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INTERIOR CONFIGURATION CONCEPTS FOR THE GATEWAY IHAB

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Abstract:
GATEWAY is planned as an international lunar-orbit space station providing a staging and technology development base for exploring the moon, Mars and other parts of the solar system. Elements such as the International Habitat (I-HAB) module are foreseen to be designed and built by European partners. The European Space Agency (ESA) issued invitations to tender for the conceptual design phases for these GATEWAY elements.

This paper focuses on the architectural aspects, the design and integration of crew systems for I-HAB within given constraints. As part of a Phase A/B study for ESA, two European industry consortia are working on two extensive parallel concept studies for I-HAB to prove the feasibility (Phase A) and develop the preliminary element definition (Phase B). One team has come together under the lead of Airbus, comprising Thales Alenia Space, Sener, Quinetiq, Space Applications Services, Crisa and LIQUIFER Systems Group to advance NASA's I-HAB layouts towards a design definition. The I-HAB will provide four astronauts for up to 30 days with life support, exercise facilities for crew health, science research facilities and stowage. Based on a preliminary set of requirements for the interior architecture, detailed 3D models depicting possible internal configurations have been developed and trade-offs conducted.

The models allow designers to understand how the various internal elements such as crew quarters, sleeping and personal hygiene facilities, exercise devices, science research containers, airlock hatches and stowage bags can best be accommodated in I-HAB. Such models are necessary inputs for performing volumetric and spatial configuration trade-off assessments for the various elements. The paper will discuss the design process and I-HAB configuration options that led to the final design requirements and recommendations.

Main design considerations are directed towards private and common spaces such as work, exercise and leisure areas. Within an overall interior volume of <50m^3 all these different programmatic functions need to be incorporated. Some of the facilities offer deployability and transformability to increase the possibilities for spatial usage and still allow the multiple pathways necessary to transition from one module to another. The I-HAB studies are considered as vital input for the European Ministerial meetings at the end of 2019 to define the next budget allocation for GATEWAY for the coming years.

I. INTRODUCTION

GATEWAY is planned as both a crewed and uncrewed autonomous space station in lunar polar orbit). The main purpose of GATEWAY is to support both astronaut and robotic exploration of the lunar surface. But its position outside of the Van-Allen belt also allows for investigation of human tolerance and testing of technology to support future deep-space missions particularly a human crewed Mars mission.

GATEWAY shall play a key role as part of the USA Artemis programme to land two astronauts on the lunar south pole by 2024; it shall be used as transfer station both for the crew heading for the lunar surface and returning to Earth. Later GATEWAY shall support four astronauts for a nominal 30-day mission performing crewed and remote robotic exploration of the lunar surface as well as autonomous robotic science and technology experiments. From 2028 a permanent crewed infrastructure is planned on the lunar surface supported by GATEWAY.

Fig. 1: The lunar orbital platform – GATEWAY: initial configuration to support ARTEMIS crewed lunar lander programme in 2024 *(courtesy of NASA)*

The NASA Space Launch System (SLS) and commercial launch vehicles such as SpaceX Falcon Heavy will be used to transport the GATEWAY elements to lunar polar orbit. Astronauts shall use the SLS and the ORION capsule for transport to GATEWAY, for transfer to the lunar landing vehicle and subsequent return to Earth.

II. INTERNATIONAL HABITATION MODULE

An international consortium under NASA leadership is developing GATEWAY with national space agencies from Canada (CSA), Europe (ESA), Japan (JAXA) and Russia (Roscosmos)

One possible European contribution is the I-HAB (International Habitation Module): I-HAB shall be the living and working module for up to four astronauts on a 30-day nominal mission. Also I-HAB shall provide docking capabilities for ORION capsules, logistics modules and lunar landing vehicles and an airlock for EVAs.

I-HAB will be an important element of a reduced GATEWAY configuration especially until planned deployment of a NASA habitation module.

The European Space Agency (ESA) has issued two parallel contracts for phase A/B studies for I-HAB led by Thales Alenia Space and Airbus Defence and Space.

II.1 I-HAB Interior Architecture Development

As part of the Airbus consortium, comprising Thales Alenia Space (Italy), Sener (Spain), Quinetiq (Spain), Space Applications Services (Belgium), Crisa (Spain), LIQUIFER Systems GmbH, Vienna, Austria, was contracted in July 2018 to develop a 3D-model of the interior architectural configuration of I-HAB. LIQUIFER has over the last 15 years been involved in international projects such as Self-deployable Habitat for Extreme Environments (SHEE), the first European foldable simulation habitat for lunar and Mars missions, or EDEN-ISS, an Antarctic greenhouse for testing new technology and plant growth for astronaut nutrition on deep-space missions.

There are many challenges and requirements in providing a crew with an optimal living and working environment to cater for their daily needs and activities. The I-HAB internal configuration has to provide adequate space under severe volume and mass restrictions for the following functions:

- Cargo storage
- Science payloads
- Private crew quarters
- Galley facilities (table, food preparation, etc.)
- Hygiene facilities (toilet, personal hygiene etc.)
- Waste management
- System boxes (CD&H, environmental control etc.)
- Internal robotic arm
- Exercise equipment
- Airlocks for transfer to other pressurized elements (one on each end of module and two radial)
- Refrigeration for food and science samples
- Water tanks
- Workstation and monitors
- External robotic arm control console

All of these functions and facilities have to be accommodated in an I-HAB interior volume of <50m^3 (September 2019).

II-II Design Requirements

Although at the start of the contract there was no formal requirements document, an overall I-HAB design concept had been agreed between ESA and Airbus. A Preliminary Requirements Review (PRR) was conducted in November 2018 followed by a consortium internal design meeting in March 2019. The System Requirements Document was released by ESA in July 2019 (REF. 1) based on NASA system requirements for GATEWAY. The architectural design development has concentrated heavily on regular teleconferences between LIQUIFER and AIRBUS regarding requirement interpretation and incorporation of requirement changes.

The main factor driving the I-HAB interior architecture is the overall interior dimensions, volume and mass that have been determined by the launch vehicle capabilities. Initially I-HAB was to be launched by SLS allowing for a launch mass of 8000 kg, a module internal length of 6.6 m and an inner diameter of 4.2 m the latter being determined by the SLS payload shroud dimensions (Fig. 2). Subsequently the SpaceX Falcon Heavy has been proposed as an alternative launch vehicle. This has further constrained the I-HAB to an inner diameter of 3.4 m due to reduced payload shroud dimensions and the need to accommodate the docking targets for the radial docking ports. Also the use of the Falcon Heavy requires that I-HAB be launched in tandem with the service vehicle for manoeuvring to lunar orbit; to accommodate both elements on Falcon Heavy requires the I-HAB module length to be reduced to 5.9 m (Fig.2).

Fig. 1: I-HAB module in SLS (*left*) and SpaceX Falcon Heavy (*right*) payload shrouds. (*© NASA/ ESA)*

A further constraint is the requirement for I-HAB to accommodate both axial airlocks to other GATEWAY pressurized elements as well as two radial airlocks for cargo vehicles and lunar landing vehicles. Both axial and radial airlocks require overhead space for the open hatch doors.

Other design drivers to be considered are:

- Separation as far as possible of crew hygiene facilities from food preparation and consumption.
- Assuring a permanent 810 mm by 1140 mm emergency egress translation path for crew.
- Separation of crew work area and living quarters.

II-III Modelling Tools

The I-HAB internal architecture model was developed using the Rhinoceros 3D software package. Model inputs/outputs were exchanged with AIRBUS in STEP format.

AIRBUS also developed an I-HAB 1:1 mock-up to support the architectural design process.

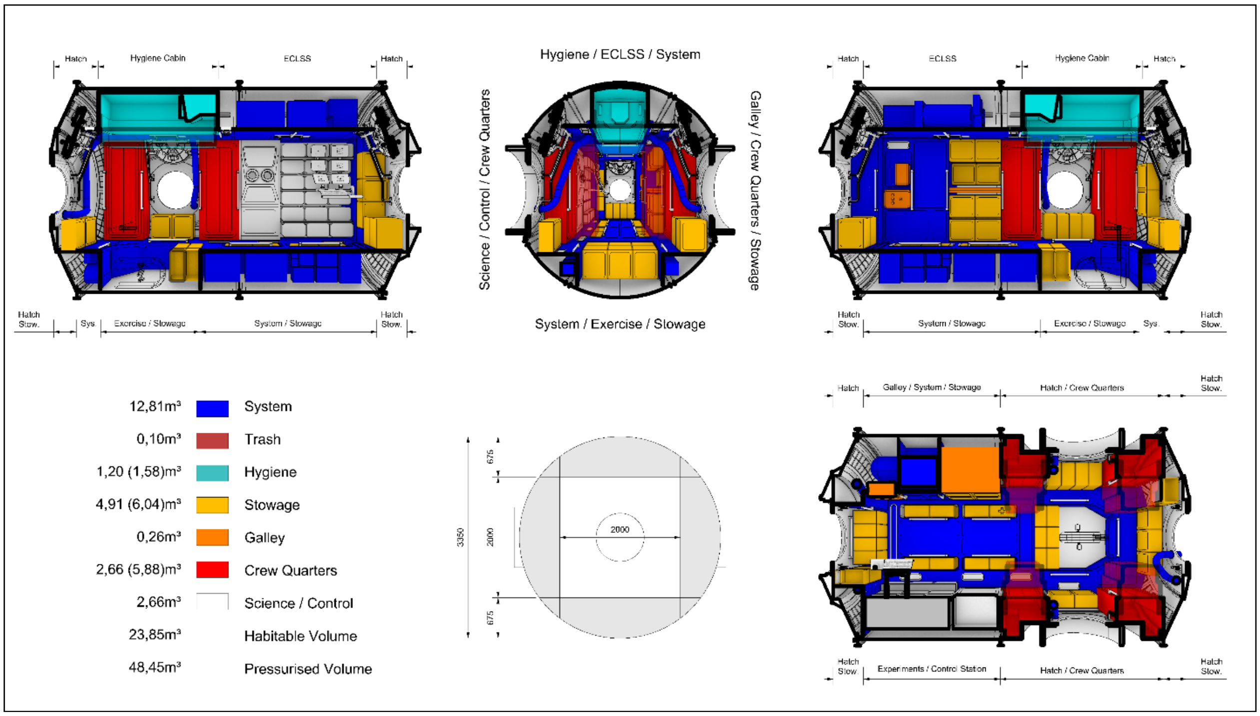

Fig. 3: Proposed I-HAB interior architecture (overall module dimensions compatible with Falcon Heavy payload shroud) (credit: Airbus DS, LIQUIFER Systems Group, visualisation: *LIQUIFER, 2019)*

II-IV I-HAB Interior Architecture Layout

The concept presented in this paper is a status report and does not represent the final and approved version submitted to ESA. The current design is a preparation for the final ESA review of phase A, B1 and will be finalised at the end of 2019.

Fig. 3 shows the proposed I-HAB internal architecture. It successfully fulfils the design requirements discussed previously by implementing some novel solutions to key elements such as crew sleep and privacy quarters.

It should be noted that the design has been developed considering crew needs. The design process was based on developing space and function diagrams that allocate the internal module volume to the different functions such as system, science, sleeping, hygiene, galley etc. The mass of individual components has not been considered. Hence some changes may be needed in the final architecture design to keep the overall module mass to 8000 kg.

The following provides more detail of the how specific crew needs have been incorporated in the proposed design.

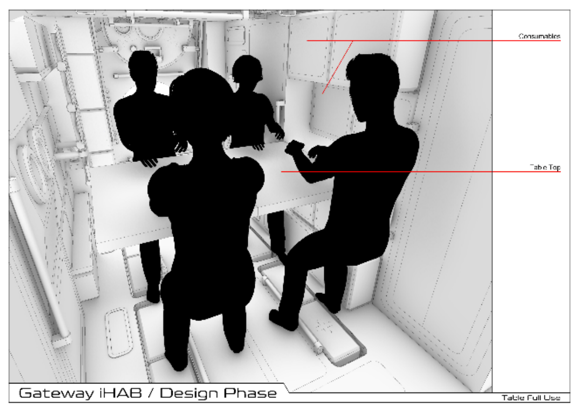

Fig. 4: Crew dining and food preparation area: retractable table fully deployed for 4 crew (credit: Airbus DS, LIQUIFER Systems Group, visualisation: *LIQUIFER, 2019)*

The crew galley facilities include a foldable table that provides space for 4 crew jointly during meals (Fig. 4). When not required the table can be fully retracted.

Crew sleeping quarters have been placed on either side of the radial airlocks (Fig. 5). First design analysis of crew sleep stations and related activities demonstrated that all requirements regarding crew quarters can be fulfilled.

A deployable sleeping facility is therefore proposed that can be retracted from its deployed volume of 1.47m^3 to 0.67 m^3 when not needed thus providing free space around the radial airlocks.

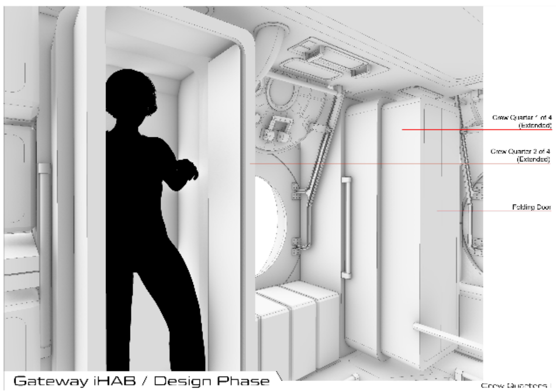

Fig. 5: Deployable crew sleeping quarters (credit: Airbus DS, LIQUIFER Systems Group, visualisation: *LIQUIFER, 2019).*

The toilet facility is housed in an overhead container between the radial hatches (Fig. 6). This position is as far away as possible from the food preparation and eating facilities given the constrained volume in I-HAB.

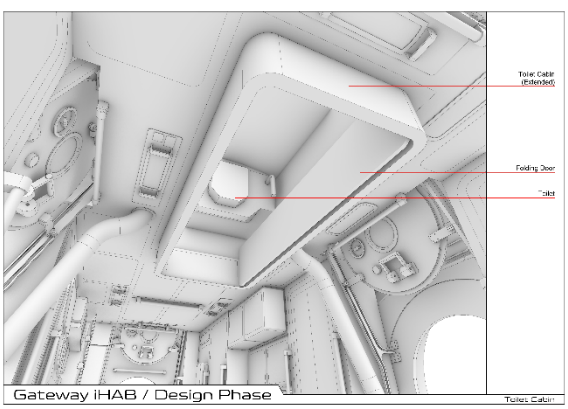

Fig. 6: Toilet facility in overhead position (credit: Airbus DS, LIQUIFER Systems Group, visualisation: *LIQUIFER, 2019)*

The crew exercise device is housed in the centre aisle sub-floor between the radial airlocks (Fig. 7). The position in the sub-floor allows that the exercise facility can always be used though it can be dismantled and stowed if required.

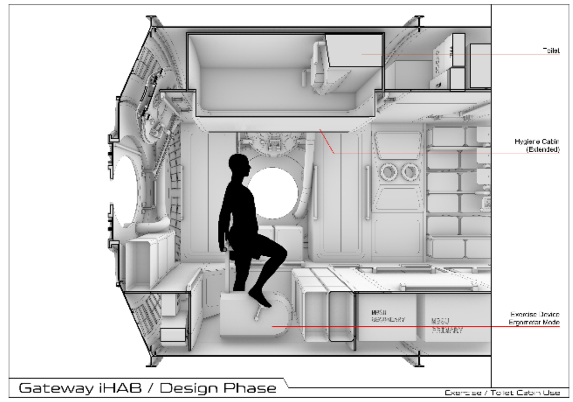

Fig. 7: Crew exercise equipment in I-HAB aft section sub-floor (credit: Airbus DS, LIQUIFER Systems Group, visualisation: *LIQUIFER, 2019).*

The crew work area is dedicated to science equipment boxes, work console, glove box and refrigerator (Fig.8).

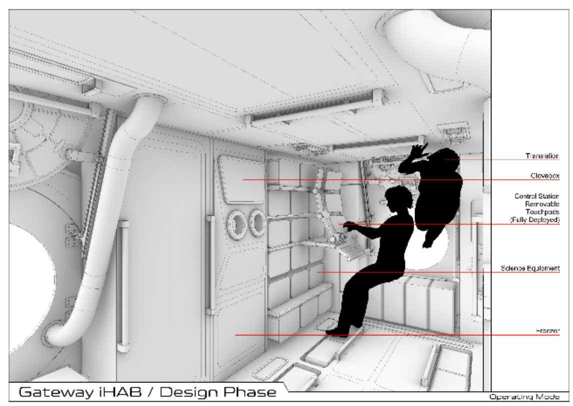

Fig. 8: Crew work area science facilities (credit: Airbus DS, LIQUIFER Systems Group, visualisation: *LIQUIFER, 2019).*

Placement of stowage containers so that they are easily accessible to the crew is an important design driver. The design presented here foresees 5-6 m^3 of stowage volume, up to 32 single Cargo Transfer Bags (CTBs) in fore section and (Fig. 9) and 29 CTBs in the aft section (Fig. 10).

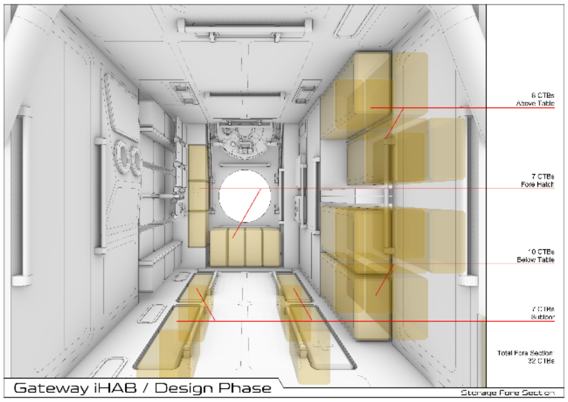

Fig. 9: Stowage volume for up to 32 single CTBs in fore section (credit: Airbus DS, LIQUIFER Systems Group, visualisation: *LIQUIFER, 2019).*

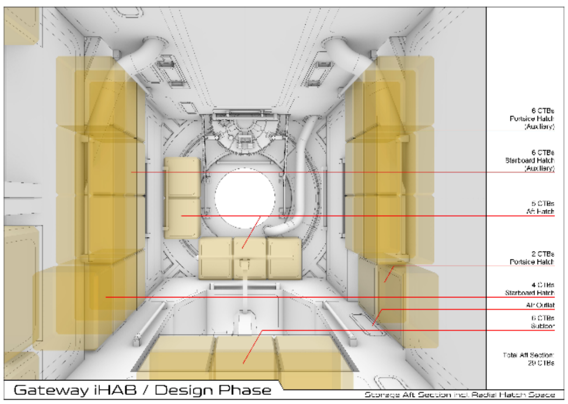

Fig. 10: Stowage volume for up to 29 single CTBs in aft section (credit: Airbus DS, LIQUIFER Systems Group, visualisation: *LIQUIFER, 2019).)*

An important safety requirement for I-HAB is the need for an 810 mm by 1140 mm diameter emergency crew transfer path at all times in the module. This means that even when systems re deployed such as crew sleep quarters and galley table for example, an emergency egress path is assured as shown in Fig- 11.

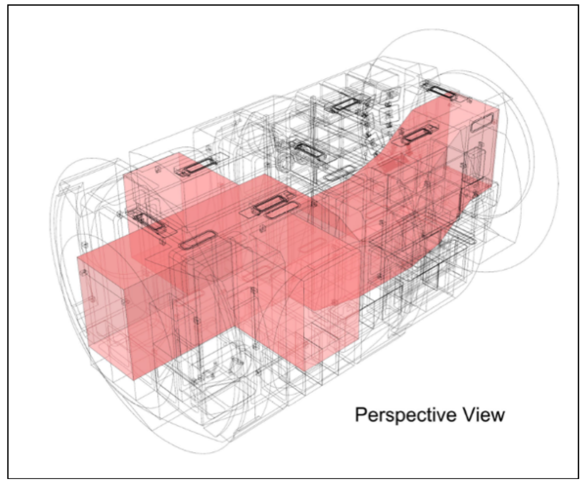

Fig. 11: Crew emergency egress translation path for all fully deployed facilities (credit: Airbus DS, LIQUIFER Systems Group, visualisation: *LIQUIFER, 2019).*

II-V Additional options

ESA in collaboration with European industry will investigate an optional window > 20 inch (51 cm) to be used by the crew for both recreational and educational needs. The window shall be lunar facing and can also be used by the crew to observe vehicle-docking operations. Other options to study include two windows, one lunar facing and the other Earth facing.

The design presented here does not include this option at present. A window has a major impact on the overall I-HAB structure both with respect to mass and structural integrity. Also a window(s) would reduce the scope for integrating all the crew needs reflected in the design presented here. One possible current position for a window is in the area of the exercise facility.

III Conclusion

The current preliminary design will be evaluated by ESA and amendments will be included by the end of the year. 2019. In the next development stages, ESA and NASA with industry will finalise requirements and make alterations if necessary. The final configuration is still to be decided and the current investigations into the details of astronaut activities displaying their life on Gateway will help to design the next phases in the progress of the project.

Gateway presents the next international cooperation to build a space station that can cater to landing humans on the moon, this time at any preferred destination. Further Gateway allows to test technologies for a future travel to the Martian surface and apply lessons learnt from ISS. This also incorporates a new focus on habitability and human factors which makes the work undertaken by Airbus and LIQUIFER especially relevant. There was no strong focus on issues of space architecture when building the ISS since the original habitation module did not get built due to financial drawbacks.

NASA is currently preparing a Memorandum of Understanding (MoU) between NASA and the other ISS partners, to define their future collaboration in addition to ongoing important budget negotiations in all partner states.

The next step from the European side has been already introduced by ESA through issuing an Invitation to Tender (ITT) for the planning phases B2 to E1 which includes detail design, implementation and on-orbit commissioning

ESA will be committed to continue the work on Gateway which has already started years ago.

IV References

REF. 1. I-HAB Phase B2/C/D/E1 System Requirements Document – Draft, ESA-DSG-HAB-RS-0001, dated 17/07/2019.