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

CQ Water Deployed Shelter

Forward Osmosis Placements

Reconfigured and Repurposed 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

- Dry Item Storage
- Potable Water – PED
- Wet Trash Storage

Common Protection Containers (CPC)

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

NASA Langley Research Center
AES RadWorks Water Wall
Water Management System

Shut Down
Auto
Manual
E-Stop
Reset

Main
Auto
Seq
Manual
Status

Main
Auto
Seq
Manual
Status

Automatic

Source
Water Tank
PWD
iCWC
PED
Bladder
Vacuum

Destination
Water Tank
PWD
iCWC
PED
Bladder
Vacuum

Initiate

Manual

Source
MV-207
MV-403
PT-202

SP NN.NN
PV NN.NN
CV NN.NN

SP NN.NN
PV NN.NN
CV NN.NN

Auto
Auto
Remote
Remote

Water Detected

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
Example factor measurements – Reconfigurable Logistics

Actigraphy results

Acceptability to complete in 20 minutes
Example factor measurements – Crew Quarters

**Actigraphy results**

![Bar chart showing averaged proportional interval mode across runs for Discretionary and Instructed conditions.]

**Acceptability to complete in 20 minutes**

![Box plot showing response variation across runs for Discretionary and Instructed conditions.]

- Human Factors Evaluation - Measurements
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

- 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.
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

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