2013 Space Human Factors Engineering Standing Review Panel Status Review

Statement of Task for:

The Risk of an Incompatible Vehicle/Habitat Design,
The Risk of Inadequate Critical Task Design,
The Risk of Inadequate Design of Human and Automation/Robotic Integration,
The Risk of Inadequate Human-Computer Interaction, and
The Risk of Performance Errors Due to Training Deficiencies

Comments to the Human Research Program, Chief Scientist

2013 Space Human Factor Engineering (SHFE) Standing Review Panel (SRP) Status Review WebEx/teleconference participants:

SRP Members:
Anna Wichansky, Ph.D. (Chair) – Oracle
Norman Badler, Ph.D. – University of Pennsylvania
Keith Butler, Ph.D. – University of Washington
Mary Cummings, Ph.D. – Duke University
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Victor Schneider, M.D.

NASA Research and Education Support Services (NRESS):
Tiffin Ross-Shepard

On December 4, 2013, the SHFE SRP, participants from the ARC, JSC, HQ, the NSBRI, and NRESS participated in a WebEx/teleconference. The purpose of the call (as stated in the Statement of Task) was to allow the SRP members to:

1. Receive an update by the Human Research Program (HRP) Chief Scientist or Deputy Chief Scientist on the status of NASA's current and future exploration plans and the impact these will have on the HRP.
2. Receive an update on any changes within the HRP since the 2012 SRP meeting.
3. Receive an update by the Element or Project Scientist(s) on progress since the 2012 SRP meeting.
4. Participate in a discussion with the HRP Chief Scientist, Deputy Chief Scientist, and the Element regarding possible topics to be addressed at the next SRP meeting.

Based on the presentations and the discussion during the WebEx/teleconference, the SRP would like to relay the following information to Dr. Shelhamer, the HRP Chief Scientist.

General Comments:

- The SRP thought the presentations were well documented and presented understandably.

- As the name implies, human-computer interaction (HCI) depends on the computing technology, as well as the human user. The cause of the risk of inadequate HCI is not a static property of nature, as with something like radiation exposure. In contrast, the risk of HCI is an artifact of the computing environment. Since the likelihood of that environment changing every few years is very high, the green (controlled) classification of HCI is based on an unlikely assumption that today's HCI risk is acceptable, so it still will be in 2024.

- The SRP understands that work on certain risks had to be suspended based on budget limitations. But HARI, HCI, TRAIN, and TASK are the majority (80%) of the SHFE risks; these will have to come into play again. It may incur added costs and missed opportunities if SHFE waits too long before restarting this work. Neglect of these risks will create serious information gaps.

- The SRP had mixed feelings about the small N/twins experiment. This N of "1" (or 2 or 3) experiment may be a creative way to take advantage of a special circumstance to deal with a hard funding environment. However, there is a steep price to be paid in reliability of results if N is only 1 (or 2 or 3). In Dr. Shelhamer's overview presentation, there was a slide titled "How large does 'N' need to be?" This tried to make the case that small N was just fine for getting the answers that were needed and that NASA could become the leader in making this happen. While an N of 1 (or 2 or 3) is better than an N of zero, it's not clear how one would test hypotheses or draw conclusions with such a small N; the SRP isn't aware of statistical techniques to do this. No specifics were provided to the SRP as to how the tradeoffs might be implemented and the risks appraised. Further discussion of why the SRP have the above comments is available in the Addendum to this report.

Comments specific to TRAIN Risk:

- Training is often developed "too little, too late" in major systems implementations. In the case of these missions, the SRP thinks that new training technologies, particularly social networking, should be evaluated for applicability, both on Earth and in space, as increasing network transmission speeds make this feasible. This might also improve the trust issues discussed under the HARI risk.

- The SRP understands that training is not going to be emphasized, but if NASA is going to maximize the International Space Station (ISS), then couldn't the astronaut do some training during the year on board and measure that compared to the proficiency at launch time? The SRP thinks it would be useful to know whether the astronaut's proficiency stayed the same or improved. The SRP questions whether an analog environment could be used in testing training after a specified period of time.

Comments specific to TASK Risk:

- The SRP has asked for the task list but has not received it at this point. This makes it difficult to evaluate the efficacy of experiments on task design. This area appears to have been transferred to the Behavioral Health and Performance Element (BHP). Certainly cognitive workload will depend upon what tasks are being performed, and interact with factors involved in many other SHFE risks. Generally, the resources used for work procedures constrain task performance, whether the task is physical or cognitive. The procedures for cognitive tasks and the corresponding workload they impose are strongly affected by the information resources that are used. Therefore, the risk of tasks and the risk of HCI are related in a way that cannot be separated. In an important sense, the risk of HCI is really the risk of the tasks it supports.

- The SRP thinks the TASK risk obviously interacts with the HAB risk, so the SHFE project may want to consider not just procedures for tasks, but also where (location) each task is performed. This is especially true if a particular piece of equipment has to be watched for feedback or for a task that involves two astronauts collaborating in the extremely cramped environment.

- The SRP thinks task design will also be critical once a landing is done and astronauts have to do explorations or at least send robotic vehicles on missions.

Comments specific to HAB Risk:

- Specific comments on the HAB risk are detailed in the Addendum.

- There appears to be increasing relative emphasis on the HAB risk in terms of funding and the number of studies, with Net Habitable Volume (NHV) a key metric. The SRP continues to ask for a basic list of tasks which astronauts will perform in space. This will strongly influence NHV, as will the required sequence, tempo, and simultaneity of tasks to be performed. The SRP thinks that not only a list of tasks to work with but an understanding of tasks that may need to be performed simultaneously would be useful.

- The SRP thinks that a definition of the HAB risk is needed. The SRP would suggest that a priority is risk to crew, then risk to vehicle that does not impact crew, risk to mission, and then lower levels of impacts. Please see the addendum for further details.

- The SRP thinks that the SHFE project should not only look at mundane tasks, but also emergency tasks and determine what NHV is needed for doing these.

- Can an analog environment be used to assess some of these issues with the HAB risk?
- With respect to NHV, it is an extensive project that can utilize staff time when real mission decisions are being made (or not). It appears comprehensive, yet unfocused. The number of variables and conditions (and the often small samples) mean that it may be more of a descriptive compendium than a predictive guideline, since the type and range of data to be accumulated is so broad. On the other hand, if this corporate memory project is essential to the survival of volatile human performance data, then by all means the SRP thinks it should be preserved just as the NASA Standard 3000 collected and preserved widely scattered human factors data.

<u>Comments specific to HARI Risk:</u>

- The HARI risk is considered by NASA to be yellow (unacceptable) until FY20 and then green (controlled). For long-duration space missions the current way of thinking about HARI will almost certainly have to be modified to deal with limitations in crew support and partial autonomy failures.

- The decrease in emphasis and funding of HARI by the HRP is coming at a time when this topic is heating up in the rest of the systems automation and human factors engineering world:
    - The National Transportation Safety Board (NTSB) investigation of the Asiana Flight 214 crash at San Francisco International Airport reveals that both under-training of the pilot and over-reliance on flight automation played significant roles in the tragedy. There was also a culturally-based “communication gap” between the pilot and the training instructor resulting in judgment deferral to the highest-ranking individual in the cabin, even though he was not in command of the aircraft.
    - The Human Factors and Ergonomics Society is offering a $10,000 prize in 2014 for the best paper on human interaction with automation[1]. This is the most important topic to the society this year. From the call for papers: Examples are: research on human trust in automation and how trust affects interactions, how team interactions are affected by automation, models of effective human automation interaction/autonomy.
    - The last two issues of *Ergonomics and Design* feature lead articles and editorials about flight deck automation[2] [3]. There are major issues with the operators not knowing what the system is doing, and the system not knowing what the operators intend.

[1] *HFES Bulletin*, December, 2013, 56 (12): 2-3

2 Eric E. Geiselman, Christopher M. Johnson, and David R. Buck. Flight Deck Automation: Invaluable Collaborator or Insidious Enabler? *Ergonomics in Design: The Quarterly of Human Factors Applications* July 2013 21: 22-26, doi:10.1177/1064804613491268

3 Eric E. Geiselman, Christopher M. Johnson, David R. Buck, and Timothy Patrick. Flight Deck Automation: A Call for Context-Aware Logic to Improve Safety. *Ergonomics in Design: The Quarterly of Human Factors Applications* October 2013 21: 13-18, doi:10.1177/1064804613489126

  - A paper from Cal State Long Beach and NASA/San Jose State Foundation last July at HCII 2013[4] indicated there was no body of research on air traffic controller training of trust of automated next generation control systems.

- The SRP thinks that the HARI Risk is an area where research should not be neglected but rather expanded, as major decisions about function, allocation, and training will rely on optimal HARI for these missions. NASA Next Gen Air Traffic Control (ATC) results, and the Army and Navy research results referred to by Randall Shumaker, Ph.D. (SRP member), may be helpful to SHFE during this funding hiatus for HARI.

- The SRP thinks there are still major issues with automation. However, as the automation becomes more and more sophisticated, NASA will need to determine the impact of novel tasks and how one can recognize malfunctions and interact to mitigate any issues. For example, the automotive industry currently has some impressive automation that helps drivers perform correctly. The SRP questions whether a person can recognize that there is a failure in one of these sensors in time to take over and correct it.

<u>Comments specific to HCI Risk:</u>

- It is understood from the presentation of Dr. Mark Shelhamer on the Integrated Path to Risk Reduction (slide 14), that the risk is coded green if the research currently funded is successful, as this creates a manageable risk for HRP. The SRP has reservations about declaring this risk green and defunding it now and in the future, for the following reasons:
  - The nature of future exploration missions is in flux, as evidenced by the Flexible Path (slide 4), which shows 10 possible objectives. If the nature of the mission is not known, then the tasks cannot be known for certain either. If the tasks are not known, then the types of user interfaces, the contexts of use, the stakeholders for HCI, and many other factors are also necessarily unknown.
  - Technology is now and will continue to be a moving target. Given the length of NASA HRP procurement cycles, the astronauts will be reaching their objectives in 10-15 years with obsolete user interfaces that people on Earth will no longer be using on computers. Windows and PCs (as we know them) will more than likely be gone. Devices will run on much smaller operating systems (OSes) or no OSes; there will be more dependency of computer users on the cloud and social networking for everyday tasks.
  - What people are willing and able to tolerate in terms of ease of use is changing, generationally speaking. If astronauts aged 25-45 will be going to Mars in 20 years, they are only aged 5-25 now. At the older end of this spectrum, they are Generation Y, growing up with gamification, social networking, speech interfaces, intelligent agents with natural language capability, infographics, and portability via mobile devices in their computing workplace. Most of the computing they do is on a smart phone today. This is a big difference from the types of user experiences the HCI gaps and research tasks currently address; in some respects, these are already based on obsolescent technologies. At the younger end of the spectrum, it is unknown what their expectations for user experiences will be, but the trend is toward simpler, more

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[4] Higham, T.M., Vu, K.-P. L., Miles, J., Strybel, T.Z., and Battiste, V. Training air traffic controller trust in automation within the NextGen environment. *Proceedings of HCII 2013***,** 8017: 76-84.

visual, more intelligent computing that requires less reading, typing, and training than before.

- Passive sensing of crew state is also lacking as a user interface (UI) tool. The next generation of users will expect systems to understand and act on their state, speech, and motions. While it is understandable that flight experiments are limited due to up mass and crew time, Earth-based studies can still determine how such position, activity, physiological and even psychological state can be used to design near future UIs with better human-state understanding. There are inherent risks and benefits to this, and they need to be properly assessed in the context of future NASA missions.

- This study assesses changes in navigation techniques on a tablet

- Therefore, it is hard for computer scientists today to feel complacent about HCI risks being manageable in this time period. The SRP thinks that this is a risk that will need to be continuously watched, reassessed, and addressed by changing the countermeasures, as the UI is the major way astronauts will interact with their space vehicle. It's too important to "let it ride" for 15 years. The fine motor control study for the one-year mission is a good start on this.

- If the HRP does not have its own funding, it should consider creative ways to influence grant work funded by other agencies, such as in-kind participation, access to data on realistic NASA problems, etc. Some researchers may find that very attractive instead of toy problems.

Response to the Addendum Questions:
The SRP thinks that collecting, archiving and indexing data is always a good thing as long as it does not consume too much of limited resources and the data is in a form that is accessible and useful. Achieving the goals of accessibility and utility are especially difficult, maybe impossible, if we are unsure precisely who might want the information and what they might want to do with it. These caveats are pivotal issues in moving ahead with the Human Performance Data Project.

- *What operational human performance data would provide an enhanced prospective ability to assess the impact of various factors on human performance on future spaceflight missions?*

The SRP thinks a variety of error analysis approaches are available for this type of activity, including critical incidents, human reliability analysis, and error modes and effects analysis.[5] The best way to access this archival data may be to use a critical incidents approach. First, there needs to be a list of common tasks the astronauts will perform. These should be at the functional level and descriptive of an intent or goal to be achieved, rather than at the keystroke level. From there, SHFE should prioritize tasks, where:

1) there is a high risk of failure, (i.e., task performances have already led to accidents or mistakes in space or in training, near misses, or it is otherwise known this is a very difficult, complex, error-prone task),
2) the risk of failure is unknown because the tasks are new,

[5] For a quick summary, see Salvendy, G. *Handbook of Human Factors and Ergonomics 4th Edition*, Hoboken: John Wiley, 2012, 714-716.

3) the task results in frequent but not serious errors during routine performance,
4) astronauts reported their own or others' past performance to be suboptimal.

The types of data to pursue depend upon the task and the level of granularity necessary to prevent an accident or a mistake. For example, in viewing a display, if astronauts have already misread a display and complained about the font size or style, then the contextual data around those incidents should be extracted. These could be the illumination, the viewing angle, acceleration and vibration levels at the time of the mistake, whether the astronaut was looking through a mask or window or directly on the display, whether he or she was using any particular medication, was ill, tired, at the end of a work shift, etc.

- *What tasks (throughout all mission phases) should be prioritized for human performance data?*

With respect to what task should be prioritized, the SRP thinks those that put the crew in danger if not completed, should be prioritized the highest, followed by impacting the mission if not completed.

Relative to the HAB risk, what tasks were directly impacted by vehicle space should be prioritized higher, according to the following criteria: injuries (collisions), navigation speed and access, task duration (longer than nominal/expected due to awkward postures), etc. This would be followed by tasks that previously produced errors, unexpected performance delays, crew inability to perform as expected (e.g., in-flight as opposed to successful execution on ground), unusual (re-)training requirements, requiring unusual physiological or mental capabilities (strength, reasoning, information look-up, etc.).

The SRP would be less interested in enumerating everything that went right, but if such data exists it will come out in data searches (see below).

- *What types of data (e.g., equipment transfers, crew translations, maintenance task completion, hand controller inputs, landing deviations, training proficiency) would you recommend be pursued to assess human performance associated with those tasks?*

The SRP recommends prioritizing acquisition of such data by frequency of prior issues. For example, if there is an abundance of critical incidents due to landing deviations, then landing deviations and related dependent variables should be included as often as possible to obtain a predictive database for future flights.

- *If it is not possible to obtain associated context data (e.g., medications, sleep, workload, stress, loss of communication, interruption for other tasks, exercise, environmental conditions such as level of lighting, crew composition) for existing datasets, what is the Panel's judgment regarding the value of the operational data?*

Lack of context data can cause misattribution of critical incidents to known vs. unknown variables. The SRP thinks that not having context NASA will most likely just attribute the errors to bad interfaces, lack of knowledge of automation status, inadequate training, etc., when in fact there may be contextual causes. On Earth, when workers get sick we know it (at least some of the time), because they can self-report and call in sick. In space, provisions need to be made for having someone out or not participating in at least critical tasks, and these incidents and concomitant causes need to be recorded as context variables.

Where context is not recorded, the operational data might still be very helpful if they lead to a root cause of the mistake. In the previous example, if it is unknown whether the astronaut had slept recently or was ill, but it was known that at the time of the error the spacecraft experienced a major vibration, that would more likely be the explanation for the display misread. The critical incident should be examined in the context of as many variables as possible, until it becomes clearly understood or identified as a type of error event; then the number of variables routinely examined for the event type may be more limited.

- *Given limited funding, how much effort should be expended to attempt to reconstruct the context surrounding historical data vs. effort to implement mechanisms to collect data and context going forward?*

The SRP thinks it depends on how much of an impact any critical incident has. If it causes major mission failure, loss of life, injury, and other serious consequences, then significant effort should be made to reconstruct the context if it is anticipated it may happen again. If a critical incident has a low probability of recurring, then more effort should be made to collect contextual data going forward, on other variables that are anticipated to put the mission at risk.

- *What future technologies would you recommend for collecting these types of data, especially for obtaining unobtrusively and noninvasively?*

Generally, the SRP thinks that for identification of critical incidents, astronaut diaries, logging, and passive videos can be helpful. An integrated tool allowing the above plus time stamping and voice-over narration on a smart tablet or similar device might work. A database that is architected and designed to accept multimodal data objects such as video, and set up to capture, analyze and generate reports on all the data variables simultaneously would be useful. Motion based automatic capture, and automatically logged data from passive sensors and human-automation interactions can be stored; however, data could be automatically purged unless flagged. Crew privacy issues should be addressed through content security measures.

Given the capabilities of modern text search engines and the speed of modern computers, the best organization for the performance data may be no overt organization at all. Merely being able to search with whatever search terms are relevant to the question (or, in fact, with the question verbatim as many search engines now allow) may be sufficient to return relevant and useful textual data. This organization into a set of cross-searchable (tagged) text files would obviate the need for a lot of pre-usage database design.

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The Risk of Performance Errors Due to Training Deficiencies

The 2013 Space Human Factors Engineering (SHFE) Standing Review Panel (SRP) will participate in a Status Review that will occur via a WebEx/teleconference with the Human Research Program (HRP) Chief Scientist, Deputy Chief Scientist and members of the Space Human Factors and Habitability (SHFH) Element. The purpose of this review is for the SRP to:

1. Receive an update by the HRP Chief Scientist or Deputy Chief Scientist on the status of NASA's current and future exploration plans and the impact these will have on the HRP.

2. Receive an update on any changes within the HRP since the 2012 SRP meeting.

3. Receive an update by the Element or Project Scientist(s) on progress since the 2012 SRP meeting.

4. Participate in a discussion with the HRP Chief Scientist, Deputy Chief Scientist, and the Element regarding possible topics to be addressed at the next SRP meeting

The 2013 SHFE SRP will produce a report/comments from this status review within 30 days of the 2013 update. These comments will be submitted to the HRP Chief Scientist and copies will be provided to the SHFH Element that sponsors the SHFE Project and also made available to the other HRP Elements. The 2013 SRP Final Report will be made available on the Human Research Roadmap public website (http://humanresearchroadmap.nasa.gov/).

Addendum to the Charge:

Human Performance Data Project:

The Human Performance Data Project (HPDP) is attempting to establish an archival repository where actual spaceflight human performance data are collected, curated, and made available for analysis by various stakeholders and user communities. This information from actual spaceflight operations will serve to better inform those with a stake in improving activities for both current and future space operations.

The goals of the project are: (1) inform research that focuses on solving operational issues, (2) inform and enhance operations to maximize crew time efficiency, and (3) inform design decisions related to human health, safety and performance for future human exploration programs in terms of SHFE risks.

The types of data we are pursuing that impact performances are: system data, human data, and contextual data. System data refers to real-time telemetry of system state, crew inputs, or data stored during operations that is collected as part of training (ground or onboard), flight analog studies, space flight operations, or mission activities. Human data refers to data reflecting human performance (e.g., `number of errors, task completion time). Contextual data refers to correlating factors associated with changes in performance, or human performance modulators (directly affecting performance), for example, length of mission, medications, sleep shifting, and training. Some of these contextual data may already be found in existing medical and research databases such as Longitudinal Study of Astronaut Health (LSAH), and Life Sciences Data Archive (LSDA).

SHFE would like the Panel's thoughts on the following questions:

- What operational human performance data would provide an enhanced prospective ability to assess the impact of various factors on human performance on future spaceflight missions?
    - What tasks (throughout all mission phases) should be prioritized for human performance data?
    - What types of data (e.g., equipment transfers, crew translations, maintenance task completion, hand controller inputs, landing deviations, training proficiency) would you recommend be pursued to assess human performance associated with those tasks?

- If it is not possible to obtain associated context data (e.g., medications, sleep, workload, stress, loss of communication, interruption for other tasks, exercise, environmental conditions such as level of lighting, crew composition) for existing datasets, what is the Panel's judgment regarding the value of the operational data?

    - Given limited funding, how much effort should be expended to attempt to reconstruct the context surrounding historical data vs. effort to implement mechanisms to collect data and context going forward?

What future technologies would you recommend for collecting these types of data, especially for obtaining unobtrusively and noninvasively?

Addendum added April 4, 2014

From: Anna Wichansky, past-Chair, SHFE SRP
Jean Scholtz, Chair, SHFE SRP
Norman Badler, Member SHFE SRP

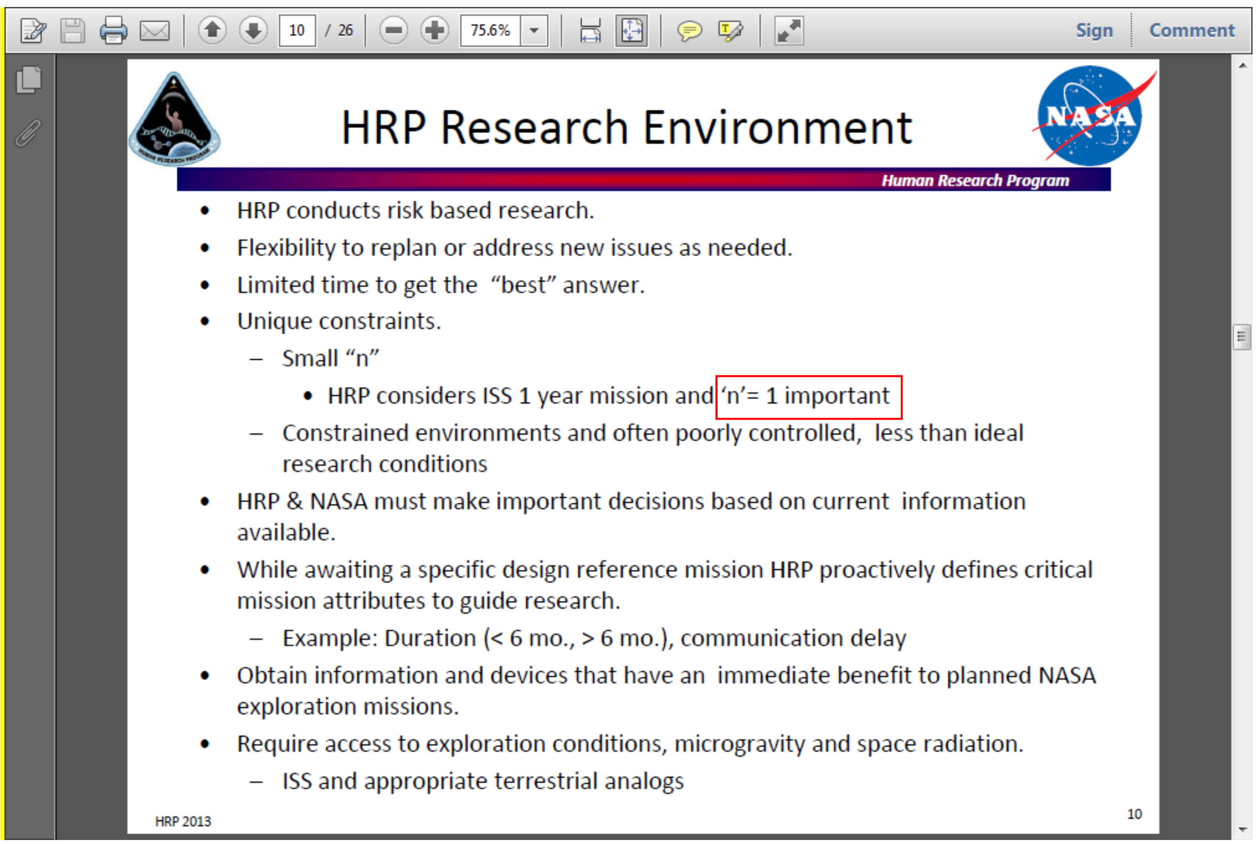
Subject: Response to NASA on Questions on 1/14/14 SHFE SRP Report

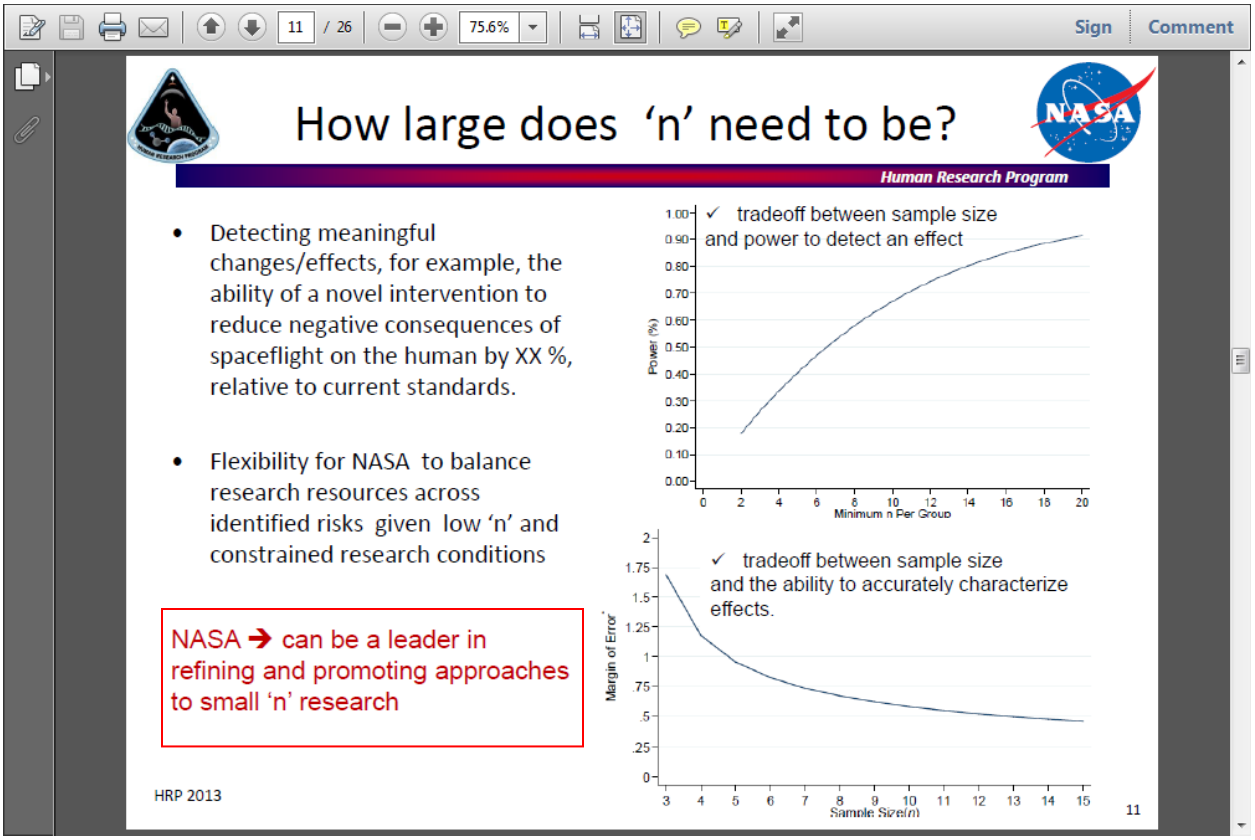
This is an addendum to the original comments the SHFE SRP provided to the SHFE Project on 1/14/14. This addendum addresses questions the SHFE Project and the HRP Chief Scientist sent to the SHFE SRP (via Tiffin Ross-Shepard) for clarification.

Small *n* and Twins Research

NASA has commented back to the SRP that we may have misunderstood or made errors in our comments on the content of their presentation on small *n* and twins research. They have said there is basically no research being conducted where n=1, and no twins study.

Below are thumbnails of slides 10 and 11 that Dr. Shelhamer presented on 12/4/13. Highlighted in red are the portions that say n=1 is important and NASA seeks to be a leader in small *n* research.





Furthermore, we assumed that the ISS mission referred to is the mission where twin astronauts will be used, one on the ground and one on the ISS, and comparisons of fine motor activity will be made; one of us was asked to review the proposal for this study earlier in 2013. Such a comparison in a within-subjects or paired t-test design is considered n=1 (1 matched pair), as the difference between the scores of the two participants would be the data analyzed. It is understood that a cosmonaut will also be aboard ISS, but that his participation was not assured. In any case, if he does participate, he would only be part of a matched pair with the ground astronaut, which would result in n=2, which is not much better statistically than n=1 for obtaining statistical power in inference testing. This is assuming it is valid for the ground astronaut to act as a control for both ISS astronauts.

Since the time of the meeting, one of us had the opportunity to discuss the small *n/n*=1, 2 or 3/ twin experimental scenario with two biostatisticians who attended the Habitation research proposal review panel in Washington, DC in March 2014. Both statisticians were skeptical that any inferential statistics could be validly and reliably performed on one matched pair. When asked what kind of statistics could be performed in such a situation, one said, “none” and the other said “descriptive statistics;” in other words, frequency plots, ranges, not inferential statistics. So hypothesis testing with statistical verification wouldn’t really be appropriate.

HAB Risk Definition

We think that the current definition of HAB risk, which attributes all the risk to “ergonomic-related disorders,” is unnecessarily restrictive and incomplete. There are many other human factors aspects of inadequate habitation environments besides development of musculoskeletal disorders such as repetitive strain injuries (RSIs.)

The current risk says: "Given that vehicle, habitat, and workspace designs must accommodate variations in human physical characteristics and capabilities, and given that the duration of crew habitation in these space-based environments will be far greater than missions of the past, there is a risk of acute and chronic ergonomic-related disorders, resulting in flight and ground crew errors and inefficiencies, failed mission and program objectives, and an increase in the potential for crew injuries."

The scope of "ergonomic-related disorders" should be clearly defined and thereby address what HAB should be doing to mitigate "flight and ground crew errors and inefficiencies, failed mission and program objectives, and an increase in the potential for crew injuries." In terrestrial environments these usually refer to musculoskeletal injury, lack of visibility, reach, or strength, and population accommodation restrictions. However, space flight and highly constrained HAB volumes increase the range of HAB risks. There need to more clearly define "ergonomic risks" such as:

- Excessive strength (force, torque or grip) requirements, need for bracing devices, and consequent musculoskeletal injuries in body locations other than the lower back.
- Reach, grasp and manipulation (range of motion) inadequacies: e.g., access routes that are gravity- and orientation-independent, usable manipulation space, and adequate (and safe) volumes for tool use.
- Hazards that arise from the nature of the environment itself: unsafe equipment hazards (protrusions, sharp points or edges, electrical shock, rotational components, escaped liquids, radiation, other hazardous material) and their need and relation to task activities (nominal as well as emergency).
- Team activity coordination where successful task completion requires two or more co-located crew activities with intersecting space requirements. Risks and injuries may be caused by another crewmember (rather than the environment itself *per se*), whether due to collision, inadequate space, tool slippage (a source of injuries to teammates or equipment), unexpected movements of heavy equipment (even in 0-g they have mass and hence could inflict significant force that could pinch, crush, or break body parts), etc.).
- Tasks that require access to specific displays or other stationary HAB equipment; in particular, when constrained tasks have to be done in parallel, is there sufficient NVH to accomplish these?
- Can the crew do multiple tasks including emergency tasks at the same time in the space they have? If they have to work round the clock when not in contact with ground control, is there room for some to work and for others to sleep?
- Visibility concerns (lighting, labeling, readability, effects of vibration).
- Communicative failures (inability to hear teammate utterances during coordinated tasks), excessive ambient noise (e.g., in servicing noisy equipment) that could result in missed communications or even (partial or temporary) hearing loss.
- Psychosocial factors that interact with environment to affect task performance:
    - The effects of lack of space and lack of solitary time on attention, alertness, concentration, work relationships, and so on.
    - The effects of lack of space on ability to rest and sleep (stiff necks, torqued backs).

  - The effects of lack of space on hygiene and therefore self-confidence, work relationships, and so on.

Many of these may not be obvious "ergonomic" risks so it may be worth enumerating (and thus defining) them. Knowing the tasks, especially the multiple-person ones, will be especially useful to establish risks and NHV for these activities. Safety is certainly a concern, but so is task performance (error free and within necessary time constraints) and even crew comfort. Some of this comes out in team coordination but not as strongly as we would like. Is some of this being looked at by the BHP folks? If so, it would seem that there should be some acknowledgment in this document.

The consequences broadening of this definition would be that there is a real gap in computational human models (shirt-sleeved or suited) that may be used to rapidly and effectively assess these risks. Without such a model, computing NHV for HAB is essentially not really possible.

HAB -09

We also believe there is a gap in computational tools that can determine required task volumes. While these exist for object insertion and extraction (called “maintenance access solids”) little work has been done to create software tools to characterize the human space occupancy required for tasks. Without good geometric models of human action spaces, NHV will be mostly guesswork.

The target for gap closure in HAB-08 is the current rate of guidelines, ground rules, processes, and a refined set of critical mission attributes necessary for determining, assessing and monitoring NHV. The issue is that of measuring NHV. HAB-07 addresses guidelines, ground rules and processes to ensure NHV. Hab-09 calls for tools, metrics, and methods to quantify NHV. The computational human-modeling is a new NRA solicitation. Did this solicitation result in research that will help in measuring NHV?

HAB-Metrics Summary

At this point in time, HAB-08 needs to be re-examined and expanded. HAB-09 can only be closed if an acceptable method for measuring NHV for volume/task/person/spatial layout/vehicle is produced along with a way to map inadequate designs to risks. HAB-07 of course is dependent on a method for computing NHV as well as a set of tasks and the resources needed for these. HAB-05 needs to draw information from HAB-08 so expanding the issues in HAB-08 may increase tasks for HAB-05. The same is true for HAB-03. As the SHFE was not tasked to look at the HAB metrics in 2013, we suggest that this be put on the agenda for the SHFE in 2014.