Factors Impacting Habitable Volume Requirements for Long Duration Missions

Matthew Simon – NASA LaRC
Deborah Neubek – NASA JSC
Alexandra Whitmire – Wyle Labs/NASA JSC

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Purpose and Outline

Purpose:

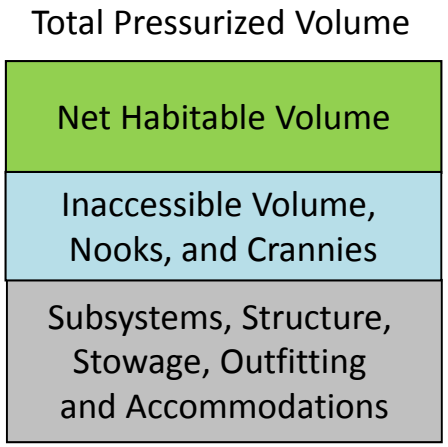
- Summarize major results from the NASA Human Research Program/Human Spaceflight Architecture Team Habitable Volume Workshop

Outline:

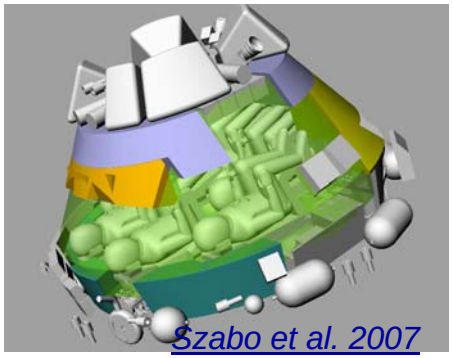
- What is Habitable Volume?
- Motivation for Workshop
- Workshop Objectives/Products
- Psychological Stressors
- Psychological Factors Mapping Matrix
- Mitigation Methods
- Research Recommendations
- Analog Selection Recommendations
- Cross-Cutting Conclusions
- Forward Work

What is Habitable Volume?

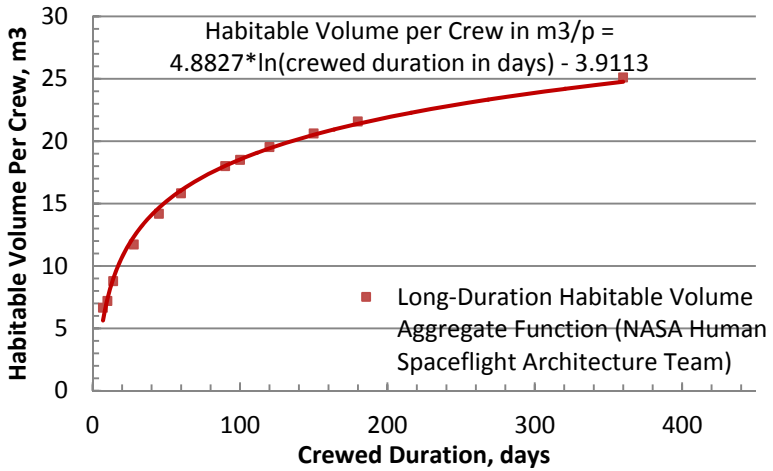
- **Habitable Volume is a measure of the space livable, accessible, and functionally usable to crew** [Rudisill 08, Simon 10]
- **Important for determining vehicle size in conceptual design, which impacts propulsion performance and habitability**
- **Providing sufficient habitable volume:**
  - Prevents psychological issues
  - Affords privacy and noise reduction
  - Improves work productivity
  - Reduces atmospheric pollution with the habitat
  - Ensures that functions required can be accommodated



Rudisill et al. 2008 (Modified)



Szabo et al. 2007



Workshop Motivation

- **There is no agreed upon standard for required habitable volume**
  - Small number of historical precedents for spacecraft volume
  - Applicability of confinement and task analyses that make up standards is questionable
  - Additional complexity of microgravity and its effect on utilization of space
- **Habitable volume (by itself) serves as a poor measure of the overall acceptability of a habitat without interior layout considerations**
- **Conducted a workshop with experts to address the habitable volume / layout acceptability issue for long duration human exploration missions**
  - Represent anthropology, neurology, psychology, human factors, medicine, naval ship building, interior design, and physiology
  - Experienced extreme isolation or long-duration confinement, thus had experience in space or terrestrial analogs

Workshop Objectives/Products

1. **Identify the psychological/behavioral health factors that impact long-duration missions**, both spaceflight and analog, and how those factors contribute to habitat volume, interior layout, and acceptability
2. **Develop the list of parameters** that can be used to adequately define how volume should be established such that psychological stressors are minimized
3. **Provide advisories** about the human factors consequences of not conforming to these metrics
4. **Identify potential countermeasures to these psychological design factors** and their subsequent impact to habitat specifications
5. **Identify critical knowledge gaps to inform future research efforts** to characterize the stressors themselves, quantify their impacts, and/or identify potential stressor mitigation techniques and measure their effectiveness.
6. **Identify work necessary** to arrive at useful design driving recommendations or requirements including numerical values for volume requirements

Two Products Summarize Results

Psychological Stressors Matrix

NASA Technical Memo

Psychological Stressors

- **During the workshop, the behavioral health and performance team identified the most salient stressors anticipated for a long duration exploration mission. These were based on scientific evidence and personal experience from spaceflight and analogs**
- **In total the team identified seventy six stressors, which we winnowed down and then "grouped" into eight primary categories (ones captured in matrix shown)**

Allocation of Space

- Lack of Personal/ Personal Space
- Feeling of "Crowdedness"
- Lack of Privacy of Waste & Hygiene Compartment

Workspace

- Lack of Meaningful Work
- Sense of Poorly Placed Stowage

General and Individual Control over the Environment

- Lack of Individual Controls over Temperature, Ventilation, or lighting
- Lack of Reconfigurable Spaces

Sensory Monotony

- Lack of Stimulation / Sensory Variability

Social Monotony

- Social Deprivation/ Lack of Common Areas
- Limited Communication with Home

Crew Composition

- Crew Composition

Physiological and Medical

- Lack of Hygiene Separation

Contingency Readiness

- Lack of "Backup Plan" / "Rescue Scenario"

Psychological Factors Mapping Matrix Spreadsheet

- **Psychological Factors Mapping Matrix provides detailed descriptions of the categories and associated stressors, with evidence linked to literature (*Full Matrix in NASA Tech Memo*)**

Psychological Stressor Category	Volume/ Configuration-Driving Psych Stressor	Details	Citation/Reference
Allocation of Space		**This category deals with the allocation and positioning of certain types of volume to meet psychological needs of the crew.**	
	Lack of Personal Space / Lack of Private Space	Private and personal space were both identified as highly important to the psychological well being of crew, providing a retreat from social stressors, separation from work areas, a place to interact with family members, and providing a location for personal items.	"A sense of privacy as well as a need for personal space becomes more important over longer durations." - HIDH p555; "ensure privacy of personal communications... (electronically as well as) from private quarters" - Stuster (1996), p211; "Antarctic experts recommend that provisions should be made to permit isolated and confined personnel opportunities to get away from their fellow crew members" Stuster (1996), p. 274; Having private crew quarters in which a crew member can be alone thus becomes extremely important on long-duration missions (Santy, 1983; Kanas and Manzey, 2008, as cited in Slack et al., 2008).
	Feeling of [illegible]	The perceived volume is adversely aff[illegible]d by th[illegible]ased number [illegible]	[illegible]IDH [illegible]572,

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Psychological Factors Mapping Matrix Spreadsheet

- Matrix also maps psychological stressors which impact volume/configuration directly to Layout Impact and Mitigations, Potential Analog Applications, Forward Work/Research, and HRP Risks

Neurobehavioral Stressor	*Crowdedness*	*Lack of simulation/ sensory variability*	*Lack of Reconfigurable Spaces*
Mitigation Methods	*Separation of high traffic functions*	*Provide virtual windows*	*Reconfigurable packaging for furniture/partitions*
Habitat Related Research Recommendations	*Incorporate habitat layout into scheduling tools*	*Evaluate effectiveness for behavioral health outcomes*	*Rapid prototype and evaluation of reconfigurable outfitting*
Analog Testing to Validate Recommendations	*Enhance scheduling tools and test on ISS*	*Deploy in remote, long duration analogs (Antarctica)*	*Deploy in ground-based analogs and test on ISS*
Human Research Program Risk Addressed	*SHFE 5 and BHP 1, 2, and 3*	*BHP 1, 2, and 3*	*SHFE 1,5 BHP 1*

HRP – Human Research Program, SHFE – Space Human Factors Engineering, BHP – Behavioral Health Program

Mitigation Methods

- **The effectiveness of mitigation methods at counteracting the psychological stressors must be characterized through additional research**
- **However, mitigations which should be implemented without additional research must be:**
  - Easily achievable mitigations with minimal design impacts
  - Mitigations for extremely well understood, critical stressors
- **Mitigations include:**
  - Providing a common area to accommodate all crew for dining and group work tasks
  - Provide means for communicating with those on the ground (including private comm. and noise control)
  - Real and/or virtual windows, video goggles or other technologies that can provide an immersive, sensory rich experience
  - Provide environmental control and protocols for utilizing environmental factors (e.g. lighting) to optimize health and performance
  - Provision of personal, private crew quarters with noise and vibration buffering

Images courtesy of NASA

Research Recommendations

- **Research recommendations out of the workshop take <u>two forms:</u>**
  1. Improving the understanding of a the stressor and its relative importance compared to other stressors
     - Risk characterization
     - Prioritization based upon impact to the astronaut or mission
  2. Testing/improving mitigation methods for each stressor
     - Prioritization based upon difficulty or cost of effective mitigation of stressor
- **EXAMPLE – Feeling of "Crowdedness" :**

Psychological Stressor	Mitigation Strategy	Research Recommendation
Feeling of "Crowdedness"	Separation of high traffic functions	• Clear definition of operations assumed during mission with detailed schedule could allow for analyses to layout interiors with significantly reduced crew congestion or crew displacement. • Development of scheduling tools that incorporate layout considerations; testing of these scheduling tools

Analog Selection Recommendations

- **Considerations when selecting analogs to perform research include:**

Physical Isolation
Reconfigurability of Interior
Control of Environment
Communications with Outside
Availability of Medical Care
Inherent Sensory Deprivation
Cost
Microgravity
Mission Duration
Net Habitable Volume
Mission Tempo
Team Size
Workload
Personal Space
Perceived Risk

- **Analog Assessment Tool – identify best fit analogs for research question**

Earth-based Laboratories
Foam/Wooden Mock-ups
NASA 20-foot chamber
Habitat Demonstration Unit (HDU)
NEEMO (and other undersea habitats)
Submarines
Antarctic Analogs (Concordia, McMurdo station)
International Space Station
Notional New Deep Space Vehicle Testing Platform



Images courtesy of NASA

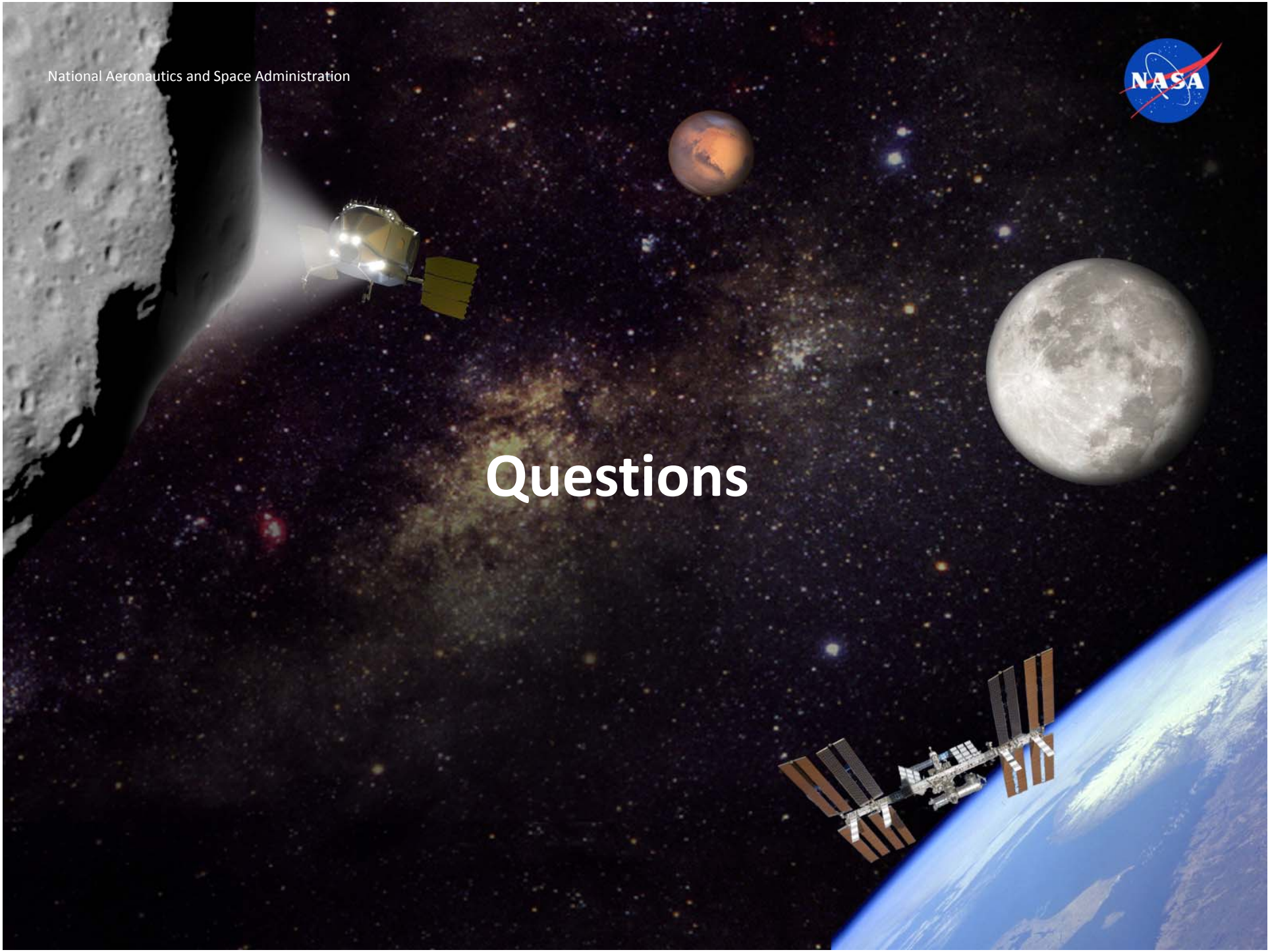
NEEMO – NASA Extreme Environment Mission Operations

Cross-Cutting Conclusions

- **Increased involvement of the HRP/BHP, Analog, and Mission Planning communities in the multidisciplinary habitat design effort is critical to address the habitable volume issue**
- **Detailed results summarized in this presentation are fully documented in the NASA TM published last year (NASA/TM-2011-217352)**
- **Volume acceptability requires a layout analysis**
  - Determining function/task volumes will require an expanded group of Anthropometry and Ergonomics experts
  - A Habitation Concept of Operations is essential in determining volume and how it is utilized in a layout
  - Analysis of overlapping task volumes can provide a first order approximation of a more realistic volume estimate
  - No single, universally acceptable numerical volume recommendation could be determine, but a range of potential volume values was suggested
- **Investigations over long duration missions in analog environments will be required to validate recommendations (e.g. Antarctic Analogs, testing on ISS, etc). The ISS also presents an optimal test bed for understanding confined environments.**

Forward Work

- **Integration of crew scheduling communities into long-duration concept of operations activity**
- **Prioritization of research into the stressors and potential mitigation strategies including:**
  - Characterization of the stressor and mitigation knowledge gaps
  - Development of methods and/or test beds allowing for future testing on the ISS
  - Identification of effective and practical metrics, methodologies, and tools for determining and assessing habitable environment and layout (including assessments in analog environments)
  - Development of reconfigurable spaces and crew accommodations consistent with mitigation strategies
  - Long-duration confinement and isolation study analogous to desired exploration missions
    - Focus on characterizing psychological stressors and the social dynamic between crewmembers in isolated confined environments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Questions