth" conditions encountered.

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