Development of Logistics for Building Radiation Storm Shelters and their Operational Evaluation

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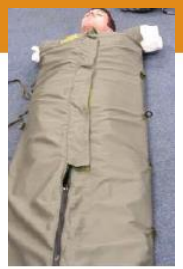
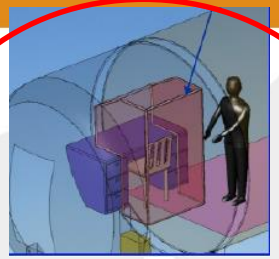
The Storm Shelter Project

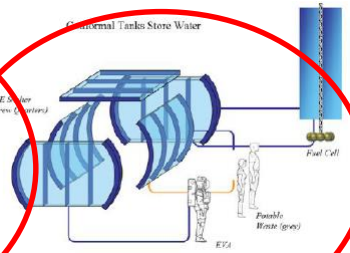
- A part of NASA's Advanced Exploration Systems (AES) Radiation Works (RadWorks) Project
- This paper summarizes year 3 of the 3 year RadWorks Storm Shelter program
  - FY12 – Trade Space Screening and Concept Selection
  - FY13 – Concept development and Use Definition
  - **FY14 – Complete Concept Development and Usage Evaluation**

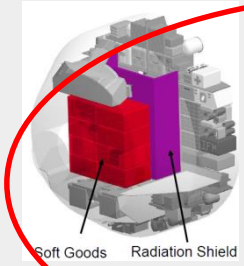
From FY12 Storm Shelter Tradespace Analysis

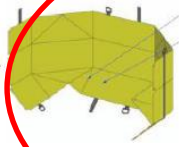



Blankets, Sleeping Bags, Vests, IVA EVA suits, Constructed Shelter Deployed Shelter

CQ Water Forward Osmosis Placements Waste Utilization

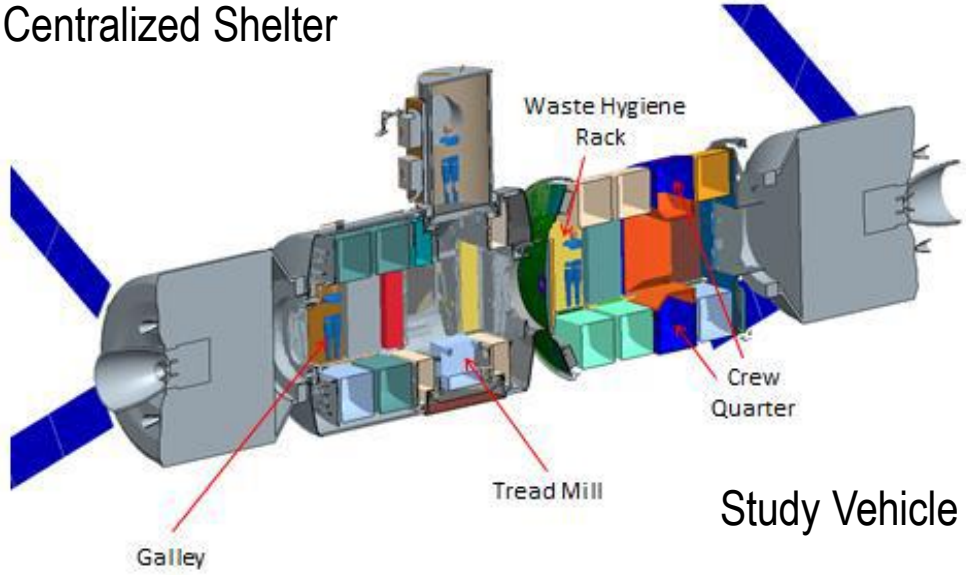



Reconfigured and Repurposed

From FY13 Concept Definition and Development

Reused Logistics in a Temporary Centralized Shelter

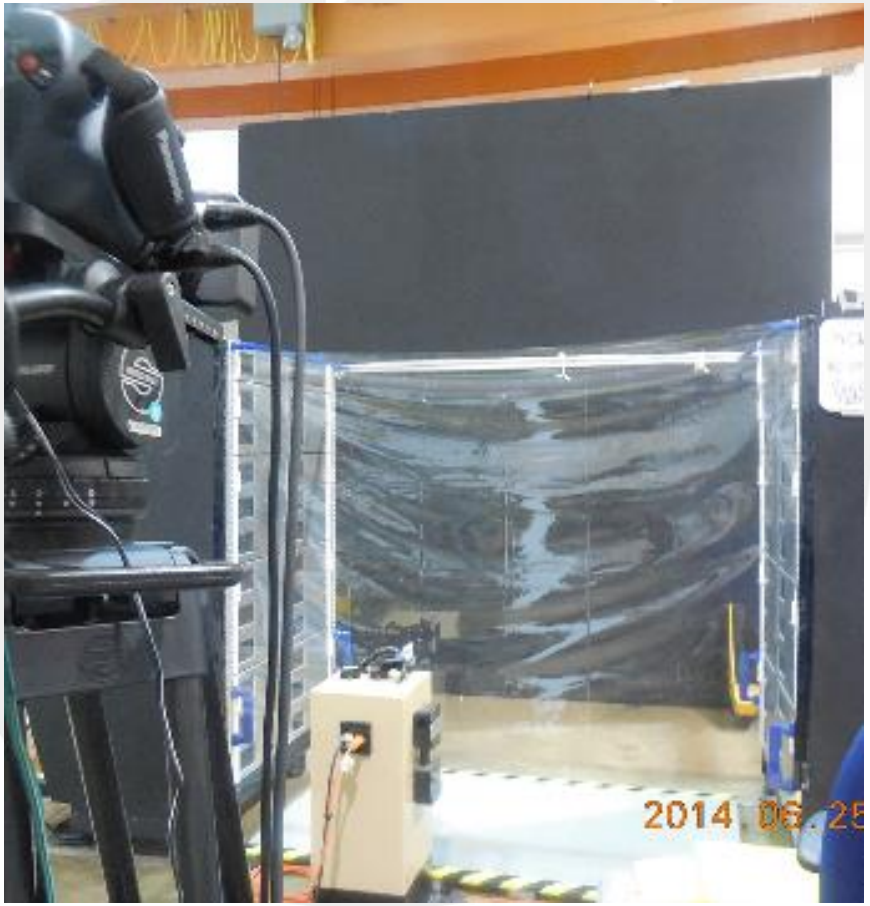
Crew Quarters Protection with a water wall



Study Vehicle – 180 day mission

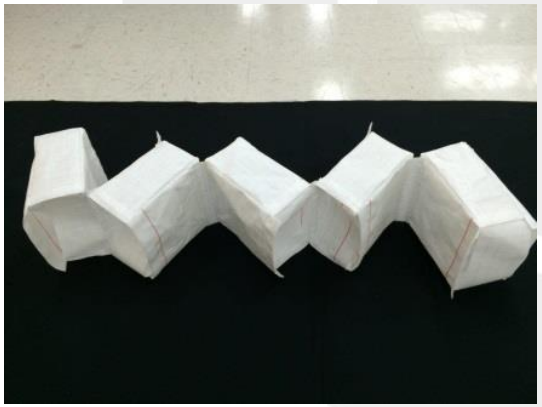
FY14 Concept Development and Testing
Reusable Logistics (RL) and Crew Quarters (CQ) waterwall

FY14 Concept Development and Testing
Reusable Logistics



Logistics for Protection - Food Storage Pouches

- Storage of food, trash bricks, misc. items
- 3.9 in. x 8.0 in wide x 7.8 in. high
- Z-Fold single and double column configurations
- Double Column fills width of MCTB



Logistics for Protection – Contingency Water Containers

- Approx. 3.9 in. dp x 19.0 in wide x 14.2 in. high
- 4.5 gal containers in single column Z-Fold arrangement
- Air filled mockups used in Human Factors evaluations
- 5 cells fill a double MCTB

ISS ICWC

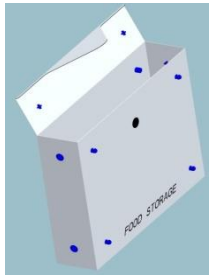
Storm Shelter ICWC

Logistics for Protection – Cargo Transfer Bags

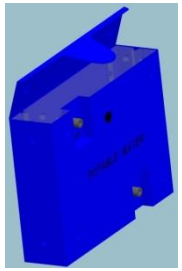
- Utilization of NASA JSC Logistics to Living Program Modified Cargo Transfer Bags (MCTB's)
- Provides
  - Initial stowage of logistics
  - backing / covering face for logistics placement

Logistics for Protection – Common Protection Containers

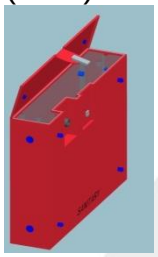
Common Protection Containers (CPC)



Dry Item Storage

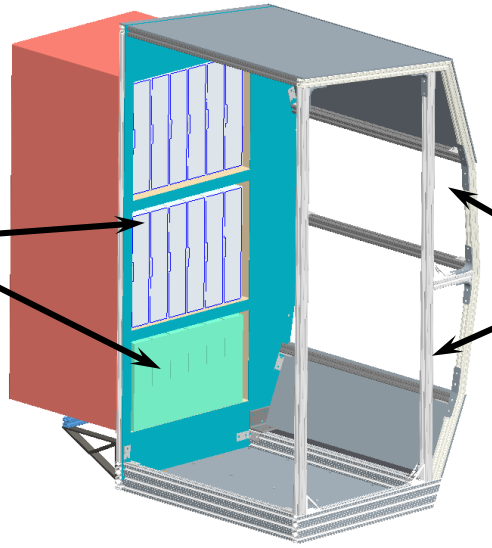


Potable Water – PED



Wet Trash Storage

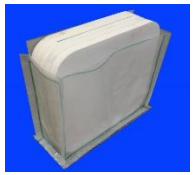
CQ with Pantry Side



Waterwall
Feedthru

ISPR Staging area, CPC's MCTB's, misc. logistics

Logistics for Protection – Miscellaneous items



Thermostabilized food

Storm Shelter “Bulk Overwrap Bag”

Thermostabilized food and Heat Melt Compacted Bricks in FSP’s

Staging of FSP packaged items in an MCTB

FY14 Concept Development and Testing
Crew Quarters (CQ) Based

- Waterwall and Pantry features
  - Bladder and Positive Expulsion Device Demonstration
- Automated Water Management and Potable Water Dispenser mockup interface

Waterwall Component Types

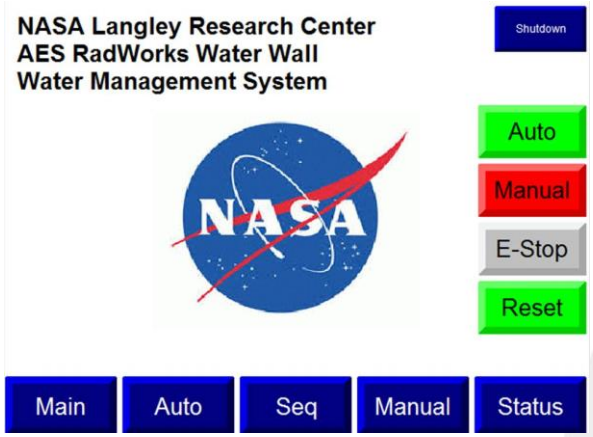
Bladder

- 8.0 in. dp. x 14.0 in. high x 30.0 in. wide
- 14.5 gal. capacity

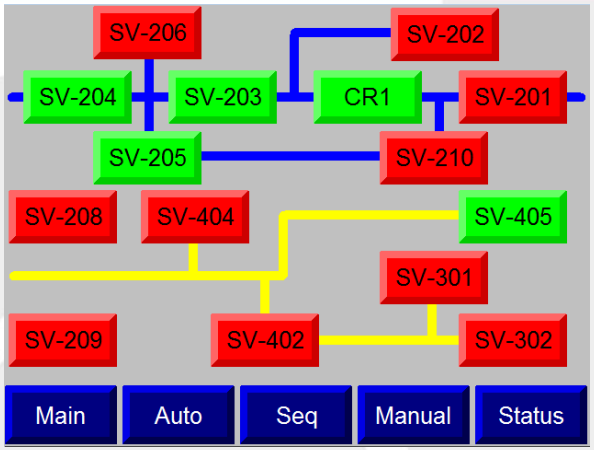
Positive Expulsion Device

- 3.5 in. dp. x 16.3 in. high x 29.8 in. wide
- 6.8 gal. capacity

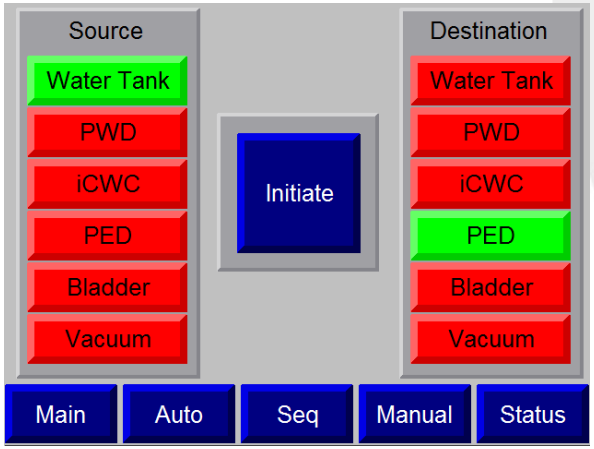
Water Wall - Tablet Interface



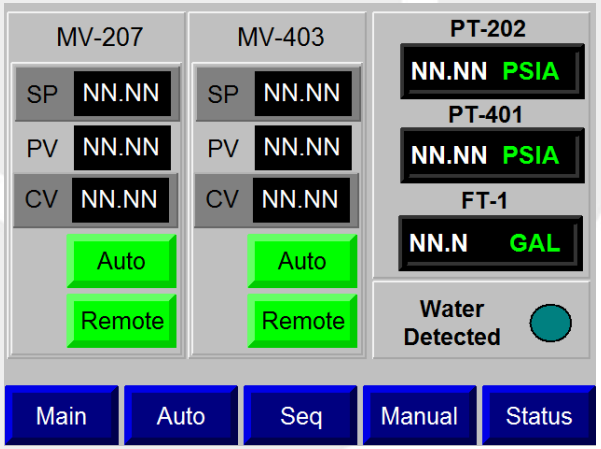
Main



Manual



Automatic



Status

Additional CQ operations – Pantry

- Use of common dimension and miscellaneous fill logistics in a CQ Pantry

Human Factors Evaluation - Process

- NASA LaRC Institutional Review Board approved evaluation process
- 12 teams
  - 6 Two crew teams – RL testing
  - 6 Single crew - RL testing
  - 8 Single crew – CQ testing
- For each experiment
  - ½ provided general guidance and written instructions
  - ½ provided general guidance only

Human Factors Evaluation – Test Sessions

- 10 and 20 min time proposed as the SPE warning period (desired time to complete shelter build)
- Instructed to behave as if in 0 g environment.
- Consideration given also to shelter quality to balance the time criterion
  - Minimize gaps and poor distribution/placement of protection items
- 3 sessions per experiment run, to assess learning improvement effect

Human Factors Evaluation - Measures

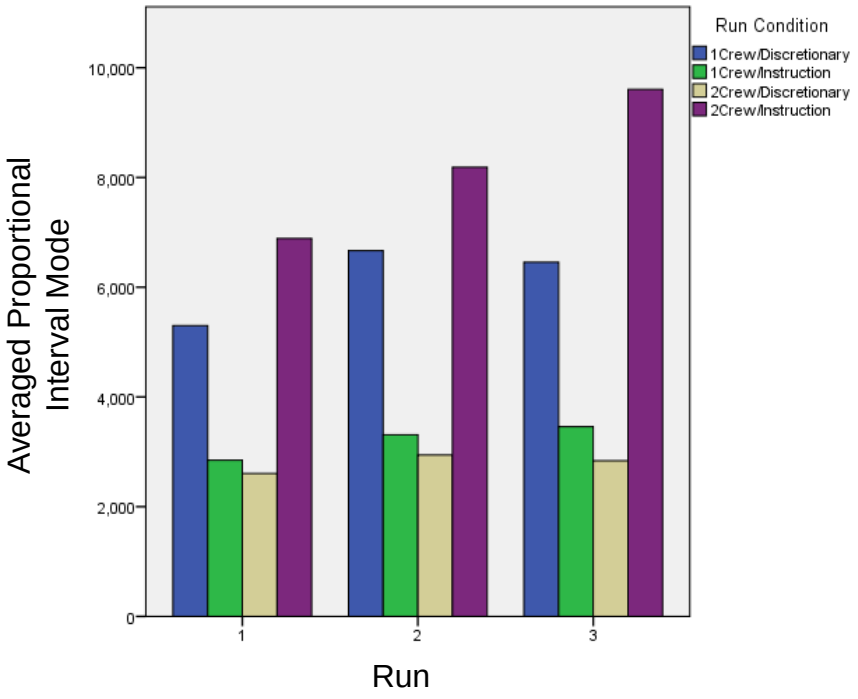
- Data captured
  - Video data
  - Time on task
  - Reference to instruction
  - Motion data – Actigraphy results

Human Factors Evaluation – subject evaluations

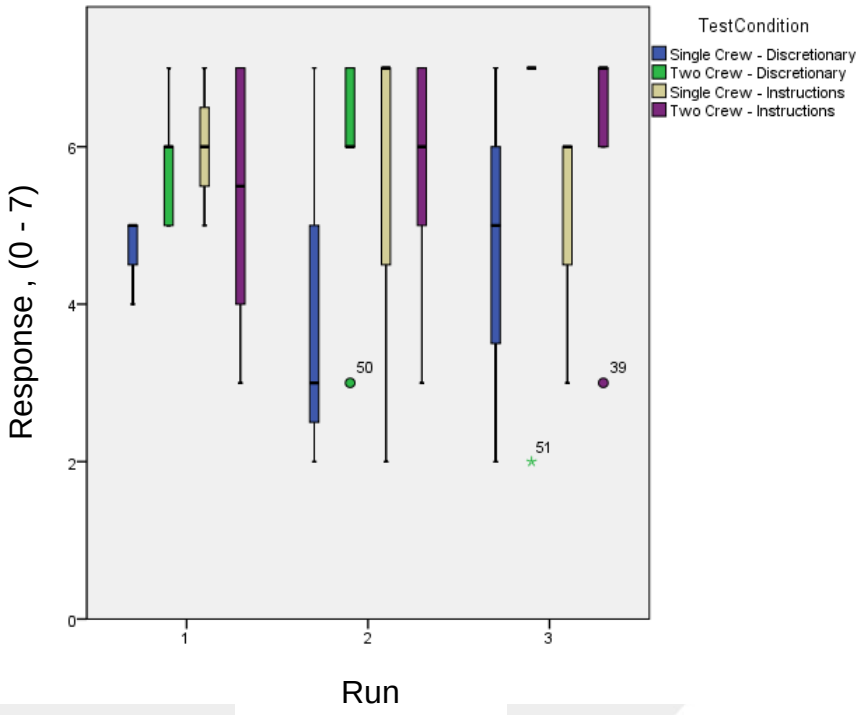
- Post test questionnaires to quantify crew assessment of shelter builds
  - Temporal demand, acceptability of completion in 10 / 20 mins
  - Mental demand
  - Physical demand
  - Perceived performance
  - Effort
  - Frustration
  - Acceptability
  - Exertion/Discomfort
  - Dexterity Required
  - Envisioned vs evolved assessment
  - Degree of protection (completeness)
  - Appropriateness of instructions
  - CQ software useability

Human Factors Evaluation - Measurements

Example factor measurements – Reconfigurable Logistics



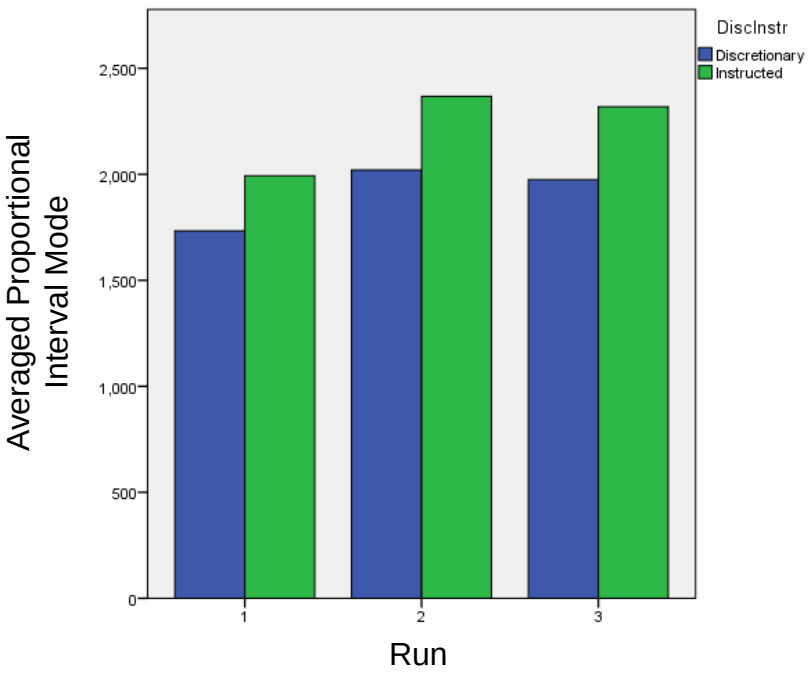
Actigraphy results



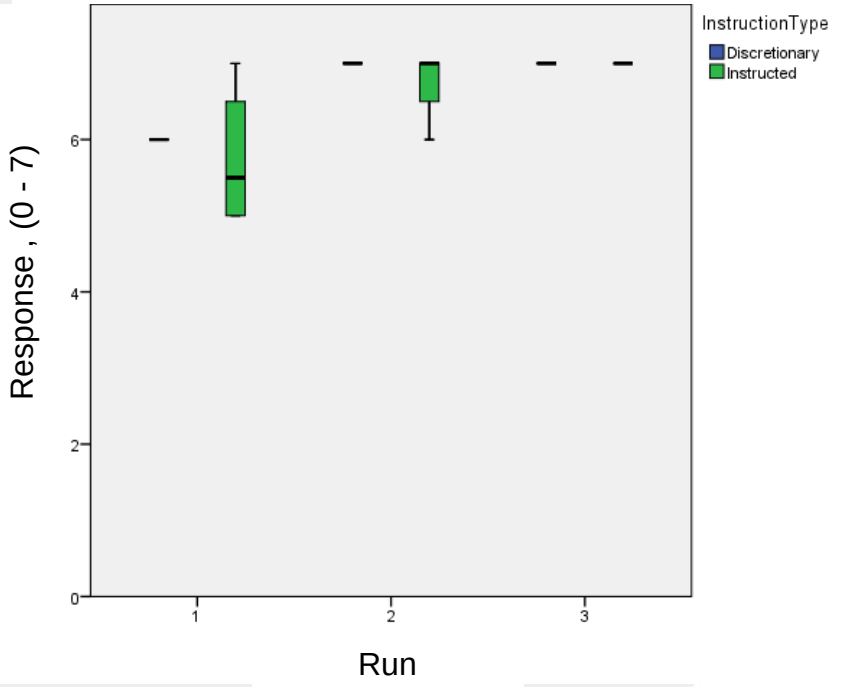
Acceptability to complete in 20 minutes

Human Factors Evaluation - Measurements

Example factor measurements – Crew Quarters



Actigraphy results



Acceptability to complete in 20 minutes

Human Factors Evaluation - Observations

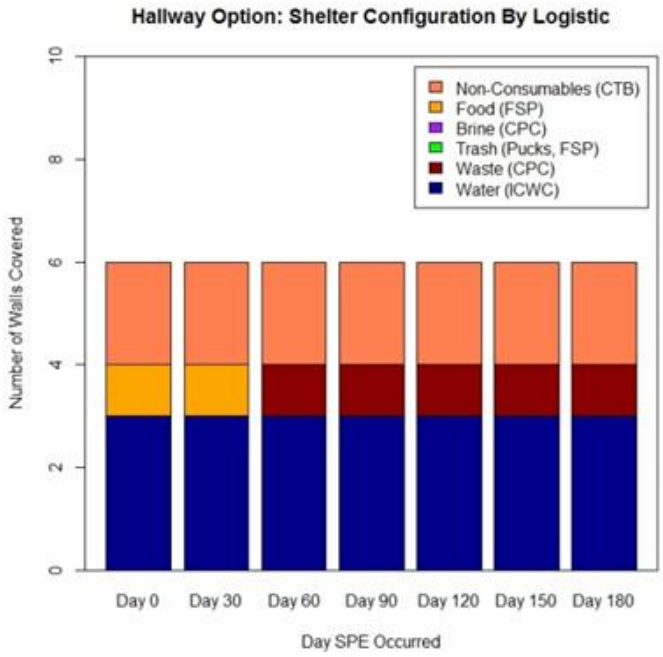
- 20 min build time – acceptable
- 10 min build time – acceptable for 2-Crew Reconfigurable Logistics shelter build, not acceptable for Crew Quarters water wall shelter
- 2-Crew Reconfigurable Logistics shelter build
  - Less physical and mental exertion, more confidence in finished quality
- Certain tasks proceed as well with / without instruction
  - Pantry fill
- Instructions
  - Useful for complex operations
  - can slow operations in intuitive procedures
- Water wall operations
  - Flagged with some degree of ambiguity in the tablet interface
- Repetitive task training definitely shown to improve speed/quality
- Design for Operations – proven as a good practice (Crew involvement in design features)

Additional and Future Activities

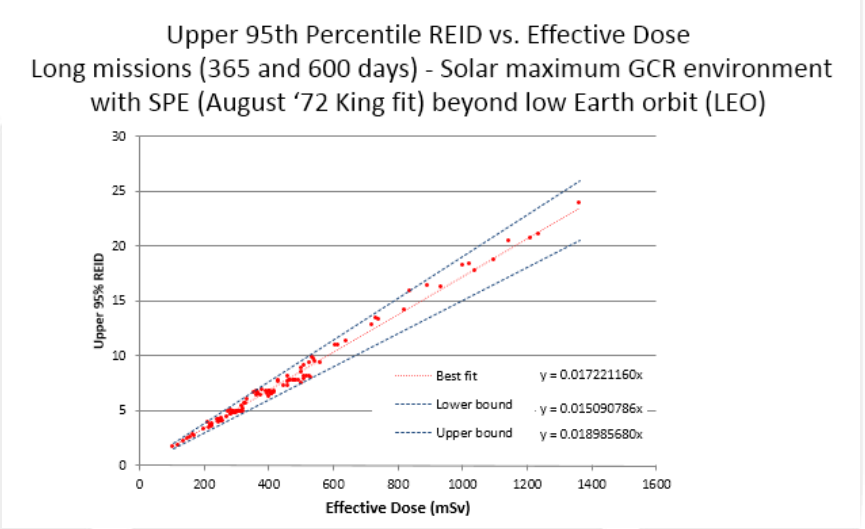
Demonstration area integration

- Completed Integration into LaRC 3m dia. X 10m lg. Inflatable Habitat

Additional and Future Activities



Discrete Event Simulation of Mission Operations



Application of REID to Concept Development

RadWorks Outreach in FY14

New Astronaut Candidates Tour the Storm Shelter Lab

- *Teams at LaRC and JSC participated in filming multiple documentaries for BBC and the Science Channel related to travels to Mars and overcoming challenges of Space Radiation.*
- *LaRC team presented Shelter Concepts to the new Astronaut Candidates, NASA Chief Scientist, and NASA Advisory Committee throughout the year during center visits.*

The Science Channel Filming the Water Wall Shielding System

Conclusions

- Logistics materials and operating equipment fabricated and tested
  - RL (logistics) and CQ (waterwall / logistics)
- Finished components integrated into a demonstration habitat facility available for future taskwork.
- Component shape/size requirements of common dimension are useful, likely a function of chosen habitat design/layout
- Design shelter building for intuitive operations
- Design with increased user involvement as habitat concepts become clearer
- Provide adequate training
- Greater development of validated DES models by operations testing would be a useful habitat design resource
- Influence of Zero gravity desired
  - ISS, neutral buoyancy, parabolic flight

Acknowledgement - The Storm Shelter Team

- Project Manager – Bobbie Gail Swan NASA / JSC
- Principal Investigator – Eddie Semones, NASA / JSC

Last	First	Responsibility	Supporting Organization
Abston	Lee	HDU CAD model developer	NASA LaRC – Engineering Directorate
Albertson	Cindy	Analyst - CQ Lead	NASA LaRC - Systems Analysis and Concepts Directorate
Andrews	Rob	Fabrication	NASA LaRC – Engineering Directorate
Araiza	Sherry	Resource Analyst	NASA LaRC – Office of the Chief Financial Officer
Castle	David	Design	NASA LaRC – Engineering Directorate
Cerro	Jeff	Technical Lead	NASA LaRC - Systems Analysis and Concepts Directorate
Clark	Terry	Design - Crew Quarters	NASA LaRC – Engineering Directorate
Clowdsley	Martha	Radiation Analysis	NASA LaRC – Research Directorate
Connolly	Heidi	Configuration Management	NASA LaRC Safety and Mission Assurance Office
Gallegos	Adam	CAD modeling	Lockheed Martin Corp.
Hintermeister	Nicole	Scheduling	NASA LaRC Space Technology and Exploration Directorate
James	Sam	Fabrication	NASA LaRC – Engineering Directorate
Jordan	Tommy	Technical Lead	NASA LaRC – Engineering Directorate
Kevin	Krohto	Fabrication	NASA LaRC – Engineering Directorate
Langford	Mike	Design	NASA LaRC – Engineering Directorate
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Le Boffe	Vincent	Design/Fabrication	NASA LaRC – Engineering Directorate
McLain	Kevin	Fabrication	NASA LaRC – Engineering Directorate

Acknowledgement - The Storm Shelter Team

Last	First	Responsibility	Supporting Organization
Moore	David	Deputy Project Manager - RadWorks	NASA LaRC – Engineering Directorate
Moses	Bob	SE&I	NASA LaRC – Engineering Directorate
Neubauer	Ken	Risk Management	NASA LaRC Safety and Mission Assurance Office
Noble	Lee	Systems Engineering and Int	NASA LaRC – Engineering Directorate
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Piske	Andrew	Configuration Management	NASA LaRC Safety and Mission Assurance Office
Scharf	Shawn	Risk Management	NASA LaRC Safety and Mission Assurance Office
Schneider	Nigel	Design	NASA LaRC Engineering Directorate
Shea	Ed	Risk Management	NASA LaRC Safety and Mission Assurance Office
Simon	Matt	Systems Engineering, Habitat Design	NASA LaRC - Systems Analysis and Concepts Directorate
Singleterry	Robert	Radiation Analysis	NASA LaRC – Research Directorate
Smith	Don	Fabrication	NASA LaRC – Engineering Directorate
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Walker	Steve	Radiation Analysis	NASA LaRC – Research Directorate
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Wittkopp	Charles	Design/Radiation Analysis	NASA LaRC – Engineering Directorate
Mclain	Kriss	Fabrication	NASA LaRC – Engineering Directorate
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Lorkiewicz	Rob	Media Services	NASA LaRC - Office of the Chief Information Officer
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