2016 Habitat Standing Review Panel

Research Plan Review for:
Deep Space Habitat: Livability, Well-being, and Performance

Final Report

I. Executive Summary and Overall Evaluation

The 2016 Habitat Standing Review Panel (from here on referred to as the SRP) met for a site visit in Houston, Texas on December 13-14, 2016 to evaluate the Research Plan Review for *Deep Space Habitat: Livability, Well-being, and Performance*. The panel was very supportive of this new paradigm by the Human Research Program (HRP), focusing on the deep space habitat rather than specific elements, and examined within the concept of Human System Interaction Design (HSID). It is clear that the various Elements expended a great deal of effort to provide current information as well as drivers and planned research strategies to enhance habitat design.

The SRP recognizes that new paradigms take some time to evolve; evaluation of an initial attempt should provide knowledge for enhancing the process in the future. A major difficulty experienced by the panel was being able to adequately answer the items on the Statement of Task (SOT). The charge to evaluate "deliverables" (defined as "standards, requirements, processes, countermeasures, protocols") was problematic because this term, used in relation to the SOT questions, was difficult to interpret (i.e., deliverables in a general sense, or specific deliverables). Presentations (appropriately in our view) had a greater focus on driving issues and research strategies for the future, rather than specific deliverables and unintended consequences. Therefore, the SRP report primarily reflects our view of gaps that need to be addressed and recommendations on research strategies and future deliverables, focused on human-centered design of the habitat for Livability, Well-being, and Performance (LWP). Overall, it is extremely important that designer and engineering personnel take under consideration the recommendations of the HRP regarding the habitat, and these professionals be included on future panels and in other discussion formats.

From a hazard analysis perspective, the panel noted that components that directly influence initial habitat design (in particular, Volume and Layout, Work Areas) appeared to be using a sequential research strategy that first utilizes engineering approaches to reduce identified risks as low as possible and then subsequently developing scientifically-derived countermeasures to deal with any residual risk. However, with respect to LWP, some risks may not be adequately identified or understood sufficiently to eliminate or reduce them to acceptable levels, in which case countermeasures will be the primary means to address the risk. Therefore, it may be more effective and efficient to use a parallel approach in which countermeasures to address hazards at the current risk level, not the residual level, are developed concurrently with the engineering efforts.

Throughout, there was a general lack of anticipating likely technological advances, and including this topic in the research strategies presented.

The current and future research strategies for the Volume and Layout component were well defined. The particular challenge for this component is that the other components under consideration either compete for volume (Work Areas, Restoration and Relaxation, Exercise, and Food System) or in some way influence volume and layout decisions (lighting, HSID and monitoring). Yet from an engineering standpoint, volume decisions will be needed very early on in the habitat design cycle. The panel recommends close examination of what aspects of the habitat induce or reduce stress on crewmembers, paying attention to the impact of one area on

another; planning for reconfigurable space and individual tailoring of personal space; and utilizing virtual environments with both digital human models and human subjects to comprehensively explore the interactions between the different components during various activities.

The Work Areas component was challenging to assess as "work area" was defined broadly and shares considerable overlap with the Volume and Layout component. Questions raised by the panel include (1) what are the decision criteria being used to assess interactions between work areas in terms of desired outcomes for LWP; (2) in the context of "deep-space", how adequate are existing guidelines for integrating and co-locating the different functional spaces; (3) what ergonomic aspects might need to be addressed? The panel also noted that flexibility and configurability of work areas needs to be included in planning during the early stages of habitat design. The component's emphasis on using both computational models and analog studies to address these issues is notable, but Human-in-the-Loop (HITL) simulations are critical to validate design models.

The deliverables presented for the Restoration and Relaxation component were well thought out with recognition that future development is needed to bring these deliverables to the highest Countermeasure/Technical Readiness levels (CRL/TRL). The use of analogs to test technologies and countermeasures is a positive feature. Driving issues and research strategies for the future were well specified, although the research strategy was not prioritized. Planning for different levels of activation/engagement (e.g., states of boredom vs. high work loads) should be included as a driving issue in terms of effects on performance; mitigation through interactions with other components needs consideration. In general, synergies and conflicts between Restoration and Relaxation and other components require greater attention.

The Food System component presented an acceptable plan to address food stability for a 5 year shelf life. The deliverables were appropriate and clearly addressed knowledge and mitigation gaps related to food systems. However, there was no integration with other components, such as the impact of food on mood states; restoration and relaxation (including communal activities); or how issues related to food might influence other components (e.g., volume and layout, work areas).

Strongly positive features of the Exercise System component were considerations of its integration with other HSID components;additional motivators to encourage exercise. Incorporating exercise into other activities could be addressed as well. Options for other forms of exercise such as tai-chi and yoga which do not rely as strongly on gravity could be explored, as well as exercise as a form of recreation. A major concern is that there is no plan presented to deal with equipment breakdown, considering there will be only one set of equipment onboard.

The state of knowledge in the Lighting System area and its relevance for the habitat was clearly presented, as was the designation of future research strategies. Attention to lighting norms for designers and operational protocols, the use of lighting to improve individual relaxation and performance, and a focus on individual differences in planning countermeasures are other positive features. Greater attention to other LWP components, including examination of work efficiency, health impact other than sleep, and personal preferences and task efficiency in lighting exposures would add to the strength of planning.

The Monitoring deliverables were presented in too vague a manner to judge their effectiveness. There needs to be a better conception of how operational monitoring measures differ from research measures, and vice versa. While unobtrusive monitoring is useful, the panel recommends a balance with self-report measures. Further, the development of psychometric norms/standards to assess changes from baseline in functioning is needed. Individual monitoring plans may be excessive, with a negative impact on LWP; efforts to make the collection of biological markers more user-friendly would be helpful. In addition, monitoring team conflicts may be as critical to address as individual health issues. Overall, it is highly important to develop strategies to enhance crewmember cooperation and compliance with self-monitoring

protocols. A significant message to impart to crewmembers is that self-monitoring is for their own benefit to enhance personal performance. Traditional concerns about a negative impact on future assignments if psychological problems are reported is not an issue on a long duration deep space mission.

The HSID concept and its beginning evolution through the 2016 SRP panel is in the panel's view a significant advance in enhancing livability, well-being, and performance. The Human Factors Behavioral Performance (HFBP) Element clearly communicated the benefits of this approach, encouraging relevant areas within NASA to incorporate a human-centered perspective. However, it is not clear how the research proposed will move HSID forward in terms of influencing the designers and engineers. There are numerous research gaps related to how to integrate HSID into complex engineered systems; the panel recommends focusing research efforts on these gaps.

Another challenge is in the tradeoffs between HSID and other design components. The strategy for implementing HSID in the various components assumes it is a clear, defined process, but HSID has more well-developed tools in some design settings (e.g., interfaces) than in other settings (e.g., structures). In addition, there are many areas where there are no accepted or validated tools or models.

Further, a better understanding of the consequences of making tradeoffs between various research strategies (task portfolios) within the components to address gaps across the components may be needed; the design process may force decisions regarding which tasks to focus on and which to relegate to lower priority or drop. Such tradeoffs would require both an understanding of the relative consequences of not addressing certain risks, as well as identifying the feasibility of specific risk reduction strategies onboard a weight-sensitive vehicle.

While this first attempt at HSID was challenging, the panel encourages the HRP group to continue with a HSID strategy in planning for other topics related to deep space missions, and on prioritizing deliverables within and among the different components. A more specific focus of the SOT should enhance future HSID efforts.

II. Review of the Research Plan for Deep Space Habitat: Livability, Well-being, and Performance

1. Evaluate whether the deliverables that address 1) the Habitat Components (internal volume and layout, restoration and relaxation, work areas, exercise system, food system and lighting system) and 2) HSID and Monitoring:

a) Adequately mitigate risks associated with the outcomes of livability, well-being and performance as previously defined.

- ♦ <u>Volume and Layout</u>
  - The research strategies (current and future) to mitigate the identified risks were well defined;
  - A crucial step will be to ensure that the plans/recommendations arising from these research efforts are delivered in a way that designers and engineers can and will utilize them effectively to design an acceptable minimum habitable volume and layout.

- Work Areas
  - A considerable amount of overlap with the Volume and Layout presentation was noted. The question arose whether Work Areas was meant to be considered as a subset of Volume and Layout;
  - The panel struggled to provide recommendations for the Work Area component; the presentation and materials provided gave more of an overview, which made it difficult to comment on any specifics;
  - The panel recognizes that the ways in which tasks will be performed is expected to change due to continual advances in technology and human-machine interfaces (i.e., controls and displays).
    - In addition, the design reference missions (DRMs) are unlikely to be defined at this level for several years. Because this makes it difficult to predict the procedural nature of any work that might be required,rather than trying to derive volume estimates for specific tasks as illustrated in the current research efforts, it may be sufficient for engineering design purposes to simply estimate the volume for higher level task categories (e.g. scientific bench work, robotic arm operations, whole body exercise).

- Restoration and relaxation
  - The state of current knowledge relevant to Restoration and Relaxation was presented in clear detail;
  - Clarifying the impact of work area design on behavioral health is a positive feature;
  - Driving issues and research strategies for dealing with this component were clearly addressed;
  - Deliverables planned for the future were well specified;
  - Planning for different levels of activation/engagement should be included as a driving issue;
    - States of boredom at one end of a dimension, high activation states related to high workloads at the other end. Mitigation of the risks associated with these conditions needs to be addressed more fully;
  - Greater attention to the synergies and conflicts between this habitat component and other components (e.g. exercise, lighting, work areas) is needed.

- Food System
  - An acceptable plan to address food stability for 5 year shelf life was presented;
    - The presentation was descriptive, lacking in integration with other components;
    - There was no consideration of how food impacts mental health, restoration and relaxation, communal activities (social aspects), and how this might influence other components (e.g., work areas, volume and layout). There also was little consideration of how alternative sensory manipulation (sight, smell, touch) could be used as a tool to improve the food experience.

- Exercise System
  - Careful consideration of the integration of the exercise component with other components addressed in this review is a strongly positive feature;

- The panel recognizes the constrained environment of the habitat as well as the necessity for the crew to exercise to maintain health, but the motivation to exercise is not always present;
    - Additional motivators to encourage exercise were addressed in part;
    - Incorporating exercise into other activities should be explored (e.g. work tasks, training, relaxation);
    - The habitat will have only one piece of equipment. Can it be made adaptable/flexible to configure the exercise protocol in ways that encourage collaboration?
    - Are there other forms of individual or two-person exericise (e.g., stretching, martial arts) that can be beneficial without any equipment?

♦ Lighting System
- The state of knowledge regarding lighting and relevance for the habitat were well presented;
- The discussion of lighting norms for designers and operational protocols were positive features;
- Clear designation of driving issues and research strategies were presented to deal with risks and gaps in knowledge relevant to lighting;
- Considering that virtual reality and augmented reality hardware likely will be used, the effects of light and sound from those devices on other aspects of functioning in the habitat need to be considered;
- There was minimal attention to other LWP components;
    - Examination of work efficiency and health impact other than on sleep was not covered.

♦ Monitoring
- Education and training of astronauts regarding the value and importance of monitoring efforts and the resulting recommendations generated by these data are needed;
- Crewmember concerns about negative consequences of monitoring their behavior may be alleviated to a considerable extent if they have a better understanding of how this information is of personal benefit in improving their overall performance;
    - Concerns about the impact of monitoring on future space assignments is not an issue for deep space missions;
    - Unobtrusive monitoring is useful, but should not be at the expense of self-reports (e.g. journals, questionnaires, inventories), which can be a rich source of data;
    - Important to maintain a balance between the two monitoring modes;
    - Individual monitoring plans may be excessive, with a negative impact on LWP;
- Team conflicts may be more critical to address than individual behavioral health issues;
- Any monitoring system should be lightweight and low power.

- Human System Interaction Design (HSID)
    - The Human Factors Behavioral Performance (HFBP) element clearly communicated the benefits of HSID. However, it is not clear at this stage how the

research proposed will move HSID forward in terms of influencing the designers and engineers;

b) Has been adequately defined and developed so that unintended outcomes or consequences, either positive or negative, can be evaluated. Are there unintended outcomes or consequences that have not been identified or addressed?

- Volume and Layout
  - There are likely a number of unidentified risks arising from the fact that Volume and Layout exists at a different "level" of design than the other habitat components. Work Area, Restoration and Relaxation, Exercise and Food Systems are subsets of the "Volume and Layout" component and each require physical layouts that compete with each other for part of the overall volume. On the other hand, lighting is an equipment-driven environmental factor that influences any physical layout.
  - Continued focus and effort on identifying interactions and synergies between habitat components and how they may lead to unanticipated or unintended risks is strongly encouraged;
  - The use of virtual reality simulations would be helpful;
  - Virtual/augmented reality systems also could be used to influence how crewmembers perceive the habitat volume; in particular, to provide an illusion of greater volume in relation to personal/work space;
  - The research challenge is considerable; it will require significant effort to identify, assess and validate significant linkages between Volume and Layout attributes and crewmember performance/behaviors correlated with psychological/physiological well-being;
  - The panel considers the continued use of Human-in-the-Loop (HITL) simulations critical for effective habitat design. Although the use of computational models as a first order design tool is appropriate, their use as the final or the only HSID tool is strongly discouraged.

- Work Areas
  - "Work" is too broadly defined in the presentation and materials (includes food preparation, exercise, etc.); defined in this way, this component becomes strictly a layout issue;
  - Are the existing guidelines sufficient and can they be practically implemented to integrate and co-locate different functional spaces?
    - Important to ensure that designers and engineers are responsive to cohabitation guidelines;
    - Flexibility and configurability of these areas must be considered well in advance of any habitat design efforts;
  - Ergonomic aspects of a work environment in a deep-space habitat beyond anthropometry need to be addressed. For example, the repetitive static exertions required to maintain a specific body position in the habitat while performing a task could lead to cumulative physical trauma;
  - Similar to Volume and Layout, the use of analogs and HITL simulations are critical to developing effective work areas.
    - Virtual and Mixed Reality (MxR) can help serve as a bridge from computational model to full physical prototyping;

        - Use of computational models as the final or the only HISD tool is strongly discouraged;
    - The panel encourages the group to continue utilizing analogs and HITL simulations wherever possible; with good planning, these studies can ensure both objective and subjective data are collected about work areas.

♦ Restoration and Relaxation
- Deliverables are well-thought out with recognition that they still need further development;
- Helpful to be more specific when listing CRL/TRL values for certain deliverables; each requires specific milestones;
- Important to continue to use analogs to test technology and countermeasures;
- A better conception is needed of how operational measures differ from research measures and conversely, how the components will move from research measures to operational measures.

♦ Food System
- Deliverables are appropriate and clearly address the knowledge and mitigation gaps related to food systems.

♦ Exercise System
- Deliverables (other than the exercise equipment) are a bit difficult to ascertain, but the plan appears to meet needs in terms of equipment design and space;
- There is no plan presented for handling equipment breakdowns;
- Suggest differentiating between exercise for health and exercise/movement for restoration and relaxation;
- Structured training regimens are important, but other exercise options could be explored;
- Alternative methods such as tai-chi and yoga that rely not as much on gravity as on opposing muscle groups are a possibility, although these options may require space to perform these motions.
    - These could be solo or duo activities, which could help with restoration/relaxation as well as interpersonal relationships.

♦ Lighting System
- How to use lighting to improve individual relaxation and performance was well-defined;
- Other positive features:
    - The effort to include individual differences in the countermeasures;
    - Emphasis on individual differences and the development of individual protocols to maintain circadian rhythms;
    - The plan to improve comfort;
    - Beginnings of integration with layout and other components;
- Specific deliverables were not designated;
- Examination of personal preferences/task efficiency in lighting exposures (e.g., screens, private space) is needed;
- Plans for lighting in all four corners of a rectangular volume or evenly spaced around the perimeter of a round or polygonal cross-section would be more appropriate than a ceiling light design since work surfaces and other items needing illumination can be present on all surfaces;

- The use of LED light sources for which crew members could chose the color temperature to fit their mood, personal preference, or activity being conducted can be an important factor in improving livability;
- Possibility of utilizing lighting projections as a countermeasure to alter the environment.
- Considering that virtual reality and augmented reality hardware likely will be used, the light and sound from those devices needs to be considered along with ambient lighting.

♦ Monitoring
- A clear description is needed of the specific measures currently used and those planned for the future in order to evaluate their effectiveness in providing accurate information about the behavioral health of crew members;
- Can collection of biological markers be made more user-friendly?;
    - Evaluation whether these data are truly necessary.

♦ HSID
- Difficult at this stage to evaluate whether the attempts described to implement HSID will be successful because the deliverables were at such a high level. The HSID approach is a cross-cutting one, but it is not clear whether an HSID process will avoid problems with tradeoffs between space/layout needed for other purposes.

2. Does the research strategy:

a) Present the prioritization of the research strategy adequately for addressing the various habitat components?

♦ Volume and Layout
Research strategy clearly defined.

♦ Work Areas
Not necessarily prioritized, but current efforts are clearly designed to support the research strategy.

♦ Restoration and Relaxation
May be the area in which prioritization is most critical, yet one in which it is not clear what the priorities are.

♦ Food System
Priorities are clearly defined and described.

♦ Exercise System
No clear prioritization provided.

♦ Lighting System
No prioritization provided, although the various strategies are described.

♦ Monitoring

The deliverables are too vaguely presented to ascertain prioritization.

♦ HSID

Prioritization is not presented, but implied. The panel recommends that the program identify what parts of HSID (e.g., function allocation, situation awareness) are most important and focus activities on those aspects.

b) Identify strengths or weaknesses in deliverables as presented?

♦ Volume and Layout

- Strengths: A well defined research plan is presented.
- Weaknesses:
  - How crewmembers can exert as much control as possible over their personal space should be considered;
  - The possibility of designing space in which several members but not the entire crew can have private time together is not addressed;
  - Consideration of methods by which crew could differentiate habitat areas from each other (e.g., work vs. dining vs. exercise vs. R&R);
  - Examination of ways to accomplish this using approaches that may not necessarily require physical separation of spaces (e.g., computer projections on surfaces; lighting; and/or configurable furniture and spaces);
  - Consideration of modularity and evolution of space needs and uses over long flight durations.

♦ Work Areas

- Strengths:
  - The research strategy is sound in attempting to incorporate behavioral health considerations into the design of work areas;
  - Important to differentiate between co-location/layout issues (which tend to be driven by behavioral factors) and volume requirements (which tend to be driven more by human factors and task-specific factors);
- Weaknesses:
  - The challenge in integration will be making a compelling link between work area attributes and characteristics that correlate with psychological/physiological well-being in a way that allows assessment of task performance, crew health and/or mission safety;
  - The subsequent challenge is that once LWP outcomes are linked to design factors, how will the relevant measures (objective and subjective) be selected, defined and assessed;
    - It will be necessary to validate and/or evaluate the links (relationships) in order to optimize designs and tradeoffs;
    - Needed is a documented plan for when and how the metrics will drive changes (i.e., reveal issues to be addressed) and how they will be tracked (i.e., “close the loop”);

- Guidelines and models are unlikely to capture all the element/integration issues, which makes it extremely important to utilize analogs and HITL simulations;.
- The concept of “meaningful activities” needs to be more explicitly defined as the term seems to cover a broader area than simply “work”;
  - This may require re-evaluation of the existing standards and guidelines;

Long duration analogs should be utilized to focus on which habitation-related factors influence the perception of “meaningful work”, possibly the most undefined element of the overall research strategy ;

- This evaluation may require that an individual be allowed to have the flexibility and creativity to design their own work (i.e., not a pre-defined procedure) in order to accomplish a specific goal or objective;
- Consideration of possible ways to enable modularity and evolution of use over longer time periods.

♦ <u>Restoration and Relaxation</u>

- Strength
  - The continued use of different types of analogs to test out technologies and countermeasures.
- Weaknesses
  - Priorities of deliverables relative to each other and to other components needs to be clearly documented.

♦ <u>Food System</u>

- Strengths:
  - The research plan is well developed.
- Weaknesses:
  - None noted.

♦ <u>Exercise System</u>

- Strength:
  - The compact exercise equipment encompasses both aerobic and strength conditioning.
- Weaknesses:
  - Attention to resilience and stress relief was lacking, as well as possible non-machine based alternatives.

♦ <u>Lighting System</u>

- Strength:
  - Lighting technology is well developed based on extensive research in laboratory and space settings.
- Weaknesses:
  - The next steps in integration of the deliverables with other HSID components were not well specified;
  - Customization of lighting to deal with individual differences in preferences for lighting was not considered.

3. ***Have the proper Monitoring deliverables (physiological, psychological, performance) been identified to assess the effectiveness of components at promoting the livability, well-being and performance state of the crew?***

- The deliverables mentioned were presented too vaguely to assess their effectiveness;
- Operational measures vs. research measures were not clearly delineated;
- Necessary to consider how research measures may evolve into operational measures over the course of the mission;
- Efforts need to be initiated to develop psychometric norms/standards to assess changes from baseline in crewmember functioning;
- Protocols for monitoring psychological/physiological states pre and post specific activities are needed across several components to assess overall functioning as well as the effectiveness of various activities or countermeasures;
- Strategies need to be developed to enhance cooperation and compliance with self-monitoring protocols;
    - Important message to crew is that compliance with monitoring is for their own benefit to enhance personal performance;
    - The concern about disclosure having a negative impact on future assignments is not an issue for crews on a long duration deep space mission.

4. ***Is the strategy for implementing HSID in development of the various habitat components appropriate?***

- The panel agrees that the first priority is to incorporate HSID into the design process;
- It is difficult for the panel to provide a general comment on this issue because the design components were presented at different levels of maturity (i.e., CRL/TRL).
- Some components such as food systems are less traditionally HSID-focused, thus requiring more HSID training/promotion than other components (e.g., lighting, work areas, volume and layout);
- The strategy for implementing HSID within the various components assumes it is a clear, defined process. However, in the panel's view, HSID tends to work better in some design settings (e.g., interfaces) but can be difficult to apply in other settings (e.g., structures);
- Needed is the assessment of HSID efficiency of application in different contexts.
- HSID activities such as function allocation, task analysis, user requirements are still in their relative infancy.
- There may not be good tools, models in certain areas that can be accepted/validated for use in certain design settings.

5. ***Based on areas of integration provided for this review, are there strengths and weaknesses of the synergies between deliverables as presented? (If so, please identify them)***

- The areas of integration and synergies were not clearly defined, so this question becomes difficult to answer;
- The component authors may have interpreted the HSID charge differently than the panel; presentations appeared to be centered on how to integrate behavioral health aspects into their respective component;

    - The panel was more focused on how the components integrate across each other;
- Clearly, synergies between deliverables exist, but the challenge is in the tradeoffs between HSID and other design elements. The prioritization of the various deliverables needs to be specified in terms of the actual design of the habitat;
    - The panel's struggle to clarify this issue may be indicative of the difficulties/challenges to all involved;
- The tailoring of spaces, food choices, etc. is an aspect that cuts across the various components. This flexibility was not discussed specifically, although hinted at.

6. Are there any important issues that are not covered above, that the SRP would like to bring to the attention of the HRP Chief Scientist?

- The panel greatly appreciated the tour to view the mockups. The ability to see and physically experience the various spaces as well as listen to anecdotes from NASA personnel provided crucial information that the panel could not have otherwise gathered from the reports and presentations, and which played a significant role in the panel's ability to fulfill the charge given;
- The presentations generally were well done, understandable, and helpful, but did not necessarily map with the Statement of Task (SOT). The panel would have appreciated presentations that followed more clearly the SOT format and addressed the questions with which the panel was charged. While research strategies were presented for each project in development, the panel was asked to discuss the research strategy in general, and not for individual projects;
- The SOT, while seeming relatively clear upon initial readings, proved quite difficult to interpret and follow in evaluating the various questions raised. At times it was not clear whether "deliverables" were meant to be assessed at a general or a more specific level. In certain cases, "deliverables" did not track with the information presented, which focused more on strategies rather than specific deliverables (e.g., plans to talk with subject matter experts, development of guidelines). The end result was a greater focus by the panel on research questions and recommendations regarding research strategies, rather than a specific evaluation of deliverables;
- The panel was unclear about the number of crewmembers on which to base discussion; documents shift between 4 and 6 crewmembers. Based on feedback from HRP staff, most of the discussion focused on a range of 3-6 crewmembers;
- Components that directly influence initial habitat design (in particular, Volume and Layout, Work Areas) appeared to be using a sequential research strategy that first utilizes engineering approaches to reduce identified risks as low as possible and then subsequently developing scientifically-derived countermeasures to deal with any residual risk. However, with respect to LWP, some risks may not be adequately identified or understood sufficiently to eliminate or reduce them to acceptable levels, in which case countermeasures will be the primary means to address the risk. It may be more effective and efficient to use a parallel approach in which countermeasures to address hazards at the current risk level, not the residual level, are developed concurrently with the engineering efforts.
- Throughout, there was a general lack of anticipating likely technological advances and including this topic in the research strategies or portfolios;
- Consideration of the aesthetics/attractiveness as well as the functionality of the habitat design is important in terms of crew comfort;

- The panel emphasizes again the importance of attention to the consequences of making tradeoffs between various research strategies within the components to address gaps across the elements, as the design process may force decisions as to which tasks to focus on and which to relegate to lower priority or drop;
- The panel expresses concern about conducting this assessment while being charged to ignore environmental influences not covered in the SRP, yet with significant impact (e.g., vibration, acoustics/noise, communications, and inventory management). The panel struggled to effectively consider the requested components separate from these other influences;
- With respect to LWP, the research strategies for the various components may want to consider 'planning for the worst': addressing resiliency should the crew be confronted with an unanticipated risk or shortcoming in design and/or countermeasures. Despite all efforts to avoid them, a negative event impacting LWP still may occur. Are there ways in which a specific component of the habitat can be designed to restore and maintain LWP (e.g., post-event countermeasures), ideally without requiring communication with mission control? As an example, how might the crew carry out resistance exercises should the exercise machine break down?;
- The panel emphasizes again the crucial importance of education and training of crewmembers regarding the value and significance of monitoring efforts and the recommendations generated by these data;
- It is important to ensure that current crewmembers are debriefed post-mission with respect to their experiences with the various components. The debrief does not necessarily have to be carried out immediately after landing;
- There was no discussion of intimate relationships or any other non-work relationships that might develop between crewmembers, although this situation could have a significant impact on overall crew functioning.

III. 2016 Habitat SRP Roster

Chair:

Gloria Leon, Ph.D.
University of Minnesota
Department of Psychology
Elliott Hall
75 East River Road
Minneapolis, MN 55455
Phone: 612-625-9324
Email: leonx003@umn.edu

Participants:

Joel Dimsdale, M.D.
University of California
Department of Psychiatry
Room 418 CTF-A Bldg.
210 Dickinson Street
San Diego, CA 92103
Phone: 619-543-5592
Email: jdimsdale@ucsd.edu

Robert Feyen, Ph.D.
University of Minnesota
Mechanical and Industrial Engineering Department
1305 Ordean Court
Duluth, MN 55812-3042
Phone: 218-726-8327
Email: rfeyen@d.umn.edu

Diane Gill, Ph.D.
University of North Carolina at Greensboro
Department of Kinesiology
Greensboro, NC 27402-6170
Phone: 336-334-4683
Email: dlgill@uncg.edu

James Hunt, B.Arch.
Behavioral Health Facility Consulting, LLC
2342 SE Alamar Road
Topeka, KS 66605-1850
Phone: 785-231-4500
Email: jim@bhfcllc.com

Steven Landry, Ph.D.
Purdue University
School of Industrial Engineering
315 N. Grant St.
West Lafayette, IN 47907
Phone: 765-494-6256
Email: slandry@purdue.edu

Joseph Marcy, Ph.D.
Virginia Tech
22A Food Science and Technology Building (0418)
Blacksburg, VA 24061
Phone: 540-231-7850
Email: jmarcy@vt.edu

Todd Richmond, Ph.D.
USC Institute for Creative Technologies
12015 Waterfront Drive
Playa Vista, CA 90094-2536
Phone: 310-574-5700
Email: trichmond@ict.usc.edu

NASA Headquarters:

Bruce Hather, Ph.D.
NASA Headquarters
300 E Street, SW
Washington, DC 20546
Phone: 202-358-1796
Email: bruce.hather-1@nasa.gov

NRESS Support Team:

Pauline Burgess
Meeting Planner
2345 Crystal Drive, Suite 500
Arlington, VA 22202
Phone: 202-479-9030 x304
Email: pburgess@nasaprs.com

Guillaume Vignaux
Peer Review Administrator
2345 Crystal Drive, Suite 500
Arlington, VA 22202
Phone: 202-479-9030 x230
Email: gvignaux@nasaprs.com