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Analog Assessment Tool Report

Human Research Program
Behavioral Health & Performance Element

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Acronyms

AEB	Agencia Espacial Brasileira
AHP	Analytical Hierarchy Process
ANSMET	Antarctic Search for Meteorites program
AUV	Autonomous Underwater Vehicle
BHP	Behavioral Health and Performance Element
BMed	Behavioral Medicine
CSA	Canadian Space Agency
CRL	Countermeasure Readiness Level
DRATS	Desert Research and Technology Studies
ESA	European Space Agency
EVA	Extravehicular Activity
NEO	Near-Earth Objects
HMP	Haughton-Mars Project
HMP-PO	Haughton-Mars Project Proposed Operations
HRP	Human Research Program
ISRU	In-situ Resource Utilization
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
JSC	Johnson Space Center
NEEMO	NASA Extreme Environment Mission Operations
NURC	National Undersea Research Center
PISCES	Pacific International Space Center for Exploration Systems
PLRP	Pavilion Lake Research Project
SCOUT	Science Crew Operations and Utility Test bed
SME	Subject Matter Expert
TRL	Technology Readiness Level
USGS	U.S. Geological Survey
USOS	U.S. Operating Segment

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THE NASA HUMAN RESEARCH PROGRAM BEHAVIORAL HEALTH AND PERFORMANCE ELEMENT ANALOG ASSESSMENT TOOL REPORT Results Year 2

Introduction

In preparation for future exploration missions to distant destinations (e.g., moon, Near-Earth Objects [NEOs], and Mars), the NASA Human Research Program (HRP) Behavioral Health and Performance Element (BHP) conducts and supports research to address four human health risks: Risk of Behavioral Conditions; Risk of Psychiatric Conditions; Risk of Performance Decrements due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team; and Risk of Performance Errors due to Sleep Loss, Fatigue, Circadian Desynchronization, and Work Overload.[1] BHP Research – in collaboration with internal and external research investigators as well as subject matter experts (SMEs) within the operational environment including NASA flight surgeons, astronauts, and mission planners – identifies knowledge and technology gaps in the research within each risk. BHP Research subsequently manages and conducts research tasks to address and close the gaps, either through risk assessment and quantification or through countermeasure and monitoring technology development. The resulting deliverables, in many instances, also support current Medical Operations and/or Mission Operations for the International Space Station (ISS).

BHP Research uses a risk-to-mitigation strategy to ensure that the research yields deliverables and products that are operationally relevant and acceptable (see Figure 1). BHP Research begins by considering the deliverable in light of the known mission requirements. Working with operational experts (e.g., flight surgeons, mission planners, astronauts), and intramural and extramural researchers, BHP Research is able to assess which best practices are currently implemented to determine whether future work in a specific area is needed. In instances where future research is proven necessary, the BHP Research Element must then determine which area is at risk and the specific gap in question, and then must decide how to implement research that would enable the development of a deliverable that adequately addresses the need within the context of the unique demands of exploration missions.

Within this risk-to-mitigation strategy, BHP Research must identify optimal analogs for research studies that can be used to test and validate those needed products and/or deliverables, or further our understanding of the risk related to future long-duration space flight missions. Analog utilizations should be used before deploying the deliverable in flight, which is resource constrained (e.g., costs, crew time) and should be used for high Technology Readiness Level (TRL)/Countermeasure Readiness Level (CRL) efforts needing final space flight validation and full testing. Those studies may employ such platforms as the shuttle or the ISS. Research efforts at lower TRL (5-6)/CRL (5-7) would utilize environments analogous to space flight, such as the undersea facility NASA Extreme Environment Mission Operations (NEEMO) or the remote, isolated analog Haughton-Mars Project (HMP). Thus, space analogs employ a significant and pertinent role within this framework to facilitate validation and a full testing process.

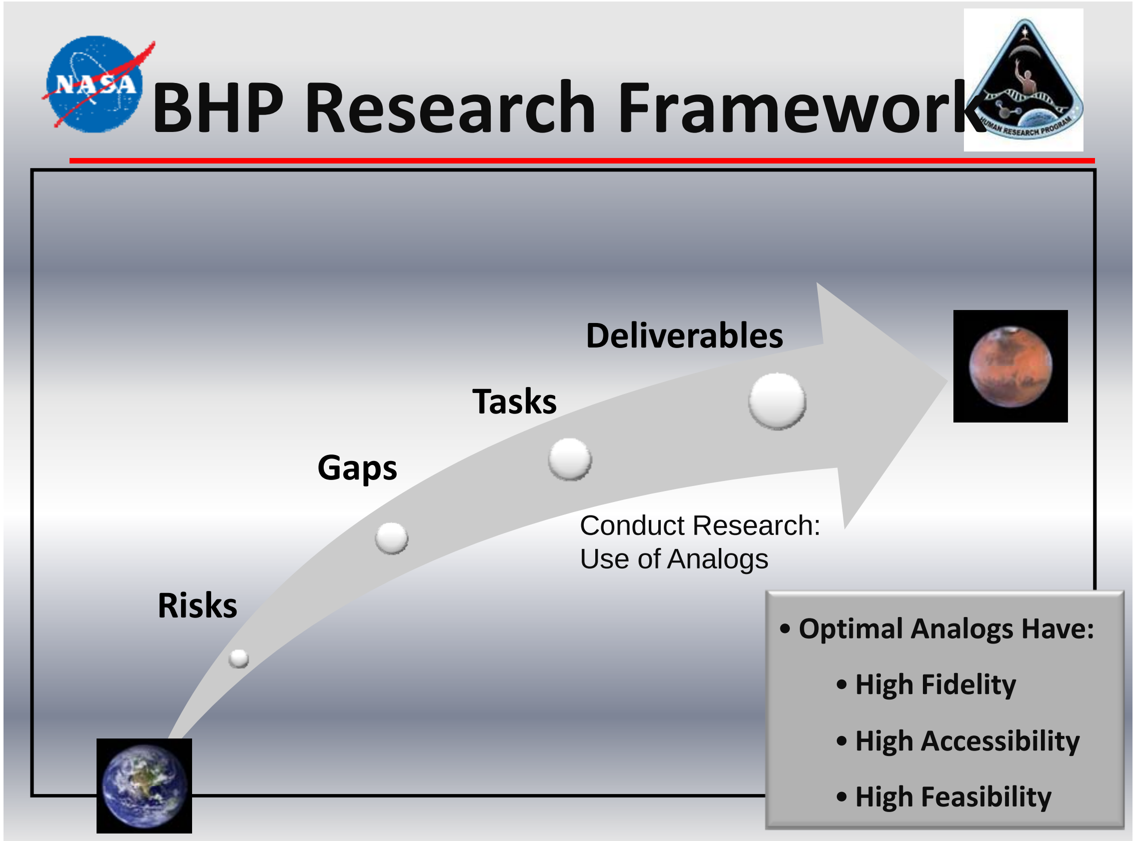

Figure 1. Risk-to-mitigation strategy ensures that the research yields operationally relevant and acceptable deliverables and products.

Ultimately, once the research is completed, BHP Research deliverables inform ISS Medical and Mission Operations, provide updates for Human Health and Habitability Standards, and update existing evidence for the three BHP Research risks.

Purpose: Need Assessment of Analog Tool

The space analog that best addresses the needs of each research study must be selected to ensure that the highest quality of research is being conducted, the research product/deliverable is tested in a condition that is meaningful for the space flight environment, and that BHP Research is able to use its funding most efficiently and effectively. However, before the development of our Analog Assessment Tool, an objective and systematic way to determine which platform would be most suitable to conduct research did not exist. BHP Research has sought to develop a process that will determine, as objectively as possible, which analogs are a "best fit" for addressing BHP Research gaps, thus reducing risk. Developers of the Analog Assessment Tool needed to consider, among other things, the importance of proposed environmental and psychosocial characteristics to BHP Research gaps, as well as the fidelity of those characteristics within the analog environment to space scenarios (i.e., NEOs and Mars). It also was essential to consider the utility of each analog in terms of its practicality and cost of conducting research in those environments.

Analogs with high fidelity to space flight are often intuitively considered ideal platforms for conducting research to inform future space flight missions. Simply considering the fidelity of an analog, however, may not be enough to ensure that the analog serves as the appropriate *platform* through which to address a research gap. The Analog Assessment Tool provides a methodology to determine not only the fidelity of analog characteristics to characteristics of a space flight mission, but also how relevant those characteristics are for specific research gaps within a research element (e.g., BHP Research Element).

Unique Characteristics of the BHP Analog Assessment Tool

Systematic and Objective Process

The Analog Assessment Tool allows a BHP investigator to carefully evaluate the needs of his/her specific study (e.g., the effects of certain stressors on behavioral health) with respect to how accurately the analogs in consideration replicate these characteristics to what is expected for a long-duration mission. Suppose an investigator, aiming to characterize the potential risks of a Mars mission, chooses to evaluate the effects of isolation on mood over the course of a long-duration mission; selecting an analog that offers key characteristics (long duration, isolation) is key to adequately addressing that question. An analogous environment such as Concordia Station in Antarctica – where small groups of individuals stay up to a year in an isolated, confined, and extreme environment – may provide an ideal setting to understand how this risk unfolds. If the investigator's aim, however, is to provide a feasible and acceptable countermeasure for mitigating that risk in a Mars mission, a full analog study in Antarctica may not be the best fit; rather, a brief assessment with an analogous population may be more appropriate. Thus, the above example demonstrates how the Analog Assessment Tool can be used by the investigator to carefully consider how to *accurately* evaluate the importance of specific characteristics, the criticality of addressing the needs of his/her specific study, and the space flight fidelity of the characteristics within the analog.

In particular, the Analog Assessment Tool maps the specific research question to the relevant aspects of an analog. Understanding that an analog has high fidelity but not capturing the components that are critical to understanding a research gap can lead an investigator down a tangential path. For example, it is known that Devon Island, just 322 km (200 miles) south of the North Pole, is bathed in sunlight during the day and through most of the night. Investigators addressing human health risks for a Mars mission scenario have taken to Devon Island for its Mars-like terrain and feel. However, investigators considering the impact of sleep and circadian issues to inform a Mars mission would need to take into account the constant sunlight factor. It is important to bear in mind that there is constant daylight on Devon Island while Mars has a similar Earth day-night cycle of 24 hours and 39 minutes. The outcomes of constant daylight (enhanced alertness, difficulty sleeping) may likely trump the Mars-like terrain for an investigation seeking to evaluate sleep effects as they pertain to living on Mars. For a mission related to understanding team work, however, the constant sunlight, while still having an indirect impact via the individual crew member's sleep (and subsequently, a possible impact on mood and cognitive capacity), may not weigh as heavily as teams being able to simulate a Mars-like excursion and task.

In sum, the Analog Assessment Tool addresses a need to objectively compare analogs based on characteristics that are important to the investigators. This process provides a systematic way to hone in on key characteristics that are relevant to the gap they are aiming to address. The results from this process then provide the necessary information for the investigators to determine which analog will provide the highest fidelity of those characteristics needed for their investigation.

Comparison of Multiple Analogs

The Analog Assessment Tool uses its comparison process to examine the fidelity of multiple analogs. It is important to include a large number of analogs for this systematic comparison process, as characteristics may differ in their level of fidelity across analogs. Indeed, the analogs considered vary in terms of strengths and weaknesses for each critical characteristic included in the assessment for addressing BHP Research; thus, the needs of the investigator will guide the selection of the most appropriate analog when considering the desired characteristics. Consider research aimed at understanding the effects of work overload on team performance. Various possible contributors should be taken into consideration: team size; team structure; and meaningful work. Arguably, there are less salient factors – physical isolation, mission duration, and danger – that could be considered potential contributors, but less so. Hence, while at first glance Antarctica seems like the ideal BHP analog to implement a research study on this topic, the results of the BHP Analog Assessment Tool suggest that the more relevant characteristics needed to address this particular research question can be found at NEEMO.

Other illustrations include the following:

- *An investigator aims to understand how predictions of the effects of chronic work-rest schedules on performance can be used to prevent work overload and mitigate risk. The Pacific International Space Center for Exploration Systems (PISCES) analog offers a mission where small teams of individuals analogous to astronauts are given exploration-like tasks and must complete those tasks in a naturalistic environment. To the external investigator, this analog seems to be a fit for the aims of the investigation. The Analog Assessment Tool, however, would provide the investigator with a rank order of best fit analogs, with NEEMO scoring higher than PISCES. Unbeknown to the investigator, NEEMO offers astronauts themselves a living (as well as working) environment and, importantly, a time-lined mission scenario with specific scheduled requirements.*

- *An investigator aims to use analogs to begin to understand the impact of space flight "type" stressors on psychosocial adaptation. Team size and structure is seen as an important characteristic to capture in an analog, but less so than mission duration. An analog that has a team size and structure similar to that anticipated in flight, such as a NEEMO analog, may be ideal for understanding team size effects on psychosocial adaptation; however, the minimal duration of NEEMO may trump that fact, with Haughton-Mars or an Antarctic station allowing for the assessment of more teams over longer periods of time.*

- *An investigator is limited by funding and time availability; although he/she considers HMP or Desert Research and Technology Studies (DRATS) as a low-cost solution and relatively adept to time-constrained processing situations, the examination of results for the specific utility characteristics identify the NEEMO mission as a likely best solution within the defined constraints above.*

Thus, by including an array of analog environments for consideration, the Analog Assessment Tool allows the investigator to determine, based on the characteristics he/she wants to assess (i.e., team structure or mission duration), which analog would render the best fit.

Customization of Results for Investigators

On a final note, it is necessary to describe how the results from the third iteration of the BHP Analog Assessment Tool can be used on a larger scale by the investigators as well as the research community. Although the above highlights numerous ways that investigators can use the results of the BHP Analog Assessment Tool, three primary uses of this tool should be considered:

1. Investigators can use the results from this most recent iteration by examining the weights of each specific characteristic across all analogs considered for a specific risk. Thus, an investigator has the ability to hone in on specific characteristics that may be most relevant to his/her study when trying to mitigate a specific BHP risk (e.g., Behavioral Medicine [BMed], Team, and Sleep).
2. Conversely, an investigator may instead look at the aggregate results for all characteristics (both research and utility characteristics) across each BHP risk by analog. This may be needed when the investigator is interested in targeting the optimal analog for a specific risk, and does not necessarily need to control for certain characteristics within the analog.
3. Finally, the investigator also can look at the summary results that combine all of the weights for each characteristic across all analogs and sum at a top level to produce a priority summary for analogs across all three BHP risks. This broad-level prioritization identifies the analog(s) that have the highest fidelity when considering the aggregate of characteristics considered in this assessment.

It should be noted that the results of this Analog Assessment Tool also can aid in the identification of specific weaknesses (rather than strengths) that an analog may possess, thus assisting in the identification of specific characteristics an analog must augment and/or improve to increase its fidelity. This insight is a great advantage of this tool as it will be necessary to include specific requirements that must be rectified to ultimately increase the fidelity of the current considered space flight analogs.

Background: Historical Perspective and Inception of Analysis Process

Previous investigators have offered a method through which to assess analog fidelity for the purpose of understanding space flight missions. Specifically, Stuster[2] proposed a systematic analysis of analogs that would help inform the "biological, psychological, and sociological" risks associated with a long-duration stay in space. Similar to the Analog Assessment Tool, Stuster provides a methodology to help determine the appropriate analog from which to glean knowledge to provide relevant recommendations for space flight. In his analysis, a group of experts identified characteristics relevant to a long-duration stay in space. Analogs that offer some level of these characteristics were then identified. Respondents were given written descriptions of these analogs, and were then asked to rate the similarity of the characteristic in that analog to the anticipated characteristic for long-duration space flight (see Figure 2). The result included a ranking of best fit analog for each characteristic for a long-duration space flight scenario.

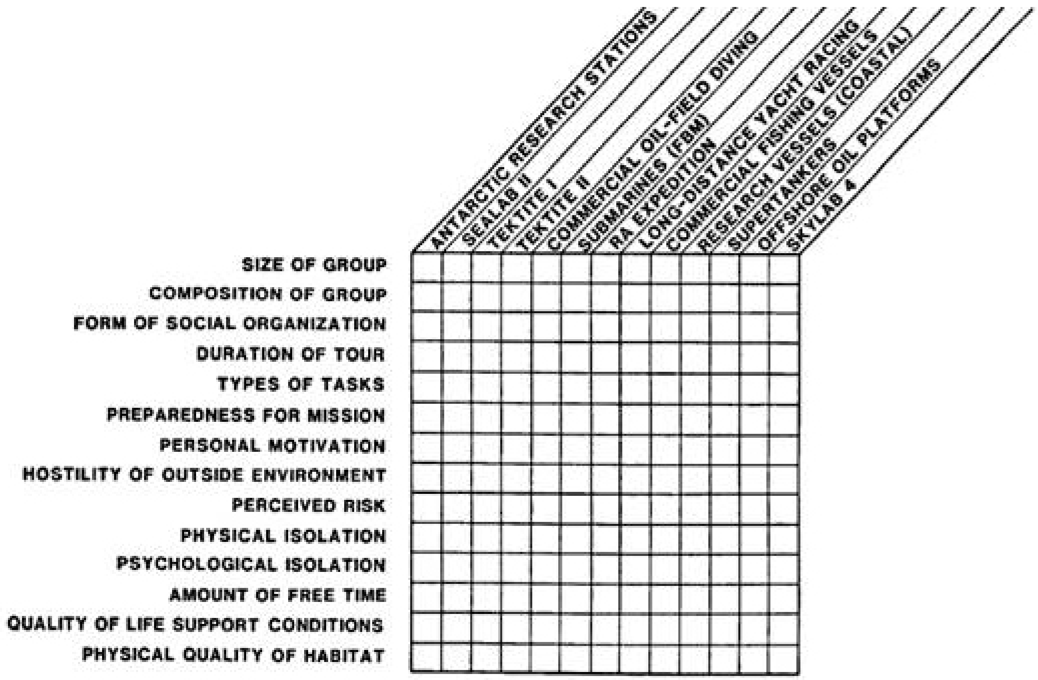

Figure 2. Matrix formed by combining information from data collection sheets where respondents rated the similarity of the characteristic in analog to anticipated characteristic for long-duration space flight.

The Analog Assessment Tool augments this methodology by including not only the characteristic match between the analog and the space flight scenario, but the relevance of the characteristic to the research question using a pair-wise comparison process to complete this evaluation (using the Analytical Hierarchical Process). As an example, Stuster found that for physical isolation, Skylab was a best match for a future long-duration space mission. If the research question, however, pertains to team performance issues, physical isolation may not weigh as heavily as the characteristic “composition of the group.” The Analog Assessment Tool therefore enhances the methodology proposed by Stuster by offering a systematic mapping from research characteristic to analog characteristic. Other updates include revised/additional research characteristics, utility characteristics (i.e., costs and data points collected), an analytical hierarchy in which to group the characteristics (ultimately influencing the pair-wise comparison questions that are posed), as well as updated analogs to those currently considered by the NASA Human Research Program.

Conceptualizing the Tool

Per the Human Research Program Programmatic Requirements Document, BHP is tasked with: "quantifiably describing the likelihood and consequences of the risks. The uncertainties associated with these quantities should be narrowed to the target values identified by each standard or, to the greatest extent practical, to facilitate proper decisions for exploration hardware and software design and mission design."[3] BHP Research relies on analogs to fulfill the requirements for characterizing and mitigating risk. This reliance is driven by the need to test and refine technologies before space flight, and the need to characterize behavioral health risks in long-duration isolated scenarios similar to a future exploration mission.

In 2008, BHP Research presented a programmatic risk related to the fact that high-fidelity analogs remained inaccessible to the element. In response to this risk, the Human Research Program tasked BHP Research with developing a systematic way to assess which of the available analogs were a best fit for addressing BHP gaps. However, BHP Research had previously provided its own comparison of fidelity of analog characteristics to space flight characteristics.[4] In this comparison, BHP-relevant characteristics were identified as being present or not present at the various analogs, but still lacked a link between the analogs to the research gaps. An unrelated presentation regarding the t-matrix from O'Donnell, Moise, and Schmidt[5] proposed a methodology that mapped a space flight task's cognitive requirements to the appropriate cognitive measures by determining which cognitive processes were primarily required to complete a task and mapping. This approach seemed a feasible way to systematically compare the analogs based on the specific needs of the BHP Research element. Thus, this conceptual idea was taken to Drs. Alan H. Feiveson and Robert Ploutz-Snyder and, together with the BHP Research team, the group was able to devise a pair-wise comparison process using an analytical hierarchy that included relevant research and utility characteristics (specific to the BHP Research Element) as well as analogs that were currently being considered for implementation purposes by BHP Research. The following is a description of the specific design components of the Analog Assessment Tool.

Design of the Tool

The Analog Assessment Tool process consists of three parts. In Part One, "criticality" or importance weightings of analog characteristics are calculated within two main categories: research and utility. Research characteristics are those that are relevant to the outcomes of BHP Element research tasks. Examples include characteristics of the habitat, environmental characteristics, and the makeup and composition of the crew and their roles. Utility characteristics are those that relate to the effectiveness and logistical considerations of actually conducting research within an analog. Examples include the number of subjects/year one can assess at a specific analog, the relevance of the participants' tasks, and the amount of data one could collect. Both research and utility characteristics apply to all analogs (see Figure 3 for a visual representation).

In Part Two, fidelity weightings are calculated across proposed analogs with respect to each of the research and utility characteristics.

Finally, in Part Three, both sets of weightings are combined to produce an overall ranking of the analogs. This procedure is implemented independently for each of the three main BHP Element risks: Team, Sleep, and BMed.

Part One: Criticality Weightings

Criticality weightings reflect the relative importance of each characteristic chosen as a criterion for comparing analogs with regard to the Element goals. In particular, how important is it that the analog include a given characteristic when addressing a risk within the BHP Research Element? For example, from the viewpoint of a principal investigator, how important would it be for the analog to be evaluated in terms of lighting conditions as opposed to team size and/or mission duration? To answer these types of questions and produce overall weightings of the characteristics, we have enlisted SMEs to provide pair-wise comparisons of research characteristics taking into account each BHP Research risk goal. These comparisons are then integrated into an overall weighting using the Analytic Hierarchy Process (AHP).[6] At the same time, BHP Element scientists serve as SMEs to make pair-wise comparisons of all utility characteristics. These comparisons are integrated into an overall set of utility weights using the AHP. It is important to note that SMEs for the utility characteristics are likely to be within the Research Element, as these characteristics are more related to the logistics of actually conducting a research task within an analog.

Part Two: Fidelity Comparisons

In contrast to the criticality comparisons, fidelity comparisons address how similar analogs are to the space scenario chosen when considering a specific research or utility characteristic (e.g., does NEEMO have a mission duration that is similar to what would be expected for a Mars mission?). In this instance, the SMEs must determine how well a specific characteristic in an analog matches that same characteristic in the space flight scenario. Similar to the procedure used with research characteristics, fidelity comparisons are made using pair-wise comparisons; however, these comparisons are made between *analogs* for each research and utility characteristic. The AHP is then used to integrate the pair-wise comparisons into an overall set of weightings of analogs with respect to each characteristic.

Part Three: Final Ranking of Analogs

Once the two sets of weightings (research/utility and fidelity) are made, the overall weight for each analog is a weighted average of its characteristic-specific weights. More specifically, let a_{ij} be the relative weight of the i-th analog with respect to the j-th characteristic, as calculated in Part Two. Also, let r_j be the relative importance weight of the j-th research or utility characteristic as calculated in Part One. Then w_i, the overall weighing for the i-th analog is given by: $w_i = \sum_j r_j a_{ij}$. Values of w_i for research and utility are then averaged to obtain the final weighting. Final rankings of the analogs are then made in terms of the averaged w_i.

Note: In the AHP, all characteristics are organized into a hierarchy, and pair-wise comparisons are made only within the same level of the hierarchy. Weights are then aggregated through the hierarchy to calculate the r_j. In principle, hierarchical aggregation of weights also could be implemented for the fidelity weights, but we have chosen not to do so because of the difficulty of constructing a meaningful hierarchy for the analog candidates.

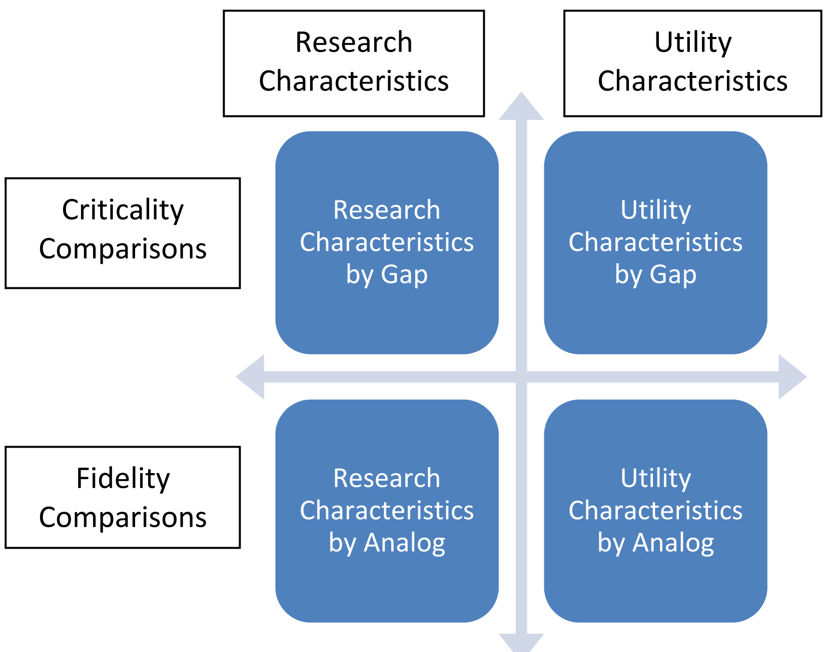

Figure 3. Both research and utility characteristics apply to all analogs.

SMEs evaluate pair-wise comparison questions based on the AHP[6] to create fidelity and criticality weights for each of the characteristics (within the research and utility categories). These two weights are then combined to create a final weight score for each of the analogs. The analogs can then be ranked to determine importance relative to the specific risk in question and the space scenario chosen. These final rankings can then be used to identify optimal analogs for proposed characteristics-specific research tasks. In addition, an overall rank order can be determined for each risk, or across each of the three BHP risks to identify which analogs will provide the most fidelity across studies/tasks addressing more than one risk. In essence, these rankings provide effective optimization of analogs for achieving BHP risk-reduction goals and objectives.

Analog Assessment Tool Process Defined

To use the Analog Assessment Tool, one must first complete the following steps:

1. Select, Define, and Categorize Characteristics:
    a. The research and utility characteristics that are chosen must be comparable across all of the analogs and be specific to the risks that are being considered (i.e., discipline or element specific).
2. Select Space Scenario:
    a. Determine which space scenario the SME group will be using to anchor the assessment.
        i. Example: Lunar Long, Mars, NEOs, etc.
3. Select Analogs:
    a. Determine which analogs are most likely to address research needs for risks that are being considered.
        i. Example: NEEMO, Russian 105-day Study, HMP, ISS,[1] etc.

Select, Define, and Categorize Characteristics

It is essential that the research and utility characteristics chosen be comparable across all analogs. More specifically, the characteristics must relate to the research risks, gaps, and specific tasks that the research will be addressing.

The research and utility characteristics that are chosen must be defined. The definitions must be clear and concise as they are included to assist the SMEs in understanding which aspect(s) of a characteristic they are supposed to be considering when they complete the exercises within the analog assessment process.

Once characteristics are selected and defined, they must be organized into distinct categories. The categories will be later used for the AHP. As a guideline, the categories should not have more than six characteristics each as they will be used in the pair-wise comparisons for AHP.

Select Space Scenario

Careful consideration must be given when choosing a space scenario. The chosen scenario should be most related to the deliverables that are specified in the tasks within each risk. This will ensure that the final outcome of the assessment tool is related to the space scenario that is most relevant to the Element's deliverables. Also, one must choose a specific scenario (i.e., Lunar Sortie, Lunar Long, Mars, etc.) as the

[1] ISS has been included as an analog as a consideration of fidelity to long-duration missions. When considering exploration missions, the characteristics of the ISS may provide high fidelity to important characteristics for specific research tasks within the BHP Research Element.

characteristics will need to be defined in terms of this scenario for the SMEs as they complete the exercises.

Once the space scenario is chosen, it is necessary to create an in-depth description of the scenario providing as much information as possible about what is known about the scenario, both in terms of the characteristics chosen and other general information. The chosen characteristics should also be defined in terms of how those characteristics are expected to exist in that specific scenario.

The information about the scenario will then be provided to the selected SMEs as they will be expected to consider the aspects of the selected scenario in relation to the characteristics chosen when they complete the exercises. It is recommended that a document be created that contains all of the information about the space scenario. The document can easily be distributed to the SMEs and used as a resource when working through the activities. Another recommendation includes providing other resources, as they are available, to the SMEs to help increase their knowledge of the selected scenario. One suggestion is to create a panel of experts on the selected scenario and arrange an in-person meeting or teleconference so that the SMEs can ask questions and/or the panel of experts can present up-to-date information on expectations for that specific scenario.

Select Analogs

The analogs that are chosen to be included in the assessment should include the most characteristics that closely resemble the space scenario desired. There is no limit to the number of analogs included; however, it should be noted that as the number of analogs increases, the time required on part of the SMEs also increases. We recommend no more than 10 to 12 analogs per assessment. As Cartreine[7] observed in a presentation he gave concerning analog fidelity, choosing an analog research setting that resembles a space mission but does not include the necessary variables is unlikely to be scientifically productive. “Nevertheless, finding environments and samples that do include the necessary variables, even if they do not ostensibly resemble space environments, can provide the best test beds needed for countermeasures.”

Once the analogs are chosen, it is necessary to create an in-depth description of selected analogs. This description should include as much information as possible, relating to both the specific characteristics chosen and other general information that may be useful to the SMEs as they complete the exercises. It is beneficial to also provide pictures and illustrations, if possible. Again, we recommend that this information be integrated into a reference document. A reference document that contains descriptions of the analogs should then be provided to the selected SMEs. In this instance, the SMEs will be expected to use their knowledge about the analogs to compare the characteristics when completing the exercises.

Once these initial steps have been completed, a pair-wise comparison process of the characteristics using the AHP[6] must be conducted. The SMEs will complete the pair-wise comparison questions. Although it is feasible to conduct analyses of the ratings received by the SMEs manually with the help of statisticians, we recommend the use of AHP software.

Role of Subject Matter Experts

Selection of the SMEs must be considered with great importance; the data that are gleaned from the Analog Assessment Tool can only be as good as the experts that participate in this process. Thus, it is essential that those selected truly possess an expertise in the area in which they are being asked to participate (i.e., completing the fidelity or criticality exercises for the research and utility characteristics). The number of SMEs chosen is up to the discretion of the Element, or user. However, for analytical purposes, it is recommended that each exercise completed have at least three SMEs. The upper limit to SME participation should only be determined by the number of true experts in a specific area that are willing to participate.

The SMEs will need to access the following information:

- Analog descriptions
- Definitions of the characteristics and the assumptions of those characteristics for the scenario chosen
- Description of scenario chosen
- Risk and gap definitions of the Element

Specifically, there will need to be at least two groups of SMEs: one group of SMEs for each risk relating to the criticality weights; and one group of SMEs for the analog portion of the assessment relating to the fidelity weights. However, an Element can choose to have multiple groups of SMEs complete the exercises for each risk for the criticality weights, if necessary; this will again be determined by the level of expertise that the SMEs possess.

Analytical Hierarchical Process

Completing the Exercises

The AHP is a structured technique using a pair-wise comparison process.[6] First, the decision or problem at hand is modeled within a hierarchy of more easily comprehended subcategories, each of which can be analyzed independently. Once the hierarchy is built, SMEs then establish priorities among the categories of the hierarchy by making a series of judgments based on pair-wise comparisons of the characteristics within each category. In making the comparisons, the decision makers can use concrete data about the elements or, alternatively, can use their judgments about the elements' relative meaning and importance. These judgments are then synthesized to yield a set of overall priorities for the hierarchy. Specifically, the AHP converts these evaluations into numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy.

This process has been adapted for the objective and systematic comparison of analogs across characteristics that are important and relevant to BHP. Characteristics are organized by research and utility characteristics and then compared in terms of importance (criticality weights) and similarity to the space scenario (fidelity weights).

Criticality Weights

For each risk, the characteristics (both the research and utility characteristics) that are selected will undergo a pair-wise comparison process in line with AHP. Specifically, for each risk (BMed, Team, and Sleep), the SMEs will be asked to compare two characteristics at a time and determine which one is more important, and the magnitude of that importance. The SME will have to repeat this pair-wise comparison process for all of the characteristics within each category (see the Select, Define, and Categorize section for more information) for each risk.

Fidelity Weights

For each characteristic (research and utility), the SMEs will have to compare the chosen analogs in a pair-wise comparison process. In this instance, the SMEs will be asked to compare two analogs at a time for each characteristic (research and utility) and determine which one is more similar to the space scenario chosen, and the magnitude of that similarity. As with the criticality weights, the SMEs will have to repeat this pair-wise comparison process for all characteristics within each category (i.e., compare all of the analogs for each of the characteristics considered).

Notes about the Assessment Process

The complexity of this process illustrates the importance of the following:

- Choosing the most necessary and important characteristics to the Element (should be based on research needs and research implementation)
- Choosing SMEs that are true experts in either the research risks that are being assessed and/or those analogs that are being considered
- Providing the resources and materials needed (i.e., characteristic definitions, assumptions, and information about the analogs and space scenario) to the SMEs to complete the exercises to the best of their ability

Specific Updates to the Third Iteration of the BHP Analog Assessment Tool

Third Iteration: Characteristics

For the third iteration of the Analog Assessment Tool, BHP considered 18 research characteristics and nine utility characteristics. These included:

Research Characteristics

- Availability of Medication/ Medical Care
- Crowdedness
- Danger
- External Light Conditions
- Internal Light Conditions
- Physical Isolation
- Autonomy
- Communication w/Outside
- Sensory Conditions
- Sensory Deprivation
- Workload
- Personal Space
- Rest & Recreation Options
- Quality of Life Support Conditions
- Leadership
- Team Size
- Team Structure
- Team Interdependence

Utility Characteristics

- Exposure Time
- Mission Duration
- Mission Timeline
- Similarity to Astronauts
- Subjects/Year
- Task Relevance
- Cost/Study
- Data Collection Feasibility
- Research Process/ Protocol Feasibility

Each of the characteristics was chosen due to its relevance to behavioral health and performance outcomes. It is important to note, however, that some characteristics are more applicable to specific BHP research questions than others. The Analog Assessment Tool process takes into account this relative importance (per the SME's evaluation), ultimately mapping each research question to its best-fit analogs.

Third Iteration: Selected Analogs & Space Scenario

Twelve analogs were chosen for the third iteration of the Analog Assessment Tool, as shown in Table 1.

Table 1. Analogs for Third Iteration of Analog Assessment Tool

Analog	New Addition
1. ISS	
2. Antarctica – McMurdo	*
3. Antarctica – Concordia	*
4. Antarctica – South Pole	*
5. Antarctica – Antarctic Search for Meteorites program (ANSMET)	*
6. NEEMO	
7. HMP	
8. DRATS	
9. Everest	*
10. Pavilion Lake	*
11. PISCES	*
12. PISCES Proposed	*

In addition, the space scenario that was selected was a Mars mission, or long-duration mission destination. This change was due to a recent redirection for NASA to abandon the Constellation Program and redirect energy and money resources to work toward long-duration destinations including Mars and possibly NEOs.

The remainder of this report reviews a working example of this process and results from the three iterations of the Analog Assessment Tool, and provides a section with overall conclusions and a discussion of forward work.

Working Example

As an example, we will review the BHP Research process of adapting this process to create the third iteration of the Analog Assessment Tool:

Selection and Definition of Characteristics

- BHP Research identified 18 research characteristics and nine utility characteristics that could be compared across analogs. These characteristics are directly related to the research gaps defined in the three risks of BHP: BMed, Team, and Sleep. While the research characteristics represent the specific characteristics within the analog that are relevant to BHP, the utility characteristics selected represent those characteristics that are important for logistical considerations of actually implementing a proposed study within the analog, and thus may not be important across all three risks.

- BHP Research then defined these characteristics – Tables 2 and 3 provide the definitions for each of the chosen characteristics.

Table 2. Definitions of Research Characteristics

Category	Research Characteristic	Definition
Environmental Characteristics	**Availability of Medication/ Medical Care**	The extent to which medication and medical care is readily available and accessible to individuals at the analog
Environmental Characteristics	**Crowdedness/Habitable Volume Characteristics**	The degree of crowdedness in an environment (can think of as a ratio: habitable volume divided by the number of people who must live in it)
Environmental Characteristics	**Danger**	The likeliness that an individual will get injured or hurt when carrying out daily tasks
Environmental Characteristics	**External Light Conditions**	The lighting conditions outside of the habitat
Environmental Characteristics	**Internal Light Conditions**	The lighting conditions within the habitat
Environmental Characteristics	**Physical Isolation**	The level of isolation an individual has from others outside of their team (operationalized as the amount of time it would take to escape the environment)
Mission Characteristics	**Autonomy***	The level of discretion that an individual and crew/team have over their choices, actions, and support in accordance with standard operating procedures
Mission Characteristics	**Communication w/Outside**	The level of access to communication with the outside world
Mission Characteristics	**Sensory Conditions**	The quality of environmental conditions affecting sensory perceptions including temperature, smell, noise, etc.
Mission Characteristics	**Sensory Deprivation**	The extent to which the environment does not provide needed sensory stimulation in terms of visual, tactile, olfactory, auditory, and taste
Mission Characteristics	**Workload**	The amount of work an individual has to perform on a day-to-day basis
Personal Aspects	**Personal Space**	The amount of personal space that an individual has to himself or herself within the habitat

Personal Aspects	**Rest & Recreation Options**	The extent to which rest and recreation options are available to crew members
Personal Aspects	**Quality of Life Support Conditions****	The quality of options related to food, hygiene, and other aspects of daily living
Team/Psychosocial Aspects	**Leadership**	The extent to which the role of the leader is clearly and strongly defined and present within a team
Team/Psychosocial Aspects	**Team Interdependence**	The extent to which the completion of assigned tasks requires collaboration among crew members
Team/Psychosocial Aspects	**Team Size**	The size of the flight crew that will be on the mission
Team/Psychosocial Aspects	**Team Structure**	The extent to which a clear structure (i.e., specific roles and/or tasks to be carried out by each individual) exists within a team

*Definition from the BHP Autonomy Workshop, 2009 (full term is called bounded autonomy)
** Stuster[2]

Table 3. Definitions of Utility Characteristics

Category	Utility Characteristic	Definition
NASA-Related	**Cost/Study**	The financial cost to implement a study within the analog (include cost for BHP representative, materials, travel, and logistics)
NASA-Related	**Data Collection Feasibility**	The level of difficulty of implementing study requirements within that analog while considering NASA constraints (e.g., logistics, technology availability, ability to create requirements within the analog, etc.)
NASA-Related	**Research Process/Protocol Feasibility**	The level of difficulty of acquiring approval through NASA research channels for a research study at that particular analog (e.g., required lead time, approvals necessary, etc.)
Analog-Related	**Exposure Time Per Subject**	The number of data points that can be collected from a participant
Analog-Related	**Mission Duration**	The length of the mission
Analog-Related	**Mission Timeline**	The extent to which the mission is structured and scheduled similar to a real mission
Analog-Related	**Similarity to Astronauts**	The extent to which the participant population is comparable/generalizable to the astronaut population
Analog-Related	**Subjects/Year**	The number of subjects that can participate/be assessed within a given calendar year
Analog-Related	**Task Relevance**	The degree to which the tasks carried out in the analogs represent similar tasks during space flight

Categorize Characteristics

- BHP then categorized the research characteristics into four separate groupings: Mission Characteristics, Environmental Characteristics, Personal Aspects, and Team/Psychosocial Aspects (see Table 4).
- Utility characteristics were separated into two categories – NASA-Related and Analog-Related – as shown in Table 5.

Table 4. Research Categories/Definitions

Research Category	Definition
Environmental Characteristics	Situational factors present in analogs that influence individual and team functioning
Team/Psychosocial Aspects	Team-related characteristics that influence crew member interaction
Mission Characteristics	Structural features of the mission that influence individual and team functioning
Personal Aspects	Non-task-related factors that influence individual functioning

Table 5. Utility Categories/Definitions

Utility Category	Definition
NASA-Related	Factors dictated by NASA's policies and procedures that influence data collection in specific analogs
Analog-Related	Factors that are dictated by analog characteristics and constraints that influence data collection in those analogs

These categories serve to create a visual representation using a hierarchical structure, per the AHP process (refer to Figure 4). This hierarchical structure will create the process for the pair-wise comparisons process, discussed in more detail.

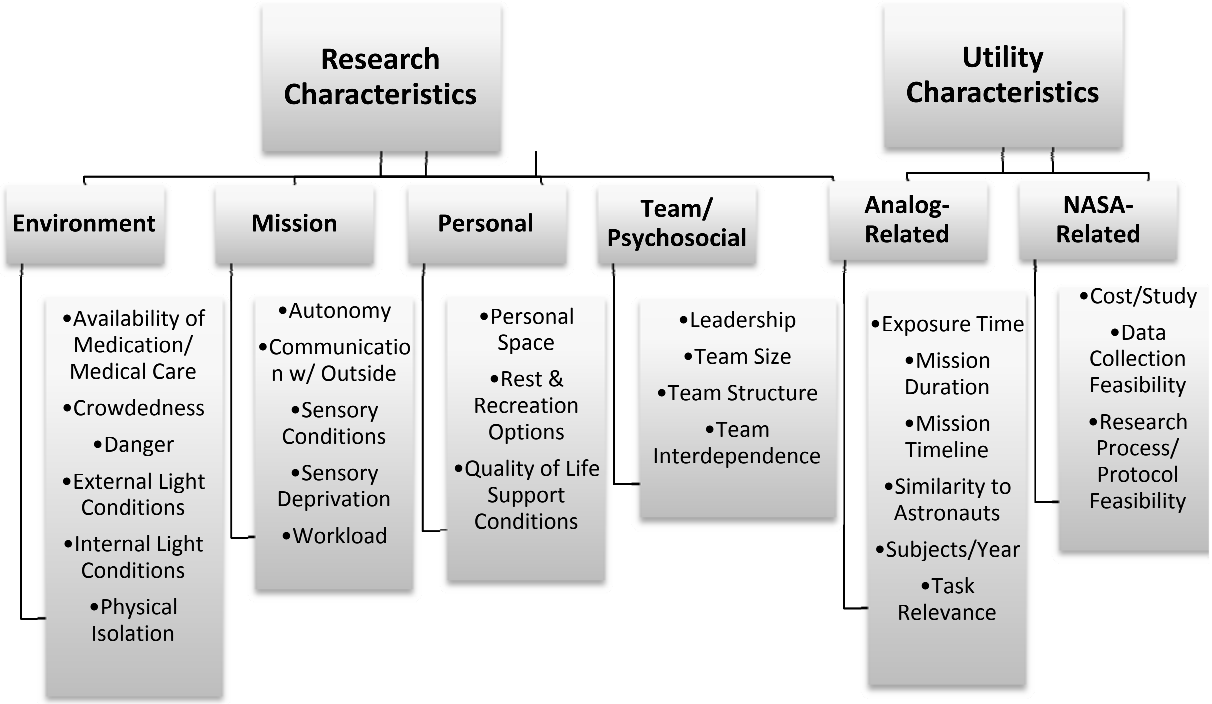

Figure 4. Visual representation of hierarchical structure.

Select Space Scenario

- For the third iteration of this tool, BHP Research determined that a Mars mission (or long-duration mission) would best address BHP Research's needs when considering the tasks and gaps within each risk, as well as represent current goals and targets for exploration missions as guided by the current direction of NASA. Once selected, the characteristics were then defined in terms of how they are anticipated to exist/express themselves in the selected scenario (see Tables 6 and 7). These assumptions are necessary for fidelity comparisons.

Table 6. Definitions of Research Characteristics in Selected Scenarios

Category	Research Characteristic	Assumptions for a Long-Duration Mission
Environmental Characteristics	**Availability of Medication/Medical Care**	Limited; basic emergency equipment available and standard medications. Crew members with basic training of emergency response and basic medical procedures.
Environmental Characteristics	**Crowdedness/Habitable Volume Characteristics**	Moderate to high; anticipated that the habitat will be the size of a modest-sized RV or smaller for four to six people (consider both transit vehicle and habitat on Mars or other surface)
Environmental Characteristics	**Danger**	Moderate to high; daily tasks carry a moderate risk of injury; ongoing environment comprises a high degree of risk of injury and/or death
Environmental Characteristics	**External Light Conditions**	Moderate; exposure to sun will likely be consistent across the time during transit and on a foreign planetary surface (e.g., Mars day is very similar to Earth's, but is 37.5 minutes longer)
Environmental Characteristics	**Internal Light Conditions**	Anticipate full artificial light spectrum (do not consider possible lighting countermeasures)
Environmental Characteristics	**Physical Isolation**	High; isolated to only other crew members. Escape would be impossible, or highly improbable.
Mission Characteristics	**Autonomy**	Anticipate the crew to be much more autonomous than current operations; a moderate to high degree discretion of crew members over their choices and actions to complete mission objectives
Mission Characteristics	**Communication w/ Outside**	Moderate to minimal; although communication options would be available, crew members will often experience communication delays with the ground ranging from 4 to 40 minutes (for a full communication loop)
Mission Characteristics	**Sensory Conditions**	Moderate; anticipate some negative environmental conditions that will influence the quality of the environment including the lack of fresh air, presence of odious smells, as well as noise from machines and support systems, etc.
Mission Characteristics	**Sensory Deprivation**	Moderate to high; anticipate a lack of sensory stimulation that would arouse a visual, tactile, olfactory, auditory, and/or taste response (e.g., unlikely to have fresh food, plants, etc.)
Mission Characteristics	**Workload**	Moderate to heavy workload, with some daily personal time. However, likely for some part of the transit, periods of low workload may be an issue.

Personal Aspects	**Personal Space**	Low; limited personal space anticipated due to the constraints of the vehicle and habitat size
Personal Aspects	**Rest & Recreation Options**	Minimal; few options for rest and recreation are currently anticipated. Those options that will be available are likely to be a standard, constrained set of options (versus a flexible, wide-range of choices and/or different venues).
Personal Aspects	**Quality of Life Support Conditions**	Minimal; some options for food, hygiene, and other aspects of daily living
Team/Psychosocial Aspects	**Leadership**	Assigned; anticipate the role of leader to be assigned and carry a strong role within the crew; also clear designation of chain of command
Team/Psychosocial Aspects	**Team Interdependence**	Moderate to high; anticipate that many daily tasks will require crew members to work together to successfully complete mission objectives; teams also will be able to eat together, and participate in team rest and recreation activities together
Team/Psychosocial Aspects	**Team Size**	Small; four to six crew members; likely to be mixed gender and multicultural
Team/Psychosocial Aspects	**Team Structure**	Clearly assigned job roles for each crew member; strong team structure

Table 7. Definitions of Utility Characteristics in Selected Scenarios

Category	Utility Characteristic	Long-Duration Mission Assumptions
NASA-Related	**Cost/Study**	Lower costs will provide the ability to conduct more research studies to help mitigate issues related to a long-duration mission
NASA-Related	**Data Collection Feasibility**	Higher data collection feasibility related to research requirements will increase the ability to implement more studies within that analog
NASA-Related	**Research Process/Protocol Feasibility**	Higher protocol feasibility will result in the ability to more easily implement additional research studies that will address/mitigate BHP risks
Analog-Related	**Exposure Time Per Subject**	Higher exposure time will increase the number of data points collected to improve the predictability of the studies
Analog-Related	**Mission Duration**	Longer mission durations (closer to 30 months) will increase the number of data points collected and improve the generalizability of studies that are conducted
Analog-Related	**Mission Timeline**	Mission timelines that are more specific, clear, and generally realistic to what is expected for a long-duration mission will provide higher generalizability for research studies
Analog-Related	**Similarity to Astronauts**	Participants that are highly similar to astronauts (e.g., in terms of intelligence, teamwork ability, and personality factors) will provide higher generalizability for research studies
Analog-Related	**Subjects/Year**	More subjects/year will increase the number of data points collected and improve the generalizability of studies that are conducted
Analog-Related	**Task Relevance**	Tasks that are more relevant and realistic to that expected on a long-duration mission will provide higher generalizability for research studies

- BHP also collected as much information as possible about the Mars mission and created a reference document to be used by the SMEs when completing the exercises. Although limited information is known about specific expectations for a long-duration mission to Mars or other exploration destinations, general information was translated into effective expectations that could be used for the purpose of this comparison process.

Select Analogs

- For this most recent iteration of the assessment tool, BHP Research selected 12 analogs. These analogs were chosen based on a consensus among the SME group as to the perceived applicability of these environments to a Mars mission. In addition, specific Antarctic stations were targeted this year, rather than using a generic Antarctica analog reference, as feedback from our SMEs during previous iterations revealed that there are stark differences between these stations.
- Specifically, the analogs chosen included:
  - ISS
  - Antarctica – McMurdo
  - Antarctica – Concordia
  - Antarctica – South Pole
  - Antarctica – ANSMET
  - NEEMO
  - HMP
  - DRATS
  - Everest
  - Pavilion Lake
  - PISCES
  - PISCES Proposed
- As a source of supplemental material,[2] BHP also created a comprehensive summary about each analog and created a reference document to be used by the SMEs when completing the exercises.

[2] Please refer to Appendix A for a description of the analogs BHP selected.

Review of Preliminary Results: First Iteration of Analog Assessment Tool

The following tables are the result of the first iteration of the Analog Assessment Tool for the BHP Research Element. Please note that this first iteration only included an examination of the research characteristics (the utility characteristics were not yet included) and did not fully utilize the developed pair-wise comparison process per the AHP. However, from this preliminary evidence, ISS proved to be the analog with the highest fidelity to the lunar long scenario across all gaps for the three risks (BMed, Team, and Sleep).

In summary, the top three analogs across each of the risks from these preliminary results were ISS, NEEMO, and HMP Proposed Operations (HMP-PO) (for Team, HMP-PO was tied with Antarctica). However, the weighting of each of the analogs is better represented though a visual representation, as the weighted results seemed to follow a tiered level structure. Figure 5 visually demonstrates these preliminary results.

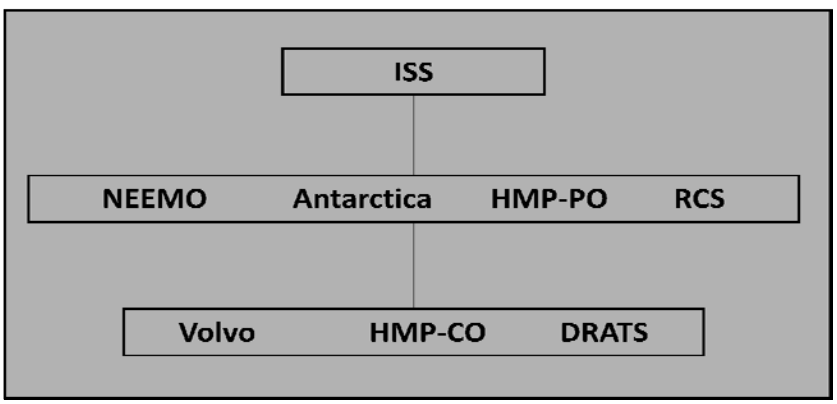

Figure 5. Weighting of each analog – preliminary results.

Gap Weights

Risk: Behavioral Medicine

Table 8. First Iteration of Analog Assessment Tool – Behavioral Medicine Risk

Analogs	BMed Gap 1	BMed Gap 2	BMed Gap 3	BMed Gap 4
Antarctica	0.0957	0.0998	0.0998	0.0935
DRATS	0.0336	0.0337	0.0337	0.0326
HMPCO	0.0738	0.0750	0.0750	0.0692
HMPPO	0.1332	0.1309	0.1309	0.1356
ISS	0.3493	0.3512	0.3512	0.3464
NEEMO	0.1317	0.1285	0.1285	0.1346
RCS	0.1035	0.1001	0.1001	0.1087
Volvo	0.0792	0.0808	0.0808	0.0794

Analogs	BMed Gap 5	BMed Gap 6	BMed Gap 7	BMed Gap 8
Antarctica	0.0928	0.0927	0.0945	0.0997
DRATS	0.0335	0.0384	0.0368	0.0338
HMPCO	0.0750	0.0831	0.0738	0.0748
HMPPO	0.1333	0.1402	0.1364	0.1305
ISS	0.3480	0.3398	0.3432	0.3528
NEEMO	0.1329	0.1324	0.1358	0.1275
RCS	0.1047	0.0945	0.1016	0.0990
Volvo	0.0797	0.0789	0.0780	0.0818

Risk: Team

Table 9. First Iteration of Analog Assessment Tool – Team Risk

Analogs	Team Gap 1	Team Gap 2	Team Gap 3	Team Gap 4	Team Gap 5	Team Gap 6	Team Gap 7
Antarctica	0.1150	0.1082	0.1099	0.1178	0.1188	0.1165	0.1093
DRATS	0.0384	0.0373	0.0383	0.0371	0.0379	0.0384	0.0384
HMPCO	0.0962	0.0949	0.0966	0.0931	0.0945	0.0953	0.0946
HMPPO	0.1370	0.1383	0.1380	0.1399	0.1336	0.1389	0.1365
ISS	0.3213	0.3218	0.3221	0.3187	0.3299	0.3209	0.3283
NEEMO	0.1195	0.1221	0.1200	0.1203	0.1141	0.1176	0.1179
RCS	0.0926	0.0969	0.0942	0.0943	0.0885	0.0921	0.0926
Volvo	0.0799	0.0804	0.0809	0.0788	0.0828	0.0804	0.0825

Risk: Sleep

Table 10. First Iteration of Analog Assessment Tool – Sleep Risk

Analogs	Sleep1	Sleep2	Sleep3	Sleep4	Sleep5
Antarctica	0.1011	0.0988	0.0929	0.0912	0.1007
DRATS	0.0315	0.0304	0.0297	0.0305	0.0301
HMPCO	0.0695	0.0658	0.0638	0.065	0.0663
HMPPO	0.1241	0.1303	0.1248	0.1298	0.1247
ISS	0.3557	0.3477	0.3666	0.3516	0.3541
NEEMO	0.1305	0.1368	0.1374	0.1406	0.1347
RCS	0.1155	0.1219	0.1107	0.1222	0.1194
Volvo	0.0720	0.0683	0.0742	0.0691	0.0700

Analogs	Sleep6	Sleep7	Sleep8	Sleep9	Sleep10
Antarctica	0.0862	0.0998	0.094	0.0888	0.0917
DRATS	0.0295	0.0351	0.0295	0.0300	0.0309
HMPCO	0.0603	0.0761	0.0655	0.0592	0.0660
HMPPO	0.1318	0.1312	0.1275	0.1299	0.1298
ISS	0.3546	0.3482	0.3589	0.3545	0.3561
NEEMO	0.1477	0.1291	0.1411	0.1448	0.1421
RCS	0.1226	0.1102	0.1130	0.1244	0.1146
Volvo	0.0672	0.0703	0.0704	0.0683	0.0688

Results of the Second Iteration of the Analog Assessment Tool

After completion of the first iteration of the Analog Assessment Tool, many areas of improvement were identified. First, it was imperative that the AHP was implemented using pair-wise comparisons for the second iteration. Second, it was essential that a utility analysis was incorporated into this process. The research characteristics, as originally defined, addressed those characteristics within the analog environment that were most relevant to specific research tasks (i.e., lighting); however, no consideration of the utility of actually implementing research within these analogs were considered (subjects/year, similarity of subject population to astronauts, etc.). Thus, it was clear that a true analog assessment would incorporate both those characteristics that were relevant to the specific research tasks, as well as those characteristics that relate to the logistics of conducting research studies within those analogs. Last, the efficiency and design of the pair-wise comparison exercises needed to follow the structure of the analytical hierarchy to reduce the workload that was required on the part of the SMEs.

The second iteration, therefore, incorporated many revisions to the original design to improve the process itself, as well as the reliability and validity of the results and conclusions that were drawn from the evaluations. First, BHP worked with Johnson Space Center (JSC) statisticians to implement a comprehensive AHP hierarchical structure and incorporated a utility analysis by creating utility characteristics that also would be compared to the specific research gaps (risks) and analogs themselves (see Figure 4). A customized online survey was designed to create the numerous pair-wise comparisons that were required so that SMEs could quickly and efficiently complete their rankings. An additional step was implemented per the guidelines of AHP that involved holding a consensus session with SMEs. Following the online survey in which SMEs completed pair-wise comparisons based on their area of expertise, these results were then analyzed for inter-rater agreement. A consensus session was then held with SMEs to discuss items with a high discrepancy in terms of rating agreement, and reach a consensus for each of these flagged comparisons. Together with the original ratings, these consensus ratings were then analyzed by JSC statisticians to produce the final weights for each analog by each gap within each risk.

The results of the second iteration of the Analog Assessment Tool are presented in Figure 6. Although we see consistency from the first iteration in that ISS is again the best analog in terms of fidelity across all gaps for the three risks (BMed, Team, and Sleep), there is less consistency for the remaining results of this second iteration than with the first. For example, for the second iteration, the top analogs across the three risks include NEEMO, RCS, and Antarctica. For this second iteration, results suggest that HMP-Proposed ranks fifth in terms of fidelity across the gaps when compared to the other analogs (it was in the top three analogs for the first iteration). The differences in results could be due to the improved pair-wise comparison process and/or the incorporation of the utility analysis. However, we see that, once again, the weighting of each analog is better represented though a visual representation, as the weighted results seemed to follow a tiered level structure (i.e., the decimal difference between the analogs on the Tier 2 level are insignificant). Figure 6 visually demonstrates these preliminary results.[3]

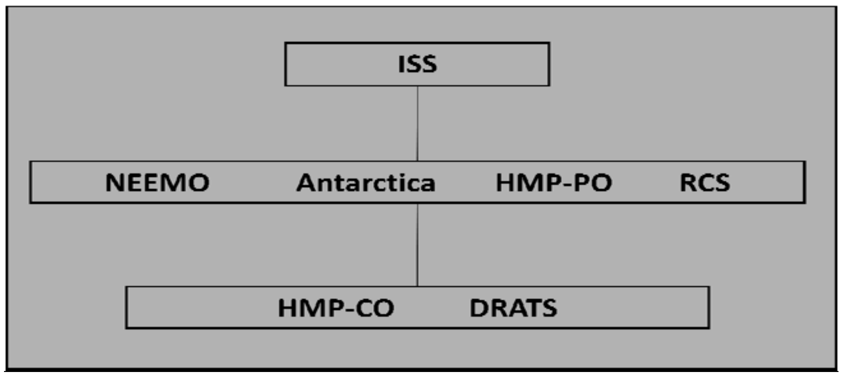

Figure 6. Visual demonstration of preliminary results for second iteration of Analog Assessment Tool.

The following tables provide the weightings for each of the analogs for each of the gaps under the three risks: BMed, Team, and Sleep. The tables have been color coded in line with the tiered figure presented above; the first tier is shaded yellow (i.e., ISS), the second tier is shaded blue, and the third tier is shaded red. The final table also includes the utility weight as a visual demonstration of what was used to average the gap scores to produce the final scores as represented in each risk table.

[3] Please note that Volvo Sailing Races were not included in the second iteration.

Gap Weights

Risk: Behavioral Medicine

Table 11. Second Iteration of Analog Assessment Tool – Behavioral Medicine Risk

Risk	Gap	NEEMO	HMP_C	HMP_P	Antarctica	RCS	DRATS	ISS
BMed	1	0.161839	0.049446	0.121552	0.130515	0.15366	0.07885	0.304139
BMed	2	0.161574	0.051638	0.1202	0.129813	0.153615	0.078236	0.304925
BMed	3	0.15816	0.050246	0.120187	0.131777	0.155368	0.078297	0.305965
BMed	4	0.159246	0.049741	0.118054	0.133125	0.155671	0.077854	0.306307
BMed	5	0.157567	0.0492	0.121336	0.134627	0.153262	0.077909	0.306099
BMed	6	0.161069	0.04964	0.118231	0.133958	0.154174	0.077652	0.305275
BMed	7	0.160754	0.050413	0.122607	0.131281	0.151869	0.078011	0.305065

Risk: Team

Table 12. Second Iteration of Analog Assessment Tool – Team Risk

Risk	Gap	NEEMO	HMP_C	HMP_P	Antarctica	RCS	DRATS	ISS
Team	1	0.156441	0.048514	0.114047	0.131895	0.161593	0.078572	0.308937
Team	2	0.156014	0.048566	0.115479	0.135768	0.159352	0.078483	0.306339
Team	3	0.162926	0.048687	0.118869	0.129987	0.157198	0.080179	0.302154
Team	4	0.158292	0.048968	0.113341	0.132892	0.161241	0.077929	0.307337
Team	5	0.160778	0.049065	0.116287	0.129711	0.160776	0.07944	0.303941
Team	6	0.161077	0.050442	0.116568	0.130089	0.15859	0.079361	0.303873
Team	7	0.164045	0.051007	0.117179	0.128645	0.156252	0.078095	0.304777

Risk: Sleep

Table 13. Second Iteration of Analog Assessment Tool – Sleep Risk

Risk	Gap	NEEMO	HMP_C	HMP_P	Antarctica	RCS	DRATS	ISS
Sleep	1	0.158498	0.047031	0.119946	0.136678	0.155634	0.080963	0.301249
Sleep	2	0.1597	0.047157	0.12266	0.136351	0.159508	0.080399	0.294225
Sleep	3	0.15586	0.047056	0.120164	0.138114	0.156543	0.079721	0.302542
Sleep	4	0.160994	0.047007	0.124997	0.135466	0.16146	0.082414	0.287663
Sleep	5	0.156929	0.046887	0.124072	0.136721	0.155985	0.080996	0.298411
Sleep	6	0.154952	0.048833	0.117131	0.139895	0.157441	0.079351	0.302397
Sleep	7	0.158745	0.048165	0.120066	0.136483	0.156884	0.079807	0.29985
Sleep	8	0.161098	0.047875	0.12211	0.135895	0.153754	0.0831	0.296169
Sleep	9	0.157962	0.04724	0.12196	0.136338	0.155441	0.080305	0.300754
Sleep	10	0.158997	0.047979	0.122034	0.135886	0.156392	0.081515	0.297197

Table 14. Second Iteration of Analog Assessment Tool (BMed, Team, Sleep) – Includes Utility Weight

Risk	Gap	NEEMO	HMP_C	HMP_P	Antarctica	RCS	DRATS	ISS
BMed	1	0.173457	0.053326	0.165765	0.073703	0.173526	0.056108	0.304116
BMed	2	0.172926	0.05771	0.163059	0.072299	0.173437	0.054881	0.305688
BMed	3	0.166099	0.054927	0.163033	0.076227	0.176943	0.055001	0.307769
BMed	4	0.168271	0.053917	0.158769	0.078924	0.177549	0.054117	0.308453
BMed	5	0.164913	0.052834	0.165331	0.081928	0.172731	0.054226	0.308037
BMed	6	0.171917	0.053714	0.159123	0.08059	0.174555	0.053712	0.306389
BMed	7	0.171287	0.055261	0.167874	0.075235	0.169945	0.05443	0.305969
Team	1	0.16266	0.051463	0.150754	0.076464	0.189393	0.055552	0.313714
Team	2	0.161806	0.051567	0.153617	0.08421	0.184909	0.055374	0.308517
Team	3	0.17563	0.051808	0.160398	0.072649	0.180602	0.058766	0.300148
Team	4	0.166362	0.052371	0.149343	0.078458	0.188687	0.054266	0.310513
Team	5	0.171335	0.052565	0.155235	0.072095	0.187759	0.057289	0.303722
Team	6	0.171932	0.055318	0.155796	0.072852	0.183386	0.057131	0.303585
Team	7	0.177869	0.056448	0.157018	0.069964	0.17871	0.054598	0.305394
Sleep	1	0.166774	0.048497	0.162553	0.086031	0.177474	0.060334	0.298338
Sleep	2	0.169179	0.048749	0.167979	0.085375	0.185222	0.059207	0.28429
Sleep	3	0.161499	0.048546	0.162987	0.088902	0.179293	0.05785	0.300923
Sleep	4	0.171766	0.048449	0.172654	0.083605	0.189126	0.063235	0.271164
Sleep	5	0.163637	0.048208	0.170804	0.086115	0.178176	0.060399	0.292661
Sleep	6	0.159683	0.0521	0.156923	0.092465	0.181088	0.05711	0.300632
Sleep	7	0.167268	0.050765	0.162793	0.08564	0.179974	0.058022	0.295539
Sleep	8	0.171975	0.050184	0.166879	0.084464	0.173713	0.064608	0.288178
Sleep	9	0.165703	0.048914	0.16658	0.08535	0.177088	0.059019	0.297346
Sleep	10	0.167773	0.050392	0.166728	0.084445	0.17899	0.061438	0.290233
Utility	1	0.150222	0.045566	0.07734	0.187326	0.133794	0.101592	0.304161

Results of the Third Iteration of the Analog Assessment Tool

The third iteration of the BHP Analog Assessment Tool focused on augmenting previous work in revising the hierarchical structure to incorporate additional research and utility characteristics (especially focusing on the utility characteristics that were added), increase the number and diversity of the analogs considered, revise the space scenario as the designated comparison mission (long-duration mission destination), and customize the results in a way that would be most resourceful to the investigator and/or the scientific community. Specifically, the user can review the results at three levels of granularity, identifying which characteristics, risks, and/or BHP-related concerns are most relevant to the research study they wish to implement within a space flight analog environment. In addition, we increased our SME pool as we felt the previous iterations proved that this methodological approach was effective and appropriate to use for analog comparisons. Over 40 (n = 41) SMEs participated in this iteration providing more than 9,300 ratings across the different surveys.

In addition to our consensus session, the online Web-based survey platform incorporated the ability to identify a super rater. This role allowed for an SME to review the answers and comments of others and then make a final rating in light of this input and their own evaluation. This feature improved the efficiency and allowed us to focus on those items that had the highest instance of disagreement among raters during the consensus session.

The results are provided from these different vantage points:

1. The first set of tables examines the specific utility and research characteristics that were considered for each risk by analog.
2. The next set of tables includes the averaged weights for all characteristics across each analog by the BHP risk.
3. The final set of tables provides a high-level summary of the results by combining all of the weights for each characteristic across all analogs and risks to produce a priority summary for analogs.

Please note that the first set of tables include the weighted averages across each characteristic for each analog. While raw scores for each characteristic within each BHP risk were more noticeably different, we see a high consistency across these final weights for the characteristics across all of the risks.

Utility Characteristics

Table 15. Behavioral Medicine Risk – Utility Characteristics per Category

BMed Risk													
Category	**Utility Characteristics**	**NEEMO**	**HMP**	**DRATS**	**Everest**	**Pavilion Lake**	**PISCES**	**PISCES Proposed**	**ISS**	**Antarctica – McMurdo**	**Antarctica – Concordia**	**Antarctica – South Pole**	**Antarctica – ANSMET**
Analog-Related	Exposure Time	0.080698	0.034048	0.038043	0.065354	0.035509	0.030987	0.074735	0.112391	0.146539	0.188736	0.155851	0.037109
Analog-Related	Mission Duration	0.022011	0.046331	0.021519	0.036387	0.022011	0.022011	0.072101	0.133065	0.159938	0.202864	0.210284	0.051477
Analog-Related	Mission Timeline	0.171292	0.062999	0.061297	0.041882	0.039459	0.036853	0.074383	0.239378	0.053571	0.070965	0.079191	0.068730
Analog-Related	Similarity to Astronauts	0.219662	0.059944	0.045656	0.025534	0.058719	0.023266	0.073213	0.289032	0.036475	0.069460	0.056920	0.042119
Analog-Related	Subjects/Year	0.026465	0.036133	0.091987	0.104288	0.039987	0.032118	0.073133	0.083090	0.245993	0.100755	0.121343	0.044709
Analog-Related	Task Relevance	0.203205	0.086081	0.057681	0.023140	0.060010	0.028956	0.075201	0.276123	0.038609	0.054506	0.048655	0.047832
NASA-Related	Cost/Study	0.252820	0.131185	0.117579	0.039086	0.049123	0.052074	0.066515	0.040000	0.106706	0.033671	0.084125	0.027116
NASA-Related	Data Collection Feasibility	0.244358	0.131367	0.118716	0.050831	0.048680	0.049295	0.064478	0.082055	0.071555	0.066027	0.044784	0.027855
NASA-Related	Research Process/Protocol Feasibility	0.174826	0.143243	0.150015	0.040832	0.048324	0.062408	0.066641	0.078260	0.078515	0.059625	0.069699	0.027612

Table 16. Team Risk – Utility Characteristics per Category

Team Risk													
Category	**Utility Characteristics**	**NEEMO**	**HMP**	**DRATS**	**Everest**	**Pavilion Lake**	**PISCES**	**PISCES Proposed**	**ISS**	**Antarctica – McMurdo**	**Antarctica – Concordia**	**Antarctica – South Pole**	**Antarctica – ANSMET**
Analog-Related	Exposure Time	0.080694	0.034049	0.038041	0.065353	0.035508	0.030986	0.074735	0.112390	0.146543	0.188738	0.155853	0.037111
Analog-Related	Mission Duration	0.022010	0.046333	0.021516	0.036385	0.022010	0.022010	0.072103	0.133063	0.159939	0.202863	0.210288	0.051479
Analog-Related	Mission Timeline	0.171289	0.062996	0.061299	0.041883	0.039460	0.036854	0.074384	0.239378	0.053570	0.070968	0.079191	0.068729
Analog-Related	Similarity to Astronauts	0.219661	0.059943	0.045657	0.025533	0.058720	0.023266	0.073212	0.289033	0.036475	0.069460	0.056920	0.042119
Analog-Related	Subjects/Year	0.026465	0.036133	0.091987	0.104297	0.039982	0.032113	0.073139	0.083074	0.245986	0.100766	0.121353	0.044705
Analog-Related	Task Relevance	0.203199	0.086077	0.057682	0.023142	0.060008	0.028959	0.075202	0.276123	0.038603	0.054507	0.048661	0.047838
NASA-Related	Cost/Study	0.252819	0.131185	0.117579	0.039089	0.049121	0.052073	0.066517	0.040000	0.106706	0.033670	0.084124	0.027117
NASA-Related	Data Collection Feasibility	0.244358	0.131365	0.118717	0.050832	0.048681	0.049297	0.064478	0.082054	0.071554	0.066026	0.044781	0.027857
NASA-Related	Research Process/Protocol Feasibility	0.174826	0.143243	0.150015	0.040832	0.048324	0.062409	0.066640	0.078259	0.078516	0.059626	0.069698	0.027612

Table 17. Sleep Risk – Utility Characteristics per Category

Sleep Risk													
Category	**Utility Characteristics**	**NEEMO**	**HMP**	**DRATS**	**Everest**	**Pavilion Lake**	**PISCES**	**PISCES Proposed**	**ISS**	**Antarctica – McMurdo**	**Antarctica – Concordia**	**Antarctica – South Pole**	**Antarctica – ANSMET**
Analog-Related	Exposure Time	0.080697	0.034038	0.038048	0.065360	0.035516	0.030989	0.074728	0.112388	0.146537	0.188743	0.155850	0.037105
Analog-Related	Mission Duration	0.022011	0.046330	0.021521	0.036388	0.022011	0.022011	0.072106	0.133059	0.159944	0.202857	0.210285	0.051475
Analog-Related	Mission Timeline	0.171288	0.062992	0.061300	0.041886	0.039457	0.036860	0.074384	0.239378	0.053568	0.070965	0.079192	0.068730
Analog-Related	Similarity to Astronauts	0.219662	0.059943	0.045655	0.025533	0.058721	0.023266	0.073209	0.289032	0.036477	0.069460	0.056921	0.042121
Analog-Related	Subjects/Year	0.026456	0.036130	0.091968	0.104270	0.040012	0.032129	0.073156	0.083070	0.245984	0.100746	0.121350	0.044730
Analog-Related	Task Relevance	0.203197	0.086075	0.057678	0.023140	0.060005	0.028957	0.075194	0.276130	0.038610	0.054511	0.048672	0.047831
NASA-Related	Cost/Study	0.252821	0.131193	0.117580	0.039091	0.049127	0.052073	0.066511	0.039997	0.106703	0.033668	0.084122	0.027113
NASA-Related	Data Collection Feasibility	0.244356	0.131368	0.118715	0.050829	0.048681	0.049296	0.064478	0.082057	0.071551	0.066027	0.044783	0.027858
NASA-Related	Research Process/Protocol Feasibility	0.174826	0.143245	0.150016	0.040832	0.048326	0.062406	0.066641	0.078257	0.078515	0.059627	0.069698	0.027612

Research Characteristics

Table 18. Behavioral Medicine Risk – Research Characteristics per Category

BMed Risk													
Category	**Characteristic**	**NEEMO**	**HMP**	**DRATS**	**Everest**	**Pavilion Lake**	**PISCES**	**PISCES Proposed**	**ISS**	**Antarctica – McMurdo**	**Antarctica – Concordia**	**Antarctica – South Pole**	**Antarctica – ANSMET**
Team/Psychosocial Aspects	Team Size	0.158885	0.026978	0.071857	0.070746	0.017234	0.024439	0.128162	0.267306	0.015647	0.110039	0.022376	0.086330
Team/Psychosocial Aspects	Leadership	0.136616	0.029141	0.037141	0.104713	0.018403	0.019408	0.177132	0.230886	0.027956	0.093739	0.040867	0.083998
Team/Psychosocial Aspects	Team Structure	0.221956	0.048832	0.081804	0.060690	0.026106	0.017370	0.094129	0.265120	0.029747	0.063758	0.028863	0.061626
Team/Psychosocial Aspects	Team Interdependence	0.216079	0.036120	0.067520	0.127101	0.023675	0.028825	0.036550	0.222230	0.041735	0.085259	0.041699	0.073206
Mission Characteristics	Workload	0.076228	0.087281	0.014013	0.199544	0.016239	0.015707	0.122561	0.037821	0.093755	0.128420	0.093060	0.115372
Mission Characteristics	Communication with Outside World	0.077392	0.096760	0.014538	0.214623	0.018428	0.024117	0.130261	0.050925	0.084896	0.083567	0.052756	0.151737
Mission Characteristics	Autonomy	0.184563	0.046217	0.020620	0.045833	0.017885	0.017235	0.052995	0.187052	0.112945	0.136860	0.110466	0.067328
Mission Characteristics	Sensory Deprivation	0.112806	0.035663	0.014002	0.044504	0.015120	0.014462	0.033033	0.271332	0.142190	0.120201	0.108894	0.087793
Mission Characteristics	Sensory Conditions	0.216471	0.102593	0.078416	0.100370	0.014820	0.016788	0.075622	0.166677	0.061374	0.056759	0.059934	0.050175
Personal Aspects	Personal Space	0.262234	0.079288	0.047028	0.063537	0.014121	0.010827	0.114486	0.142923	0.051895	0.073014	0.054625	0.086021
Personal Aspects	Rest & Recreation	0.177935	0.089577	0.026528	0.058105	0.016154	0.014726	0.134800	0.219955	0.032412	0.104616	0.038121	0.087070
Personal Aspects	Quality of Life Support Conditions	0.181730	0.051142	0.022037	0.072936	0.014552	0.014309	0.113633	0.221244	0.052500	0.112345	0.072344	0.071230
Environmental Characteristics	Internal Light Conditions	0.045916	0.047702	0.016081	0.092394	0.014062	0.015868	0.021036	0.256465	0.137041	0.162188	0.096489	0.094761
Environmental Characteristics	External Light Conditions	0.292261	0.050314	0.028345	0.030446	0.015082	0.011885	0.070977	0.202829	0.076752	0.089114	0.059710	0.072284
Environmental Characteristics	Danger	0.113641	0.037095	0.012328	0.191539	0.015532	0.013802	0.014232	0.276112	0.102194	0.087358	0.066737	0.069430
Environmental Characteristics	Physical Isolation	0.076628	0.096341	0.034060	0.063977	0.030557	0.040371	0.066229	0.161986	0.076127	0.147361	0.136295	0.070066
Environmental Characteristics	Habitable Volume Characteristics	0.166631	0.033522	0.025594	0.031609	0.028606	0.023784	0.127572	0.206708	0.108041	0.107208	0.098752	0.041974
Environmental Characteristics	Availability of Medication/Medical Care	0.047877	0.069148	0.012885	0.128645	0.042334	0.022993	0.024662	0.211031	0.059536	0.167523	0.120546	0.092819

Table 19. Team Risk – Research Characteristics per Category

Team Risk													
Category	**Characteristic**	**NEEMO**	**HMP**	**DRATS**	**Everest**	**Pavilion Lake**	**PISCES**	**PISCES Proposed**	**ISS**	**Antarctica – McMurdo**	**Antarctica – Concordia**	**Antarctica – South Pole**	**Antarctica – ANSMET**
Team/Psychosocial Aspects	Team Size	0.158880	0.026972	0.071864	0.070741	0.017244	0.024446	0.128171	0.267311	0.015643	0.110031	0.022364	0.086333
Team/Psychosocial Aspects	Leadership	0.136619	0.029144	0.037137	0.104710	0.018404	0.019406	0.177132	0.230883	0.027953	0.093742	0.040869	0.084001
Team/Psychosocial Aspects	Team Structure	0.221970	0.048828	0.081785	0.060675	0.026099	0.017348	0.094149	0.265135	0.029753	0.063738	0.028885	0.061638
Team/Psychosocial Aspects	Team Interdependence	0.216086	0.036127	0.067511	0.127094	0.023660	0.028820	0.036560	0.222235	0.041747	0.085245	0.041710	0.073207
Mission Characteristics	Workload	0.076230	0.087283	0.014012	0.199543	0.016240	0.015706	0.122561	0.037820	0.093752	0.128419	0.093062	0.115371
Mission Characteristics	Communication with Outside World	0.077394	0.096765	0.014534	0.214622	0.018434	0.024120	0.130255	0.050926	0.084900	0.083567	0.052756	0.151727
Mission Characteristics	Autonomy	0.184563	0.046220	0.020623	0.045833	0.017886	0.017233	0.052997	0.187045	0.112946	0.136861	0.110464	0.067328
Mission Characteristics	Sensory Deprivation	0.112802	0.035663	0.014014	0.044497	0.015129	0.014451	0.033038	0.271337	0.142192	0.120197	0.108900	0.087781
Mission Characteristics	Sensory Conditions	0.216475	0.102593	0.078427	0.100357	0.014821	0.016784	0.075619	0.166681	0.061366	0.056757	0.059934	0.050185
Personal Aspects	Personal Space	0.262230	0.079287	0.047030	0.063537	0.014118	0.010831	0.114486	0.142921	0.051896	0.073015	0.054628	0.086022
Personal Aspects	Rest & Recreation	0.177942	0.089586	0.026517	0.058093	0.016138	0.014731	0.134803	0.219945	0.032396	0.104624	0.038136	0.087089
Personal Aspects	Quality of Life Support Conditions	0.181725	0.051143	0.022054	0.072917	0.014563	0.014311	0.113634	0.221230	0.052494	0.112348	0.072340	0.071240
Environmental Characteristics	Internal Light Conditions	0.045916	0.047699	0.016082	0.092395	0.014056	0.015865	0.021032	0.256466	0.137040	0.162192	0.096489	0.094767
Environmental Characteristics	External Light Conditions	0.292273	0.050317	0.028331	0.030459	0.015080	0.011870	0.070959	0.202837	0.076745	0.089138	0.059724	0.072266
Environmental Characteristics	Danger	0.113633	0.037092	0.012335	0.191539	0.015538	0.013807	0.014239	0.276109	0.102186	0.087362	0.066739	0.069422
Environmental Characteristics	Physical Isolation	0.076643	0.096391	0.034031	0.063947	0.030563	0.040379	0.066240	0.161984	0.076114	0.147349	0.136300	0.070060
Environmental Characteristics	Habitable Volume Characteristics	0.166635	0.033521	0.025594	0.031609	0.028608	0.023781	0.127570	0.206708	0.108045	0.107208	0.098750	0.041972
Environmental Characteristics	Availability of Medication/Medical Care	0.047880	0.069160	0.012900	0.128645	0.042340	0.022989	0.024643	0.211037	0.059540	0.167512	0.120541	0.092811

Table 20. Sleep Risk – Research Characteristics per Category

Sleep Risk													
Category	**Characteristic**	**NEEMO**	**HMP**	**DRATS**	**Everest**	**Pavilion Lake**	**PISCES**	**PISCES Proposed**	**ISS**	**Antarctica – McMurdo**	**Antarctica – Concordia**	**Antarctica – South Pole**	**Antarctica – ANSMET**
Team/Psychosocial Aspects	Team Size	0.158876	0.026940	0.071793	0.070773	0.017184	0.024465	0.128149	0.267366	0.015582	0.110092	0.022426	0.086355
Team/Psychosocial Aspects	Leadership	0.136612	0.029129	0.037152	0.104709	0.018407	0.019420	0.177139	0.230862	0.027967	0.093724	0.040864	0.084014
Team/Psychosocial Aspects	Team Structure	0.221920	0.048918	0.081848	0.060610	0.026010	0.017348	0.094256	0.265111	0.029828	0.063713	0.028873	0.061565
Team/Psychosocial Aspects	Team Interdependence	0.216114	0.036101	0.067443	0.127174	0.023630	0.028881	0.036593	0.222186	0.041680	0.085330	0.041680	0.073187
Mission Characteristics	Workload	0.076233	0.087281	0.014012	0.199543	0.016240	0.015707	0.122560	0.037817	0.093750	0.128423	0.093065	0.115370
Mission Characteristics	Communication with Outside World	0.077403	0.096760	0.014538	0.214618	0.018447	0.024123	0.130254	0.050924	0.084900	0.083561	0.052744	0.151727
Mission Characteristics	Autonomy	0.184565	0.046218	0.020623	0.045828	0.017893	0.017226	0.052995	0.187051	0.112946	0.136867	0.110459	0.067329
Mission Characteristics	Sensory Deprivation	0.112818	0.035670	0.014007	0.044519	0.015147	0.014442	0.033009	0.271296	0.142190	0.120202	0.108909	0.087790
Mission Characteristics	Sensory Conditions	0.216471	0.102605	0.078405	0.100367	0.014828	0.016786	0.075608	0.166672	0.061374	0.056758	0.059941	0.050184
Personal Aspects	Personal Space	0.262232	0.079285	0.047028	0.063541	0.014111	0.010831	0.114493	0.142920	0.051894	0.073022	0.054625	0.086019
Personal Aspects	Rest & Recreation	0.177916	0.089546	0.026526	0.058076	0.016167	0.014754	0.134830	0.219903	0.032412	0.104615	0.038142	0.087113
Personal Aspects	Quality of Life Support Conditions	0.181683	0.051169	0.022053	0.072908	0.014597	0.014283	0.113640	0.221237	0.052504	0.112306	0.072359	0.071260
Environmental Characteristics	Internal Light Conditions	0.045917	0.047699	0.016082	0.092395	0.014061	0.015870	0.021037	0.256461	0.137036	0.162189	0.096490	0.094763
Environmental Characteristics	External Light Conditions	0.292258	0.050309	0.028349	0.030439	0.015102	0.011893	0.070974	0.202826	0.076744	0.089108	0.059729	0.072270
Environmental Characteristics	Danger	0.113635	0.037088	0.012323	0.191531	0.015531	0.013808	0.014234	0.276117	0.102200	0.087368	0.066734	0.069430
Environmental Characteristics	Physical Isolation	0.076613	0.096357	0.034066	0.063960	0.030590	0.040369	0.066231	0.161986	0.076149	0.147340	0.136263	0.070078
Environmental Characteristics	Habitable Volume Characteristics	0.166633	0.033520	0.025593	0.031609	0.028604	0.023781	0.127573	0.206708	0.108043	0.107210	0.098749	0.041976
Environmental Characteristics	Availability of Medication/Medical Care	0.047870	0.069152	0.012891	0.128652	0.042326	0.023000	0.024652	0.211022	0.059543	0.167522	0.120543	0.092826

Table 21. Summary of Results by Combining Weights for All Characteristics

Analog	Utility Characteristics			Research Characteristics			Average		
BHP Risk	BMed	Team	Sleep	BMed	Team	Sleep	**BMed**	**Team**	**Sleep**
NEEMO	0.155037	0.155036	0.174826	0.153658268	0.153661	0.153654	**0.154348**	**0.154348**	**0.164240**
HMP	0.081259	0.081258	0.143245	0.059095227	0.059099	0.059097	**0.070177**	**0.070179**	**0.101171**
DRATS	0.078055	0.078055	0.150016	0.034710929	0.03471	0.034707	**0.056383**	**0.056382**	**0.092362**
Everest	0.047481	0.047483	0.040832	0.094517375	0.094512	0.094514	**0.070999**	**0.070997**	**0.067673**
Pavilion Lake	0.044647	0.044646	0.048326	0.019939411	0.01994	0.019938	**0.032293**	**0.032293**	**0.034132**
PISCES	0.037552	0.037552	0.062406	0.01927319	0.019271	0.019277	**0.028413**	**0.028411**	**0.040842**
PISCES Proposed	0.071156	0.071157	0.066641	0.085448456	0.085449	0.085457	**0.078302**	**0.078303**	**0.076049**
ISS	0.148155	0.148153	0.078257	0.199922334	0.199923	0.199915	**0.174039**	**0.174038**	**0.139086**
Antarctica – McMurdo	0.104211	0.104210	0.078515	0.072596833	0.072595	0.072597	**0.088404**	**0.088402**	**0.075556**
Antarctica – Concordia	0.094068	0.094069	0.059627	0.107184956	0.107184	0.107186	**0.100626**	**0.100626**	**0.083406**
Antarctica – South Pole	0.096761	0.096763	0.069698	0.072363101	0.072366	0.072366	**0.084562**	**0.084565**	**0.071032**
Antarctica – ANSMET	0.041618	0.041619	0.027612	0.08128992	0.08129	0.081292	**0.061454**	**0.061454**	**0.054452**

Table 22. Priority Summary of Analogs

Priority of Analogs Across BHP Risks			
Analog	**Research Characteristics**	**Utility Characteristics**	**Average**
NEEMO	0.153658	0.161633	0.157645
HMP	0.059097	0.101921	0.080509
DRATS	0.034709	0.102042	0.068376
Everest	0.094514	0.045266	0.069890
Pavilion Lake	0.019939	0.045873	0.032906
PISCES	0.019274	0.045837	0.032555
PISCES Proposed	0.085452	0.069651	0.077551
ISS	0.199920	0.124855	0.162387
Antarctica – McMurdo	0.072596	0.095645	0.084121
Antarctica – Concordia	0.107185	0.082588	0.094886
Antarctica – South Pole	0.072365	0.087741	0.080053
Antarctica – ANSMET	0.081291	0.036949	0.059120

The results summarized in Tables 16 through 22 show general consistency when compared to previous iterations of the BHP Analog Assessment Tool; however, these results also are distinct in several ways. First, although ISS was still the highest-ranking analog, the relative difference in weights between NEEMO and ISS was not significant. Second, although the results seem to denote a specific clustered ranking, the overall ranking of some of the analogs that were previously considered have changed, especially when the utility characteristic weights are considered (see Figure 7). Third, we see a stark contrast in some of the specific Antarctica stations that were considered, thus we see the utility in dividing the Antarctica analog into substations as was suggested by our SMEs. Finally, these results demonstrate how research and utility characteristics can impact the level of these results. For example, although HMP scored fairly low for research characteristic weight, the utility characteristic weight was high, thus the average weight placed HMP as a second-tier analog. This example also points to the power of providing the detailed tables as it allows the researcher to examine the results at the level of specificity they desire: results at the analog level (across risks); at the risk level (weights for each analog); or at the characteristic level (weights for each characteristic for each risk).

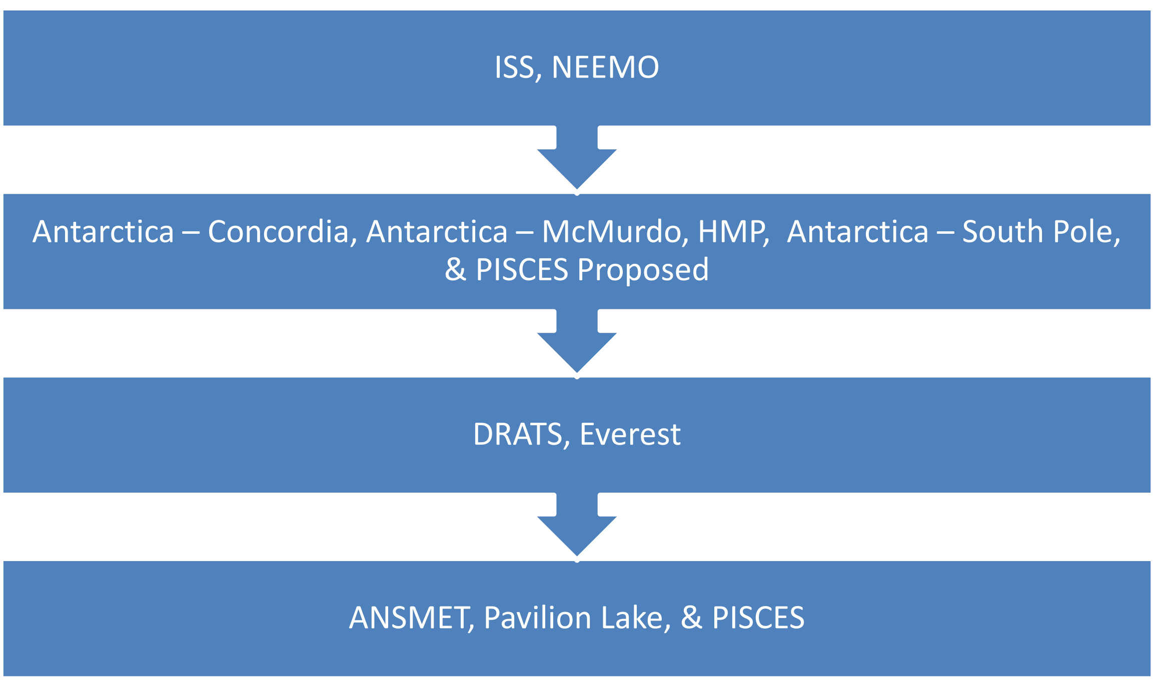

Figure 7. Overall ratings of analogs.

Conclusions and Defined Forward Work: Analog Assessment Tool

Many conclusions can be drawn from the efforts of creating the Analog Assessment Tool and the analyses that were conducted on the data collected. First, the Analog Assessment Tool demonstrates that it is possible to objectively and systematically compare analogs across specific characteristics that are relevant to research. Second, this process exemplifies the importance of considering both research and utility needs when conducting research; it is necessary to consider those specific characteristics that are essential for creating a high-fidelity environment as well as those characteristics that pertain to the logistics of conducting research within a specific analog. Third, the results across all three iterations demonstrated high reliability, which provided evidence-based support in using a pair-wise comparison process to examine analogs based on the specific characteristics that are collected. The AHP serves as an exemplary method of decision making to complete these difficult comparisons within a hierarchical structure.

On a grander scale, the results from this process also demonstrate that ISS and NEEMO serve as a high-fidelity analog to conduct BHP-related research for a Mars mission or alternate long-duration destination. Other analogs, including Antarctica – Concordia, Antarctica – McMurdo, HMP, PISCES Proposed, and Antarctica – South Pole, also are high-fidelity analogs and should be considered as viable alternatives to conduct behavioral and performance-related research.

The Analog Assessment Tool has implications for other uses as well; its malleability allows researchers to consider which analog would provide the highest fidelity across BHP risks (when relevant). The results from this process can provide insight as to the weights for specific characteristics within each analog. Researchers can choose to look at specific weights at a more detailed level among the analogs to make a better selection of fidelity when choosing a location to implement a research task. In addition, results from this iteration can be used to identify those characteristics in which analogs are weak (indicated by a small weight in comparison to the other analogs), and use this information to specifically identify which characteristics need to be improved to increase the fidelity of the analog environment to the space scenario in question. In terms of forward work, future updates will be determined as needed, pending a substantial change of analogs considered, the space scenario selected, and/or research and utility characteristics that were included. These updates will be shared annually at the BHP Working Group.

In conclusion, this report provides an account of the development and implementation of the Analog Assessment Tool for the BHP Research Element. The outcomes of this process will be used in future work within BHP Research when identifying analogs that would represent the highest fidelity for specific research tasks. This report also serves as an example for others to use this process so that they may objectively determine which analog will provide the highest fidelity to space flight when considering specific research. And finally, this report serves as a resource to researchers and others in the research community to make informed decisions about where to implement research within those analogs that most highly replicate the characteristics desired for behavioral health and performance-related issues and the long-duration environment.

As the Human Research Program tasked BHP Research with providing a summary of this process and recommendations for the Flight Analog Project to be able to use a similar methodology, we view this report as fulfilling this request. We anticipate that this tool will continue to develop and improve, and will provide the valuable resource information that is necessary to implement sound research within analog environments that have high fidelity to the space flight environment.

References

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[3] Human Research Program (2010). Human Research Program Requirements Document, HRP- 47052.

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Thank you!

Appendix A

Supplemental Material for Analog Assessment Tool

Descriptions of Analogs

NEEMO (NASA Extreme Environment Mission Operations)

NEEMO is an environment for studying human survival in the Aquarius underwater laboratory in preparation for future space exploration. Aquarius, an underwater habitat located near Key Largo, Florida, is owned by the National Oceanic and Atmospheric Administration and operated by the National Undersea Research Center (NURC) at the University of North Carolina–Wilmington as a marine biology study base. NASA has used it since 2001 for a series of missions, usually lasting 10 to 14 days, with research conducted by astronauts, other NASA employees, and NURC Habtechs (aquanauts that help support the NASA crew member during the mission; they stay inside the habitat for the duration of the mission and ensure that safety and NURC policies and guidelines are followed). The crew members are called aquanauts instead of "divers." They perform extravehicular activities (EVAs) in the underwater environment, as well as perform other scientific-based studies within the habitat. Groups of NASA employees and contractors live in Aquarius for up to approximately 3 weeks at a time. For NASA, Aquarius provides an environment similar to space living, and NEEMO crew members experience some of the same tasks and challenges underwater as they would in space. There are four to six crew members: three to four aquanauts, one commander, and one to three mission support personnel who conduct the science, exploration, and environmental studies. There are always two NURC habtechs (one lead and one support) whose main job is to ensure the safety of the team as well as complete the daily maintenance of the habitat. The habitat is the size of the Destiny module on board ISS. The habitat is a steel cylinder 3 m (~9.8 ft) in diameter by 14 m (~46 ft) in length, providing 11 m^3 (388 ft^3) of living and lab space. Once the crew members have been underwater for approximately 6 hours, they are then required to complete a 17-hour decompression process before their ascent to the surface or risk decompression sickness or possibly even death. A support staff (topside) of approximately five to 10 is located on shore. The staff's duties resemble mission control. An NURC support team, also located on shore, operates a 24-hour watch desk, pot (delivers and retrieves) items daily, and supports EVAs. A structured timeline/schedule Onboard Short-Term Planning Viewing is used for each mission day's activities. The crew members have full communication with ground support (topside) as well as internet and video conferencing capabilities. The lighting within the habitat is similar to the ISS.

- www.nasa.gov/mission_pages/NEEMO/index.html

- www.uncwil.edu/aquarius/thumb_cam.htm
- http://www.uncw.edu/aquarius/index.html
- http://www1.nasa.gov/pdf/448866main_NEEMO14%20factsheet-508c.pdf

NEEMO – Description of Analog by Characteristic	
Characteristic	**Description**
Internal Light Conditions	Similar to ISS lighting; artificial light (not full spectrum)
External Light Conditions	18.9 m (62 ft) underwater, similar to submarine lighting
Danger	Moderate level of danger associated with diving while performing EVAs and generally living underwater for an extended period of time
Physical Isolation	Underwater for approximately 2 to 3 weeks
Crowdedness/Habitable Volume Characteristics	11 m^3 (388 ft^3) of living and lab space with approximately six crew members in the space
Team Size	Up to six crew members (three to four astronauts; two habtechs)
Leadership	One commander
Team Structure	One commander, others for mission support, habtechs ensure safety and complete daily maintenance
Personal Space	Size of Destiny module on ISS, 11 m^3 (388 ft^3) of living and lab space
Rest and Recreation Options	Able to communicate with friends/colleagues, read, eat, rest, plan dives, research for next day, work with data found
Quality of Life Support Conditions	Mainly dehydrated food although can be sent fresh food on occasion; similar to what astronauts have in space. Bottled water or water from a specialized tank.
Workload	Structured timeline for each mission day's activities
Communication with Outside	Communication with topside, internet and video conferencing capabilities
Availability of Medication/Medical Care	There is a Dive Medical Officer (topside), but crew likely will be required to deal with emergencies on their own without the assistance of a doctor
Autonomy	Partial mission time spent with being fully autonomous (independent from mission control – delayed communication)
Sensory Conditions	The interior atmospheric pressure is equal to the surrounding water pressure; dank smell in the habitat (e.g., issues related to fungus) and moderate level of noise
Sensory Deprivation	Environment provides rich stimulation for all senses
Team Interdependence	High; team members must rely on each other to complete mission objectives, particularly during the autonomous phase

Haughton-Mars Project Research Station/Devon Island (Current Operations)

The Haughton-Mars Project (HMP) is an international, multidisciplinary, scientific field research project centered on the exploration of the 38-million-year-old Haughton impact crater and surrounding terrain on Devon Island, Nunavut, Canada. Devon Island, at 75 degrees North latitude, is a high arctic desert. The unique combination of rocky polar desert, permafrost, and analogous geological formations afford comparisons to the possible evolution of Mars. Devon Island, High Arctic is viewed as a terrestrial analog for future exploration missions to Mars. In addition to the cold operating temperatures, there is dust everywhere. Dust is perhaps one of the most significant issues facing lunar and martian surface exploration. Devon Island is the largest uninhabited island. The rocky polar desert setting, geologic features, and biological attributes of the site offer unique insights into the possible evolution of Mars. HMP is light 24 hours a day during the summer and dark 24 hours a day during the winter. This includes the history of water and of past climates on Mars, the effects of impacts on Earth and on other planets, and the possibilities and limits of life in extreme environments. In parallel with its Science Program, the HMP supports an Exploration Program aimed at developing new technologies, strategies, behavioral health and humans factors experiences, and field-based operational know-how key to planning the future exploration of the moon, Mars, and other planets by robots and humans. The HMP is managed and operated by the Mars Institute with support from the SETI Institute. HMP-2008 was the 12th field season.

HMP provides the ultimate test bed for evaluating system implications (man, machine, and mission) of long-duration missions in deep space. A variety of habitat considerations could be evaluated, including habitat relocation and mobility, dual use space for science and operations, greenhouse operations, life support systems, communications, power distribution, and in-situ resource utilization. The environment makes this ideal for testing EVA and rover traversing, and navigation. With the proper planning, an entire end-to-end planetary surface mission scenario could be accomplished with training integrated with hardware development. The Haughton Crater site functions as an analogue planetary base, supporting a diverse array of exploration technology and engineering test projects that benefit from the Mars-like terrain, remoteness, and exploration activities.

The HMP base on Devon Island is at 75°N 90°W. The base includes the airfield, fuel farm, satellite site, research station, and tent city. The research station proper includes a main mess tent, communication-systems tent, operations office tent, two science laboratory tents, medical tent, maintenance tent, an autonomous research greenhouse, and an octagonal core module that will eventually unite the buildings into a single base-like structure. HMP can currently accommodate up to 45 people at a given time, with researchers sleeping in individual tents a short distance from the main camp, away from the food and hence the polar bear risk. In a typical field season at HMP, multiple teams of researchers come in for 1 to 2 weeks throughout the roughly 4- to 6-week field season. Approximately seven to 10 core group researchers and a base camp manager ensure the day-to-day operations during the entire duration of the mission. A timeline/schedule is not used at this time, but there is discussion for use of one in future missions. If emergency medical evacuation is required, it could take up to hours/days – depending on current weather conditions – to be removed from the facilities. Distance and time to definitive medical care make Devon Island a realistic analog to space exploration. It would be quicker to med-evac someone from ISS than it would be to provide a Devon Island casualty with immediate return and quick access to definitive medical care. Planetary protection procedures could definitely be evaluated here. HMP has full communication, internet, full medical support, and telemed/video conferencing capabilities. HMP funding is provided by NASA and the Canadian Space Agency. The project is managed by the Mars Institute, the SETI Institute, and Simon Fraser University (British Columbia, Canada). The Mars Institute manages and operates the HMP Research Station.

- http://spacelogistics.mit.edu/pdf/HMP%20Final%20Report%20NASA%20TP-2006-214196.pdf
- http://humanresearch.jsc.nasa.gov/analogs/analog_haughton.asp
  http://www.space.com/scienceastronomy/solarsystem/mars_next_step_010905-1.html
- www.marsonearth.org/

HMP – Current Operations – Description of Analog by Characteristic	
Characteristic	**Description**
Internal Light Conditions	Lighting powered by generators; artificial light
External Light Conditions	Light (sun) 24 hours day during summer and dark 24 hours a day during winter
Danger	Moderately low danger; environment has potential of polar bears, but threat is low
Physical Isolation	Isolated and remote, polar location
Crowdedness/Habitable Volume Characteristics	No close quarters, tents set up for work, separate tents for sleeping
Team Size	Seven to 10 core members, then up to 40 at any given time
Leadership	Defined leader of HMP who makes final decisions
Team Structure	Approximately 50 people working together on projects; lack of clearly assigned roles
Personal Space	"Tent City"; individual tents for sleeping
Rest and Recreation Options	Not much down time, takes effort to find leisure time
Quality of Life Support Conditions	Difficult to get immediate emergency medical treatment

Workload	No current timeline/schedule for work/tasks
Communication with Outside	Full communication, internet, video conferencing
Availability of Medication/Medical Care	Basic medical treatment is available on site but a serious accident or illness would require air transport to a “health center” in Resolute Bay or the nearest hospital in Iqaluit, 1,550 km (963 miles) from Resolute Bay
Autonomy	Moderate to high; often research project dependent, many teams do have autonomy from a ground control, though some do not
Sensory Conditions	Quality of environmental conditions is satisfactory and should not affect sensory perceptions
Sensory Deprivation	Environment is isolated and remote (lack of greenery, landscape changes, etc.)
Team Interdependence	Low to moderate; teams do exist but likely only subsets of team must work together to complete mission objectives (research project dependent)

Desert RATS (Research and Technology Studies)

Desert Research and Technology Studies (DRATS) – or Desert RATS – is a combined group of inter-NASA center scientists and engineers, collaborating with representatives of industry and academia for the purpose of conducting remote field test activities. These activities provide the capability to validate experimental hardware/software and mission operational techniques, and identify and establish technical requirements applicable for future planetary exploration. In recent years, tests have been conducted near Meteor Crater, located approximately 55 km (35 miles) east of Flagstaff, Arizona, near Winslow. The locations include Cinder Lake, Grand Falls, SP Mountain, Joseph City, Bar-T-Bar Ranch, and Meteor Crater.

One purpose of the DRATS effort is to drive out preliminary exploration operational concepts for EVA system requirements by providing hands-on experience with simulated planetary surface exploration EVA hardware and procedures.

The analog has been used for field testing of equipment in high desert environment – e.g., Science Crew Operations and Utility Test bed (SCOUT) vehicle – but the sites have not been used to simulate isolation or confinement of flight crews. The remote location of these sites, however, suggests the possibility that their use could perhaps be adapted to simulate these features of space exploration.

There is a daily/weekly schedule, but it typically is not timelined like a mission. There is large (approximately 50-member) support team for suits and equipment. The support personnel commonly put in 12-hour days and participants may be in EVA suits for 6 to 8 hours. There is a control trailer where communication and video is integrated and allows the "ground" support personnel to track status of hardware, suits, and consumables while the suited personnel are driving out in a rover and interfacing with the field equipment and completing tasks. There is an individual who leads the efforts. DRATS has a team with defined roles; however, it is not a mission support team like with NEEMO. At the end of the day, the support team members retreat to their hotel at a nearby local town.

Historically, these sites were used to support training of Apollo astronauts in geology. These sites are the location of U.S. Geological Survey's (USGS) Astrogeology Branch. Acquisition of land use permits, host accommodations, use of USGS facilities and equipment, and extensive planetary geology reference sources are available through memoranda of understandings between USGS and NASA.

- http://www.nasa.gov/exploration/analogs/desert_rats.html
  http://search.nasa.gov/search/search?q=desert+rats&output=xml_no_dtd&sort=dateADALAd1&site=nasa_collection&ie=UTF-8&client=nasa_production&oe=UTF-8&proxystylesheet=nasa_production
- www.en.wikipedia.org/wiki/Desert_Research_and_Technology_Studies

DRATS – Description of Analog by Characteristic	
Characteristic	**Description**
Internal Light Conditions	N/A
External Light Conditions	Natural light
Danger	Low danger; although remote, the desert does not provide a significant amount of danger
Physical Isolation	Not highly isolated; nearest town is within driving distance
Crowdedness/Habitable Volume Characteristics	Not crowded; plenty of open space
Team Size	Approximately 100 participants each year
Leadership	One individual who leads the efforts; somewhat not clearly defined role
Team Structure	Team has clearly defined roles to carry out and complete mission objectives
Personal Space	Personal space is high
Rest and Recreation Options	Not many recreational options available
Quality of Life Support Conditions	Crew often stays at a local hotel; quality of life support conditions are generally high
Workload	Daily/weekly schedule, but not timelined
Communication with Outside	Mission support team retreats at the end of the day to a nearby hotel, but puts in 12-hour days

Availability of Medication/Medical Care	All sites are within 120-km (75-mile) radius of Flagstaff, Arizona, which provides a source of logistical support for medical facilities; medical officer on site also
Autonomy	The sites have not been used to simulate autonomy of the crew from a mission control
Sensory Conditions	Quality of environmental conditions are satisfactory and should not affect sensory perceptions
Sensory Deprivation	Environment is isolated and remote; however, greenery and some landscape does exist; animals are often seen, etc.
Team Interdependence	High; they stage mock explorations of the desert, try out various procedures/techniques for accomplishing the mission. Suited crew members work side by side with robots, and are connected to one another and to the robots by a wireless network.

Antarctica

A number of facilities are located in Antarctica. Winter stations' population varies from two to 250 participants. The external lighting is dependent upon the season. Some stations are seasonal and some are year round. Each station is operated by a National Antarctic Program. Approximately 64 stations are operated by approximately 20 different nations. Antarctica is an extreme, isolated, and confined environment.

Scientists believe that Antarctica's climate, terrain, temperature, and isolation provide an environment on Earth that most closely parallels the conditions of isolation and stress to be faced on long-duration human missions in space. Thus, the Antarctic space analog will provide a unique and accessible test bed to develop prototype lunar and Mars systems and technologies.

Research disciplines at the many Antarctic stations include astronomy, atmospheric sciences, biology, Earth science, environmental science, geology, glaciology, marine biology, oceanography, climate studies, and geophysics.

- http://quest.nasa.gov/antarctica/background/NSF/mc-stay.html
- http://antarcticconnection.com/antarctic/stations/index.shtml
- http://humanresearch.jsc.nasa.gov/analogs/analog_antarctica.asp

McMurdo

McMurdo Station provides a good venue for conducting studies requiring relatively long-duration missions and reasonable levels of isolation and confinement. Due to the sophistication of the communications infrastructure, McMurdo is an excellent test facility for telemedicine. Subjects are typically scientists and technicians wintering over for other purposes. Human life science activities would likely require the resident station physician for oversight and, potentially, assistance, so early involvement of this individual is a key to success. This analog is unique in its ability to provide ambulatory subject populations participating in long-duration stays in an outpost isolated from the world outside Antarctica.

McMurdo Station (77° 51' S, 166° 40' E), the main U.S. station in Antarctica, is a coastal outpost on the volcanic hills at the southern tip of Ross Island, about 3,864 km (2,415 miles) south of Christchurch, New Zealand, and 1,360 km (850 miles) north of the South Pole. The mean annual temperature at McMurdo Station is –18°C (0°F). Temperatures may reach 10°C (50°F) during the austral summer and –58°F (–50°C) in winter. The average wind speed is 12 kt, but winds have exceeded 100 kt.

At McMurdo station, the participants work schedule is from 7:30 am to 5:00 pm, 6 days a week. Participants only receive an occasional day off. McMurdo operates a personnel selection for the participants who winter over. Winter over is from February to October. McMurdo has communications for 12 hours each day. Each winter-over participant has his or her own individual sleep quarters and the participants share common areas. There is a station manager who is the leader for the mission, and he/she is supported by team members who each have defined roles.

- http://en.wikipedia.org/wiki/McMurdo_Station

Antarctica – McMurdo – Description of Analog by Characteristic	
Characteristic	**Description**
Internal Light Conditions	Dim, artificial light
External Light Conditions	Dependent on season: summer – always sun; winter – never sunny
Danger	Moderate danger; issues with expeditions, building and structure development of the station, etc.
Physical Isolation	Isolated and remote; although many people at station, completely cut off from the rest of the world
Crowdedness/Habitable Volume Characteristics	Very large site, few issues with crowdedness
Team Size	Can be up to 250 people at a station; likely to have smaller teams
Leadership	Station manager who is the leader

Team Structure	Station manager and team members with defined roles that support manager
Personal Space	Individual sleep quarters, but share common areas
Rest and Recreation Options	Many options: "clubs," bowling alley, weight rooms, etc.
Quality of Life Support Conditions	Water and food available, gardens planted for fresh fruit and vegetables also
Workload	Working hours: 7:30 am - 5:00 pm, 6 days a week
Communication with Outside	Only have communications with outside for 12 hours a day
Availability of Medication/Medical Care	The remote nature of the facilities poses a barrier to immediate advanced medical care if a serious accident or illness should occur. A medical clinic and physician are available at McMurdo Station, but serious emergencies and illness may require evacuation.
Autonomy	Moderate to high station does report to a mission control base but does not monitor and assign daily tasks; station lead does guide team activity
Sensory Conditions	The extremely hostile nature of the environment also poses health risks from exposure to the outside environment. Potential health risks in Antarctica include dehydration, sunburn, frostbite, altitude sickness, and snow-blindness
Sensory Deprivation	Although greenhouse is provided, sensory stimulation may be significantly affected
Team Interdependence	Research project dependent but smaller work teams at this station are highly interdependent to complete daily activities.

Concordia

Concordia Station is the third permanent, all-year research station on the Antarctic Plateau (along with Vostok Station and the Amundsen-Scott Station) at the South Pole. It is jointly operated by scientists from France and Italy. It has space for 45 persons in summer, but usually drops to 10 or slightly less in winter. Geostationary communication satellites provide broadband communication 24 hours a day. Concordia station has been touted as the most optimum location on Earth for astronomy research capabilities.

- http://en.wikipedia.org/wiki/Concordia_Station
- http://www.gdargaud.net/Antarctica/Concordia.html

Antarctica – Concordia – Description of Analog by Characteristic	
Characteristic	**Description**
Internal Light Conditions	Dim, artificial light
External Light Conditions	Dependent on season: summer – always sun; winter – never sunny
Danger	Moderate danger; issues with expeditions, building and structure development of the station, etc.
Physical Isolation	Isolated and remote; although many people at station, completely cut off from the rest of the world
Crowdedness/Habitable Volume Characteristics	Moderate; summer months are significantly more crowded than winter months; size of habitats are relatively small
Team Size	Can be up to 45 people at a station (winter – 10 people)
Leadership	Station manager who is the leader
Team Structure	Station manager and team members with defined roles that support manager
Personal Space	Limited; share sleeping quarters
Rest and Recreation Options	Few options for rest and recreation
Quality of Life Support Conditions	Water and food available, but limited
Workload	Working hours: 7:30 am - 5:00 pm, 6 days a week
Communication with Outside	Continuous broadband capabilities provided by satellite
Availability of Medication/Medical Care	The remote nature of the facilities poses a barrier to immediate advanced medical care if a serious accident or illness should occur. Basic medications and a medical kit are available.
Autonomy	Moderate to high station does report to a mission control base but does not monitor and assign daily tasks; station lead does guide team activity
Sensory Conditions	The extremely hostile nature of the environment also poses health risks from exposure to the outside environment. Potential health risks in Antarctica include dehydration, sunburn, frostbite, altitude sickness, and snow-blindness.
Sensory Deprivation	Sensory stimulation may be significantly affected
Team Interdependence	Research project dependent but smaller work teams at this station are highly interdependent to complete daily activities

South Pole *(Amundsen-Scott South Pole Station)*

The station stands at an elevation of 2,835 m (9,301 ft) on the interior of Antarctica's nearly featureless ice sheet, about 2,850 m (9,350 ft) thick at that location. Recorded temperature has varied between −13.6°C (7.52°F) and −82.8°C (−117°F). Annual mean is −49°C (−56°F); monthly means vary from −28°C (−18°F) in December to −60°C (−76°F) in July. These temperatures, combined with low humidity and low air pressure, are only survivable with proper protection. During the summer, the station population is typically over 200. Most personnel leave by the middle of February, leaving several dozen (43 in 2009) "winter overs" – mostly support staff plus a few scientists – who keep the station functional through the months of Antarctic night. The station's winter personnel are isolated between mid February and late October.

South Pole is more of a small town and has a station manager who is responsible for day-to-day operations. There are always things to do at the South Pole for recreation: a gym with a weight room, volleyball, basketball, music, and classes, in addition to work.

- http://en.wikipedia.org/wiki/Amundsen-Scott_South_Pole_Station
- http://www.nsf.gov/od/opp/support/southp.jsp

Antarctica – South Pole – Description of Analog by Characteristic	
Characteristic	**Description**
Internal Light Conditions	Dim, artificial light
External Light Conditions	Dependent on season: summer – always sun; winter – never sunny
Danger	Moderate danger; issues with expeditions, building and structure development of the station, etc.
Physical Isolation	Isolated and remote; although many people at station, completely cut off from the rest of the world
Crowdedness/Habitable Volume Characteristics	Moderate; summer months are significantly more crowded than winter months
Team Size	Can be over 200 people at a station (winter ~40 people)
Leadership	Station manager who is the leader
Team Structure	Station manager and team members with defined roles that support manager
Personal Space	Limited; share sleeping quarters
Rest and Recreation Options	Many options: "clubs," bowling alley, weight rooms, etc.
Quality of Life Support Conditions	Water and food available, but limited
Workload	Working hours: 7:30 am - 5:00 pm, 6 days a week

Communication with Outside	Continuous broadband capabilities provided by satellite
Availability of Medication/Medical Care	The remote nature of the facilities poses a barrier to immediate advanced medical care if a serious accident or illness should occur. A medical clinic and physician are available at McMurdo Station, but serious emergencies and illness may require evacuation.
Autonomy	Moderate to high; station does report to a mission control base but does not monitor and assign daily tasks; station lead does guide team activity
Sensory Conditions	The extremely hostile nature of the environment also poses health risks from exposure to the outside environment. Potential health risks in Antarctica include dehydration, sunburn, frostbite, altitude sickness, and snow-blindness.
Sensory Deprivation	Sensory stimulation may be significantly affected
Team Interdependence	Research project dependent but smaller work teams at this station are highly interdependent to complete daily activities

ANSMET *(Antarctic Search for Meteorites program)*

The goal of ANSMET for the 2009−2010 field season was full-scale systematic meteorite recovery from ice fields immediately west of the Miller Range in the central Transantarctic Mountains. Four previous visits to the region (reconnaissance in 1985 and 2000 and systematic searching in 2005−2006 and 2007) led to the recovery of over 1,000 meteorites so far; these finds have included several lunar and martian specimens.

Each person at ANSMET has a snowmobile for transportation to the surrounding ice fields to search in systematic parallel sweeps, which is also sometimes done by foot. A campsite is set up for living arrangements, the crew camps at Meteorite Hills and is outfitted for eight people at a time. ANSMET camps are self-sufficient with equipment, gear, fuel, and food. A typical stay lasts 48 days. There is e-mail and telephone access.

- http://geology.cwru.edu/~ansmet/
- http://www.psrd.hawaii.edu/Feb02/meteoriteSearch.html

Antarctica – South Pole – Description of Analog by Characteristic	
Characteristic	**Description**
Internal Light Conditions	Dim, artificial light
External Light Conditions	Dependent on season: summer – always sun; winter – never sunny
Danger	Moderate danger; issues with expeditions, building and structure development of the station, etc.
Physical Isolation	Isolated and remote; although many people at station, completely cut off from the rest of the world
Crowdedness/Habitable Volume Characteristics	High; must share tent/living quarters with other teammate
Team Size	Total team is 40 to 50 individuals (but smaller teams are comprised of two to three individuals)
Leadership	Team leader is assigned over larger team
Team Structure	Team members with defined roles that support leader
Personal Space	Extremely limited; share sleeping quarters in small tents
Rest and Recreation Options	Few if any; can bring a few own personal items
Quality of Life Support Conditions	Water and food available, but extremely limited
Workload	Working hours: 7:30 am - 5:00 pm, 6 days a week
Communication with Outside	Limited technology capabilities for communication purposes
Availability of Medication/Medical Care	Low; the remote nature of the facilities poses a barrier to immediate advanced medical care in the event a serious accident or illness should occur
Autonomy	High; teams do not report to a mission control base; complete assigned tasks and objectives independently
Sensory Conditions	The extremely hostile nature of the environment also poses health risks from exposure to the outside environment. Potential health risks in Antarctica include dehydration, sunburn, frostbite, altitude sickness, and snow-blindness.
Sensory Deprivation	Sensory stimulation may be significantly affected
Team Interdependence	Research project dependent but smaller work teams at this station are highly interdependent to complete daily activities.

Pavilion Lake

The Pavilion Lake Research Project (PLRP) is an international, multidisciplinary, science and exploration effort to explain the origin of freshwater microbialites in Pavilion Lake, British Columbia, Canada. PLRP was founded to characterize the morphogenesis (formation) and preservation potential of the microbialites in Pavilion Lake.

PLRP research is conducted from the lake's surface, as well as underwater. The underwater operations with humans and robots provide a learning opportunity for understanding how to operate in the hostile and challenging environments of the moon and Mars.

According to the PLRP website, the activities at the site are considered analog research and of great interest to the Canadian Space Agency and NASA for two main reasons:

- The microbialite structures provide a modern analog to ancient fossilized microbialites preserved on Earth. Studying how these modern structures form and are preserved in the rock record will provide us with tools to identify signatures of ancient life on our own and other planets.
- Our research and exploration using remotely operated vehicles, autonomous underwater vehicles (AUVs), scuba divers, and submersibles provide an analog to human exploration missions on the moon and Mars. The research and exploration methods developed at Pavilion Lake will contribute to future human mission planning and exploration science on the moon and Mars.

Our submersible pilots and divers are exposed to harsh conditions that require life support systems to study the microbialites. This is analogous to astronauts in space who require spacesuits and rovers to explore the surface of the moon and, in the future, Mars. Our exploration methods are closely monitored so we can learn how to efficiently explore new planets and conduct science in extreme environments.

The PLRP brings together a large and diverse group of students, expert scientists, engineers, and astronauts to explore and study Pavilion Lake's unique microbialite structures. Richard Arnold (astronaut) and Mike Gernhardt (astronaut) are currently involved with PLRP. The summer of 2009 featured an expanded DeepWorker science program, and involved seven astronauts who will become integrated into the Analog Missions Program. These astronauts, including several Canadians, will become integrated into the science operations at Pavilion Lake, and develop their skills as field scientists. (June 26-July 9, 2010.)

- http://www.pavilionlake.com/

Pavilion Lake – Description of Analog by Characteristic	
Characteristic	**Description**
Internal Light Conditions	When in AUVs, artificial light; otherwise, N/A
External Light Conditions	Natural light when above water's surface; as much light as available when underwater
Danger	Low to Moderate; plenty of support crew above water but danger does exist for diving
Physical Isolation	While in AUV, only room for one person; otherwise, not physically isolated
Crowdedness/Habitable Volume Characteristics	Inside AUVs: just enough room for one person to fit inside, the pilot's head sticks up into a Plexiglas bubble that is hinged open for access
Team Size	Approximately 60 people present at PLRP
Leadership	A lead principal investigator; leader of a crew is not necessarily clearly defined
Team Structure	Lead principal investigator with team members holding defined roles/positions
Personal Space	High; individuals usually have their own hotel room
Rest and Recreation Options	Moderate; participate in research activities at the lake but participants/researchers reside at a local hotel
Quality of Life Support Conditions	High quality, moderate availability at hotel location
Workload	Moderate to high; dependent on number of research projects; spend most of the day searching lake
Communication with Outside	Available and easily accessible
Availability of Medication/Medical Care	High; in proximity to facilities if emergency occurs
Autonomy	Low; no present mission control but carry out tasks at the direction of the principal investigator
Sensory Conditions	Normal environmental conditions above water
Sensory Deprivation	Low; deprivation to senses are nominal
Team Interdependence	High; dives require teamwork and interdependence to complete mission objectives

PISCES (Pacific International Space Center for Exploration Systems)

PISCES is an international research and education center dedicated to the development of new technologies needed to sustain life on the moon and beyond. When it is fully developed, PISCES will feature a simulated lunar outpost on the Big Island of Hawaii, where research will be conducted, new technologies will be developed, students will be educated, K-12 students will be taken for field trips and a Space Camp, and the public will be invited to experience first-hand what it will be like to live and work on the moon and, eventually, on Mars. The PISCES Analog Lunar Outpost will help to "keep the dream alive" of lunar colonization and serve as a reminder that one day humanity will go back to the moon to stay, hopefully in a peaceful international endeavor.

Goals

- To conduct research and develop educational programs to enable and promote the human settlement of space.
- To host international tests and technology demonstrations at the PISCES test site.
- To promote science, technology, engineering, and math education, inspiring students by connecting Hawaiian culture to space exploration and settlement.
- To involve the commercial sector, spinning off technologies to help the local Hawaiian economy.
- To develop a full-scale, technically valid, analog lunar/martian outpost on the Big Island.

From January 23, 2010, to February 13, 2010, PISCES hosted teams from NASA, the Canadian Space Agency, and the German Space Agency for tests and demonstrations of equipment and concepts for in-situ resource utilization (ISRU) to sustain human life on the moon and Mars. These international teams were composed of scientists, engineers, and technicians working together to test concepts such as remote operation of ISRU systems, road and landing pad construction, solar concentrator sintering of lunar regolith, excavation, oxygen generation for fuel cells and rocket fuel, carbothermal reduction of lunar oxides, augmented reality and space medicine. Preliminary results of the testing were reported at the PISCES meeting, which was held in Hilo on February 10-12, 2010. Permanent facilities are still in the process of being built and no concrete timeline for activities and research projects exists currently.

- http://pisces.hilo.hawaii.edu/

PISCES – Description of Analog by Characteristic	
Characteristic	**Description**
Internal Light Conditions	N/A
External Light Conditions	Natural Light
Danger	Minimal physical dangers; although in a remote location, daily activities and environment do not pose a significant threat
Physical Isolation	In a remote location although within driving distance to a nearby town
Crowdedness/Habitable Volume Characteristics	N/A (facilities being built)
Team Size	Variable and research dependent; there will be researchers, university student researchers, volunteers, staff and faculty (of Univ. of Hawaii)
Leadership	Research dependent; presumably a principal investigator or staff member can create a study that would have a designated leadership position
Team Structure	Research dependent; presumably a principal investigator or staff member can create a study that would have an organized team with defined roles
Personal Space	N/A (facilities being built)
Rest and Recreation Options	Rest and recreation activities are available and allowed
Quality of Life Support Conditions	Moderate; likely to include some hygiene and personal amenities with new facilities being built
Workload	Research dependent but can vary
Communication with Outside	Internet and telephone communications are available but may be intermittent
Availability of Medication/Medical Care	Accessible from nearby facilities (unknown of any on site availability)
Autonomy	Research dependent; ability to create a study in which autonomous conditions were manipulated within the analog
Sensory Conditions	Normal environmental conditions
Sensory Deprivation	None assumed
Team Interdependence	Research dependent; again ability to create a study in which autonomous conditions were manipulated within the analog

Everest

Mount Everest is situated at the edge of the Tibetan Plateau on the border between Nepal and Tibet. The two main climbing routes on Everest include the technically easier Southeast Ridge from Nepal, and the less-frequently used Northeast Ridge from Tibet. The Southeast Ridge (Nepal) Base Camp is located at 5,380 m (17,700 ft) and takes mountaineers roughly 6 to 8 days to reach on foot with yak and porter support. The Northeast Ridge (Tibet) Base Camp is at 5,180 m (16,990 ft) on a gravel plain below the Rongbuk Glacier. While other 8,000-m (26,247-ft) peaks may be technically more demanding, the weather, altitude, time required to summit, and difficulties crossing through the Khumbu Ice Fall and over the Hillary Step make even the easiest route on Everest an enormous challenge.

While most Everest climbers don't carry more than about a 35-pound pack at any time, due to the extreme altitude, frigid conditions, avalanche hazards, and many days of repeated effort to reach the summit, it is one of the most challenging – physically and psychologically – climbing experiences available. The most common time to try climbing Everest is during April and May when winds die down a bit before summer monsoon season begins.

A typical expedition will last about 2 months. After trekking several days to reach Everest Base Camp, the process of gradual acclimatization on Mt. Everest will begin. Teams go up and come down from gradually higher and higher camps until they are ready to try for the summit. This acclimatization process can take 4 to 6 weeks before a summit attempt is made.

- http://en.wikipedia.org/wiki/Mount_Everest
- http://www.explorersweb.com/everest_k2/
- http://onorbit.com/everest

Everest – Description of Analog by Characteristic	
Characteristic	**Description**
Internal Light Conditions	Often, teams stay at teahouses along the way with electricity; then camp in tents (no electricity)
External Light Conditions	Natural light
Danger	High; numerous dangers associated with attempting to climb Mt. Everest
Physical Isolation	Stay with group/team for entire climb, should never be alone; however, isolated from others outside of team and those climbing mountain
Crowdedness/Habitable Volume Characteristics	Most climbers will have their own tent and each expedition will have several larger tents dedicated to communal activities (mess tent, dining, communications, etc).
Team Size	Varies by climbing team; most are large climbing groups
Leadership	One to two "official" climb leaders of group
Team Structure	Highly interdependent on one another; work together and help one another
Personal Space	Minimal; although open space, often share tents with other teammates
Rest and Recreation Options	Time for rest, most groups take multiple rest days due to rough conditions, minimal to no recreational activities other than climbing
Quality of Life Support Conditions	Should pack enough food and water for duration of climb, no conventional bathing/showers and infrequent, pack own appropriate clothing, requires oxygen supply
Workload	Constant physical demands, daily, 24/7
Communication with Outside	Intermittent internet access, satellite phones available
Availability of Medication/Medical Care	Medical monitoring via satellite phone and webcam in base camp with mountain doctors; fully equipped medical suitcase with electrocardiogram, Ultrasound & Tough Book Laptop; medical kits
Autonomy	Team as a whole will be able to make autonomous decisions (no mission control), but not individually
Sensory Conditions	Temperature is the only affecting sensory perception, harsh, cold temperatures and winds (may impact noise and visual)
Sensory Deprivation	Environment provides needed sensory stimulation
Team Interdependence	Highly interdependent on one another to complete mission objectives

ISS (International Space Station)

The ISS is a research facility that was assembled and recently completed in outer space; the on-orbit construction began with the Zarya module in November 1998. The space station is in a low-Earth orbit and can be seen from Earth with the naked eye. It orbits at an altitude of approximately 350 km (190 miles) above the surface of the Earth, and travels at an average speed of 27,700 kph (17,500 mph), completing 15.7 orbits per day.

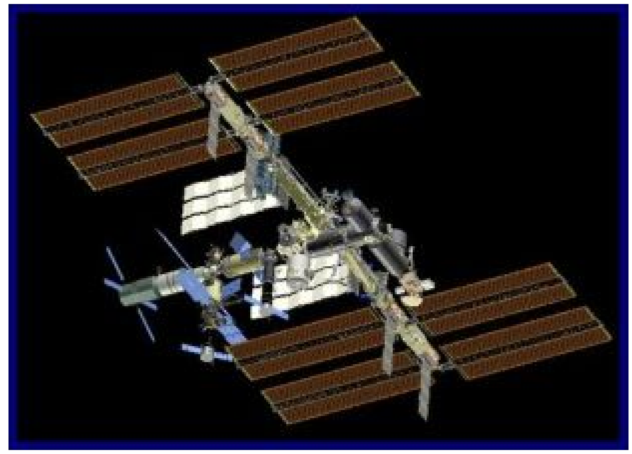
The space station is a joint project among the space agencies of the United States (NASA), Russia, Japan (Japan Aerospace Exploration Agency [JAXA]), Canada (Canadian Space Agency [CSA]), and eleven European countries (European Space Agency [ESA]). The Brazilian Space Agency (Agencia Espacial Brasileira [AEB]) participates through a separate contract with NASA. The Italian Space Agency similarly has separate contracts for various activities not done in the framework of ESA's ISS works (where Italy also fully participates).

The ISS is a continuation of several other previously planned space stations; Russia's Mir 2, the U.S. Space Station Freedom, the European Columbus laboratory, and the Japanese Kibō laboratory. The project was completed in 2010, with the station remaining in operation at least until 2020. As of 2008, the ISS is larger than any previous space station.

The ISS has been continuously staffed since the first resident crew, Expedition 1, entered the station on November 2, 2000, thereby providing a permanent human presence in space. The crew of Expedition 23 is currently aboard the ISS. Starting with Expedition 19, the station began maintaining a capacity of six crew members. Early crew members all came from the Russian and American space programs, until German ESA astronaut Thomas Reiter joined the Expedition-13 crew in July 2006, becoming the first crew member from another space agency. The station has been visited by astronauts from 16 different nations, and was the destination of the first five space tourists.

The station is serviced primarily by the U.S. Space Shuttle and the Russian manned Soyuz spacecraft and unmanned Progress spacecraft. On March 9, 2008, the ESA launched an Ariane 5 with the first automated transfer vehicle, Jules Verne, an unmanned spacecraft that carried over 8,000 kg (17,636 lb) of cargo to the ISS. Several other servicing vehicles are in various stages of planning.

- http://www.nasa.gov/mission_pages/station/main/index.html
- http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V1N-4FSCV4D-1&_user=2148702&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000056362&_version=1&_urlVersion=0&_userid=2148702&md5=53d5da7a3f73921a5e7d7a2341eda7de



Post 1J Configuration [1]

Date	May 31, 2008
Length	74 m (243 ft) [2, 5]
Width	94 m (308 ft)
Mass	276,807 kg (610,256 lb) [2, 3]
Habitable Volume	10,616 [6]
Pressurized Volume	738 m^3 (26,052 ft^3) [2, 3]
USOS Power Generation	6 solar arrays = 63 kW [4]

Assembly Complete [1]

Date	July 1, 2010
Length	74 m (243 ft) [2, 5]
Width	108 m (356 ft)
Mass	366591 kg (808,195 lb) [2, 3]
Habitable Volume	12,627 [6]
Pressurized Volume	676 m^3 (32,857 ft^3) [2, 3]
USOS Power Generation	8 solar arrays = 84 kW [4]

Notes:
(1) Based on (SSP 50110) Multi-Increment Manifest Rev H
(2) Properties do not include visiting vehicles: Progress, ATV, and HTV
(3) Properties include one docked Soyuz up to 17A [2009]; includes two docked Soyuz post 17A to account for six crew
(4) U.S. Operating Segment (USOS) Power Margin available for payloads at 10A = 21.42 kW; USOS Power Margin available for payloads at 20A = 34.6 kW
(5) Length from tip of the solar array to Service Module Aft.
(6) Progress and Soyuz are not considered in habitable volume calculations

ISS Configuration Independent Characteristics

Orbital Inclination /Path	51.6 degrees, covering 90% of the world's population
Altitude	370 km (200 nautical miles) (on average) above the Earth
Speed	27,700 kph (17,500 mph); orbiting the Earth 16 times per day

ISS – Description of Analog by Characteristic	
Characteristic	**Description**
Internal Light Conditions	Artificial Light
External Light Conditions	Only experienced on EVAs and through windows; sun rises and sets 16 times every 24 hours
Danger	High; numerous dangers associated traveling to and living aboard the ISS
Physical Isolation	Moderate; isolated from the rest of the world. Interaction with crew members but can spend whole day in a separate module than team members completing tasks aboard ISS
Crowdedness/Habitable Volume Characteristics	Moderate; ISS is currently a little larger than the size of a soccer field (108.5 m x 72.8 m [~356 ft x 239 ft])
Team Size	Six crew members
Leadership	Designated leader for each Expedition mission
Team Structure	Moderate interdependence within the team; many tasks are performed by either astronauts or cosmonauts or independently
Personal Space	Minimal; although somewhat large area, ISS is highly cluttered and little room for personal space
Rest and Recreation Options	Moderate; crews can enjoy special care packages, movies, books, calls to home, internet, etc.
Quality of Life Support Conditions	Low to moderate; can only shower intermittently, and limited hygiene and other related products available
Workload	Moderate to high; schedule to work 6 days a week for 8 hours a day (many times, it exceeds this time)
Communication with Outside	Moderate; constant communication with mission control; can also contact family and friends via phone and/or internet
Availability of Medication/Medical Care	Medical kit available; other medical necessities as well as some medications; crew is trained on basic medical procedures but would not be able to handle a serious emergency situation
Autonomy	Low; mission control creates schedule for crew; most decisions are made by mission control
Sensory Conditions	Issues with quality of environmental conditions including noise, smells, temperature, etc.
Sensory Deprivation	Environment does not provide some sensory stimulation that is needed for olfactory, visual, auditory, and tactile sensations
Team Interdependence	Low to moderate; team does often spend time together during rest and recreation activities and when eating together; however, many tasks are completed independently

Descriptions of Utility Characteristics by Analog

ISS – Description of Analog by Characteristic	
Characteristic	**Description**
Exposure Time	High; opportunity to collect multiple data points as more science is being encouraged on ISS
Mission Duration	Currently 6-month increments
Mission Timeline	Very structured; timeline created by ground control
Similarity to Astronauts	NASA astronauts
Subjects/Year	Three to six people
Task Relevance	Space flight environment in which astronauts provide a variety of technical, maintenance, and scientific tasks
Cost/Study	$400K+
Data Collection Feasibility	Moderate to high difficulty; have to consider up-mass, software and technology logistics, etc.
Research Process/Protocol Feasibility	Moderate to high difficulty; estimates are at 1½ years to implement a study on ISS

Antarctica – McMurdo – Description of Analog by Characteristic	
Characteristic	**Description**
Exposure Time	Medium to high; data collection opportunities are available (longitudinal but perhaps not daily assessments)
Mission Duration	Inhabited all year; however, “winter overs” usually last 7 months
Mission Timeline	Work 6 days a week and get 1 day off and have defined roles. However, there is not a daily timeline.
Similarity to Astronauts	Scientists , technicians, and support workers
Subjects/Year	There are about 1,000 personnel on base during the summer months, falling to around 250 in the winter.
Task Relevance	Does not simulate astronaut tasks (except in regards to conducting research experiments); however, does provide a test bed for telemedicine
Cost/Study	~$75K to $100K
Data Collection Feasibility	Low to moderate difficulty; have to consider software and technology logistics, surveys would not be a problem
Research Process/Protocol Feasibility	Moderate difficulty; estimates are 6 months to implement a study at McMurdo

Antarctica – Concordia – Description of Analog by Characteristic	
Characteristic	**Description**
Exposure Time	Medium to high; data collection opportunities are available (longitudinal but perhaps not daily assessments)
Mission Duration	Inhabited all year. However, “winter overs” usually last 7 months

Mission Timeline	Usually work 6 days a week and get one day off and have defined roles. However, there is not a daily timeline.
Similarity to Astronauts	Scientists and support staff
Subjects/Year	45 people in the summer which usually drops to 10 or slightly less in winter
Task Relevance	Does not simulate astronaut tasks (except in regard to conducting research experiments); however, does provide a test bed for telemedicine
Cost/Study	~$100K to $150K
Data Collection Feasibility	Low to moderate difficulty; have to consider software and technology logistics, surveys would not be a problem
Research Process/Protocol Feasibility	Moderate to high difficulty; do not have many solidified contacts – estimates are 6 months to 1 year to implement a study at Concordia

Antarctica – South Pole – Description of Analog by Characteristic	
Characteristic	**Description**
Exposure Time	Medium to high; data collection opportunities are available (longitudinal but perhaps not daily assessments)
Mission Duration	Inhabited all year. However, “winter overs” usually last 7 months
Mission Timeline	Usually work 6 days a week and get one day off and have defined roles. However, there is not a daily timeline.
Similarity to Astronauts	Scientists and support staff
Subjects/Year	There over 200 personnel on base during the summer months, falling to around several dozen in the winter (mid February to late October)
Task Relevance	Prime location for astronomical observations; not highly relevant to astronaut daily routine (except for conducting research experiments)
Cost/Study	~$75K to $100K
Data Collection Feasibility	Low to moderate difficulty; have to consider software and technology logistics, surveys would not be a problem
Research Process/Protocol Feasibility	Low to moderate difficulty; have to consider software and technology logistics, surveys would not be a problem

Antarctica – ANSMET – Description of Analog by Characteristic	
Characteristic	**Description**
Exposure Time	Low to medium; data collection opportunities are available (longitudinal but maybe only weekly or monthly assessments)
Mission Duration	48 days on average (usually 5 to 7 weeks)
Mission Timeline	Usually work 6 days a week and get 1 day off and have defined roles. However, there is not a daily timeline.
Similarity to Astronauts	Invites graduate students and senior researchers with a history of research involving Antarctic meteorites to participate on a volunteer basis
Subjects/Year	Crew camps at Meteorite outfitted for about 20 to 25 people (note that the 2004-2005 expedition had 12 people)
Task Relevance	Using snowmobiles spaced 30 m apart, they scan the blue ice for meteorites

	(example of how research tasks may be relevant) but daily tasks are not highly relevant
Cost/Study	~$150K
Data Collection Feasibility	Moderate to high difficulty; very isolated, so surveys may even be an issue; have to consider software and technology logistics
Research Process/Protocol Feasibility	Moderate to high difficulty; do not have many solidified contacts – estimates are 6 months to 1 year to implement a study at Concordia

NEEMO – Description of Analog by Characteristic	
Characteristic	**Description**
Exposure Time	Moderate to high; have opportunity to collect data from participants more than once each day
Mission Duration	Usually 14 to 21 days
Mission Timeline	Very structured; very similar to what is experienced on ISS
Similarity to Astronauts	Usually consists of some astronauts as well as NASA employees and contractors (moderate to high comparability in terms of intelligence and personality)
Subjects/Year	Six (three to four crew members, two habtechs)
Task Relevance	EVAs underwater, scientific-based studies within habitat
Cost/Study	$25K to $75K
Data Collection Feasibility	Low to medium; can work with NEEMO contacts to get logistics and requirements built into the mission design; high technological capability that can be used
Research Process/Protocol Feasibility	Low to medium; usual submission process; not too many extra requirements to get approval of study through

HMP – Description of Analog by Characteristic	
Characteristic	**Description**
Exposure Time	Low to medium; longitudinal data collection is possible as they are able to participate in data collection efforts daily. However, data collected so far have high rate of non-response.
Mission Duration	4- to 6-week field session
Mission Timeline	Little structure. Although there is not a timeline/schedule used at this time, there is discussion for use of one in future missions.
Similarity to Astronauts	Researchers, students, support staff, media persons (somewhat comparable in terms of intelligence and personality)
Subjects/Year	Seven to 10 core team members; up to 45 participants
Task Relevance	Simulated EVAs by underlying assumptions of what it would be like on Mars or in space in general
Cost/Study	$50K to $75K
Data Collection Feasibility	Low; BHP involvement over the past missions allows for relatively easy and accessible data collection

Research Process/Protocol Feasibility	Low to medium; usual submission process; not too many extra requirements to get approval of study through

DRATS – Description of Analog by Characteristic	
Characteristic	**Description**
Exposure Time	Low to medium; longitudinal data collection is possible as they are able to participate in data collection efforts daily. However, data collected so far have high rate of non-response.
Mission Duration	Varies; usually around 14 to 21 days
Mission Timeline	There is a detailed daily/weekly schedule, but not typically time-lined like a mission
Similarity to Astronauts	NASA scientists and engineers and non-NASA industry and academia representatives
Subjects/Year	Approximately 100 possible participants per year (unlikely all would participate, will have smaller teams)
Task Relevance	Develop and validate necessary levels of technical skills and experience, hardware/software, and mission operational techniques for future exploration missions. Explore EVA system requirements and participants may wear EVA suits for 6 to 8 hours
Cost/Study	~$50K to $75K
Data Collection Feasibility	Low; BHP involvement over the past missions allows for relatively easy and accessible data collection
Research Process/Protocol Feasibility	Low to medium; usual submission process; not too many extra requirements to get approval of study through

Everest – Description of Analog by Characteristic	
Characteristic	**Description**
Exposure Time	Medium to high; longitudinal data collection is possible as they are able to participate in data collection efforts daily. However, data collected so far had incidences of non-response.
Mission Duration	2 weeks in total, but variable
Mission Timeline	Can vary depending on group/team, but there are scheduled plans for each day
Similarity to Astronauts	Those who climb Everest are a very diverse, varying group – thrill seekers, students, researchers, climbing enthusiasts, astronauts
Subjects/Year	~150 climb Everest each year
Task Relevance	Tasks focus on the climb, but a large amount of risk is involved, which is similar to space flight; tasks are not highly relevant to what astronauts would be completing each day
Cost/Study	High cost for subjects who are climbing Everest; $150K to $200K
Data Collection Feasibility	Moderate to high difficulty; very isolated, so surveys may even be an issue; have to consider software and technology logistics
Research Process/Protocol	Moderate to high difficulty; do not have many solidified contacts – estimates

Feasibility	are about 1 year or more to implement a study

Pavilion Lake – Description of Analog by Characteristic	
Characteristic	**Description**
Exposure Time	Low to medium; longitudinal data collection is possible as they are able to participate in data collection efforts daily. However, data have never been collected here on behalf of BHP-R.
Mission Duration	Field season – summer months; dependent on research study; usually between 14 and 21 days
Mission Timeline	Daily activities to be accomplished
Similarity to Astronauts	Graduate students, NASA scientists/researchers, engineers, other researchers, astronauts
Subjects/Year	Over 60 research and supporting participants
Task Relevance	Underwater operations with humans and robots provide a learning opportunity for understanding how to operate in environments of moon and Mars. Use remotely operated vehicle, AUV, and scuba divers
Cost/Study	$100K to $150K
Data Collection Feasibility	Moderate to high difficulty; unsure as to the ability to implement surveys or other technological-type instruments – seems likely but logistics would need to be worked out
Research Process/Protocol Feasibility	Moderate difficulty; new analog, never before utilized by BHP as an analog, which may cause more difficulty, but has been used by other NASA agencies and groups

PISCES – Description of Analog by Characteristic	
Characteristic	**Description**
Exposure Time	Unknown but likely to be to collect daily assessments; data collection opportunities are available (longitudinal but perhaps not daily assessments)
Mission Duration	Ability to define mission duration (at least 21 days or more)
Mission Timeline	Daily activities to be accomplished; flexibility to create a strict timeline
Similarity to Astronauts	Researchers, professors
Subjects/Year	New analog that is being developed – possibility to include many teams
Task Relevance	Will focus specifically on space flight-related activities including the development of new technologies (highly relevant regarding research-type tasks); ability exists to create tasks that are highly relevant to astronaut work
Cost/Study	$100K to $150K
Data Collection Feasibility	Moderate to high difficulty; unsure as to the ability to implement surveys or other technological-type instruments; seems likely but logistics would need to be worked out
Research Process/Protocol Feasibility	Moderate difficulty; new analog, never before utilized by BHP as an analog, which may cause more difficulty, but has been used by other NASA agencies and groups

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13. ABSTRACT *(Maximum 200 words)*

Behavioral Health and Performance Element (BHP) Research has sought to develop a process that will determine, as objectively as possible, which analogs are a "best fit" for addressing BHP Research gaps, thus reducing risk. Developers of the Analog Assessment Tool needed to consider, among other things, the importance of proposed environmental and psychosocial characteristics to BHP Research gaps, as well as the fidelity of those characteristics within the analog environment to space scenarios (i.e., Near-Earth Objects and Mars). It also was essential to consider the utility of each analog in terms of its practicality and cost of conducting research in those environments. Analogs with high fidelity to space flight are often intuitively considered ideal platforms for conducting research to inform future space flight missions. Simply considering the fidelity of an analog, however, may not be enough to ensure that the analog serves as the appropriate platform through which to address a research gap. The Analog Assessment Tool provides a methodology to determine not only the fidelity of analog characteristics to characteristics of a space flight mission, but also how relevant those characteristics are for specific research gaps within a research element (e.g., BHP Research Element).

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