MOON BASE ASSESSMENT: PERSONNEL TRAINING

INTERNATIONAL CONFERENCE MOON BASE A CHALLENGE FOR HUMANITY VENICE WORKSHOP, MAY 26TH - 27TH 2005

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Abstract

In the recent past years, the international space community has taken into consideration the exploration program of the space and, in this frame, the realization of a base permanently inhabited on the Moon surface, as starting point for the further exploration of Mars. The training programmes of the future astronauts will have a fundamental role for the utilisation of the Moon Base. Such programmes shall be based on a realistic representation of the lunar habitation context, able to let the astronauts to achieve the needed skill in the management of the vital functions of the base, as well as to prepare their psychological aspects. At this aim, it will be necessary to build a suitable Training Infrastructure on Earth, composed by a set of Habitation Modules and by a Support and Management Structure, where the astronauts and the instructors will perform the training sessions. In the realisation of this Training Infrastructure, simulators will be widely used, because it is commonly acknowledged that the "virtual simulation" is the most effective and efficient technique for training purposes. However, the Moon Base project is quite innovative, with reference to the projects carried out so far by the human kind, and then, to use a facility so conceived only for training purposes would deprive the Moon Base project of an exceptional instrument for the base study and for the base design definition and verification. Therefore, the facility, conceived thus as dual-use (at the beginning, as supporting the design, and after, as a training facility), should be implemented in the initial phase of the Moon Base programme. For Italy, to take the initiative in the implementation of this facility, by using the introductory know-how earned in the analogous experiences of the International Space Station and Columbus programmes, would mean to maintain that central role acquired in the past, and in addition, to be provided with a centre of excellence, reference point for the research associated to the exploration and colonization of the outer space.

Introduction

In the past years the international space community has taken into consideration the exploration program of the space and, in this frame, the realization of a base permanently inhabited on the Moon surface.

Italy, that historically has had a particular attitude in the great exploration adventures, has continued with this vocation and has put itself in a prominent position in the frame of the international space community in the pursuing of these aims, also thanks to the position of

excellence earned by the Italian aerospace industry in the realisation of the International Space Station, the real first step towards the conquest of the outer space.

These solid basis are the starting point for a stream of initiatives that will have, as objective, at first the study and the design of the Moon Base, to be carried out in combination and strict relationship with the studies for the definition of the modalities of transfer on the lunar surface of the materials for the implementation of the base and the modalities of transfer, towards and from the lunar base, of the astronauts.

Taking into account the complexity and the ambitiousness of the Moon Base project, however, it will be necessary to apply a new way to design it, which involves complementary but essential issues since the first phases of conception and definition, such as, for example, the training of the personnel that will implement the Moon Base and will live in it, and that will be involved in the most critical phases of its utilisation.

Also referring to the training issue, Italy has acquired a prominent position within the international space community, having actively and significantly participated in the design and implementation of the Columbus training facilities, realised and resident at the European Astronauts Centre in Cologne.

The fundamental role of the training

The realisation of a Moon Base is functional to the objective of allowing the human presence on the lunar surface for long periods and in complete safeness, of both the humans there resident and of the implemented inhabitation infrastructures.

Once that a suitable Moon Base has been realised, such a continuative human presence can be achieved only throughout a complete and detailed training programme, to be conducted mainly on Hearth, to which all the future inhabitants of the Moon Base will be submitted.

The training programme will be based on a representation of the lunar inhabitant context provided with the required degree of realism, suitable to the execution of training sessions focused on the vital activities and equipment, such as, for example:

- the management of the health and technological emergencies, also in consideration of the fact that at the occurrence of these emergencies, the inhabitants of the base will not have the means to perform an immediate re-entry on the Earth,
- the management of the production and stocking of the electrical energy needed to support the Moon Base, by taking into account also the lunar phases, which cause the absence of the solar light for periods of time of 14 terrestrial days,
- the management of the systems and of the resources for the life support, such as, for example, water, the air for the respiration, the food, etc.,
- the management of the environment and of the systems for its control, in terms of, for example, the thermal control, the contamination control, the control of the protection from the radiation,
- the management of the elimination and recycling of the rubbish, also in the respect of the anti-pollution policies of the lunar surface (it would not be ethically plausible to pollute the Moon as done for the Hearth).

However, the training programme will not be only focused on the globally usage of the Moon Base in complete safeness and on the specific usage of the individual equipment

needed for determined vital functions, but it will have to be used for the training on the management of the psychological effects related to the peculiarities of the life in the Moon Base, such as, for example:

- the prolonged absence from the Hearth,
- the reasonable certainty that the inhabitants of the Moon Base will rely only on their own resources and knowledge, for their survival,
- the compulsory cohabitation and/or the solitude.

A second training level will regard the objectives for which the Moon Base will be realised, that is, the realisation of a starting point, a true advanced base, for the further exploration expeditions towards Mars.

The Training Infrastructure on Earth

The aim of the training programmes previously defined will require the realisation of suitable and dedicated training infrastructures, located in an appropriate multidisciplinary centre, accessed and shared by the scientific and space international community, by the astronauts and by the future inhabitants of the Moon Base. These infrastructures will be of the same typology of those already realised by the European Space Agency at the European Astronauts Centre in Cologne, Germany, where the Columbus Trainer is located. The Columbus Trainer is the training facility of the astronauts of the Columbus Laboratory that will be attached to the International Space Station.

The Moon Base Training Infrastructure shall be composed by the following main parts:

- a set of Inhabitation Modules suitable to reproduce the internal environment of the Moon Base,
- a set of modules for the reproduction of specific sectors of the lunar surface, external and adjacent to the above modules. They are necessary to carry out specific training sessions related to extra-internal habitat activities,
- a Support and Management Structure.

These parts will be suitable to reproduce the isolation and the confinement of a group of inhabitants of the real Moon Base for a period of time compatible with the expected durations of continuative presence

The Inhabitation Modules and the modules reproducing the external environment will be isolated from the rest of the infrastructure, in order to reproduce the same isolation conditions of the real Moon Base. Some access points will be created in order to allow the inhabitants of the base to go to and to return from the modules reproducing the external environment.

The Training Infrastructure will be provided with a set of simulators suitable to simulate the real equipment and the devices of the real Moon Base.

These simulators will realistically reproduce the various equipment and devices of the real Moon Base, from both the functional and physical viewpoints. They will provide the astronauts with an interface well suitable to the execution of the training sessions of both the nominal operations and of the contingency operations.

The human-machine interface component of the simulators (the simulators front-end) will be located at the internal of the Inhabitation Modules and at the internal of the module

reproducing the external environment. The Simulator Front-End will be connected to the modelling and real-time simulation component (the simulator back-end), located in the frame of the Support and Management Structure of the whole Training Infrastructure, throughout suitable data communication lines.

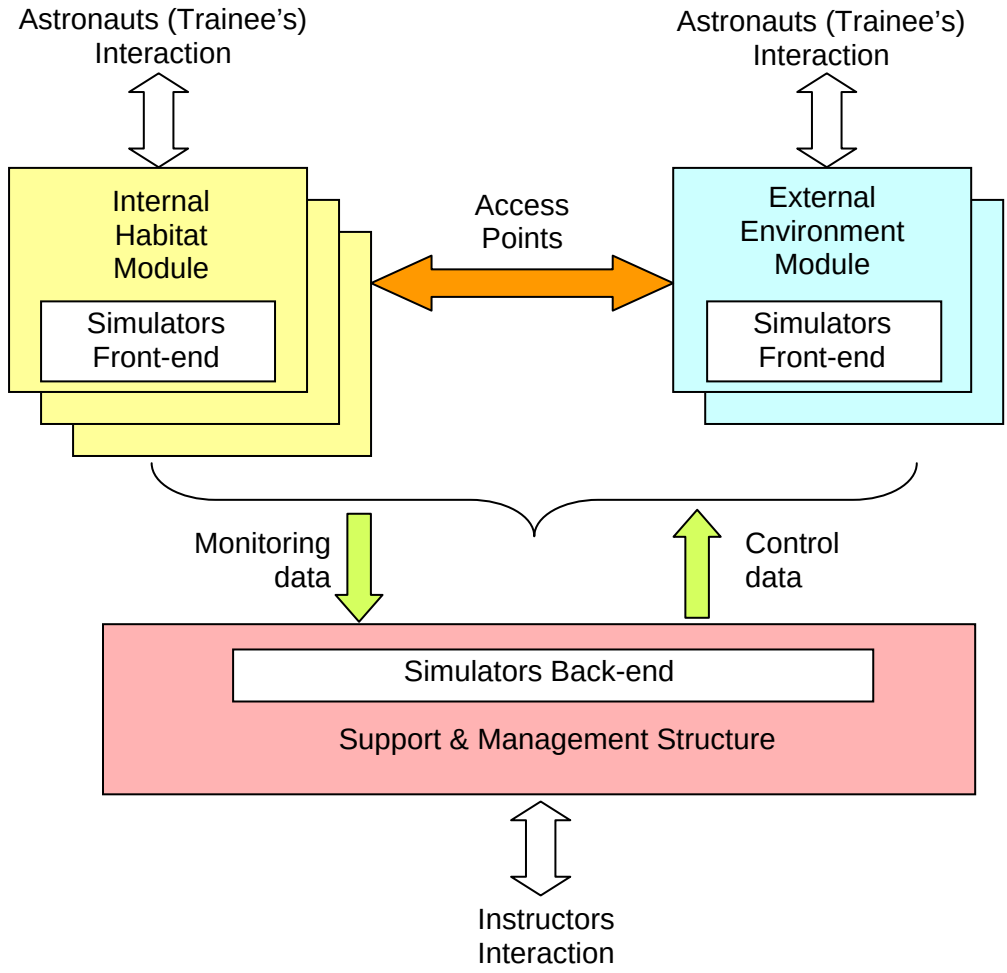

Figure 1: Moon-Base Training Infrastructure.

Simulation in Training

Simulation is often used in the training of a various type of personnel. This usually occurs when it is prohibitively expensive or simply too dangerous to allow trainees to use the real equipment in the real world. In such situations they will spend time learning valuable lessons in a "safe" virtual environment. Often the convenience is to permit mistakes during training for a safety-critical system.

Training simulations typically come in one of three categories:

- "live" simulation, where real people use simulated (or "dummy") equipment in the real world;
- "virtual" simulation, where real people use simulated equipment in a simulated world (or "virtual environment"), or

- "constructive" simulation, where simulated people use simulated equipment in a simulated environment. Constructive simulation is often referred to as "wargaming" since it bears some resemblance to table-top war games in which players command armies of soldiers and equipment which move around a board.

The simulation adopted in the Training Infrastructure of the Moon Base, considering how this has been conceived, is of the “virtual simulation” typology.

Training simulations recreate situations that people face on the job and stimulate the trainee to react to the situation until the correct responses are learned. These devices produce well prepared personnel without the expense of making mistakes on the job. Perhaps the best known of these are flight simulators, which model dangerous environments where life threatening situations can be mitigated through learning in a non-lethal environment. Military simulators replicate the performance characteristics of the aircraft, instruments in the cockpit, effects of weapons, support from other combat systems, communications with other pilots, and terrain over which the events occur. Similar systems are used to train the captains of large ocean-going ships to dock without destroying both a real ship and a real dock. Entire mock-ups are made of nuclear power control centers to teach operators how to respond to emergency situations and to identify potential hazards before a crisis occurs. Modern medical equipment is so expensive and scarce that simulations have been constructed to allow interns and nurses to practice, develop, and certify their skills without having to schedule training time on the real equipment, competing for its use by real patients.

Therefore the simulation technique, thanks to the benefits that it offers for the training purposes in the above mentioned fields of applications, is well suited to be used in a training system for the Moon Base, which offers most of the characteristics provided by the examples of single fields of applications here above listed.

The Support and Management Structure

The Support and Management Structure, other than to contain the Back-End Simulation component, will be composed by all the necessary means to conduct and to control the various training sessions, to carry out the related preparation and planning, and to carry out the successive post-processing and analysis of the data gathered during the training sessions execution.

The life-cycle of a typical training session is essentially composed by the following main phases:

- the preparation and planning phase,
- the execution phase,
- the post-processing and analysis phase,
- the debriefing phase.

During the preparation and planning phase, the instructors will define the details of each individual training session and, if needed, will produce the data necessary to their execution. Typically, the output of this phase is a set of procedures that will be executed by the trainee and that use the prepared data in automatic or semi-automatic mode.

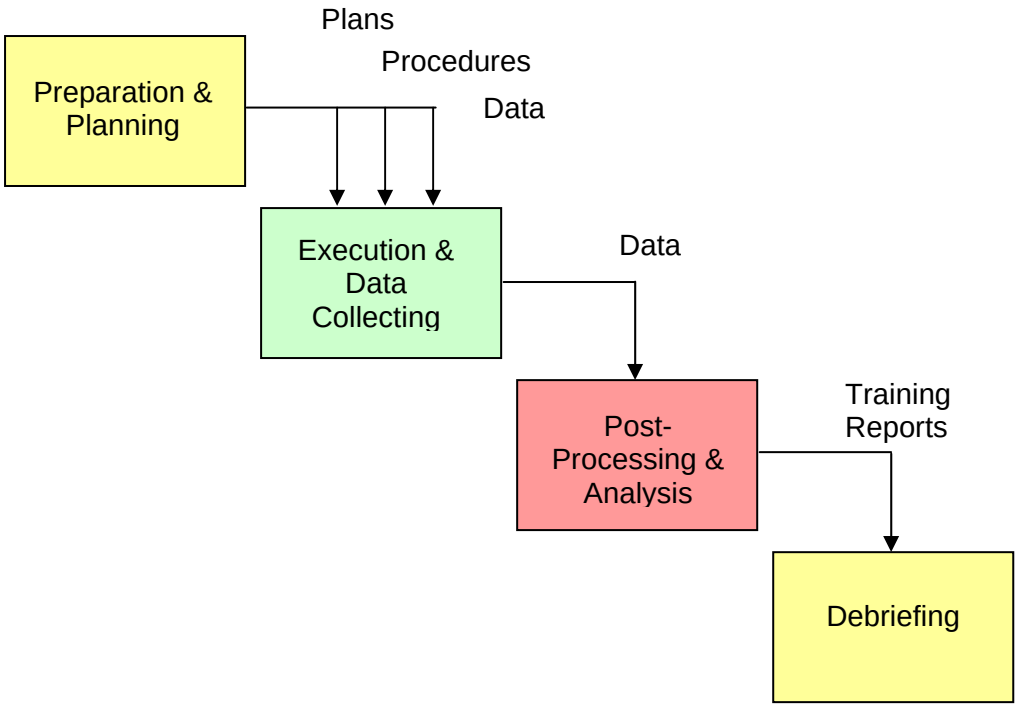

Figure 2: Training Phases.

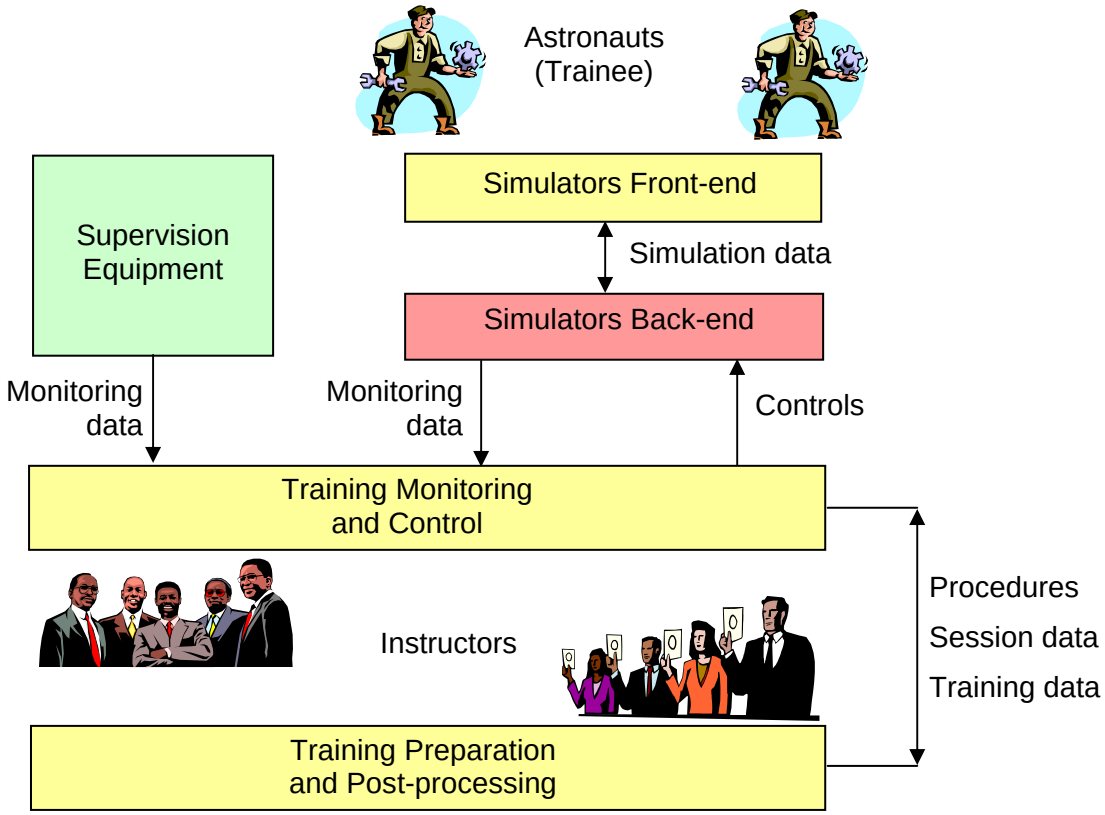

Figure 3: Support & Management Structure.

The execution phase consists in the real training session. In this phase, the astronaut under training (i.e. the trainee) is inside the Inhabitation Modules or inside the modules reproducing the environment external to the base and, depending on the purpose of the session, has to execute a series of actions on one or several equipment and/or devices of the Moon Base. These actions must be executed in a determined correct chronological order. At the same time, the instructors located in the Support and Management Structure, supervise the execution of the training session, starting and controlling the relative procedures and intervening manually when required, and collecting the data produced during the training session.

The training sessions can be individual sessions or group sessions. An individual training session is conducted by only one astronaut. A group training session is conducted by more astronauts. Further, they can be independent or joint. An independent training session involves one or more astronauts but it is in the frame of the Moon Base only. A joint training session involves one or more astronauts in the frame of the Moon Base and one or more external entities, such as, for example, a space vehicle carrying out a docking manoeuvre or the Moon Base Control Centre on the Earth, similarly to what currently performed for the International Space Station.

In the post-processing and analysis phase, the instructors process and analyse the data gathered during the execution of the training sessions and produce the reports on their execution, that will be reviewed and discussed together with the trainees during the conclusive debriefing phase.

When to realise the Moon Base Training Infrastructure ?

In the development programmes of complex systems, usually the training infrastructures are realised in the final phases, after having completed and validated the design, and at an advanced stage of the implementation. In practice, the training infrastructures are realised essentially to support the Operations and Exploitation phases of such systems.

To apply the same rationale and development cycle also to the Moon Base programme, however, will not be very efficient, because it would deprive the initial Moon Base feasibility and design phase of a greatly useful tool for the conduct of the necessary and introductory analysis.

In fact, for the Moon Base system, we do not have the same mass of experience acquired by the international industrial community in the development of traditional systems, even very complex, should they be satellites, launchers, defence systems or also inhabitation modules such oil platforms or Antarctic units.

The reason is that while such systems are intrinsically terrestrial, and completely realised on Earth, and some of them used also on Earth, a base on the Moon is a system whose implementation imply to transport its components on the Moon, to physically assemble them there, and even there test the implementation for the subsequent living by humans.

This argument that would seem quite trivial, is the main reason to think to a different development life-cycle for the Moon Base.

Therefore, due to the peculiarities of such a new Moon Base system, it would be more convenient to realise the training infrastructure previously described, already since the initial design phases and use it for the conduct of the studies and experimentations for the definition of the design choices to drive the implementation of the Moon Base to be built

afterwards. In other words, a sort of prototype that, once the design is completed and validated, would be used as training facility for the future Moon Base inhabitants.

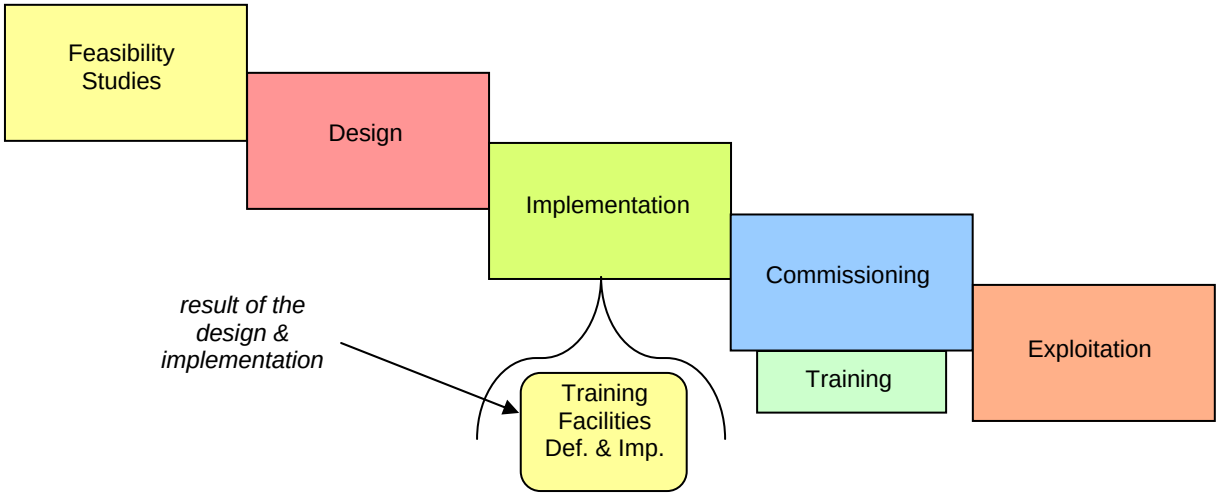

Fig. 4: Traditional System Project Development Lifecycle.

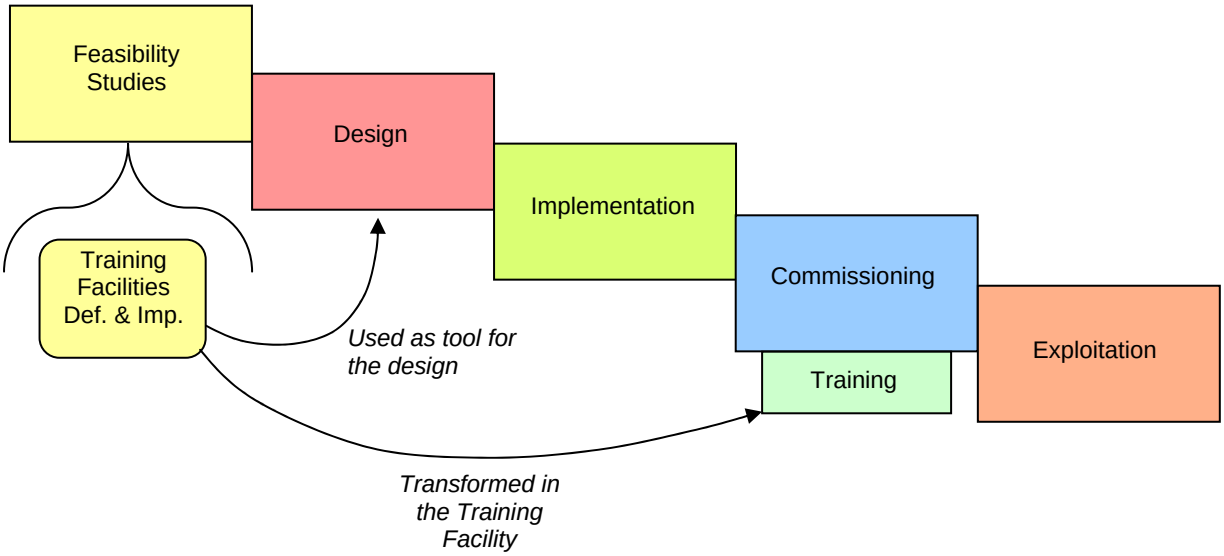

Fig. 5: Proposed Moon Base Project Development Lifecycle.

In order to accomplish with this twofold utilisation, the facility should be realised by assuring:

- modularity, in order to add progressively the prototypes of the Inhabitation Modules as the experimentations are carried out,
- flexibility and configurability, in such a way to be able to modify the lay-out depending on the results of the experimentations on the prototype structure realized until that time.

By means of this tool, a wide range of experimentations and studies could be conducted, such as, for example:

- experimentations on the structures of the inhabitation and operational modules,
- experimentations on the internal fitting of the inhabitation modules, suitable to verify the habitation needs, the ergonomic, the safeness, the security, etc.,
- Experimentations on the human behaviours in such environments.

An interesting opportunity for ASI and for the Aerospace Italian Industry

The realisation of a dual-use infrastructure, to support the design and as a facility for the training of astronauts and Moon Base inhabitants is a big opportunity for Italy, so that Italy could authoritatively candidate to have a meaningful role in the frame of the future scenarios of outer space exploration and colonisation of the Moon

The know-how and the technologies necessary for the realisation of this facility are already in possession on the Italian aerospace industry, and are a valuable starting point for their further expansion and consolidation.

As already previously mentioned, only referring to the International Space Station and to the Columbus laboratory, the Italian aerospace industry has significantly contributed both to their design and implementation and to the design and implementation of the related training facilities.

Only limiting to consider the contribution of the industrial group that I represent, i.e. Dataspazio and Datamat, Dataspazio has realised some important and central components of the Columbus Trainer, the training facility presently located at the European Astronauts Centre (EAC) in Cologne.

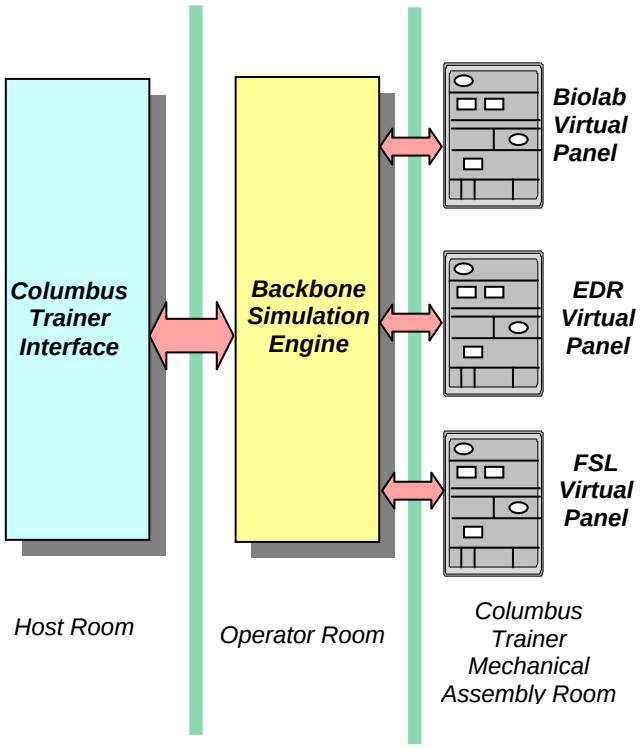

Fig. 6: Columbus Trainer Simulator Architecture.

Fig. 7: Training session with Columbus Trainer Simulators.

Moreover, for the EAC, Dataspazio is developing the simulators of the payloads of the first increment of the Columbus laboratory, i.e., the BioLab, the European Drawer Rack (EDR) and the Fluids Science Laboratory (FSL). These simulators will be used in the training sessions of the astronauts that will carry out the mission on board of the Columbus laboratory.

Such simulators have been developed by using very innovative and state-of-the-art European simulation and human-machine interfacing techniques and technologies, that have been very much appreciated by ESA.

Conclusions

In the frame of the realisation of the Moon Base and of its successive utilisation, the training of the astronauts and the training facility needed to this purpose assume a fundamental role, especially if they are conceived not only for this purpose (the training), but also as a tool for the experimentation and definition, verification and validation of the Moon Base design.

This concept, quite innovative, implies that, differently from what done in the development life-cycles of traditional systems, the realisation of this dual-use facility, i.e. support to the design and training, be carried out at the beginning of the development life-cycle.

If Italy, i.e., the Italian Space Agency and the Italian Aerospace Industry, on the base of the know-how and technologies earned in the participation to the realisation of the International Space Station and of the Columbus Laboratory, will take the initiative and will significantly promote themselves to contribute to the realisation of the facility proposed in this paper, possibly on the Italian territory, Italy will be able to continue to maintain the central role acquired since now in the international scenario and, at the same time, will be provided with a world-level excellence centre, being a reference point for the development and research activities related to the outer space exploration programmes.