**Lyndon B. Johnson Space Center**
Houston, Texas 77058

# Technical Support Package

## Design Concepts for the ISS TransHab Module

NASA Tech Briefs
MSC-23090

National Aeronautics and
Space Administration

# Technical Support Package

for

## DESIGN CONCEPTS FOR THE ISS TRANSHAB MODULE
## MSC-23090

*NASA Tech Briefs*

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**Report A**

# BIO-PLEX HAB CHAMBER RECONFIGURABLE OUTFITTING CONCEPT

## BRIEF ABSTRACT

Reconfigurable interior outfitting system for the NASA/JSC B10-Plex Hab Chamber, to support habitability studies in all planned human-rated Advanced Life Support Tests.

## SECTION I – DESCRIPTION OF THE PROBLEM OBJECTIVE

### A. General Description of the Problem

A concept was required which would support optimum habitability for a crew of four during the Advanced Life Support tests in the BIO-Plex for periods of 120 days, 240 days, and 425 days.

### B. Key Problem Characteristics

1. Programmatic allotment of activity centers necessary to support good habitability in this facility was not known;

2. BIO-Plex is an Advanced Life Support testbed; therefore, all ECLSS systems are in development and at a very low level of maturity, so facility architecture must plan to accommodate changing or expanding systems H/W;

3. All habitability and support functions must take place within a horizontal cylinder, 15 ft (4.52 m) in diameter and 36 ft (11.27 m) long, in 1-G — this configuration is inefficient for a single-level plan, and very restricted for two levels;

4. Basic HE requirements must be met, including accommodation of the 95th percentile male; and

5. Activities to be accommodated included: food processing and preparation (ALS menu), sleep quarters for 4 crew; personal workstations for 4 crew; personal hygiene; personal waste management; facility oversight center; dining; conferencing/group work; up to 2 $m^3$ storage; robot recharging station; socializing and recreation; exercise.

## C. Prior Art

Prior an was unacceptable for socialization, inefficient use of volume, and awkward to use (ref. LMSMSS-32517, “Human Factors Evaluation of the Bio_Plex Habitation Chamber”).

# SECTION II – TECHNICAL DESCRIPTION

A structural system was devised whereby all habitability functions could be accommodated on two levels, with allowance for reconfiguration of the HAB in between tests.

## A. Description

The purpose of this was the following:

1. To permit habitability testing to take place during the human-rated ALS tests, so as to determine what allotment of private/public volume (“program”) would be preferable for a long-duration habitat;

2. To permit limited reconfigurability by the crew while resident; and

3. To allow for systems changeout and modification.

## B. Method

1. All outfitting was designed to a base module of 90 cm to permit flexibility in interior organization;

2. Secondary structures were planned to permit variable stair options and placement with minimum loss of usable volume;

3. Exercise was moved to the lower level of the LAB, near the utility center, to separate the noise of this activity from the HAB functions and to colocate it with laundry and hygiene facilities;

4. Two basic plans were developed for the first two tests, with strong variance in relative amounts of private and public space.

## SECTION III – UNIQUE OR NOVEL FEATURES

Novel or advantageous features of this innovation include:

1. Outfitting system and structures maximize the use of this volume chamber by a crew;

2. All levels and units are designed to optimize habitability;

3. Units highly volume-efficient;

4. Reconfigurability allows one facility to be used for multiple tests;

5. Saves costs and time over operational lifetime by designing for chamber retrofitting; and

6. Facility has added flexibility BY DESIGN.

## SECTION IV – POTENTIAL COMMERCIAL APPLICATIONS

Potential commercial applications include:

- Private aircraft outfitting;
- Commercial or charter aircraft (changing functions);
- Containerized housing;
- Outfitting for tour buses (sports teams, music groups); and
- Emergency relief shelters.

**Report B**

## TRANSHAB PHASE TWO LAYOUT: CONFIGURATION CONCEPT DEVELOPMENT

### BRIEF ABSTRACT

The three-level "vertical" configuration of TransHab was developed to meet and exceed habitability, systems and H/W requirements.

## SECTION I – DESCRIPTION OF THE PROBLEM OBJECTIVE

### A. General Description of the Problem

The main objective was accommodation of a complex set of habitability requirements along with basic systems requirements in a unique inflatable architecture.

### B. Key Problem Characteristics

Specific problems included:

1. Accommodation of the 95th percentile male crewmember within private crew quarters in a radiation-shielded environment;

2. Provision of translation paths that permit internal translation of ISS-type racks or other large equipment;

3. Provision of discrete activity center for: exercise, wardroom/conferencing, crew sleep quarters, galley, full-body cleansing and personal hygiene, and telemedicine;

4. Isolation of all life-support machinery in an accessible volume;

5. Accommodation of stowage; and

6. Provision of Earth-viewing windows in both exercise and wardroom areas.

### C. Prior Art

Prior technique had been rack-based functionality in a single-volume ISS-type HAB module.

### D. Disadvantages

Disadvantages of the ISS-type HAB include:

1. Inability to separate functions by activity;

2. Need to stow/deploy activity-related equipment for rack translation;

3. Insufficient height for crewmembers above the 89th percentile in racks;

4. Difficulty of meeting acoustic requirements;

5. Colocation of exercise with wardroom, hygiene and sleepstations; and

6. Impossible to locate group activities outside of the main path of translation.

## SECTION II – TECHNICAL DESCRIPTION

The innovation consists primarily of developing a three-level internal configuration for the ISS-TransHab in such a way as to permit the following:

1. Separate or discrete volumes (or "rooms") for different types of activity on board;

2. All activity centers are situated outside of the main path of translation and are dedicated: stowage and redeployment of equipment is not necessary for their use;

3. Mechanical equipment is launched with the vehicle, mounted to shelves which are relocated to the second level on orbit to become "walls" within an enclosed, acoustically-isolated area of fully accessible dimensions;

4. Exercise is located in a discrete and dedicated area adjacent to the personal hygiene station but acoustically and physically separated from other functions — with sufficient height for comfortable use of exercise equipment (two pieces) and an Earth-viewing window;

5. Wardroom and galley area are collocated on Level One, capable of accommodating ISS galley hardware and seating up to 12 crewmembers (full ISS and Shuttle crew) at a permanent table, and situated in their own volume with a 14-ft clear height and an Earth-viewing window;

6. Crew sleep and personal quarters are located inside the core within a radiation-shielding water tank, outside the main path of equipment translation, with a clear height of 7'-0" (accommodates the 95th percentile male); and

7. Over 800 cubic feet of stowage is accommodated in fully visible, fully accessible array of standard stowage units on Levels 1 and 3.

## SECTION III – UNIQUE OR NOVEL FEATURES

TransHab's layout constitutes a new paradigm in space architecture. It is launched in a minimized, cylindrical package and is then inflated and reconfigured on-orbit into a complex, three-level habitat which supports a wide array of functions. It is the first human rated vehicle to provide:

1. Full-height crew quarters;

2. Radiation shielding on crew quarters, which can also serve as a safe-haven area during solar particle events; and

3. Dedicated areas for all private, personal and group activities; and

4. Centralized area for critical machinery, separate from living/working quarters.

## SECTION IV – POTENTIAL COMMERCIAL APPLICATIONS

1. Possible applications to future commercial space vehicles and other facilities; and

2. Possible applications to design of temporary or transportable housing.

**Report C**

# TRANSHAB INTERNAL CONFIGURATION CONCEPT: VERTICAL STACKING

## BRIEF ABSTRACT

This internal configuration concept greatly increased the usability, habitability, and efficiency ratio of the TransHab vehicle by offering adjustments to the dimensions of the proposed spacecraft and an axially-oriented internal layout which used subsidiary launch structures to create a three-level environment with discrete, dedicated activity centers.

## SECTION I – DESCRIPTION OF THE PROBLEM OBJECTIVE

### A. General Description of the Problem

The problem was how to render the proposed TransHab — an inflatable shell mounted on a central core structure — useable as a human-rated habitation module for microgravity.

### B. Key Problem Characteristics

A radically different architecture had to be developed than had been applied in previous spacecraft. The outfitted TransHab had to have the ability to provide:

1. Useable functional areas for dining, conferencing, exercise, hygiene, galley, medical services, and crew personal/sleep stations for a crew of four to six;

2. Standard habitability in conformance with NASA-STD 3000 and established lessons learned: a single local vertical, accommodation for crewmembers ranging from the 5th percentile Japanese female to the 95th percentile American male, accessibility to maintenance areas, and appropriate acoustic environment (including separation of group activity centers from areas dedicated to private and personal activities);

3. Radiation shielding for the crew; and

4. Capacity for all outfitting to be packaged inside the core during launch, and reconfigured on orbit to final configuration.

## C. Prior Art

The prior concept for a layout to meet these requirements was a set of four partitioned areas pinwheeled about the core, each one having its own local vertical orientation, a consistent quarter-round cross-section, and only a small segment of available core structure for attachment of equipment. This layout was highly unsatisfactory in that it met structural requirements but provided volumes of low efficiency in useable volume ratio, multiple local verticals, no discrete area for containment of essential machinery or hardware, no core pass-through. It also required considerable subsidiary structures in order to mount any hardware or large outfitting elements in a manner which would be acceptable for regular use. Finally, due to the volumetric inefficiency and the geometry of its available areas, it was impossible to meet all functional requirements for a HAB with this configuration.

# SECTION II – TECHNICAL DESCRIPTION

The vertical layout centralized the vehicle around its core axis, using bipartite core fairing on light struts to create a three-level plan which a single orientation. Thus, large equipment could be mounted directly to the preexisting core structures, and all interior volumes rate increased usability because they are vertical in the plane of the crewmember, and in a plane which is consistently parallel to the vehicle's core axis.

In addition, basic dimensions were proposed for a central pass-through (32" min.) and for the optimal core-to-shell distance (7'-0"), so as to optimize restraint, mobility and usability of the vehicle.

Overall, this layout features:

1. Allows room to translate through the core;

2. Separate "rooms" are created between the core and shell on different levels for optimal accommodation of specific activities;

3. All Hab functional requirements are met;

4. Systems hardware can be installed in its original packaging and designed orientation without elaborate subsidiary structures; and

5. Sections can be created within the habitable volume for-separate accommodation of personal or private activities or for isolated accommodation of mechanical equipment.

## SECTION III – UNIQUE OR NOVEL FEATURES

This layout led directly to the development of the TransHab as a unit which has the highest habitability rating of any spacecraft proposed. This is true in part because it incorporates the following unique features:

1. Activity centers are dedicated (do not require stowing or deployment of equipment for use);

2. All major translation follows a path separate from (but with access to) the activity centers;

3. Wardroom can accommodate the full crew at a single, permanent table so as to support group cohesion as well as conferencing and other team activities;

4. Floor-to-floor and core-to-shell dimensions were determined by human engineering requirements and recommendations for accessibility, usability and translation;

5. A minimum amount of pressurized (gross) volume is lost to inaccessible geometry; and

6. Layout is consistent with terrestrial architecture analogs and so helps reduce SAS-related confusion and maintains a high level of productivity.

## SECTION IV – POTENTIAL COMMERCIAL APPLICATIONS

1. Broad potential application in future design of flexible, multi-use human-rated spacecraft;

2. Limited potential application and design and development of transportable, reconfigurable terrestrial habitats or other temporary structures for extreme environments.

**Report D**

# ISS TRANSHAB CREW QUARTERS OUTFITTING CONCEPT AND PERSONAL UNIT DESIGN

## BRIEF ABSTRACT

Outfitting concept and of outfitting elements for TransHab personal Crew Quarters.

## SECTION I – DESCRIPTION OF THE PROBLEM OBJECTIVE

### A. General Description of the Problem

Outfitting of six TransHab personal crew quarters for easy assembly and optimal habitability.

### B. Key Problem Characteristics

1. Provide maximum acoustic separation between functional units;
2. Workstation must be useable by full range of crew;
3. Sleep restraint must be useable by full range of crew;
4. Irregular, tetrahedral shape poses potential difficulties for performance and optimization of volume;
5. Workstation requires integrated power and data connections;
6. Flexibility of use for different operations: personal work and other activities, stowage, sleep, donning and doffing of clothing;
7. Maintain positive/negative air flow;
8. Integrate stowage compartments for microgravity access of individual items; and
9. Support attachment of ISS-standard equipment.

### C. Prior Art

None applicable. Skylab Orbital Workshop Crew Quarters had fixed stowage lockers and sleep restraints, with unsatisfactory habitability ratings. ISS Crew Quarters not yet designed.

## SECTION II – TECHNICAL DESCRIPTION

The Crew quarters outfitting is all attached to six launch shelves in the Level 2 core area, which are reconfigured on orbit to a hexagonal pattern. Sleep restraints are fastened to one shelf; opposite them, a personal unit made up of two primary subassemblies — a vertical element (A) and a table element (B) — is mounted in the corner. The personal unit accommodated the cabling for Data and Power supply, mountings for seat-track to attach laptop or other ISS crew equipment, caution and warning hardware, and stowage niches for personal items. Ergonomic table element is shaped to accommodate laptop or handwriting or other work materials and human engineered for maximum usability with minimum impact on available volume.

## SECTION III – UNIQUE OR NOVEL FEATURES

### A. Novel or Unique Features

1. Acoustic separation between functional units is effected by application of absorbent material panels to the inside of the launch shelves, and by staggering the placement of sleep restraints and workstations so that only one crewmember is sleeping on any one shelf;

2. Workstation is set at an angle to the main volume so as to allow 42 in. clear at elbow level (neutral-body posture) to accommodate use by the 95th percentile male;

3. Sleep restraint is attached vertically to a full-height launch shelf, with 7’-0” clear height maintained;

4. Vertical workstation element is parallel to sleep restraint, so that awkward corner space is minimized, and a perception of regularity is restored to the room;

5. Integrated power and data connections are designed into the back of the workstation vertical element, bringing the cabling down from the supply soffit overhead without exposing the cables;

6. Shape and location of the workstation vertical and table elements maximizes use of the volume and leaves a central volume clear for various activities, while allowing for flexible use of the table;

7. Positive air flow is ducted from the upper outer edge of the Crew Quarters, and air return grilles are located in the door component at the lower outer wall;

8. Individual items can be stowed in and easily retrieved from small niches embedded in the workstation vertical element; and

9. Hard mounts for seat track are provided on the vertical workstation element and on the sleep-restraint shelf for accommodation of ISS-standard equipment.

## SECTION IV – POTENTIAL COMMERCIAL APPLICATIONS

Some potential may exist for commercial application in a broad range of transportable habitats or in facilities which must be reconfigurable and serve a variety of functions; in aircraft; and in commercial space vehicles.

## Report E

# ISS TRANSHAB LEVEL 2 INTEGRATED SOFFIT DESIGN

## BRIEF ABSTRACT

Design for preintegrated local-area utility distribution in TransHab Crew Quarters cluster (Level 2).

## SECTION I – DESCRIPTION OF THE PROBLEM OBJECTIVE

### A. General Description of the Problem

The objective was to design a single, preintegrated architectural element which provides utilities to the core area of Level 2.

### B. Key Problem Characteristics

The particular problems in meeting this objective consisted of the following:

1. Provision of air supply in both vehicle configurations (launch configuration, and assembly configuration);

2. Housing for power and avionics cabling;

3. Integrated housing for lighting at optimal angle form nonreflective light delivery;

4. Provide thermal attenuation for Solid-State Lighting fixtures;

5. Support easy accessibility to all utilities for maintenance;

6. Consistent profile for easy housekeeping and human engineering;

7. Must support vehicle reconfiguration on-orbit;

8. Minimal “cut” in core-located launch shelves; and

9. Minimal use of subsidiary hardware.

## SECTION II – TECHNICAL DESCRIPTION

A single unit is built in to the inner wall of the water tanks in the Level 2 core area of the TransHab. This soffit unit consists of two subassemblies, the duct assembly (A) and the cabling assembly (B). The duct assembly consists of a 1/8-in. thick panel with 1-in. interior insulation, attached at top to the CQs upper closeout ("ceiling") and at side to the water tank inner panel. Insulation continues in this area around the closeout and water tank panel, so that a fully-insulated 5-in. diameter opening is provided at center for air supply. The outer edge of this assembly, facing the open volume of the Crew Quarters, has a segment canted at 45° in which two identical openings are made in each Crew Quarter: one for air supply diffuser, and one for installation of the SSL fixture. This location is optimized for the light fixture in that: a.) 45° is the optimal angle for nonreflective task lighting; and b.) all heat generated at the fixture is designed to draw to its back panel; the fixture thus situated has a permanent air-cooling of its back panel thanks to the air movement within the duct.

The cabling assembly B consists primarily of a single closeout panel — or, more specifically, a row of identical faceted, removable panels — which is permanently fixed at its base in a hinged fixture to the inner panel of the water tank, and which clips in to a lip in the upper duct assembly. Thus, any segment of this assembly can be "popped" open for review, maintenance or repair of the cabling and then re-closed. Power cables run in a set of clips along the top of this chaseway, and avionics cables are strung along the back, in clips which are attached to the water tank panel.

## SECTION III – UNIQUE OR NOVEL FEATURES

### A. Novel or Unique Features

Novel features of this innovation include:

1. The ability to provide continuous cabin air supply in both vehicle configurations;

2. Uncomplicated method for housing cabling;

3. Integrated housing for lighting at optimal angle for nonreflective light delivery;

4. Thermal attenuation for integrated Solid-State Lighting fixtures;

5. Ease of accessibility to all segments;

6. Consistent profile for easy housekeeping and human engineering;

7. Architectural integration of design supports vehicle reconfiguration from launch to assembly-complete layouts;

8. “Cut” in core-located launch shelves falls within Engineering parameters; and

9. Subsidiary hardware is minimized by use of two sides of a panel and integrated insulation in place of a duct.

## SECTION IV – POTENTIAL COMMERCIAL APPLICATIONS

Some potential may exist for commercial application in a broad range of transportable habitats or in facilities which must be reconfigurable and serve a variety of functions; in aircraft; and in commercial space vehicles.

## Report F

# ISS TRANSHAB CREW QUARTERS DOOR PANEL CONCEPT AND DESIGN

## BRIEF ABSTRACT

Concept development for movable door panel unit for TransHab Crew personal quarters.

## SECTION I – DESCRIPTION OF THE PROBLEM OBJECTIVE

### A. General Description of the Problem

Develop door panel for six TransHab Crew Quarters which meets all requirements for translation assembly, operations, installation of hardware, and human engineering requirements.

### B. Key Problem Characteristics

1. Provide maximum acoustic separation between functional units and public passageway;
2. Door panel must complete Crew quarters enclosure, attaching to core shelves;
3. Panel must allow sufficient CQs volume to meet human engineering requirements;
4. Option must exist for panel to stow sufficiently to allow rack translation through core pass-through;
5. Air return vents and other H/W must be capable of mounting in the door elevation of the CQs; and
6. Panel unit must be capable of launch with TransHab vehicle and easy, permanent installation in assembly phase.

## SECTION II – TECHNICAL DESCRIPTION

The Crew Quarters hard door panel is designed to attach between any two core-area launch shelves for Crew Quarters, extending the depth of the Crew Quarters to 38 in. A tetrahedral section, its two side arms span a sixty-degree angle; the front panel is 24 in. across the front, into which the door opening is inset and, below it, mountings for air vents and other equipment.

In the event that central core translation of large equipment such as racks should be desired, the door panel is attached at its right side to the adjacent launch shelf on a track along which it slides far enough to clear a 61 in. diameter circle in the center of the core. Under normal ops, however, the door is locked in to its fully-extended, permanent position.

## SECTION III – UNIQUE OR NOVEL FEATURES

### A. Novel or Unique Features

1. Acoustic separation between functional units and the pass-through is effected by a sandwich of rigid materials and acoustic barrier materials in the door panel;

2. Door panel is attached vertically to two full-height launch shelves, with 7’-0” clear height maintained;

3. Door side panels offer a continuation of the angles of the repositioned launch shelves for consistency and efficient use of volume;

4. Integrated power and data connections or any other necessary cabling are carried to the door along the right-hand launch shelf (permanent, sliding attach point) under sleep restraints, from preintegrated soffit at the upper circumference of the CQs;

5. Shape and location of the panel maximizes interior volume while allowing an acceptable clearance for translation both through the door panel and past it; and

6. Positive air flow is ducted from the upper outer edge of the Crew Quarters, and air return grilles are located in the door component at the lower outer wall in an integrated design.

## SECTION IV – POTENTIAL COMMERCIAL APPLICATIONS

Some potential may exist for commercial application in a broad range of transportable habitats or in facilities which must be reconfigurable and serve a variety of functions; in aircraft; and in commercial space vehicles.

## Report G

# ISS TRANSHAB HUMAN CENTRIFUGE CONCEPT

## BRIEF ABSTRACT

Concept for human short-arm centrifuge on TransHab.

## SECTION I – DESCRIPTION OF THE PROBLEM OBJECTIVE

### A. General Description of the Problem

Provide a centrifuge for application of intermittent hypergravity to human subjects in the ISS-TransHab.

### B. Key Problem Characteristics

1. Centrifuge must operate entirely in the region outside the spindle of the structural core (between core and shell);

2. Concept must not abrogate any other functions or use of facilities in TransHab;

3. No moment transferred to ISS;

4. Accommodate at least two crewmembers in variable positions (forward, left or right-facing to velocity vector);

5. Accommodate exercise and/or human powering of centrifuge; and

6. Accommodate variable speeds.

## SECTION II – TECHNICAL DESCRIPTION

The TransHab core is lengthened by 3 ft in the upper region of Level 3, allowing for installation of the centrifuge in that area without impeding use of Level 3 activity centers, access to racks or translation of other crewmembers while in use. Centrifuge is attached to the central of three friction rings which comprise a collar around the structural longerons in this segment. The upper and lower rings accommodate an electrically served counterweight and flywheel, which rotates about the collar in the opposite sense from the centrifuge arms at variable speeds, so as to provide a zero-moment compensation for the moment generated in spin-up, spin-down and general operation. This counterweight can also function as an electric brake on the system during periods of rest.

Two crewmembers are accommodated on opposing poles of the system, one at each end, feet outward to maximize the force applied to the lower extremities. Each crew station supports an impact-loaded cycle ergometer which can pivot 180° about its support; a "cab" covering may be accommodated around the head and shoulders of the subject in order to reduce negative adaptive effects. The total diameter of the human centrifuge at the feet is 4 m.

## SECTION III – UNIQUE OR NOVEL FEATURES

### A. Novel or Unique Features

This entire concept is a completely novel approach to centrifuge design.

### B. Advantages

1. This centrifuge system allows a larger radius than any others proposed for ISS applications;

2. Because of its construction, subjects can be pivoted to different attitudes relative to the velocity vector for a broader range of testing; and

3. A triple-ring collar allows for development of a highly sophisticated electric flywheel system. for low-profile moment control.

## SECTION IV – POTENTIAL COMMERCIAL APPLICATIONS

Some potential may exist for commercial application in commercial space vehicles.

**Report H**

# ISS TRANSHAB CORE SHELF HUMAN ENGINEERING

## BRIEF ABSTRACT

Development of allowable attachment zone of TransHab core shelves for human access and deployment.

## SECTION I – DESCRIPTION OF THE PROBLEM OBJECTIVE

### A. General Description of the Problem

Develop requirements for allowable human access (as required) to core shelf attachments.

### B. Key Problem Characteristics

1. Provide location for core shelf integrated fasteners which allows for crew access in removal and reattachment;

2. Provide allowable area on each core shelf within which systems integrators could plan to install TBD equipment without impeding access to fasteners;

3. Both requirements must be equally operational with shelves in launch configuration and final assembly configuration.

## SECTION II – TECHNICAL DESCRIPTION

The first part of the problem was addressed by drawing a center line for shelf integrated fasteners at 2 in. from the shelf edge. This dimension allows manual access with an actuating tool to the fasteners at all sides, whether in close quarters or open volumes.

The second part of the problem involved the protection of the aforementioned fastener access by restricting the location of TBD equipment to be mounted to the center portion of the core shelves for launch and assembly configurations. Since all details were not known on what hardware would be attached or their characteristics, it was important to establish a boundary rule that would be applicable for all equipment items and whose application would guarantee that no hardware would be so attached as to impede access to the shelf integrated fasteners. Following similar methods of height/mass restrictions commonly applied in city zoning and building codes, a pyramidal envelope was drawn rising from the fasteners center line at a 45° angle toward the center of the shelf. No item may occupy any single shelf which violates that envelope; as a result, a hardware item which is 4 in. in depth must be located at least 4 in. from the fastener center line; 12 in. in depth — 12 in. setback restriction, etc.

Any piece of equipment which is too large to fit within this envelope must be so located within the TransHab core that there are no adjacent mounted items: in other words, a waiver is granted only under the condition that the equipment on that shelf also occupy the total available envelope for its two adjoining shelves.

## SECTION III – UNIQUE OR NOVEL FEATURES

### A. Novel or Unique Features

1. Application of urban zoning tools to space vehicle architecture; and

2. System allows flexibility in development of vehicle design and systems architecture while reducing areas of conflict, even when starting from an early conceptual stage.

## SECTION IV – POTENTIAL COMMERCIAL APPLICATIONS

Potential application in design and integration methodology.

**Report I**

# ISS/TRANSHAB MODULAR REFRIGERATOR/FREEZER CONCEPT

## BRIEF ABSTRACT

Design for Refrigerator/Freezer which provides frozen foods on orbit and is flexible in platform: suits ISS racks, MPLM, TransHab and others.

## SECTION I – DESCRIPTION OF THE PROBLEM OBJECTIVE

### A. General Description of the Problem

The objective was to initiate a modified design for the ISS Refrigerator/Freezers which would allow the cooled food storage units to be translated, installed and utilized at a sub-rack level so as to reduce crew loading and to increase flexibility of platform for the hardware. If the same R.FRs can be accommodated equally well on TransHab (no racks) as on ISS (3 racks).

### B. Key Problem Characteristics

The particular problems in meeting this objective consisted of the following:

1. The technical design is already well underway, and can only reasonably be altered if the new food container solution is compatible with technical design.

2. Food must be kept cool during removal from MPLM (or other delivery platform) and until connection to cooling units.

3. Resupply effort must be kept to a minimum.

4. The same units must be able to provide full chilled food requirements in a number of different architectures.

5. Refrigerator/Freezers must be easy and efficient to run, maintain and use.

### C. Prior Art

Four built-in cooled compartments in each of 3 ISS racks, each with its own compressor. The full rack must be translated in and out and returned empty to the ground for resupply. This is time-consuming, costs extra launch weight, and is difficult to render compatible with any architecture other than ISS.

## SECTION II – TECHNICAL DESCRIPTION

### A. Purpose and Description

The objective is met in the design of one ORU-type (removable) cooler unit, 19 in. h × 28 in. d × 37 in. w, which is passive and cooled by a single connection to its supporting cooling unit (cold air). Three of these units fit nicely into the ISS rack; all nine of them fit into the allotted locations for the galley functions in TransHab; each individual unit is easy to translate by a single crewperson without advance preparation.

### B. Identification of Component Parts and Mode of Operation

Each of these units can be cooled by the same cooling technology already in place and under detailed development for this function. As each unit is emptied, its corresponding compressor and data panels can be turned off, saving power to the system. Additionally, they can be used for a variety of other needs before return to ground for resupply, and can be accommodated on alternate launch platforms. Dual doors on each unit reduce the volume of open thermal exchange to a 16 in. width, and increase ease of use due to lower reach range.

### C. Functional Operation

All nine of these units accommodate approximately 90 $ft^3$ of frozen food storage, at –20 °C.

## SECTION III – UNIQUE OR NOVEL FEATURES

### A. Novel or Unique Features

1. Flexibility of the hardware to different architectures, launch platforms and applications; and

2. Design for optimal human use.

**B. Advantages**

1. Translation and crew loading are saved;

2. Can meet various geometries with relative efficiency; and

3. Easy to maintain and resupply.

## SECTION IV – POTENTIAL COMMERCIAL APPLICATIONS

Some potential may exist for commercial application in a broad range of transportable habitats or in facilities which must be reconfigurable and serve a variety of functions; in aircraft; and in commercial space vehicles.

## Report J

## TRANSHAB WARDROOM TABLE DESIGN

## BRIEF ABSTRACT

Design of TransHab Wardroom Table.

## SECTION I – DESCRIPTION OF THE PROBLEM OBJECTIVE

### A. General Description of the Problem

Develop design for TransHab wardroom table to accommodate crew operations.

### B. Key Problem Characteristics

1. Vehicle's unique architecture provides unique attachment point for table, limited to two longerons in the Level one Nadir area;

2. Table must accommodate seven crewmembers for normal daily operations and as many as twelve crewmembers for periodic ISS-Shuttle operations;

3. Foot restraints must be simple and accommodate the full crew size range at all positions at table;

4. Launch platform potentially limited by size; table must conform to TransHab structure if launched with vehicle;

5. Table must be capable of supporting a range of activities (dining, conferencing, recreation);

6. Table must support attached Flight Crew hardware (e.g., Utility Outlet Port, Portable Fire Extinguisher, temporary trash containment).

## SECTION II – TECHNICAL DESCRIPTION

The TransHab Wardroom Table concept involves dedication of one of TransHab's core launch, shelves, 50 in. $\times$ 84 in., for use in the assembly configuration. This shelf is removed from its position in the core and attached to the longerons in position in Level One; four flyleaves are folded out from the shelf's edges and fastened into position in the same plane as the shelf using the same integrated fasteners by which the shelf was secured in the core for launch. Restraints in the form of foot and knee bars of the same outer shape as the table are assembled from telescoping elements and secured to the longerons in lower positions. Spacing of these bars accommodates flexible restraint for all crewmembers. Hardware such as Utility Outlet Ports can be integrated into the flyleaves so that their operating surface is flush with the table plane. Translation clearance of 32 in. is maintained at all areas around the table.

## SECTION III – UNIQUE OR NOVEL FEATURES

### A. Novel or Unique Features

1. Table is manifested at a fraction of its total mass because 75 percent of the unit is reused from launch structure;

2. "Extra" launch shelf need not be accommodated elsewhere;

3. Flyleaves permit up to 12 persons to use table at one time;

4. Flyleaf attachments are reused from launch structure;

5. Table is simple and easy to maintain;

6. Restraints are relatively universal, permit flexible seating without special adjustments;

7. Railings can be designed into the outer edges of the flyleaves for universal, integrated restraint and attachment points for personnel and equipment;

8. Table can be used for a wide range of activities, including dining, conferencing, work surface, recreation.

### C. Prior Art

None extant (concepts only for ISS wardroom table is not applicable to TransHab):

1. Stowable/deployable design undesirable in dedicated wardroom area;

2. Multiple leaves cause higher crew loading impact for maintenance, housekeeping;

3. Not large enough to accommodate full crew;

4. Attachment is dependent on ISS common architecture;

5. Not consistent in form or dimensions with TransHab core structure.

## SECTION IV – POTENTIAL COMMERCIAL APPLICATIONS

Some potential may exist for commercial application in a broad range of transportable habitats or in facilities which must be reconfigurable and serve a variety of functions; and in commercial space vehicles.

**Report K**

# TRANSHAB SOFT STOWAGE ARRAY

## BRIEF ABSTRACT

The TransHab module will accommodate ISS-standard soft stowage units in a structurally-integrated system.

## SECTION I – DESCRIPTION OF THE PROBLEM OBJECTIVE

### A. General Description of the Problem

The main objective was accommodation of sufficient stowage for a Mars human expedition in a manner which was accessible and consistent both with TransHab architecture and with ISS program requirements.

### B. Key Problem Characteristics

Specific problems included:

1. Selection and accommodation of stowage units;

2. Identification of a method for securing and arraying these units without attachment to the shell;

3. Design to prevent buildup of condensation and permit flow of return air;

4. Design to accommodate crew restraint and mobility; and

5. Maximize the net stowage per gross volume.

### C. Prior Art

Prior technique had been rack-based functionality, stowage in trays ISS-type HAB module.

### D. Disadvantages of Prior Art

1. Inefficiency low net stowage ratio;

2. Requires hard racks in an incompatible architecture;

3. Would require considerable additional weight, structure to accommodate; and

4. Insufficient total stowage to meet goal.

## SECTION II – TECHNICAL DESCRIPTION

### A. Purpose and Description

*Purpose*: To support stowage and inventory of stowed items aboard TransHab or any similar lightweight space inflatable structure.

*Description*: Lightweight shelves are installed at the periphery of the nadir side of Levels 1 and 3 with major vertical elements having structural connection to the floor struts and to compression rings, minor vertical elements having structural connection to compression rings and to lateral elements, and lateral elements spanning each bay between major vertical chords. All elements are sized to accommodate any number of modules of the ISS-standard Cargo Transfer Bag (CTB) at 20-in. depth, 10-in. width and 17-in. height. Both major vertical and lateral elements include built-in handrails for full crew accessibility and restraint and attachment of temporary items (lamps, eg). Minor vertical and lateral elements are heavily perforated in the area behind stowage units to permit return air flow from habitable area to mechanical area.

### B. Functional Operation

*Stowage and Inventory Management*: All stowed items are supported so that each unit's label is visible and contents are accessible from aisleway. Bungees, webbing are utilized to accommodate units of different modules and to support unit restraint, removal and replacement.

*Air Flow/Thermal*: The stowage array forms a plenum against the shell wall for channeling flow of all return air from Level 1 and Level 3 to the mechanical area — obviates the need for ducted air return anywhere on TransHab.

## SECTION III – UNIQUE OR NOVEL FEATURES

The TransHab Soft Stowage Array is a method for integrating a flexible, highly usable and easily maintainable system for stowage into an inflatable architecture. As such, it represents a completely new solution to problems of on-orbit stowage. It is consistent with developing and advanced HE and logistical requirements of the ISS Integrated Stowage Plan. Flexible accommodation of modular units. Lightweight supports assembled on-orbit are easy to ship and deploy. Architecture of the array assists air/thermal engineering in optimizing return air flow for the vehicle. Maximum crew accessibility to stowed items and inventory system.

## SECTION IV – POTENTIAL COMMERCIAL APPLICATIONS

1. Possible applications to future commercial space vehicles and other facilities; and

2. Possible applications to design of temporary or transportable housing.

## Report L

# TRANSHAB INTEGRATED SOFFIT CONCEPT AND PRELIMINARY DESIGN

## BRIEF ABSTRACT

Local-area utilities serving each level of the TransHab spacecraft are integrated into three portions of the permanent vehicle architecture.

## SECTION I – DESCRIPTION OF THE PROBLEM OBJECTIVE

### A. General Description of the Problem

The objective was to provide data, power and coolant lines, air supply and (where applicable) housing for light fixtures in the TransHab in a manner which was optimal for utility functions, vehicle architecture, internal outfitting, and housekeeping and maintenance.

### B. Key Problem Characteristics

The particular problems in meeting this objective consisted of the following:

1. The vehicle has two radically different configuration stages: launch configuration and assembly configuration.

2. Utilities required some degree of connectivity in the densely-packed launch configuration, but full connectivity not only upon assembly-complete but also during the assembly phase.

3. In addition, crew time for vehicle assembly is severely limited and the task of running or re-connecting flexible lines was deemed prohibitive to assembly ops.

4. Launch Load control: Because of the dense packing of TransHab in its launch configuration, extra or redundant assemblies, chases or ductwork would have constituted added weight and limited other vehicle capabilities.

### C. Prior Art

In its requirement to overcome the reconfiguration of the vehicle, this is a new problem; hence, there is no prior art. However, utility chaseways and standoffs designed into the ISS standard modules consist of open framework in the four corners between racks. While well-protected from dust and debris in the nominal configuration, removal of a rack exposes all lines to the cabin and exposes crewmembers working there to potential hazards. By the same token, in order to access any of these lines it is necessary first to remove and displace at least one rack.

## SECTION II – TECHNICAL DESCRIPTION

### A. Purpose and Description

The objective is met in the creation of three integrated soffits within TransHab, which are consistent with the architecture of both launch and assembly configuration, nonobtrusive, and preintegrated into the vehicle's primary structures. One is located within the core structure at each level, serving as an insulated air-supply duct as well as a covered, accessible chaseway for data and power lines. These units are a part of the core architecture and therefore require no disassembly or reassembly. This design is also intended to minimize the impact of disconnection or reconnection of the main utility lines which serve them.

### B. Identification of Component Parts and Mode of Operation

Two of these soffits, one at Level One and one at Level Three, are extensions of closeouts which were necessary in covering the 9-10 inches of the core structure immediately above or below the end bulkhead. The third soffit, which rings the Crew Quarters cluster inside the water tank in Level 2, is a single consistent unit which aids in crew perception of local vertical and is optimized for accessibility and air delivery as well as for minimal impact on the structural shelves which it penetrates.

### C. Functional Operation

Air is supplied in a ring from the soffit, which replaces any ductwork in each level, to the local area served. Additionally, all power and data lines necessary within the local area served are integrated into a noninsulated segment of the same soffit, which has removable panels for easy access in event of replacement or other maintenance ops. Powered equipment at any stretch around each ring soffit can run short lines directly to the soffit with standard connectors to access the necessary utilities.

### D. Maintenance/Reliability

The integrated soffit concept is a simple, robust, easily-maintainable solution to a complex problem.

## SECTION III – UNIQUE OR NOVEL FEATURES

### A. Novel or Unique Features

1. Streamlining by combining power, data and/or coolant lines with air supply as a built-in segment of the vehicle's architecture;

2. Consolidation of support assemblies for these utilities (chaseways, clips, ductwork) into a single unit of two segments whose structure also serves as a closeout, thus supporting the utility runs while simultaneously protecting them from dust or debris and forming a clean, maintainable surface element within the vehicle; and

3. Ease of accessibility to the utilities.

### B. Advantages

1. All local-area utility service (wiring, ductwork) are in place prior to launch and capable of functioning fully from either launch or assembly configuration;

2. Valuable crew time is saved during assembly operations;

3. Weight is saved in consolidating structural and closeout components;

4. The soffits are consistent with vehicle interior outfitting; and

5. The soffits are easy to clean.

## SECTION IV – POTENTIAL COMMERCIAL APPLICATIONS

Some potential may exist for commercial application in a broad range of transportable habitats or in facilities which must be reconfigurable and serve a variety of functions; in aircraft; and in commercial space vehicles.