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Habitat Demonstration Unit

• HDU Background Concept:
  – Constellation Lunar Architecture studies
  – Remote robotic assembly
  – Surface optimized pressure vessel
  – Horizontal expandability
  – Vertical expandability

• Rapid Prototyping Development:
  – Analogs and testing
  – If you build it they will come (technology integration)

• Selected Technologies and Subsystems
• Lessons Learned
Remote Robotic Assembly
‘Scenario 12.1’ End-state Outpost

- Solar arrays
- Fuel cells and reactant tanks
- PEM excursion module
- Radiators:
  - PCM 24m²
  - PEM 5m²
  - PLM 5m²
- Inflatable airlock
- LER (4 x)
- PCM core module
- PLM logistics module
‘Scenario 12.1’ Highly Mobile Outpost
Ring frame
Cargo web walls
Logistics CTBs stacked
Microhab Instrument Bulkhead

- Ethernet Remote control power switcher
- Ethernet hub
- Mini PC
- Temperature monitors
- Voltage sensors
- CO₂ / humidity monitor
- Light controller (behind)
- Power Supply Unit (PSU) rechargeable battery pack
- Tropos modem (behind)
- Package air conditioner (analog for ECLSS)
- LED light power supply
D-RATS 2011 Base Camp

Configurations:
2010 Pressurized Excursion Module (HDU-PEM), Lunar surface destination
2011 Deep Space Habitat (HDU-DSH), Near Earth Asteroid destination
2012 Deep Space Habitat (HDU-DSH), Mission Operations Test
HDU-DSH Configuration
DRaTS HDU-DSH Configuration

- Lift upper hand railing
- Overhead stowage
- Atrium Plant Growth system
- Radial Internal Material Handling System (RIMS)
- Lift column
- Lift platform and lower hand railing

Diagram labels:
- X-HAB LOFT
- DUST MODULE
- LAB MODULE
- HYGIENE MODULE
# HDU-DSH Technology & Innovations Demonstrations

1. Inflatable Loft (X-Hab 2011)
2. Logistics-to-Living
3. Autonomous Ops:
   A. “Intelligent” Habitat System Management Software
   B. SHIELD & ACAWS
4. iHab Digital Double (D²)
5. Power Generation & PM&D Systems
6. Environmental Protection Technologies
   A. Dust Mitigation Technologies
      a. Electrodynamic Dust Screen to repel dust from surfaces
      b. Lotus Coating
      c. Vent Hood at the General Maintenance Workstation
      d. Operational Concept for End-to-End Dust Contamination Management
      e. Vacuum Cleaner
   B. Micrometeoroid Mitigation Technologies
      a. MMOD Hab Impact Monitoring System
      b. Flat Surface Damage Detection system
   C. Radiation
      a. Operational Demonstration of Cargo Transfer Bags to deployable blankets for Radiation Protection and ECLS water purification demo
7. HDU Core Computing, Wireless Communication and RFID
9. Geo-Science Lab Glovebox/Workstation
10. Telerobotic Workstation
11. General Maintenance/EVA Workstation
12. Medical Ops/Life Science Workstation
13. Partial-G Material Handling
14. Food Production: Atrium concept
15. LED Lighting
16. 3-D Layered Damage Detection System for Surfaces
17. Habitability / Habitation, Hygiene, Trash Management RFID
HDU-DSH Plan Views

HDU-Deep Space Hab:
HDU Core = 56.0 m^3
X-Loft = 69.9 m^3
Airlock = 8.6 m^3
Hygiene Module = 14.1 m^3
Total P. Volume = 148.1 m^3

Level 1

Geo-Science porch
Docked Rover faces this way

Level 2

Level 3

Docked Rover faces this way

Exercise
Logistics & Stowage
Lift
Galley
Wardrm / Meeting
IV W/S

Crew Sleep Area
Crew Sleep Area
Crew Sleep Area
Crew Sleep Area

OPEN
Geo-Lab Workstation

Overhead axis camera – remote controllable locally and from ground crew

Screen computers

Microscope

Cameras and other instruments through side ports

Glove box with three sample pass through airlocks to the exterior

Control box
Geo-Lab Glovebox
Roboticly-Assisted GeoScience Operations
TeleRobotics Work Station Early Design
General Maintenance Workstation

D-RATS 2010

D-RATS 2011

MCT 2012
Dust Containment at General Maintenance W/S
Waste and Hygiene Module
X-Loft Living Space
X-Hab Loft Early Designs

Photo: James W. Young
X-Loft Final Design

- 8020 frame
- CTB stowage loft
- Crew quarters bowed out around perimeter (notional only – need to work out tension and compression poles)
- Access ladder
- Galley
- CTB rack
X-Loft Plan View

- Line of HDU below
- Access ladder
- Deployable table (folds up and out of the way) – space for all crew members to work/eat and watch projection
- CTB rack
- Access lift well
- Projection area above
- Galley
- Emergency egress
- Avionics section C floor clear access
X-Loft Section View Showing Projection Surface

- Line of dome section
- Digital projector (virtual window, possible 4 bays)
- CTB stowage loft beyond
- Crew quarters bowed out around perimeter
- Access ladder
- Projection area
- Deployable table folds up and out of the way
- CTB rack
- Lift access well
- Line of HDU section

Dimensions:
- 53" from top of deck
- 82" to top of deck
- 78" clear
X-Loft Final Design (360 degree image)

- Dome above
- Crew Quarters level
- Habitation level (under construction)
- Deployable table deployed
- Deployable table stowed
X-Loft Galley / Wardroom
X-Loft Crew Quarters
Virtual Window Crew Interaction

Dome above

Projection screens (back of crew quarters)

Digital projectors (mounted low in this case – could be mounted above)

Remote crew display

X-Loft deck below

Interactive crew member
Radial Internal Material Handling System (RIMS)

- Plant growth system (rests on top of RIMS inner track)
- Stowage system
- RIMS outer track
- Cross beam with hoist
- RIMS outer track
- Underside of fold-down stowage units
- RIMS inner track
- Cross beam with hoist
Radial Internal Material Handling System (RIMS)

- RIMS outer track
- Stowage system
- Underside of plant growth system trays
- RIMS cross beam
- RIMS inner track
- Plant growth “Atrium” (illuminated by LED red / blue spectrum)
- Central cargo lift
RIMS System: a Radial Bridge Crane

- Inner track
- Cross beam
- Outer track
Suitlock: Conversion / Deployment

Folded membrane

End bulkhead

Middle bulkhead nested

Suitport system stowed

Mesh deck deployed

Mesh deck folded

Suitport panel in “Suitlock Mode”

Suitport panel opens up in “Large Volume Airlock Mode”

Deployed membrane and pneumatic beams
Suitlock: Overall Dimensions

- Membrane inflatable
- Domed ends
- Suitlock in stowed configuration
- Deployable EVA porch
- EVA crane
- Suitlock in deployed configuration
- Expandable support cradle

Top View
- 2.2m (85”)

Side View
- 2.8m dia (110”)
- 5.0m (196”)
- 2.3m (90”)
- 4”

Hab Side
DEVAP Requirements

- Interface with suitlock bulkhead structure
- Manually deployable / stowable by two persons
- Can be latched or unlatched by a person from ground level
- Have lugs to permit lifting by crane by itself, or in tandem with suitlock
- Gratings on deck to permit dust to fall freely to the ground beneath
- Support a load of 100 lbs/sq ft on the Main Deck and Ramp
DEVAP Operational Prototype

- DEVAP shown with augmented dirt mount with wood blocks at base (left), and handrails partially deployed (right)
DEVAP Operational Prototype

- DEVAP shown during deployment / stow sequence
Lessons Learned

• Design is a cycle that includes build, integrate, test, evaluate, repeat
• Build many versions
• Six month cycle works very well to keep team excited and motivated
• Keep things functional, but not expensive during design cycles (Home Depot effect)
• Design to a mission, but consider multifunction for other scenarios as well
• NASA is not a jobs program
• Powerpoint engineering will get you nowhere
• Never list requirements before you build !!!!
• Build and test to find out what the requirements are
• Put student interns in the critical path – they stretch to meet expectations
• Don’t rush to flight – take time to get it right using many prototypes
The Team

Note: only part of team is shown
Thank you