Human exploration capabilities must keep the crew healthy so they can adequately perform their mission and return safely to Earth. These two subtopics seek innovative technologies in Human Health Countermeasures and Autonomous Medical Care to prevent degradations in performance and health from the adverse physiological responses to the space flight environment and to provide medical support in both normal activities and medical emergencies. They assure that there will be no long-term adverse health consequences while supporting a healthy and productive sustained human presence. The Lunar In Situ Autonomous Health Monitoring (X14.02) subtopic seeks an innovative multiparameter monitoring system suitable for monitoring astronaut health during Extravehicular Activity on the lunar surface which can also find use in intravehicular medical monitoring and care. The Health Preservation in the Space Environment (X14.01) subtopic seeks either an instrumented treadmill or resistance exercise system suitable for flight mission and ground research use, a method for monitoring the effectiveness of pharmaceuticals in space, instrumentation for non-invasive measurement of intracranial pressure during space flight, or a non-invasive method for assessing strength via micro- and macro-architecture.

Subtopics

X14.01 Health Preservation in the Space Environment

Lead Center: JSC
Participating Center(s): ARC, GRC

Living and functioning efficiently and safely in space and in the hypogravity of the Moon (1/6g) or Mars (3/8g), requires an understanding of the effects of micro- and hypogravity and other space-environment related factors on human physiology responses and adaptations to a unique set of imposed demands. As a result, a variety of countermeasures are needed to mitigate the deleterious changes that occur during space flight and upon subsequent exposure to reduced-gravitational environments. The ability to monitor the effectiveness of countermeasures and alterations in human physiology during space exploration missions, particularly when several countermeasures are used concurrently, is equally important.

This subtopic seeks innovative technologies in several very specific key areas. As launch costs relate directly to mass and volume, instruments and sensors must be small and lightweight with an emphasis on multi-functional capabilities. Low power consumption is a major factor, as are design enhancements to improve the operation, design reliability, and maintainability of these instruments in the environment of space and on planetary surfaces. As the efficient use of time is extremely important, innovative instrumentation setup, ease of usage, improved
astronaut (patient) comfort, noninvasive sensors, and easy-to-read information displays are also very important considerations. Extended shelf-life and ambient storage conditions of consumables are also key necessities. Ability to operate in 0g, 1/6g, and 3/8g become more important as we march towards human Moon and Mars missions.

**Exercise and Related Hardware**

Miniaturized exercise hardware (treadmill or resistance exercise); physiological monitoring devices; and metabolic gas (carbon dioxide, oxygen) analysis systems for use with exercise and miniaturized interactive feedback and entertainment systems. A tool or toolkit should simulate and visualize the exercise device design and performance. A comprehensive, scaled 3D/virtual human model interface would be valuable to show biomechanical and kinetic effects of the exercise device. Relative physiological data from anthropometry to stress/fatigue to trauma/insult onset should be targeted.

**Noninvasive Pharmacotherapy and Monitoring**

Development of innovative technologies resulting in noninvasive methods for diagnosis, treatment, and therapeutic drug monitoring is needed to facilitate effective pharmacotherapy of humans in space. Many questions remain about the effectiveness of pharmaceuticals in micro- and hypogravity environments, which may interfere with their activity by sensitizing or desensitizing the crew member or interfering in other ways with the desired physiological effect. Micro-encapsulation of drugs and development of novel drug delivery systems under micro- and hypogravity conditions. Devices for continual monitoring of physiology during pharmacotherapy would also be advantageous to ensure that on-orbit expression of therapies relates to on-earth histories.

**Instrumentation for Noninvasive Measurement of Intracranial Pressure During Space Flight**

Abrupt transitions between differing gravitational environments have profound physiologic impacts on human space travelers. For instance, immediately following insertion of the spacecraft into Earth orbit, cephalad fluid shifting occurs. Over the next several days, all crewmembers onboard suffer from what has been termed Space Adaptation Syndrome (SAS) that varies in severity from person to person. The prevailing theory for the appearance of the constellation of symptoms (headache, malaise, vomiting, vertigo, etc.) which comprise this syndrome implicates a "sensory conflict" in information provided by the adapting vestibular system and by visual inputs. Another theory implicates the increased intracranial pressure (ICP) that likely accompanies the cephalad fluid shifts in the genesis of SAS. Additionally, decreased ICP following return to Earth's gravity may explain symptoms experienced by many crewmembers. Thus, novel approaches to noninvasive measurement of ICP are needed to determine the etiology and pathogenesis of the untoward physiologic effects that plague human space travelers during abrupt transitions between different gravitational environments. A more complete understanding of these phenomena will lead to better prevention and treatment modalities that will in turn decrease risks to the health and performance of crewmembers during transitional periods of both high to low and low to high gravity environments.

**Noninvasive Technology to Assess Bone Micro- and Macroarchitecture**

A complete assessment of bone strength will better monitor life-time skeletal integrity and will generate data critical for developing probability fracture risk models in younger crew members. Novel technology for non-invasive assessments of "bone quality" indices such as microarchitecture, macroarchitecture and trabecular bone mineral density (BMD).
X14.02 Lunar In Situ Autonomous Health Monitoring

Lead Center: JSC
Participating Center(s): ARC, GRC

Exploration missions to the lunar surface will be characterized by science goals and objectives which will require crewmembers to actively investigate the accessible exterior environment via Extravehicular Activity (EVA). During the EVA sorties, it will be critical for the crewmembers to be able to monitor their personal health status and to make decisions based on feedback from intrinsic biomedical monitoring systems. Furthermore, it will be necessary to simplify these systems for rapid donning and doffing, automatic checkout capability, annunciation and guidance during suit anomalies, and ensuring the health and safety of each crewmember. Therefore, the sensors that will be used for biomedical monitoring need to be low profile (perhaps incorporated into an undergarment), accurate, reliable, and with as few wires as possible. In addition, the use of electrodes with electrode gel and overtapes has not been highly successful, resulting in skin irritation, adhesion problems, stowage concerns and limited life/inventory issues. Furthermore, our experience has demonstrated that commonality between and among systems is highly beneficial. For this reason, the biomedical sensors used for monitoring EVA should be applicable for intravehicular use as well. Some of the parameters that would be desirable for EVA monitoring include:

- Metabolic Rate
- Heart Rate
- Thermal Control
- ECG (possible)
- Oxygen Consumption Rate
- \( \text{CO}_2 \) Level (in the oronasal area)
- \( \text{CO}_2 \) Generation Rate
- Core and/or Skin Temperature
- Radiation Monitoring (possible)
- Oxygen Saturation Level

In addition, development of device(s) capable of being used in an IVA system which is common with the EVA system is highly desirable. All of these, whether used for IVA or EVA, must be comfortable for the crewmember, allow the crewmember to continue performing tasks, and must not preclude normal activities when used for IVA monitoring (e.g. hygiene, eating, working at the computer, and exercising).