NASA SBIR 2007 Phase I Solicitation

X13 Space Human Factors and Food Systems

The new Vision for Space Exploration encompasses needs for innovative technologies in the areas of Space Human Factors and Food Systems. Operations in confined, isolated, and foreign environments can lead to impairments of human performance. This Topic seeks methods for monitoring, modeling, and predicting human performance in the spaceflight environment. These methods and tools are needed for accurate and valid human system integration into vehicle design and operations. Additionally, significant advancements in food technologies will be needed for long-duration Lunar and Mars missions. This Topic seeks innovative technologies for providing shelf-stable food with a shelf-life of 3 - 5 years, new food packaging technologies that eliminate or minimize waste, and new technologies for on-orbit meal preparation and dining.

Subtopics

X13.01 Space Human Factors Assessment Tools

Lead Center: JSC

Participating Center(s): ARC

The Human Research Program (HRP) and the Behavioral Health and Performance Research Program (BHP) are among NASA's major Space Human Factors research programs. In collaboration with these two programs, the SBIR program is looking for research proposals that address the following two research areas: (1) an Automated Human Factors Incident Reporting Tool (AHFIRT) and (2) a Cognitive Assessment Tool (CAT).

Automated Human Factors Incident Reporting Tool (AHFIRT)

The HRP provides human health and performance countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive long-duration human space exploration. Objectives of the HRP include developing capabilities and technologies to support and mitigate risks to crew health and performance, reducing human systems resource requirements (mass, volume, power, data, etc.), and ensuring effective human-system integration across exploration systems.
To support these objectives, the HRP determines that obtaining timely and context-specific Human Factors (HF) incidents data is a technology gap the program wants to address. Currently, space HF data come from crew debriefs. Such debriefs rely on retrospective recall, which could suffer delays of up to six months. Furthermore, opportunities to discuss HF issues in detail during these debriefs are limited. Consequently, the HRP sees the need to develop an Automated Human Factors Incident Reporting Tool (AHFIRT).

Objective: Development of an AHFIRT that assists the gathering and reporting HF incidents for long-duration space missions.

Requirements: In general, the AHFIRT will be used to help detect areas where HF can contribute to mission success, access the effects of operational and hardware changes, and complement existing HF data sources for operations including crew debriefs. Specifically, the AHFIRT shall meet the following requirements:

- The crew shall have easy access to the tool at any time to eliminate the need for the crew to recall information retrospectively.
- An easy-to-use data gathering protocol with the following functionalities:
  - Allow data to be entered either as text, audio, and/or video inputs
  - It is desirable for AHFIRT to detect system anomaly automatically and immediately record system status. At the minimum, however, the tools should provide an easily accessible event marker for the crew to mark the context and take a snapshot of the system and operator system status.
- Provide a user-friendly automated data search engine for extracting meaningful incident information from the raw data. Examples of desirable search schemes include natural language, spatial, temporal searches, etc.

Phase 1 Requirements: Technology Evaluation

The technical merit of the AHFIRT will be explored to evaluate feasibility. This process shall include:
- Evaluating/researching/developing automated data mining technologies
- Defining optimal data gathering protocol
- Determining optimal hardware/software design
- Developing hardware and software algorithms

Phase 2 Requirements: Prototype Development

The process shall include:

- Developing a working AHFIRT prototype
- Evaluate and test the functionality and usability of the prototype device

Cognitive Assessment Tool (CAT)

The NASA Behavioral Health and Performance Research Program (BHP) identifies and characterizes the behavioral health and performance risks associated with training, living and working in Space, and return to Earth. The BHP Research Element develops strategies, tools, and technologies to mitigate these risks. Currently, the BHP has the need for a Cognitive Assessment Tool (CAT).

Due to the high-intensity workload, disturbed sleep conditions, and other stressors of spaceflight, some astronauts have reported experiences of disturbed cognitive processes and fatigue.

Presently, a tool is utilized on the International Space Station (ISS) to detect neurocognitive deficits as a result of physical changes to the brain, which can occur from an injury to the head or exposure to a toxin. However, this assessment is designed as a programmed test that is not sensitive to crewmember fatigue. Consequently, there has been increased interest for a validated tool that that can:

- Detect cognitive decrements as a result of fatigue or other stressors of spaceflight
- Support the Astronauts with an entertaining assessment activity(s)
- Support crew autonomy by providing objective feedback directly to the crewmember regarding their behavioral health
Objective: Design, develop, and fabricate a handheld, CAT that is in the form of a video game.

Requirements: The CAT game may include a suite of games as opposed to one single game. Ideally, the game would determine whether the player's deficit is a result of fatigue, stress, or neurocognitive impairment. Specifically, the CAT shall be as follows:

- In a hand-held video game format
- Portable hand-held unit
- Enjoyable and entertaining
- Flexible enough for increasing levels of difficulty
- Able to detect and identify cognitive decrements catalysts such as fatigue, stress, and/or neurocognitive deficits
- Able to provide immediate feedback to crewmembers, especially flight surgeons, with recommended countermeasure(s) based on his/her cognitive performance to support crew autonomy

Potential means for the CAT to assess performance may include measures of:

- Reaction times
- Accuracies
- Memory recall
- Complex decision making
- Physiological measures, such as heat rate via thumbs
- Speech acoustic analysis
- Facial monitoring
- Eye analysis

Note that the aforementioned methods are provided as examples of current research developments and are not intended as an all-inclusive or restrictive mandate for the development of the CAT.

Phase 1 Requirements: CAT Start-Up
The technical merit of the CAT will be explored to evaluate feasibility. This process will include:

- Defining predictors of cognitive decrements
- Determining which aspects of cognition should be assessed
- Determining optimal hardware design
- Hardware and software algorithms development

Phase 2 Requirements: CAT Research and Development

Content development of the CAT games should be determined based upon results of a qualitative study conducted with sample population (similar to Astronauts) to ensure corroboration and interest prior to the following stages:

- Develop software for gaming, data analysis, feedback, and recommended countermeasures
- Develop prototype hardware
- Develop manual and trouble shooting guide
- Evaluate and test the functionality of the prototype device.

X13.02 Advanced Food Technologies

Lead Center: JSC

The purpose of the Advanced Food Technology Project is to develop, evaluate and deliver food technologies for human centered spacecraft that will support crews on missions to the Moon, Mars, and beyond. Safe, nutritious, acceptable, and varied shelf-stable foods with a shelf life of 3 - 5 years will be required to support the crew during future exploration missions to the Moon or Mars. Concurrently, the food system must efficiently balance appropriate vehicle resources such as mass, volume, water, air, waste, power, and crew time. One of the objectives during the lunar outpost missions is to test technologies that can be used during the Mars missions.

This subtopic will concentrate on two specific areas; food packaging and lunar outpost food preparation and food
Non-Foil High Barrier Materials

Development of shelf-stable food items that use high-quality ingredients is important to maintaining a healthy diet and the psychosocial well being of the crew. Shelf-life extension may be attained through new food preservation methods and/or packaging. New food packaging technologies are needed that have adequate oxygen and water barrier properties to maintain the foods' quality over a 3 - 5 year shelf life. The packaging must also minimize waste by using high barrier packaging with less mass and volume.

The current flexible pouch packaging used for the thermostabilized and irradiated food items contains a layer of foil. Although the foil provides excellent oxygen and water barrier properties, it also contributes to added waste. Food packaging will be a major contributor to the trash on the lunar or Mars surface. One of the proposed methods to dispose of trash on the lunar or Mars surface is incineration. However, the foil layer will not incinerate completely and there will be ash formed.

Two emerging food preservation technologies, high pressure processing and microwave processing, are being considered for future NASA missions. However the current high barrier packaging material cannot be used for these processes. The material delaminates during high pressure processing and cannot be used in microwave processing. Hence, any food packaging material developed in response to this subtopic should be compatible with one or more of the following food preservation technologies - retort processing, microwave processing, and/or high pressure processing. In addition, the material should have an oxygen transmission rate that shall not exceed 0.06 cc/m2/24 hrs/atm and a water vapor transmission rate that shall not exceed 0.01 gm/m2/24 hrs as stated in the MIL-PRF 33073F specification.

Effect of Partial Gravity and Reduced Atmospheric Pressure

It will require approximately 10,000 kg of packaged food for a 6-crew, 1000 day mission to Mars. For that reason, it has been proposed to use a food system which incorporates processing of raw ingredients into edible ingredients and uses these edible ingredients in recipes in the galley to produce meals. This type of food system will require food processing and food preparation equipment. The equipment should be miniaturized, multipurpose and efficiently use vehicle resources such as mass, volume, water, and power. Food preparation may include gourmet kitchen appliances such as food processors or bread makers in addition to the standard stove and oven. Proposed food processing equipment may include a mill to produce wheat and soy flour, a soy milk/tofu processor, and a concentrator.

The Moon's gravity is 1/6 of Earth's gravity. In addition, it is being proposed that the habitat will have a reduced atmospheric pressure of 8 psia which is equivalent to a 16,000 foot mountain top. These two factors will affect the heat and mass transfer during food processing and food preparation of the food. Heat transfer is required for
proper microbial kill and to produce the desired texture and appearance of the food prior to consumption. At this pressure, the boiling temperature of water will be 181°F which has significant implications for preventing microbial contamination and to acceptable food quality.

Prior to any design of food processing or preparation equipment, the effects of partial gravity and partial atmospheric pressure as it relates to fluid management, heat and mass transfer and chemical reactions must be determined. Once the effects are determined, countermeasures must be developed. All of this needs to happen prior to any fabrication of actual food processing or food preparation equipment that can be used in the Lunar Habitat.

The response to this subtopic should (1) develop food packaging technologies that respond the above requirements, (2) develop a technology which will aid in determining the effects of reduced cabin pressure and reduced gravity and/or (3) develop a technology that will enable safe and timely food processing and food preparation in reduced cabin pressure and reduced gravity.