Human exploration capabilities must keep the crew healthy so they can adequately perform their mission and return safely to Earth. These subtopics seek innovative technologies 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.

**X12.01 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.

**Non-invasive Pharmacotherapy and Monitoring**

Development of innovative technologies resulting in non-invasive 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.

Non-invasive 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-aged crew. Novel technology for non-invasive assessments of "bone quality" indices such as microarchitecture, macroarchitecture and trabecular Bone mineral density (BMD).

Technologies to Detect Biomarkers

Develop technologies to detect products of bone demineralization in urine during Flight and the biomarkers of bone degradation include N-telopeptide (NTX), C-telopeptide (CTX), pyridinoline and deoxypyridinoline collagen cross-links, and calcium ion. Develop technologies to monitor bone specific alkaline phosphatase and osteocalcin in serum samples.

Portable Motion Simulator

Develop a portable research platform to investigate the influence of spatial disorientation on manual control tasks during lunar-type landings. A 6-DOF motion simulator with full visual motion display will be developed to simulate landing tasks with and with visual motion (brownout) conditions. The simulator should be portable, and fit within standard (8 ft) room heights. The power requirements should be limited to 240VAC 30A. The subject restraint should accommodate both standing and seated positions. The control system should allow the user to import motion profiles, and provide the capability to evaluate various pilot-induced filter (PIO) options from a hand-held controller.

X12.02 Crew Exercise Systems

Lead Center: JSC
Participating Center(s): GRC

1) Identify compact, multi-function exercise devices to protect muscle and cardiovascular health during lunar sortie missions (missions with total duration less than 30 days). This device must be 10kg or less including all accessories, require no vehicle power to operate, include materials/components that can be flight certified and do not pose risk to the crew vehicle/habitat, and be stowed within 1 cubic foot of space aboard the Crew Exploration Vehicle/Orion and/or Lunar Surface Access Module. The device must be require no crew calibration or maintenance (for missions less than 30 days), require minimal deployment/setup time (easily portable between vehicles), and include instrumentation to document exercise session parameters using portable electronic media. The device must be capable of providing whole body and individual joint resistive loading that ideally simulates free weights. The load must be adjustable in increments no greater than 2.5 kgs and provide adequate loading to protect muscle strength to levels specified per the NASA Space Flight Human System Standards, Volume 1. The
same device must be capable of providing whole-body aerobic exercise levels necessary to maintain aerobic fitness per the NASA Space Flight Human System Standards, Volume 1.

2) Identify compact, reliable multi-function exercise devices/systems to protect bone, muscle, and cardiovascular health during lunar outpost missions (missions with total duration less than 6 months). This device should be easily configured and stowed, require minimal power to operate, include instrumentation to document exercise session parameters including portable electronic media, and require minimum periodic calibration (no more than 2X/year). The device must be capable of providing whole body axial loading and individual joint resistive loading that ideally simulates free weights. If unable to match the inertial properties of free weights, then the device must provide near constant loading at any given load setting and achieve an eccentric to concentric load ratio greater than 90%. The load must be adjustable in increments no greater than 2.5 kgs and provide adequate loading to protect muscle strength and bone health to levels specified per the NASA Space Flight Human System Standards, Volume 1. The same device must be capable of providing whole-body aerobic exercise levels necessary to maintain aerobic fitness per the NASA Space Flight Human System Standards, Volume 1. Finally, the ideal device should also stimulate the sensory-motor system which controls balance and coordination.

3) Identify small, lightweight, sensor-based exercise monitoring systems that can be used to assess periodic fitness during lunar outpost missions and transit to Mars. Devices should be small, employ re-usable elements (versus requiring consumables), and be minimally invasive to measure heart rate and rhythm, oxygen consumption and lactic acid threshold. The ideal system would also include other medical monitoring capabilities such that it could be utilized to assess other crew health variables (e.g., imaging capabilities, respiration rate, blood parameters, etc.).

X12.03 Exploration Medical Capability
Lead Center: GRC
Participating Center(s): ARC, JSC

On-board clinical diagnostics to monitor crew member physiology must be available for both mid-term lunar and long-term Mars exploration missions. As in terrestrial medicine, devices with which to measure multiple constituents of small volume samples of bodily fluids are crucial components in assessing astronaut health. Nevertheless, mass, space, and power requirements of such devices are an obvious concern in an environment with scarce resources. Miniaturized laboratory analysis sensors represent a potential solution, given that these devices and supporting hardware are designed to be small, lightweight, and require little power. However, current sensor cartridges are typically single-use with limited shelf life. In order to satisfy the needs of longer duration exploration missions, reusable laboratory analysis sensors with increased shelf life must be designed without compromising accuracy or sensitivity. NASA seeks proposals for developing such reusable laboratory analysis sensors for measuring complete blood count with differential. Both the actual chips and associated electronics should minimize the use of electrical power and be as small as possible. Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 breadboard demonstration.