BOEING/SICSA PROPOSAL FOR THE NEXT DEEP SPACE GATEWAY

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ConOps	Concept of Operations
ECLSS	Environmental Control Life Support System
DSG	Deep Space Gateway
ISS	International Space Station

Final Assembly - Habitat - Airlock - Node Hab - Bus

Start	Task	Duration (minutes)	Module	Location	Automatic task	Tools used
6:00	Waking up	10	Habitat	Sleeping space	Adapative LED lighting - Alarm clock	Speaker-LED light-Storage
	Dressing up	25	Habitat	Personal Space		Storage
	Toilet break	10	Node/Hab	Waste compartment		
6:40	Breakfast	50	Habitat-Node/Hab	Galley/Personal space		Microwave-Water distributor-Kitchen tools
	Conference	15	Habitat	Personal Space/Wardroom		Camera
	Experiment	150	Habitat-Node/Hab	Depends on the task		
	Weekly Housekeeping	150	Habitat-Node/Hab	Depends on the task		
	Exercise	60	Node/Hab	Work-out space		Bike
	Shower	10	Habitat	Personal space/Waste compartment		Water distributor - Storage
13:00	Lunch	60	Habitat-Node/Hab	Galley/Personal space		Microwave-Water distributor-Kitchen tools
	Experiment	150	Habitat-Node/Hab	Depends on the task		
	Weekly Housekeeping	150	Habitat-Node/Hab	Depends on the task		
	Exercise	60	Node/Hab	Work-out space		ARED
	Shower	10	Habitat	Personal space/Waste compartment		Water distributor - Storage
	Conference	15	Habitat	Personal Space/Wardroom		Camera
	Diner	60	Habitat-Node/Hab	Galley/Personal space		Microwave-Water distributor-Kitchen tools
	Free time	120	Habitat	Personal space/VR space		VR set-Personal storage-EVA
21:30	Sleep	510	Habitat	Sleeping space		Speaker-LED light-Storage
	Total	925				

Figure 1: One day inside the DSG

- Introduction

This project is built upon the research and studies done at SICSA and Boeing. The number of modules is fixed as is their diameter and length, based on heritage technology and current launcher technology. The general diameter of each module except for the power module is around 4.5 meters. The maximal length authorized for the habitat module is 8 meters, trade-studies were conducted to evaluate the right length. The conclusion of those comparisons were that in order to provide the minimal private habitable space and accommodate some space for experiments, 8 meters long was the best choice. The con-ops were developed based on ISS standards and was adapted to the new configuration of this station. The habitable volume per crew is smaller than on the ISS, going from 60 cubic meters to 20. This new confined space requires new accommodations and new techniques. This paper will explore those techniques and the decisions required.

- Design Intent and approach

For the Boeing/SICSA DSG proposal, the goal was to come up with an alternative design for the interior of the space-station, to optimize habitability and functionality. To achieve these goals, it was important to learn about the different studies that have been conducted [1] on the same subject. After an analysis phase, the next step was to reconfigure the different elements in a more compact and pleasing way for the crew, the emphasis was put here on the notion of separation to increase the sensation of privacy and reduce the possibility of social exasperation which occurs in every long-term mission done so far. The technical aspects of the project for the storage of consumables or the way heat rejection and the recycling of the atmosphere will be dealt with actual knowledge based on the experience gained with the ISS [2].

The ISS was designed with modularity in mind, the rack system was designed to be removed and replaced on a regular basis, the renewal of equipment was not an important factor here as most of the scientific equipment will be already installed. Small changes and movement will probably occur but the conception of the station is based on fixed systems.

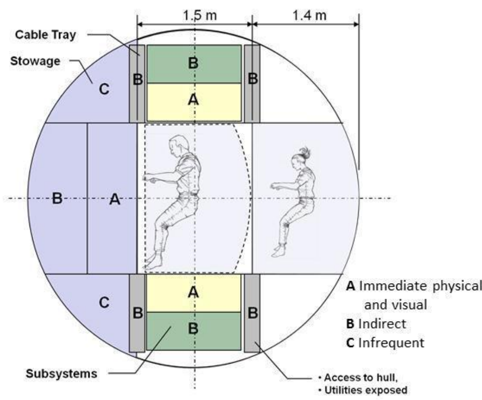

Figure 2: Organization of the Nod/Hab module [1].

- Vision, Mission, Goal and Objectives

As mentioned previously, the goal of separating inside the habitat module the different activities was done to induce a sensation of privacy to the crew. How can we provide a space built for efficiency while at the same time procuring a generous personal space for each crew during the day?
Separate each activity by physical and visual division and divide the experiment area by workstation instead of having one general common area.
The objectives of such a project is to achieve a visual division between each space while at the same time having a continuous seamless experience of impeccable interior design that is geared at the well-being of the crew based on simple lighting and perception principles.

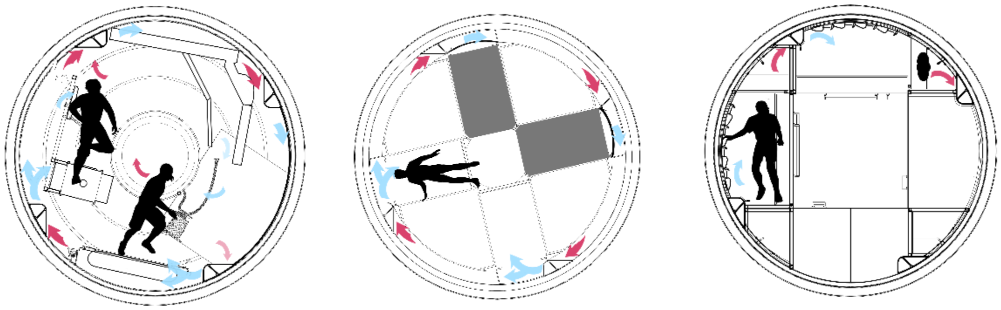

Figure 3: Space organization of different areas

- Design Assumptions & Requirements

A general clearway was built to guarantee the crew a way to escape danger and an easy circulation between different areas and modules. The diameter of that clearway along each module and at each intersection is slightly superior to the interior diameter of the international port standard, around 85cm wide. This first assumption will drive most of the organization of the module.
The quantity of consumables is expected to extend the duration of the mission to 300 days at max with 4 crew members, therefore the internal volume of the space-station is supposed to accommodate 11.3 cubic meters of consumables, assuming a 90% rate of water recycling (clothing=1.20m^3, water=1.60m^3, food=8.5m^3) This space is not considered habitable and will need to be changed during the mission as some of these consumables will be changed to trash.
Inside pressure and air composition will be very similar to the ones on the ISS (14.7 psia / 75kpa, 21% 02 78% N 1% CO2).
This DSG will have to simulate and experiment with different scenarios that might happen during a long transit to Mars and during a possible orbit around this planet [3].
Radiation exposure will also be an issue, polyethylene tiles 2” thick will be considered for the crew quarters.
Power and avionics will be provided by other modules, the power module and the Node/Hab.

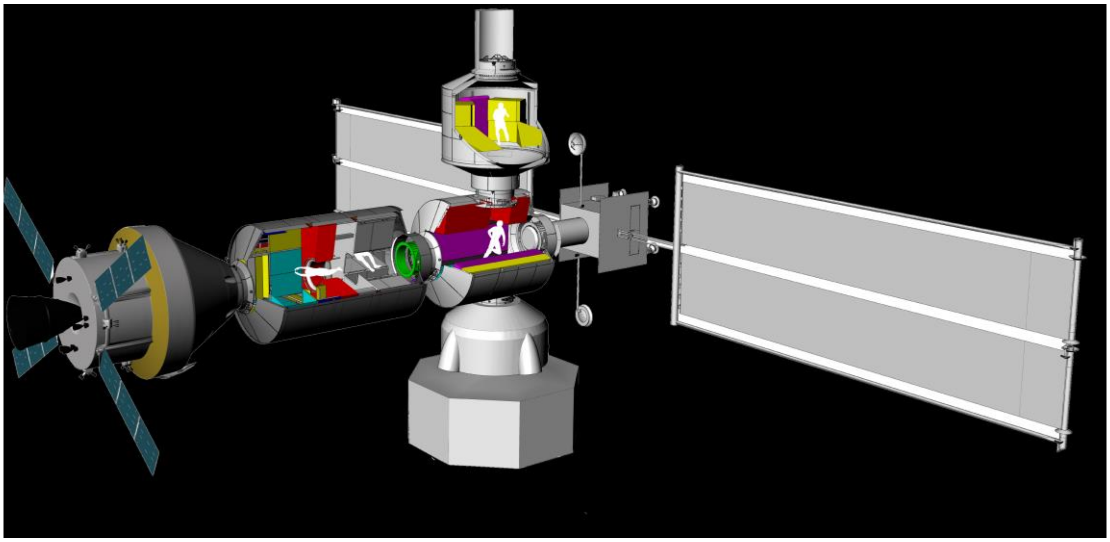

Figure 4: General layout of the DSG

- Overview of Research, Analysis, and Design

This project is slightly different as the inclusion of a RECLSS system was not possible since the delays in research & development could not permit such an installation. The study was then strictly focused on mechanical ECLSS systems and therefore, Molly Anderson's input was extremely valuable. It brought precise sizing for the recycling mechanism and exact amount of storage for consumables, predictions based on her research assume a 90% recycling rate for water as mentioned previously. Food and water storage were also considered as was the preparation, the difference between dry-mass and the need to bring water to those portions was a valuable lesson for the availability of water dispensers and also the way exercises should be done and the logistic around it. The idea of having a unified and centrally located ECLSS system paired with the waste management system and in direct proximity of the exercise area came around after considering the amount of pipes and systems needed to convey water and human waste to the systems.
Therefore, a central donut-shaped system was devised to ensure the simplicity and centrality of the systems for the habitat module of the deep-space gateway.
Air circulation was also very important to the design of the sleep-pods, as Molly Anderson explained to us, the presence of dead zones (no air-flow) can be extremely dangerous for the crew and careful consideration was then taken to ensure a regular movement of air throughout the crew quarters.

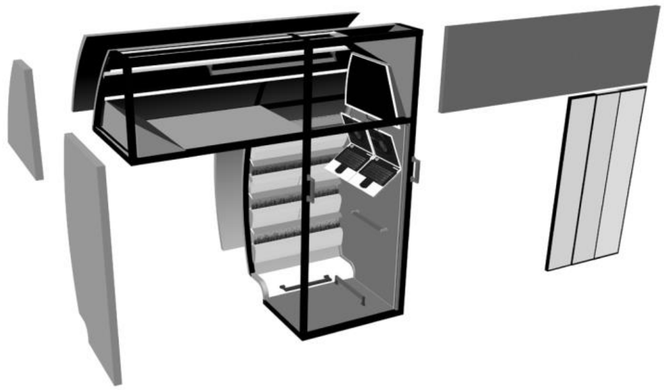

Figure 5: Division of the crew quarters in two distinct areas

- Design parameters and details sufficient to convey the concept

Surfaces in the exercise area will be coated in a reflective material that also prevents the development of bacteria and fungi. Reflectivity will be important in the general design of the habitat as it allows the brain to imagine the space as being bigger.
The crew quarters will have a central space for gathering and handling of personal storage, each crew quarter's will be 4 cubic meters. These crew quarters will be divided, giving the crew a real sleep area free of visual reminders of their working schedule. The other area will serve a dual purpose, it will be used as an entertainment space with private gardens and spaces for laptops and tablets. The other use of that division will be for dressing and personal care with a wide mirror and a storage space. Each opening for the crew quarters will direct to a personal storage space instead of another door, increasing the sensation of personal space.
Personalization of one's quarter will also be important, the possibility to choose a coating for your front door will bring the crew satisfaction. The experiment area will feature 4 different areas with a central circulation space, allowing access to 2 out of 3 sides of the experiment racks. Enabling better configuration and better wiring, preventing clutter in the central area. The disposition of electric wiring will happen behind the experiment racks to prevent visual discomfort, rejection of the heat coming from the experiment will be handled by convection, preventing the quantity of pipe and the possible perforation of such pipes by incoming objects.
One of the design goal was to have access to the hull in case some reparation was necessary.

Figure 6: Inside the exercise area

- Conclusion

This study, after exploring new organizations, new secondary structure and a new heat transfer system, concludes that it is possible to divide the inside of a small module by using new systems and pre-installed components.

An optimal location of sleeping areas and sport equipment along the distribution lines of fresh and polluted air was the main factor for the way spaces are arranged, each area being almost independent in their settings and therefore their requirements. A division seemed the natural way to arrange the interior. Those two requirements, distribution of air and division of activities is the main factor for the general design of the station and ended up with a satisfying combination of rigid requirements with a pleasant livable space.

- References

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