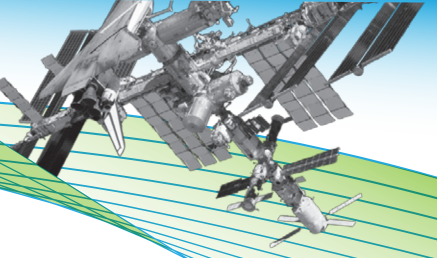
National Aeronautics and Space Administration

HUMAN RESEARCH PROGRAM

2012

Fiscal Year Annual Report

Human performance. Human potential.



Message from the Program Manager

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> "The Human Research Program will... stay FOCUSED on the most SIGNIFICANT problems to ENSURE a highly SUCCESSFUL human space EXPLORATION program."

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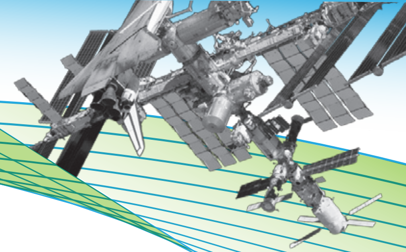
Michael R. Barratt, M.D.
Program Manager



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Overview

Background

Crew health and performance are critical to successful human exploration beyond low Earth orbit. Risks to health and performance include physiologic effects from radiation, hypogravity, and planetary environments, as well as unique challenges in medical treatment, human factors, and support of behavioral health. The scientists and engineers of the Human Research Program (HRP) investigate and reduce the greatest risks to human health and performance, and provide essential countermeasures and technologies for human space exploration.

In its seventh year of operation, the HRP continued to refine its management architecture of evidence, risks, gaps, tasks, and deliverables. Experiments continued on the International Space Station (ISS), on the ground in analog environments that have features similar to those of spaceflight, and in laboratory environments. Data from these experiments furthered the understanding of how the space environment affects the human system. These research results contributed to scientific knowledge and technology developments that address the human health and performance risks.

As shown in this report, HRP has made significant progress toward developing medical care and countermeasure systems for space exploration missions which will ultimately reduce risks to crew health and performance.

Goal and Objectives

The goal of the HRP is to provide human health and performance countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration. These are the specific objectives of the HRP:

1) Develop capabilities, necessary countermeasures, and technologies in support of human space exploration, focusing on mitigating the highest risks to crew health and performance. Enable the definition and improvement of human spaceflight medical, environmental and human factors standards.

2) Develop technologies that serve to reduce medical and environmental risks, to reduce human systems resource requirements (mass, volume, power, data, etc.) and to ensure effective human-system integration across exploration mission systems.

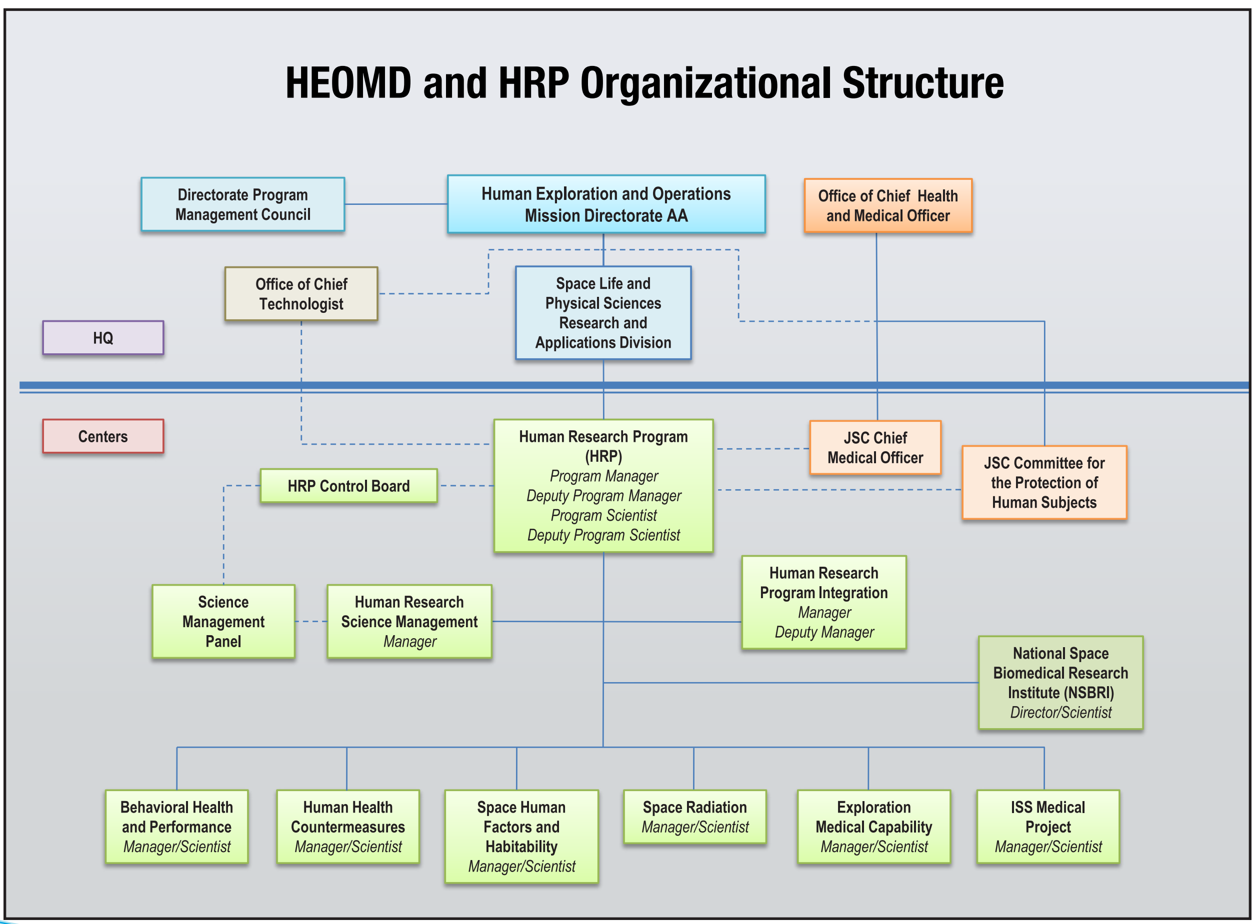
3) Ensure maintenance of Agency core competencies necessary to enable risk reduction in the following areas: space medicine, physiological and behavioral effects of long duration spaceflight on the human body, space environmental effects, including radiation, on human health and performance and space human factors.

Program Organization

The HRP's organization is designed to support and accomplish the goals of the Human Exploration and Operations Mission Directorate (HEOMD) and NASA's Office of the Chief Health and Medical Officer (OCHMO). To that end, HRP conducts research and develops technology that enables the OCHMO to establish and maintain NASA-wide human health and performance standards. Furthermore, HRP provides HEOMD with methods of meeting those standards in the design, development, and operation of technological systems for exploration missions.

Organizationally, HRP resides within the HEOMD; however, the management of HRP is located at the Johnson Space Center. The HRP Program Manager and Deputy Manager lead all aspects of the program and the HRP Program Scientist and Deputy Scientist lead the science management and coordination. Two offices support program and science management and provide integration across the Program. There are six Elements that comprise the Program and are focused to accomplish specific goals for investigating and mitigating the highest risks to astronaut health and performance.

The Science Management Office (SMO) and Program Integration Office (PIO) provide coordina-

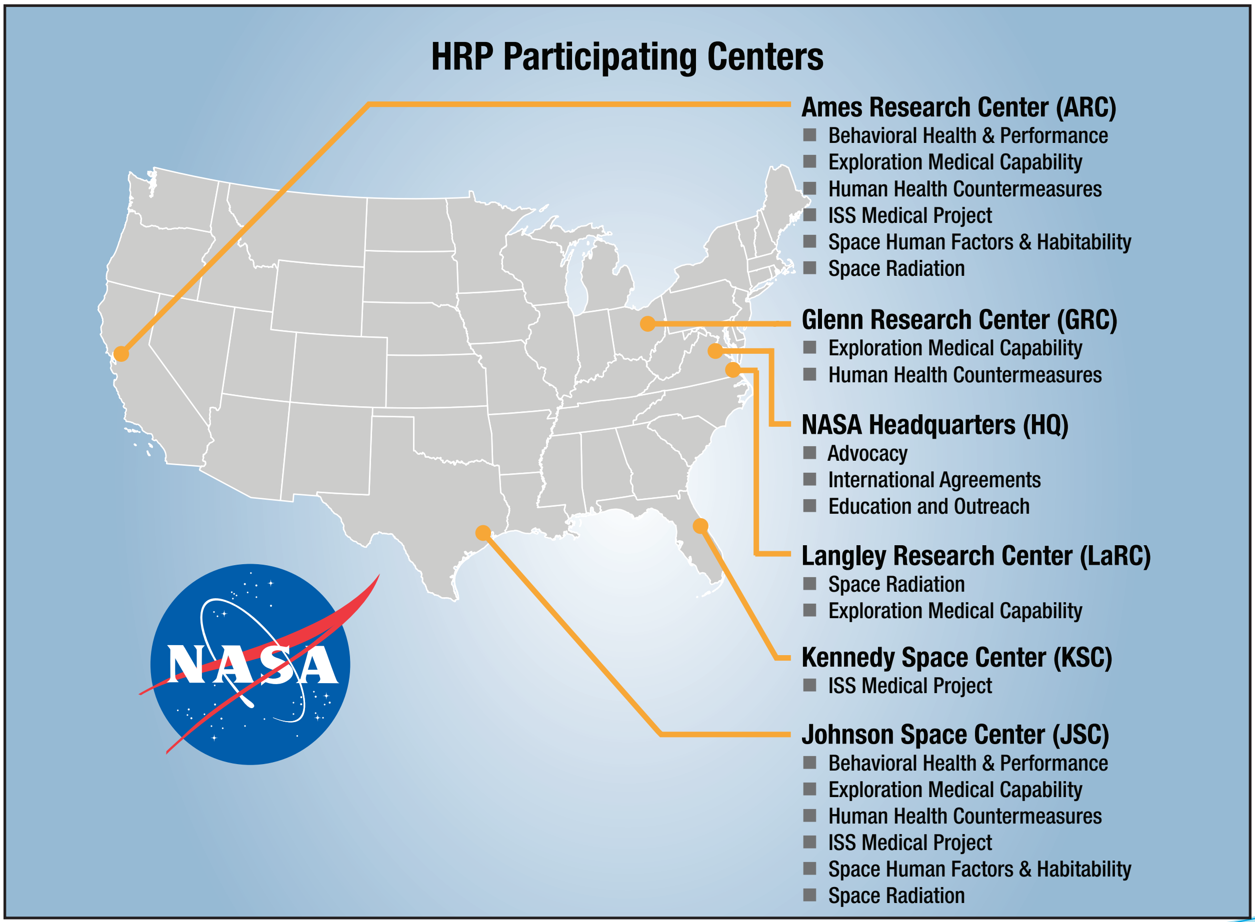


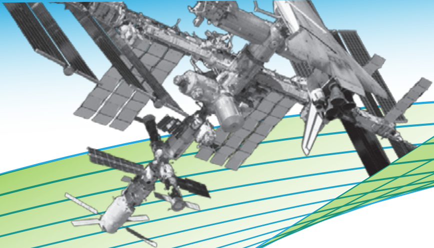
tion of HRP activities in support of the Program Manager, Program Scientist, and all other Program components. The SMO maintains scientific integrity of the HRP's research, reviews and integrates science tasks, reviews the prioritization and implementation of flight and ground analog tasks, communicates research needs to other NASA programs and cultivates strategic research partnerships with other domestic and international agencies. The PIO provides program planning, integration, and coordination across the HRP. This office ensures close coordination of customer needs and the HRP's deliverables developed to meet those needs.

Six subject areas or Elements comprise the HRP: International Space Station Medical Project, Space Radiation, Human Health Countermeasures, Exploration Medical Capability, Space Human Factors and Habitability, and Behavioral Health and Performance. These Elements provide the HRP's knowledge and capabilities to conduct research to address human health and performance risks of spaceflight, and they advance the readiness levels of technology and countermeasures to the point where they can be transferred to the customer programs and organizations. Each Element consists of related projects and research tasks focused toward developing products that reduce the highest risks in that area. To learn more about the HRP Elements, please visit: http://www.nasa.gov/exploration/humanresearch/elements.

Partnerships and Collaborations

The HRP works with universities, hospitals, and federal and international agencies for the purpose of sharing research facilities and multi-user hardware, and for collaboration on research tasks of mutual interest. The HRP uses bed rest facilities at the Uni-





versity of Texas Medical Branch in Galveston, Texas, to study changes in physiologic function associated with weightlessness. Many of these changes occur in people subjected to bed rest with the head tilted downward at a 6-degree angle.

The NASA Space Radiation Laboratory (NSRL) at the Department of Energy's Brookhaven National Laboratory in Upton, New York, conducts research using accelerator-based simulations of space radiation. The HRP also utilizes radiation research facilities at the Loma Linda University Medical Center in Loma Linda, California.

The National Space Biomedical Research Institute (NSBRI), an academic institute funded by the HRP, investigates the physical and psychological challenges of long-duration human spaceflight. Founded in 1997 through a NASA competition, the NSBRI is a nonprofit research consortium that connects the research, technical, and clinical expertise of the biomedical community with the scientific, engineering, and operational expertise of NASA. NSBRI is located in the BioScience Research Collaborative (BRC) at Rice University. Additional information about the NSBRI can be found at: www.nsbri.org.

The HRP also maintains collaborative relationships with the ISS International Partners through various working groups. These relationships enhance the research capabilities of all partners and provide synergism of research efforts.

Examples of Partnerships and Collaborative Relationships with Universities, Industries, and Government Agencies

Examples of HRP Partnerships and Collaborations	Benefits to Exploration
National Space Biomedical Research Institute	Investigates the challenges of long-duration human spaceflight and bridges the expertise of the biomedical community with the scientific, engineering, and operational expertise of NASA
International Space Life Sciences Working Group (Canada, Japan, Germany, Ukraine, France, and the European Space Agency)	Provides coordination of international development and use of spaceflight and ground research facilities by identifying mutual interests and compatibilities, enhancing communication, and encouraging a unified effort among participating space life sciences communities around the world
US-Russian Joint Working Group	Enhances research capabilities and provides synergy in operations and optimal use of the ISS
National Institutes of Health, Department of Energy, Centers for Disease Control and Prevention, Department of Agriculture, Department of Defense	State-of-the-art research facilities, research activities, and technology development of mutual interest
General Clinical Research Center and the Lerner Research Institute at the Cleveland Clinic/University of Washington	Provides facilities for bed rest and 6-degree head-down-tilt simulation along with a zero-gravity locomotion simulator in support of HRP research
NASA Extreme Environment Mission Operations (NEEMO) at the Aquarius Undersea Habitat and other analog environments such as Antarctica and Devon Island	Research performed in analog environments in the areas of physiologic adaptation, medical technology, and behavioral health and performance
University of Texas Medical Branch, Galveston, TX	Provides bed rest facilities to study changes in physiologic function associated with weightlessness
Department of Energy - Brookhaven National Laboratory	State-of-the-art facility conducts research using accelerator-based simulation of space radiation
Loma Linda University	Space radiation research and facilities
European Union in Radiobiology Research Program	Space radiation research
International Council of Radiation Protection	Recommendations for radiation protection in space
Massachusetts Institute of Technology Man-Vehicle Laboratory	Working to define the role of the human in complex space systems

Overview

Examples of HRP Partnerships and Collaborations	Benefits to Exploration
Texas Instruments	Assists with new content development for the Math and Science @ Work and Exploring Space Through Math projects
American Association of Retired Persons Convention; Hispanic Engineering, Science, and Technology Week; National Space Symposium; NASA Day on the USS Intrepid; NASA-on-the-Hill	Allowed for public dissemination of information on the Human Challenges of Space Exploration

Overview

The HRP organizes and participates in international collaborative meetings and coordinates research and technology workshops. The workshops are conducted to inform researchers outside of NASA about the HRP's research and to obtain information about research going on outside of NASA.

International Coordination Meetings and Research and Technology Workshops

Meeting	Meeting Description
International Space Life Sciences Working Group (ISLSWG) http://www.nasa.gov/exploration/about/islswg.html	Works to bring agencies together by identifying their mutual interests and programmatic compatibilities, enhancing communication, and encouraging a unified effort among the participating space life sciences communities around the world
Meeting of the US-Russian Joint Working Group	Discussed space biology and space medicine emphasizing ISS research and opportunities for collaboration, and education and outreach opportunities to inspire the next generation of scientists and physicians who will work in future human spaceflight endeavors
63rd International Astronautical Congress http://iafastro.org	Shared information about space for human benefit and exploration, and provided information on HRP Education and Outreach activities
23rd Annual NASA Space Radiation Investigators' Workshop http://www.dsls.usra.edu/meetings/radiation2012	Provided an opportunity for active researchers in the NASA Space Radiation Program to share the results of their work and to explore new directions of research that may benefit the NASA program
Net Habitable Volume Workshop	Participants address the "habitable" and "net habitable" volume necessary for long-duration human spaceflight missions by identifying both the design issues, as well as the psychological issues that will impact the human.
33rd Annual International Gravitational Physiology Meeting http://www.isgp.org	Present investigative results in space and gravitational biology, physiology and experimental medicine
83rd Annual Scientific Meeting of the Aerospace Medical Association http://www.asma.org	Multi-faceted forum for all aerospace medical disciplines. Data is presented on the latest results of clinical and research studies.

Major Program-Wide Accomplishments

Program Status Review Conducted by 2012 HRP Standing Review Board

A Program Status Review (PSR) and Independent Assessment was conducted in FY2012, and culminated with a site visit by the HRP Standing Review Board (SRB) in September 2012, at JSC. During this visit, HRP presented information as requested by the SRB in the areas of the program's management approach and performance, science and data management, education and outreach, and Element-specific risks and concerns. All actions from previous Program Implementation Reviews and PSRs were closed. As a result of their review, the SRB identified twelve strengths and no issues for HRP. They relayed five actionable concerns along with several helpful observations.

The SRB reported that "the HRP program schedule and resources are managed in an effective manner, consistent with the research program guidance [...] HRP has been reviewed frequently to assess its execution readiness since its inception in 2006. In addition, each program element has a panel of experts who conduct an annual peer review of the project contents and recommend changes, as appropriate. The program/element content formulation process [...] is well conceived, as it provides a strong focus to the human health and performance requirements of human spaceflight. The program has enjoyed stable funding and has benefitted greatly from the leadership of a mature, experienced management team. The HRP has contributed significant results to human spaceflight standards and has delivered knowledge, strategies, and technologies to retire or mitigate numerous risks to human health."

The SRB determined that HRP continues to meet Agency needs and commitments and successfully met the PSR success criteria to continue implementation of the program.

Mission X: Train Like an Astronaut Fitness Challenge Expands Global Reach

The Mission X: Train Like an Astronaut 2012 (MX12) worldwide competition hosted 9,846 children on 286 teams. They came from 15 countries and 11 space agencies that use 13 languages. Organizers of the competition had one mission—to assist youth on a global scale to live healthier lifestyles and learn about human space exploration. MX12 was the first of three international fitness challenges that will make up the MX Multi-year Campaign. Compared to the MX11 Pilot Challenge, MX12 added three countries, five languages, and more than doubled

Mission X: Train Like an Astronaut activities such as the Agility Astro-Course are adapted to their local environments to allow students from around the globe to participate. During FY2012, students from fifteen countries—ranging from the slopes of Austria to the lush rain forests of French Guiana—took part in the challenges and blogged about their experiences

the number of students and teams that participated in the challenge.

With the goal of improving upon last year's numbers, MX12 organizers sought greater participation by the space agencies in coordinating and implementing programs and events. Organizers also addressed point system concerns, and added training videos, a training webinar, and a pilot survey. Four countries participated in the pilot survey, and a total of 1164 surveys were collected and analyzed. After modification of the survey questions, the MX survey will be offered to all future participants.

New to MX12 was the International Closing event, hosted by the UK Space Agency in London, England. Twelve of the 15 countries participating in the competition were present for the closing event. The NASA EDGE podcast on the event had over 500,000 downloads during the first four-month posting http://www.nasa.gov/multimedia/podcasting/nasaedge/NE00051912_33_MissionX_2012.html.

2012 Investigators' Workshop Provides a Forum for Researchers to Present Findings

The Human Research Program (HRP) Investigators' Workshop is the primary conference where researchers funded by NASA and the National Space Biomedical Research Institute (NSBRI) present the results of their studies. The workshop's goal is to provide an informal, collegial atmosphere for cross-disciplinary interaction and is jointly sponsored by NASA Johnson Space Center (JSC), NSBRI, and the Universities Space Research Association (USRA). In FY2012, the HRP held its annual Investigators' Workshop in February at the Westin Galleria in Houston, Texas. The theme of the workshop was "ISS Assembly Complete: Gateway to New Destinations," and the event drew 530 participants from six countries.

The general session included talks by HRP managers, researchers, and the NASA Chief Scientist. Principal investigators delivered oral presentations in 28 discipline-specific sessions. Two poster sessions were held and recipients of the NSBRI Student Poster Award and USRA New Investigator Award were recognized. Finally, a series of briefings by HRP and NSBRI scientists were held.

The meeting program and abstracts can be viewed

The SBIR Program is a competitive three-phase award system which provides small businesses with opportunities to propose innovations to meet specific research and development needs.

on-line at: http://www.dsls.usra.edu/meetings/hrp2012.

Independent Reviewer Impressed by HRP Processes; Provides Additional Suggestions

The Institute of Medicine (IOM), an independent, expert advisory institution, conducted a review of the scientific merit assessment processes used to evaluate the HRP's directed research tasks. This review included a public workshop, held in March 2012 in Washington, D.C., focused on identifying and exploring best practices in similar peer-reviewed applied research programs in other federal agencies.

The committee was composed of people from academia and government agencies and was chaired by a former NASA Payload Specialist and Associate Professor of Physiology, Kinesiology and Medicine at Pennsylvania State University. The committee produced a report on its evaluation of the review processes and decision-making criteria. The report also recommended what measurements are needed to assess the effectiveness of the scientific merit assessment process in approving directed research projects that meet the operational needs of NASA.

The committee was impressed with the scientifically rigorous and thorough processes that have been developed to conduct merit assessments of directed research. Where opportunities exist for improvement, the IOM provided a few recommendations.

One suggestion was to improve the initial decision process to determine if a proposal meets the definition of directed research. The committee believes that HRP's current decision criteria are appropriate and similar to those of other organizations. However, they recommended that HRP narrow the scope of directed research and clearly make a distinction between task and supporting activities. They also recommended that HRP improve and expand communications about available directed research opportunities and awards.

In addition, all directed research should go through a peer-review process, and the Chief Scientist should decide whether the review will be performed by an external or mixed panel of peer reviewers.

The committee also suggested using activity and performance metrics to conduct continuous quality improvement efforts to improve the process for assessing the merit of research. HRP is currently incorporating the committee's suggestions and will

The IOM is an independent, non-profit organization that works outside of government to provide unbiased and authoritative advice to decision makers and the public.

report next year on the progress made.

New Research Solicitations and Selections

HRP's priority is to promote full and open competition for research and technology investigations through periodic research solicitations issued by both NASA and NSBRI. Additionally, their priority is to maintain a balance between the selection of internal to NASA investigations and external investigations. When research results are needed quickly or studies are heavily embedded with mission operations, the HRP may use directed research investigations to accomplish the desired research. Currently, 74% of research tasks are derived from open competition, while 26% are directed research

The 2011 NASA Research Announcement (NRA) for **"Research and Technology Development to Support Crew Health and Performance in Space Exploration Missions"** jointly solicited proposals for NASA and NSBRI. For this solicitation, special emphasis was placed on the high-priority research area of visual impairment and intracranial pressure. To address this, proposals were solicited by HRP in the areas of visual acuity, ocular structure and function, and fluid distribution.

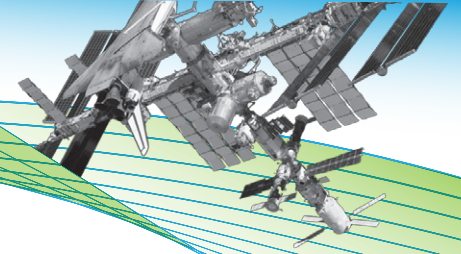
Additionally, proposals were solicited in the areas of team social, technical, and task roles as well as the effects of constrained communication on operational tasks. HRP also requested proposals for short-term investigations or technologies that provided innovative approaches to lowering any of the risks defined in the HRP Integrated Research Plan.

Proposals were solicited by NSBRI in the areas of microgravity-induced visual alterations and intracranial pressure, cardiovascular alterations, human factors and performance, musculoskeletal alterations, neurobehavioral and psychosocial factors, sensorimotor adaptation, and smart medical systems and technology. Peer review of the 47 NASA Step-2 proposals and 57 NSBRI Step-2 proposals submitted

The SBIR Program is a competitive three-phase award system which provides small businesses with opportunities to propose innovations to meet specific research and development needs.

in response to the solicitation occurred in March 2012. Twenty-nine awards were announced in April 2012, with 14 of the principal investigators of these studies joining HRP and 15 joining NSBRI's team-based research program.

The 2012 NRA for "**Research and Technology Development to Support Crew Health and Performance in Space Exploration Missions**" was released on July 30 along with jointly solicited proposals for HRP and NSBRI. Proposals were solicited by NASA in the areas of sensorimotor impairment and space motion sickness, epidemiological evidence of spaceflight-induced cardiovascular disease, computational models of cephalad fluid shifts, spaceflight biochemical profile, maintenance and regulation of team function and performance over extended durations, and development of safety and efficiency metrics for human-automation systems. HRP also



requested proposals for short-term investigations or technologies that provided innovative approaches to mitigating any of the risks defined in the HRP Integrated Research Plan.

Proposals were solicited by NSBRI in the areas of cardiovascular alterations, human factors and performance, musculoskeletal alterations, neurobehavioral and psychosocial factors, sensorimotor adaptation, and smart medical systems and technology. A total of 157 Step-1 proposals were received in September. Final selections will be announced in April 2013.

The NRA "**Ground-Based Studies in Space Radiobiology**" was released in January 2012. It solicited proposals for ground-based research in the areas of cancer risks from galactic cosmic rays and central nervous system risks from space radiation. Proposals were solicited in the area of space radiation biology to use beams of high-energy heavy ions to simulate space radiation at the NASA Space Radiation Laboratory at Brookhaven National Laboratory. A peer review was conducted in July to evaluate 50 Step-2 proposals. Twelve awards were announced in August.

The NASA Small Business Innovation Research (SBIR) Program Management Office released the 2012 SBIR Phase 1 Solicitation in September. The five HRP topics included in the solicitation were exploration countermeasure capability, exploration medical capability, behavioral health and performance, advanced food systems technology, and in-flight biological sample analysis. Proposals will be reviewed and awards announced in February 2013. Also, five HRP 2010 SBIR Phase 2 awards were announced in December 2011. For the 2011 Phase 1 cycle, 11 HRP awards were announced in November 2011.

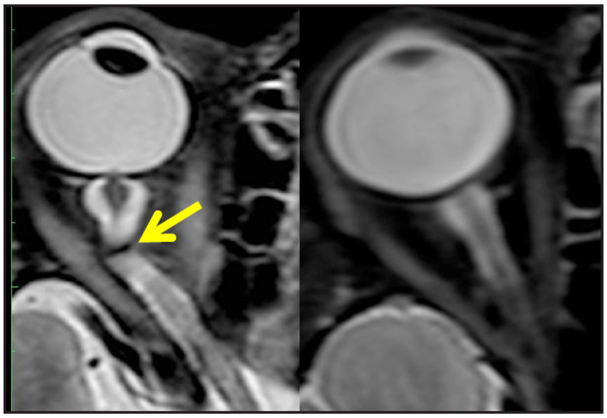
Expert Team Compiles VIIP Evidence Book and Releases Future Research Plans

Long-term exposure to microgravity and the spaceflight environment causes changes in the anatomical structure and function of the eye for the majority of astronauts. These changes can include degraded vision, flattening of the globe, swelling of the optic disc, choroidal folds, and cotton-wool spots. Some astronauts also exhibit elevated intracranial pressure—an increase in the pressure of the fluid that surrounds the brain and spinal cord. Some of these changes in vision and pressure persist even after returning to Earth. Concerns about the long-term effects of these changes have heightened efforts to quickly characterize the health risk and the cause of this syndrome.

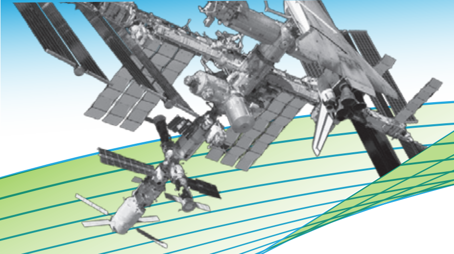
NASA has assembled an expert team from clinical and research communities involved with the systems responsible: the cardiovascular system, the ocular system, and the central nervous system. The team and syndrome are named Visual Impairment/Intracranial Pressure (VIIP), as elevated intracranial pressure is the leading hypothesis to explain the changes.

The VIIP team compiled an evidence report containing the results of an exhaustive literature review and mining of NASA's astronaut health database. With the help of the HRP Science Management Office, a Wiki-based version of the VIIP Evidence Report is now available to the public for expanded collaboration. The link to the VIIP Wiki site is http://en.wikipedia.org/wiki/VIIP.

To mitigate the risk to astronaut long-term health, a series of studies were defined to close the gaps in NASA's understanding of this unique problem and guide future work in countermeasure development. The VIIP Research Plan was incorporated into HRP's broader vision for future research needs and is available online at the Human Research Roadmap website, http://humanresearchroadmap.nasa.gov/.



An MRI of the optic nerve taken from the fourth crewmember exhibiting visual changes from long-duration spaceflight. The image (left) was taken 30 days post-landing and shows a tortuous optic nerve and kink (arrow). The image (right) shows a control, or normal, optic nerve.

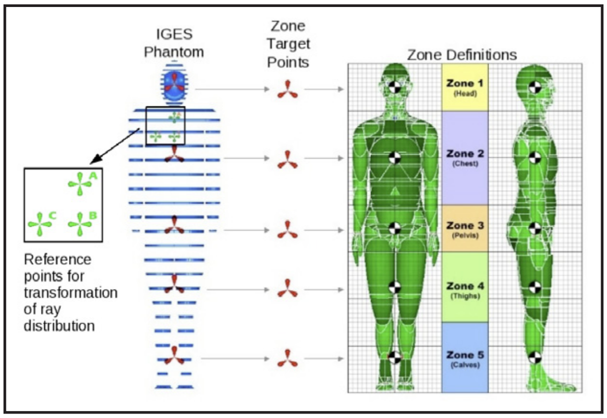


Design Tool for Vehicle Radiation Shielding Assessments and Optimization

The On-Line Tool for the Assessment of Radiation in Space (OLTARIS) is a web-based set of tools and models that allow engineers and scientists to evaluate and optimize protection from space radiation for human or electronic systems such as spacecraft, spacesuits, rovers, habitats, and instruments. Significant upgrades were made to OLTARIS during FY2012 which greatly enhanced the analysis fidelity.

First, vehicles can now be analyzed with a bi-directional, ray-by-ray transport method utilizing up to 100 different materials, in any order. This capability provides significant improvement for a detailed look at mature spacecraft designs in which components and materials have typically been defined in a master equipment list. Previous methods relied on interpolation-based estimates using three or four materials commonly defined as equivalent aluminum, polyethylene, regolith, or tissue, combined together in a fixed order.

Second, users can now upload their own vehicle trajectories and then analyze missions, either as an averaged environment over the entire trajectory to compute mission totals, or at every point along the trajectory for a detailed response–versus-time history. In addition, new environmental models are now available including the 2010 Badhwar-O'Neill galactic cosmic ray environment and a lunar neutron albedo environment.



The OLTARIS tool offers both male and female models with up to 5 target zones to model radiation exposure to internal organs and tissues.

Updates to the 2010 high charge and energy (HZE) space radiation transport (TRN) code, HZETRN2010, including the production and transport of light ions and neutrons, are also made available through the OLTARIS website. Models, methods, and limitations have been independently verified and validated, and are fully documented with online access. The tool set is configuration-managed and makes a current change log available to users. OLTARIS is capable of supporting commercial space partners and Advanced Exploration Systems habitat and space vehicle design teams to assess and mitigate radiation exposures. The website may be found at https://oltaris.nasa.gov.

New Findings on Protecting Astronauts' Bones Through Diet and Exercise

Eating enough calories and exercising in space may help protect astronauts' bones and help solve one of the key problems facing future explorers heading beyond low Earth orbit. This finding was published in the *Journal of Bone and Mineral Research*.

The Nutritional Status Assessment project evaluated the mineral density of specific bones as well as the entire skeleton of astronauts who used the Advanced Resistive Exercise Device (ARED). The ARED was added to the ISS in 2006 and can produce resistance of as much as 600 pounds in microgravity allowing astronauts to "lift weights" in weightlessness.

The researchers found that astronauts using the ARED returned to Earth with more lean muscle and less fat, and maintained their whole-body and regional bone mineral density at about the same levels as when they launched. Crewmembers using the ARED also consumed sufficient calories and vitamin D, among other nutrients. These nutrients support bone health and likely contributed to the results.

Normal, healthy bone constantly breaks down and renews itself, a process called remodeling. As long as breakdown and renewal are in balance, bone mass and density stay the same. Earlier studies of Russian *Mir* space station residents found an increased rate of bone breakdown but little change in the rate of regrowth, so that an overall loss in bone density resulted.

The new study, examining crewmembers who used the ARED, bone breakdown still increased, but bone formation also tended to increase, likely resulting in the maintenance of bone mineral density. The increase in both breakdown and formation suggests that the bone was being remodeled, but a key question remains as to whether this remodeled bone was as strong as the bone before flight.

The September 2012 issue of the Journal of Bone and Mineral Research featured new research findings on maintaining bone density through exercise and nutrition.

Additional studies to evaluate bone strength before and after flight are currently under way. Besides answering the bone strength question, further study is required to determine the best combination of exercise and diet for long-duration crews. Dietary effects on bone are currently being studied on the ISS. In one experiment researchers are evaluating the effect on bone health of different ratios of animal protein and potassium in the diet. In another they are looking at the benefits of lowering sodium intake and its effect on bone.

International Space Station Medical Project

Overview

The International Space Station Medical Project (ISSMP) provides planning, integration, and implementation services for HRP research tasks. The objectives of the ISSMP are to maximize the utilization of the ISS for research to assess the effects of long-duration spaceflight on human systems, to develop and verify strategies to ensure optimal crew performance, and to enable development and validation of an integrated suite of physical, pharmacologic, and nutritional countermeasures to protect the health and performance of crewmembers.

The ISSMP develops efficient plans for conducting human research performed on the ISS to ensure the maximum science return with the available resources. ISSMP provides integration support for experiments, including the testing, certification, and delivery of flight hardware to ISS resupply vehicles including the Russian Soyuz and Progress vehicles, the European Space Agency (ESA) Automated Transport Vehicle (ATV), the Japanese Aerospace Exploration Agency (JAXA) H-Transfer Vehicle (HTV), and commercial launch vehicles.

The ISSMP supports research investigators by implementing the science objectives and offering services such as developing crew procedures and providing training, monitoring real-time on-orbit operations, and facilitating data transfer to the principal investigators. The ISSMP team also coordinates with the ISS International Partners to develop mission-specific science complements, and negotiates inter-agency schedules, usage agreements, and international crewmember subject participation.

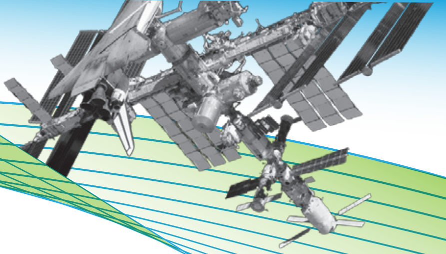
Additional ISSMP services include the Telescience Support Center (TSC), which provides a focal point for real-time ISSMP research operations and a distribution point for remote investigators to monitor their experiments and acquire telemetry data. The TSC provides investigators and ground teams with ISS space-to-ground communication capabilities that allow the relaying of commands and software uplinks for all ISSMP in-flight operations. The TSC serves as a gateway to securely distribute ISS digital data and video over virtual private networks to support ISSMP science and engineering communities.

To learn more about the ISSMP, please visit: http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-issmp.html

During FY2012, the ISSMP coordinated and optimized the research supporting ISS Increments 29-33. This included the launch and return of crewmembers on four Soyuz vehicles, launch of supplies on four Progress vehicles as well as the HTV and ATV vehicles, and return of samples at ambient temperature on three Soyuz return flights. In FY2012, two investigations completed all in-flight operations and ten studies continued in-flight operations. Also in FY2012, three new investigations began flight operations, nine new investigations initiated development of flight requirements to support future missions, and one new investigation is undergoing a feasibility assessment awaiting a future select-for-flight decision.

The following table lists all ISSMP active flight experiments, the number of subjects they require, FY2012 progress, and status to date.

		Subjects		
Investigation Title	**Ops Title**	**Required**	**Participation Through Increment 33**	**Status**
Investigations Continuing Flight Operations in Fiscal Year 2012				
NASA Biological Specimen Repository	Repository	All	29	Recruitment continues for all future ISS missions.
Cardiac Atrophy and Diastolic Dysfunction During and After Long Duration Spaceflight: Functional Consequences for Orthostatic Intolerance, Exercise Capacity, and Risk of Cardiac Arrhythmias	Integrated Cardio-vascular	12	12	In-flight operations continued throughout ISS missions in 2012. Final data collection expected to be completed in FY2013.
Physiological Factors Contributing to Changes in Post-Flight Functional Performance	FTT	13 Shuttle 13 ISS	7 Shuttle 7 ISS	This pre- and postflight investigation completed data collection for short duration shuttle subjects and is continuing data collection with long duration ISS crewmembers.
Dietary Intake Can Predict and Protect Against Changes in Bone Metabolism During Spaceflight and Recovery	Pro K	16	10	Additional subjects participated during the ISS Increment 30-32 missions.
Psychomotor Vigilance Self Test on ISS	Reaction Self Test	24	19	In-flight operations continued with missions in 2012 and are planned to continue in 2013.
Integrated Resistance and Aerobic Training Study	Sprint	20 Control 20 Active	4 Active 1 Control	In-flight operations continued throughout missions in 2012.
Behavioral Issues Associated with Long Duration Space Expeditions: Review and Analysis of Astronaut Journals	Journals (6 crew)	10	5	Study began with data collection during Increments 29/30. Study previously conducted when crew size was three. Ten additional subjects being pursued now that crew size increased to six.

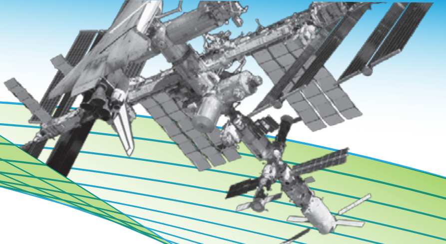


International Space Station Medical Project

Investigation Title	Ops Title	Subjects: Required	Subjects: Participation Through Increment 33	Status
Nutritional Status Assessment	Nutrition	30	31	Subject number increased from 24 to 30 in 2011. Recruitment of subjects was completed in 2012; in-flight data collection is expected to be completed during FY2013.
Maximal Oxygen Uptake During Long Duration International Space Station Missions	VO2max	12	14	In-flight operations continued with ISS missions in 2012. Study completion expected with landing of the Increment 32/33 crew in early FY2013.
Biomechanical Analysis of Treadmill Exercise on the International Space Station	Treadmill Kinematics	6	7	Flight operations began during Increment 27/28 and are expected to be completed with the landing of the Increment 32/33 crew in early FY2013.
Investigations with Initial Flight Operations in Fiscal Year 2012				
Bisphosphonates as a Countermeasure to Space Flight Induced Bone Loss	Bisphos-phonates (CONTROL)	10	1	Participation in the control group began with Increment 31.
Risk of Intervertebral Disc Damage After Prolonged Spaceflight	IVD	12	1	This pre- and postflight investigation began pre-flight data collection with Increment 33 crew in FY2012.
Assessment of Operator Proficiency following Long-Duration Spaceflight	Manual Control	8	1	This pre- and postflight investigation began pre-flight data collection with Increment 33 crew in FY2012.
Investigations Completing In-Flight Operations in Fiscal Year 2012				
Validation of Procedures for Monitoring Crewmember Immune Function	Integrated Immune	17 Shuttle 17 ISS	18 Shuttle 19 ISS	The short-duration Shuttle and long-duration ISS phases of this study have been completed. Data analysis is continuing.
Bisphosphonates as a Countermeasure to Space Flight Induced Bone Loss	Bisphos-phonates (ACTIVE)	10 (5 Alendronate and 5 Zoledronic Acid); 10 controls	7 (Alendronate)	Final subjects participated in alendronate phase during Increment 28/29; subjects for zoledronic acid administration are no longer being pursued. Data analysis is continuing.

International Space Station Medical Project

Investigation Title	Ops Title	Subjects: Required	Subjects: Participation Through Increment 33	Status
Investigations Initiating Flight Development Activities in Fiscal Year 2012				
NASA Biochemical Profile Project	Biochem-ical Profile	All USOS	0	Selected for flight in 2012. Informed consent briefings begin with the ISS Increment 37/38 crew.
Assessing the Impact of Communication Delay on Behavioral Health and Performance: An Examination of Autonomous Operations Utilizing the International Space Station	Comm Delay Assessment	3	0	Selected for flight in 2012. Informed consent briefings begin with the ISS Increment 35/36 crew.
Occupational Risk Surveillance for Bone: Pilot Study-Effects of In-Flight Countermeasures on Sub-Regions of the Hip Bones	Hip QCT	10	0	Selected for flight in 2012. This pre- and postflight study will recruit subjects that have already flown on ISS, as it can utilize data collected for a previous investigation.
Study of the Impact of Long-Term Space Travel on the Astronaut's Microbiome	Microbiome	9	0	Selected for flight in 2012. Informed consent briefings begin with the ISS Increment 35/36 crew.
Spaceflight Effects on Neurocognitive Performance: Extent, Longevity and Neural Bases	Neuro-Mapping	13	0	Selected for flight in 2012. Informed consent briefings begin with the ISS Increment 37/38 crew.
Prospective Observational Study of Ocular Health in ISS Crews	Ocular Health	12	0	Selected for flight in 2012. Subject recruitment to be presented to the ISS Increment 35/36 crew.
The Effects of Long-Term Exposure to Microgravity on Salivary Markers of Innate Immunity	Salivary Markers	6	0	Selected for flight in 2012. Informed consent briefings begin with the ISS Increment 37/38 crew.
Sonographic Astronaut Vertebral Examination	Spinal Ultrasound	6	0	Selected for flight in 2012 and will begin in-flight operations in FY2013 starting with the Increment 34 crew.



International Space Station Medical Project

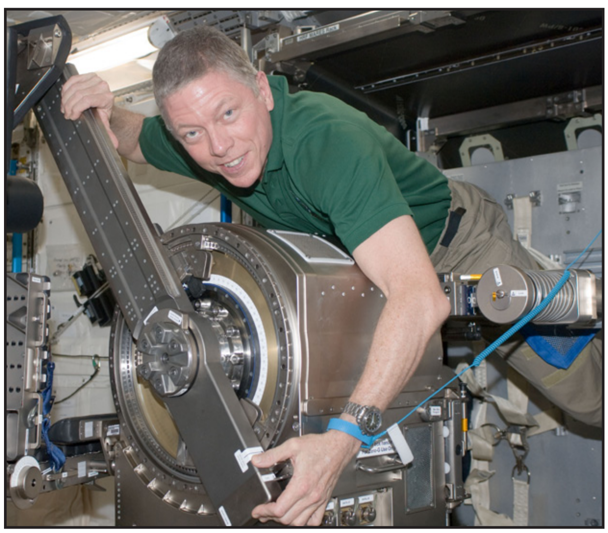
		Subjects		
Investigation Title	Ops Title	Required	Participation Through Increment 33	Status
Defining the relationship Between Biomarkers of Oxidative and Inflammatory Stress and the Risk for Atherosclerosis in Astronauts during and After Long-duration Spaceflight	Cardio OX	12	0	Selected for flight in 2012. Informed consent briefings begin with the ISS Increment 37/38 crew.
Investigations Awaiting Select for Flight Decision				
Quantification of In-flight Physical Changes – Anthropometry and Neutral Body Posture	Body Measures	12	0	Study is undergoing peer review and ISSMP Feasibility Assessment.

MARES Operational Management Transferred to European Space Agency

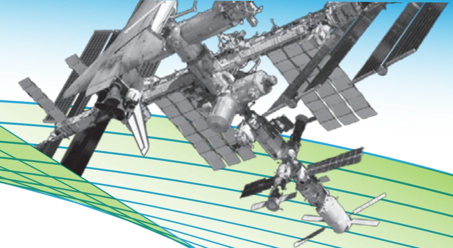
The operational management of the Muscle Atrophy Research and Exercise System (MARES) was transferred from HRP to ESA's Columbus Operations Division in FY2012. Since the transfer, ESA has taken responsibility for operations, including additional performance tests and experiment utilization, as well as management of the interfaces of MARES with the ISS. ESA has also assumed the role of the MARES Payload Integration Manager.

The MARES was a collaboration between NASA and ESA for development of a system to assist in musculoskeletal research and countermeasures validation on the ISS, and was delivered on STS-131 in 2010. It is located in the Columbus module on the ISS in close proximity to the two Human Research Facility racks and the European Physiology Module. Each agency will retain sustaining engineering responsibility for the components they provided.

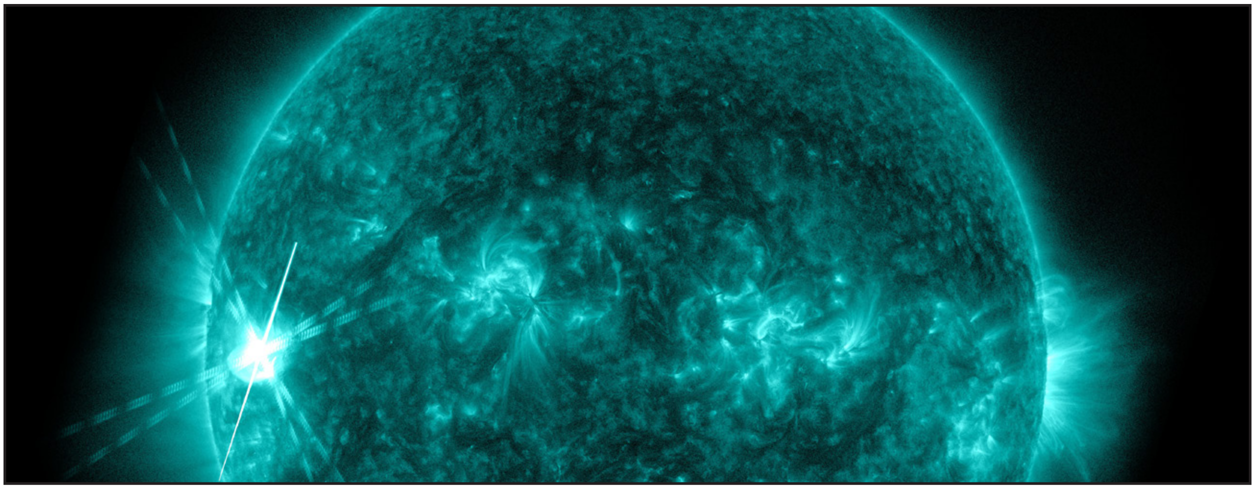
The first scientific use of the MARES is currently planned by ESA during the Sarcolab experiment. Furthermore, the MARES will be available for use by all International Partners in accordance with the International Space Life Sciences Working Group. Ground models used for training are currently located in Cologne, Germany and Toulouse, France. Primary operation and control for MARES will be at the CADMOS User Support Operations Center in Toulouse. An additional ground unit to be used for baseline data collection will be delivered to the Johnson Space Center in 2013.



The Expedition 29 Commander works with the MARES device in the Columbus module.



Space Radiation Element



Overview

The goal of the Space Radiation Element (SR) is to ensure that crewmembers can safely live and work in space without exceeding acceptable radiation health risks. Space radiation differs from radiation encountered on Earth.

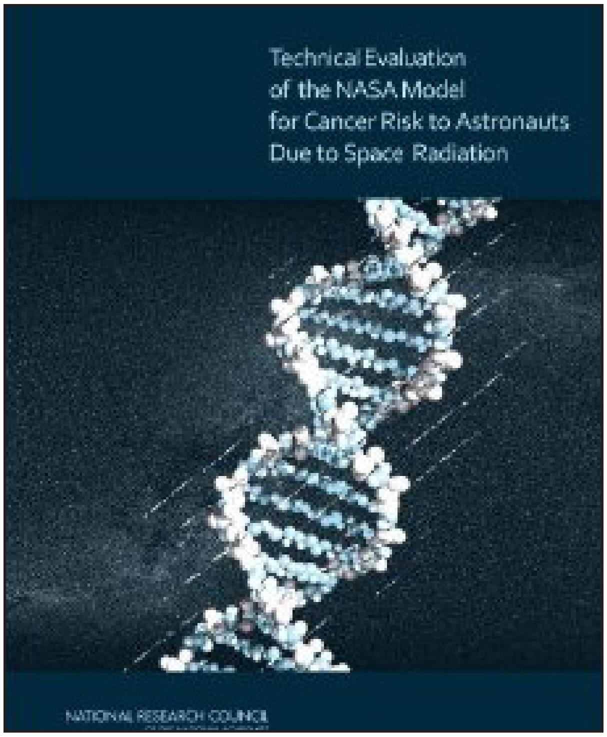
The main sources of space radiation are galactic cosmic rays (GCRs), which consist of protons and electrons trapped in Earth's magnetic field and solar particle events. GCRs permeate interplanetary space and include particles with high ionizing energy. At the cellular and tissue levels, these heavy ions cause damage that is largely different from the damage caused by terrestrial radiation such as x-rays or gamma-rays because of their significantly higher ionizing power and associated uncertainties in quantifying biological response. Shielding against GCRs is much more difficult than shielding against terrestrial radiation because a greater mass of shielding material is required and GCRs can penetrate shielding material.

Health risks from space radiation may include an increased incidence of cancer; acute radiation sickness; degenerative tissue damage; diseases such as heart disease, cataracts, and radiation sickness; and early and late central nervous system (CNS) damage. Cancer risks pose the largest challenge for exploration. The uncertainties in cancer risk projection have large impacts on exploration mission designs, limiting NASA's ability to adjust mitigation measures such as shielding and biological countermeasures. For the CNS and degenerative risks, there are uncertainties in the dose thresholds and latency. Research is needed to optimize radiation protection practices in shielding and operational procedures to prevent acute radiation sickness.

The results of space radiation studies contribute to human exploration by providing a scientific basis to accurately project and mitigate health risks from space radiation. Research in radiobiology and physics guides and supports risk assessment and protection strategies. The results will provide tools for evaluating shielding recommendations for habitats and vehicles as well as requirements for storm shelters and early warning systems for solar particle events. To read more about the Space Radiation Element, please visit: http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-srpe.html.

National Academy of Sciences Reviews NASA Cancer Risk Model

NASA's current missions to the International Space Station (ISS), and potential future exploration missions involving extended stays by astronauts on the surface of the moon, near-Earth asteroids, or Mars, present challenges in protecting astronauts from



The National Academy of Sciences (NAS) provided an independent review of NASA's Model for Cancer Risk and concluded that the new model was a definitive improvement.

radiation risks. Currently, NASA uses the model recommended by the National Council of Radiation Protection and Measurements (NCRP) for estimating the risk of radiation-induced cancer for ISS crews as well as assessing mitigation strategies for future missions. Proposed changes to the current risk model incorporate recent research directed at improving the understanding of and quantifying the health risks posed by space radiation.

The National Academy of Sciences (NAS) was asked to provide an independent review of these proposed updates. The updates include a revision of low linear energy transfer (LET) cancer risk coefficients based on cancer incidence data, dose- and dose-rate effectiveness factor changes, evaluation of distinct radiation quality factors for solid cancers and leukemia and the replacement of LET dependence with charge and energy dependence, and revised uncertainties for low-LET human data, space environments, and organ exposures. NASA's proposed model is defined by the 2011 report *Space Radiation Cancer Risk Projections and Uncertainties - 2010*.

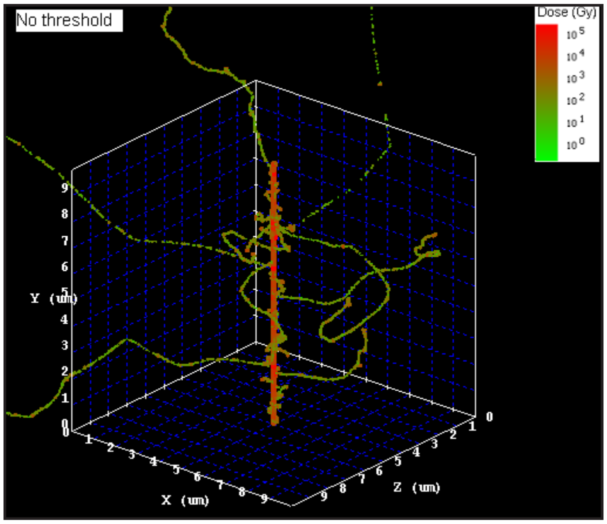
The NAS completed its evaluation in FY2012, and their report finds that the revised NASA Cancer Risk Model uses state-of-the-art methods and is a definite improvement over the previous model. The new model integrates new findings and methods; newer epidemiological data and analyses; new radiobiological data indicating that quality factors differ for leukemia and solid cancers; an improved method for specifying quality factors in terms of radiation track structure; the development of a new statistical model of solar particle events; and updates to galactic cosmic ray (GCR) and shielding transport models. The NAS made several recommendations to be considered by NASA, to improve treatment of epidemiology data and clarify the proposed updates.

The report also identifies important research areas for further study related to cancer and non-cancer risks from space radiation including smoking status and its potential implications for projecting risk for smoking-related cancers; quantifying the relative biological effectiveness for radiation-induced cardiovascular disease; delayed effects such as genomic instability on assessment of risk; the quantitative difference between heavy ions and terrestrial radiation; and the qualitative and quantitative contributions of non-targeted effects that are directly related to radiation-induced carcinogenesis. The full NAS report can be found at http://www.nap.edu/catalog.php?record_id=13343.

Space Radiation Tool Receives JSC Exceptional Software Award for 2012

The space radiation environment encountered by astronauts includes high-energy protons and heavy ions (HZEs) as well as secondary protons, neutrons, and other heavy ions affecting shielding and tissue. The deposition of energy by these particles as they pass through different materials is highly dependent

Space Radiation Element



Simulation of energy deposition along a 1 GeV/amu Fe ion track using RITracks

on the radiation type. The Relativistic Ion Track Structure Code (RITracks), developed as part of the NASA Space Radiation Risk Assessment project, calculates the unique ionization and oxidative damage from space radiation in biological materials through Monte Carlo simulations. Monte Carlo simulations are a class of computational algorithms that rely on repeated random sampling to compute their results.

RITracks includes models of human chromosomes for the entire genome. This feature allows the user to score the position of DNA damage in whole cells. These positions are important for modeling biological effects to characterize and mitigate space radiation health risks. The source code for RITracks was selected for the JSC Exceptional Software Award in FY2012. In addition, RITracks was identified by the software review committee as the 2012 JSC nominee for the NASA Agency Software of the Year competition held by the Inventions and Contributions Board.

New Version of Web-Based Acute Radiation Risk Model Released

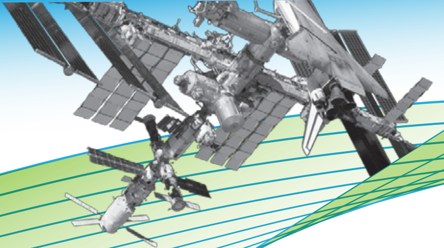
The new Web-based version of the Acute Radiation Risk and BRYNTRN Organ Dose (ARRBOD) was released in FY2012 and is now available at http://spaceradiation.usra.edu/irModels/. The ARRBOD model predicts potential early health effects on crews from exposure to large solar particle events (SPE), which may occur on lunar and Mars missions. According to the model's assumptions, if effective vehicle shielding and medical countermeasures had not been provided, exposure to historical SPE would have caused moderate early health effects on crewmembers.

Major model updates in version two of ARRBOD are blood system responses, additional capabilities for modeling shielding from SPE, and biodosimetric tools with clinical hematologic data for acute and protracted exposure.

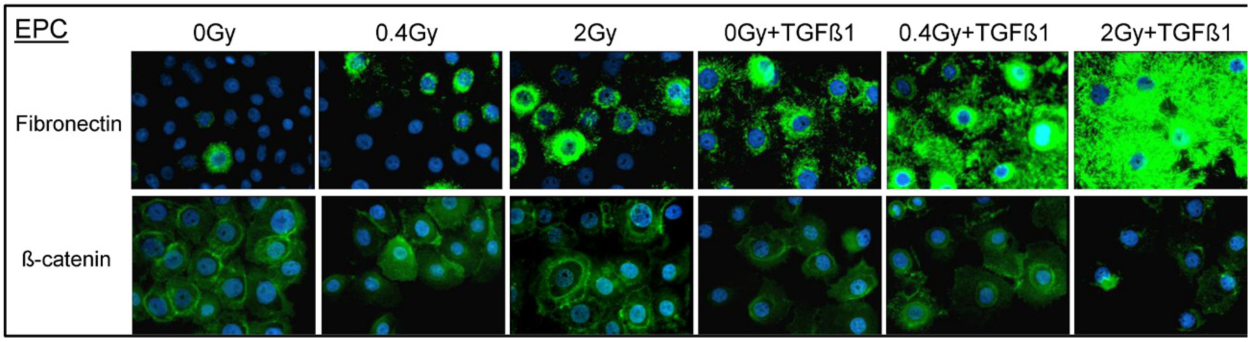
NASA Research in Space Radiobiology Benefits Cancer Treatments on Earth

Proton radiation therapy has grown in importance as a modality for cancer treatment, in part because it can spare normal tissues whereas conventional radiation does not. Nearly 100,000 patients have been treated by proton irradiation for cancers of the prostate, esophagus, lung, head, and neck, and a growing number of new proton treatment centers worldwide are being built each year.

Enhanced sparing of tissue is possible by careful placement of the proton peak energy deposition, which occurs as a particle slows down before it comes to rest. The close proximity of the esophagus to other tissues such as the heart, lung, and spinal cord makes the treatment of esophageal cancer difficult. This makes proton therapy an excellent choice for treating patients with esophageal cancer. Given that some proton exposure will still occur in tissue near the edges of the tumor, and the possibility that biological effects produced by high linear energy transfer (LET) protons may be qualitatively different from those produced by low-LET radiation such as x-rays, it is important to study how protons may specifically affect the cells and tissues.



Space Radiation Element



An illustration of the biological effects of low energy protons on epithelial cells. From left to right, the increasing amount of green depicts the enhancement of transforming growth factor beta 1 (TGF β 1) - mediated processes important to cancer risk as the dose rate increases.

Results of a study conducted by researchers at the Johnson Space Center and Lawrence Berkeley National Laboratory, suggest that the benefits of proton therapy need to be weighed against potentially detrimental effects of even low proton doses on normal tissue. The potential for these proton exposures to increase cancer risk has not been well studied, so the researchers' objective was to study the biological effects of low-energy protons on epithelial cells and their potential to enhance tumor progression. The study revealed that proton irradiation of normal cells can elicit changes associated with cancer progression.

Because protons are a major component of space radiation, results from this study can inform not only our understanding of enhanced cancer risk from proton irradiation for astronauts, but also for patients on Earth.

Expert Panel Makes Recommendations for Research on Radiation Risks to the CNS

Missions beyond the Earth's electromagnetic field will expose astronauts to energetic protons and high-energy (E), heavy charged (Z) particle radiation —denoted as HZE particles. Current technologies are incapable of shielding astronauts from these particles, which makes assessing their health effects, particularly on the central nervous system (CNS), an important goal. However, limited knowledge exists to estimate the clinical relevance of such effects.

NASA-funded studies of animals exposed to high-energy particles have demonstrated that some brain alterations can occur at total exposures that fall within the range of exploration missions. These experiments raise the question of whether deep-space radiation might cause changes in cognition that could affect astronaut performance during prolonged missions, as well as whether radiation exposure may increase the risk of accelerated onset of Alzheimer's disease, Parkinson's disease, cerebrovascular disease, or other neurodegenerative diseases.

In FY2012, a panel of experts in the field of CNS research met in Houston to consider the potential risks that space radiation may pose to astronauts in space. The panel identified a number of limitations in the evidence presented on CNS space radiation risk that need to be addressed to enable a more definitive determination of the CNS risk related to radiation exposure. The panel also recognized the need to share samples between CNS and carcinogenesis studies and to continue using rodent models with a long-term goal of moving to a non-human primate to assess cognitive risk to humans.

Because of the current gaps in understanding the causes of neurodegenerative disease, the CNS experts thought that a true estimate of the risk of accelerated neurodegenerative disease due to space radiation would be difficult to establish in the near future. However, development of a predictive risk model that estimates the acute exposures that have a reasonable likelihood of causing acute or subacute neurological impairment was considered feasible.

Prototype of Small Tissue Equivalent Proportional Counter Developed

NSBRI investigators at Ames Research Center, Colorado State University, and Texas A&M University have developed radiation dosimeters small enough to fit inside a backpack or extravehicular activity (EVA) suit. The Tissue Equivalent Proportional Counter (TEPC) device will be sensitive to a wide range of charged particles and can measure radiation dose and dose rate inside and outside a spacecraft. As the radiation intensity increases during SPE, the dosimeter can issue a warning directly to astronauts as well as mission control. This would be a signal for astronauts to implement countermeasures such as termination of an EVA and travel to a safe haven that contains protective shielding.

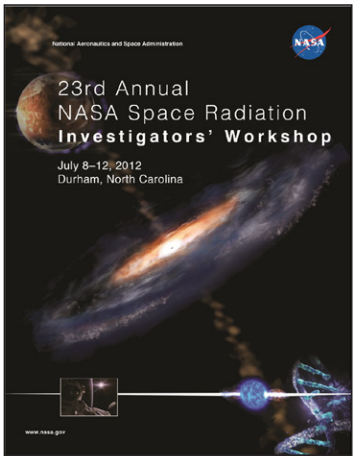
During long-term missions, space radiation will present a risk to astronaut health and may affect the performance of equipment. Future exploration missions will have to closely monitor astronauts' prolonged exposure to GCR radiation because the materials used in current vehicle designs cannot provide the crew with sufficient protection. SPE that accompany a coronal mass ejection can accelerate protons to energies capable of penetrating the structure of spacecraft. The rapid increase in radiation penetrating the vehicle can place astronauts at risk by inducing the early-onset effects associated with an acute radiation exposure.

The TEPC prototype also has potential for other industries, such as first responders to nuclear accidents or terrorist attacks. It can provide real-time dosimetry during diagnostic and therapeutic medical procedures such as proton radiation therapy, and surveillance activities associated with U.S. homeland security and nuclear non-proliferation.

23rd Annual Space Radiation Investigators' Workshop Held at Duke University

Approximately 200 people attended the 23rd Annual NASA Space Radiation Research Investigators' Workshop, held July 8-11 in Durham, North Carolina. Duke University served as the co-host for the workshop which featured more than 50 oral presentations and 62 posters presented by investigators, as well as 21 posters presented by postdoctoral candidates, graduate students, and undergraduates in the Student Poster Competition.

The presentations and posters covered research across all radiation risk areas, including radiation carcinogenesis, acute and latent CNS effects, degenerative tissue risks, and acute radiation syndromes. Sessions were presented in the areas of space physics, technology, and radiation environments. Special refresher lectures were held in space radiation biophysics and CNS radiobiology. Additionally, two debates discussed the status of cancer and CNS radiation research.



Human Health Countermeasures Element

Overview

NASA uses the term "countermeasures" to describe the procedures, medications, devices, and other strategies that help keep astronauts healthy and productive during space travel and return to Earth. The Human Health Countermeasures (HHC) Element is responsible for understanding the normal physiologic effects of spaceflight and developing countermeasures to those with detrimental effects on human health and performance. They provide the biomedical expertise for the development and assessment of medical standards, vehicle and spacesuit requirements and countermeasures that ensure crew health during all phases of flight. Pre-flight countermeasures involve physical fitness and exercise and physiologic adaptation training. In-flight countermeasures include nutritional health, physical fitness, pharmaceuticals and sensory-motor training protocols. Post-flight countermeasures target rehabilitation strategies. Prior to flight testing, candidate countermeasures and technologies are developed and refined using ground-based studies.

The HHC is comprised of five portfolios that address physiological research, countermeasure validation and technology development. Major FY2012 accomplishments are reported in each portfolio's respective section: Vision and Cardiovascular, Exercise and Performance, Multi-System, Bone, and Technology and Infrastructure. To learn more, please visit: http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-hhc.html.

✦ VISION AND CARDIOVASCULAR PORTFOLIO

Next-Generation Anti-Gravity Suits

The cardiovascular system readily adapts to the microgravity environment of spaceflight. Some of its adaptations are reducing blood volume, decreasing cardiac muscle mass, and changing the way the brain controls blood pressure. Although these adaptations are appropriate for spaceflight, they can have adverse effects when an astronaut re-enters Earth's atmosphere and gravity. Orthostatic intolerance—a condition leading to symptoms such as dizziness or fainting—can occur when a person tries to stand upright after spaceflight, mainly because blood pools in the lower body instead of being more evenly distributed throughout the body.

To counteract the blood pooling that occurred during space shuttle reentry, NASA used an inflatable anti-gravity suit that provided up to 1.5 psi of compression to the legs and abdomen. This garment was an effective countermeasure during re-entry, but it was uncomfortable to wear, and quickly lost pressure when crewmembers exited the shuttle. International Space Station (ISS) astronauts who return to Earth

Advanced gradient compression garment consists of thigh-high stockings with overlapping shorts and provides continuous compression from the feet to the abdomen.

on the Soyuz spacecraft wear a mechanical compression garment that is more comfortable and does not require a compressed air source; therefore it can be worn for multiple days after landing. However, during extended use it can cause painful swelling in uncompressed areas such as the knees and groin.

Along with commercial textile experts, researchers at the Johnson Space Center (JSC) Cardiovascular Laboratory designed and evaluated a three-piece, gradient-compression garment to determine its effectiveness as a post-spaceflight countermeasure. Garments were custom made for seven astronauts and evaluated within two hours of landing after a short-duration space shuttle mission. These garments were comfortable to wear and prevented signs and symptoms of orthostatic intolerance that are normally present after spaceflight. Because these garments provide continuous compression, without allowing swelling in any uncovered areas, they can be worn for several days after a mission to aid the astronaut during readaptation to Earth's gravity environment.

✦ EXERCISE AND PERFORMANCE PORTFOLIO

Assessment of Operator Proficiency Following Long Duration Spaceflight

Evidence from the Space Shuttle program suggests that even short-term exposure to microgravity impairs an astronaut's ability to pilot a spacecraft. This is a critical issue for future exploration missions to distant bodies—how does long-term exposure to weightlessness affect an astronaut's ability to perform landing maneuvers and other postflight operator tasks? A new study titled "Assessment of Operator Proficiency Following Long Duration Spaceflight" was started to answer this question by assessing the ability of astronauts to perform full-motion simulations after their return from six months aboard the ISS.

The simulator used for the study is installed at JSC and consists of a custom-built cabin with a 180-degree display. It includes controls such as a steering wheel, control stick, aircraft throttle, and gas and brake pedals and is mounted on a motion base that allows both angular and linear movement. The simulations consist of driving a car along a twisting road while maintaining lane position, landing a T-38 jet at Ellington Field in Houston, and operating a Mars rover by navigating to and docking with habitat modules and other rovers.

The performance of astronauts in the simulator one day after landing will be compared with their

A test subject in the Motion Simulator attempts to maintain lane postion on a twisting road. This study addresses the potential risks of a long-duration crews' ability to perform complex sensorimotor tasks such as landing a spacecraft or operating a rover.

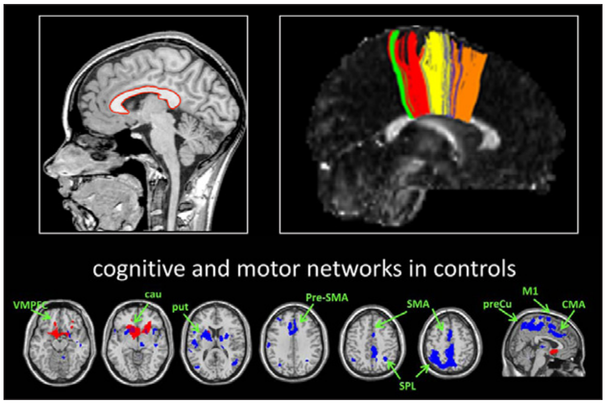
pre-flight results to quantify deficits in proficiency caused by extended exposure to microgravity. Additionally, the length of recovery will be determined by testing the astronauts four and eight days after they return from the ISS. All test sessions include a battery of tasks that assess sensorimotor and cognitive function. The results of these tests will be used to identify the underlying physiological basis for post-flight impairment of operator proficiency, and provide a framework for future countermeasure development. Two subjects have completed pre-flight data collection, and a total of eight crewmembers are scheduled to participate in this study.

Start of Neuromapping Study to Identify Changes in Brain Structure

A new study, "Spaceflight Effects on Neurocognitive Performance: Extent, Longevity, and Neural Bases," was initiated in FY2012. The intent of the study is to identify any changes in brain structure and function that occur with spaceflight, and to determine whether they are associated with a decline in cognitive and sensorimotor functions such as balance and motor control.

NASA investigators, collaborating with university partners, will utilize cutting-edge brain imaging techniques to study the brain's functional and structural networks in 12 astronauts at multiple time points before and after ISS missions. The team will use advanced imaging techniques to measure structural and functional network connectivity strength in the brain. Changes in brain volume will be measured with structural MRI and task-relevant recruitment will be studied with functional MRI.

The investigator team will also measure balance, functional mobility when astronauts navigate an obstacle course, spatial cognition and orientation, manual motor control, cognitive-motor dual tasking, and vestibular function. Astronaut subjects will perform a subset of this test battery at three time points, one of which includes an ISS in-flight assessment. All of the measures will be integrated to allow an overall assessment of brain changes occurring with spaceflight, their behavioral consequences, and the longevity of any such effects.



Structural MRI (left image) can measure changes in regional brain volumes. Diffusion weighted MRI (right image) measures structural pathway integrity. Functional MRI (lower images) indicates the communication between brain regions.

✦ MULTI-SYSTEM PORTFOLIO

A New Approach to Understanding the Changes in Astronauts' Vision

Recent research findings from the ISS show that a link may exist between nutrition and vision problems experienced by some astronauts. In the "Nutritional Status Assessment" experiment, blood and urine samples are collected from astronauts before, during, and after flight. The samples are analyzed for nutrition markers and other aspects of health. Twenty astronauts have participated in the study. Five had vision issues and 15 did not. The investigator team has found a significant relationship between vision issues and changes in a specific metabolic pathway, the "one-carbon metabolism pathway." This is a complex pathway that involves several enzymes and B vitamins. It is involved in moving single carbon atoms to and from different chemicals in the body. This is an important step in DNA synthesis, among other cellular functions.

The study suggests that in astronauts who had vision problems, this metabolic pathway was not functioning properly. Biochemical pathways are like factory assembly lines, and if one step slows down, upstream parts build up. In this study, the blood of affected astronauts contained increased levels of four chemicals in this pathway before flight.

One of the reasons the pathway might not have been functioning properly could have been that the astronauts with vision changes were among the many people who have slight differences in chemical structure of enzymes that control the pathway. It is possible that once a person is in space, there is an interaction between the enzyme change and some aspect of the effects of spaceflight on the human body. It could be an effect of weightlessness, such as shifting of body fluid and changes in cardiovascular function, or even some environmental aspect of spaceflight, such as carbon dioxide in the cabin atmosphere. This interaction of an enzyme change and an aspect of spaceflight might be the cause of vision changes in some individuals and not others. A follow-up study is currently underway.

Results of the team's studies may be found in the March 2012 issue of the *Journal of Nutrition*, and are described in greater detail at http://www.nasa.gov/mission_pages/station/research/news/vision_changes.html.

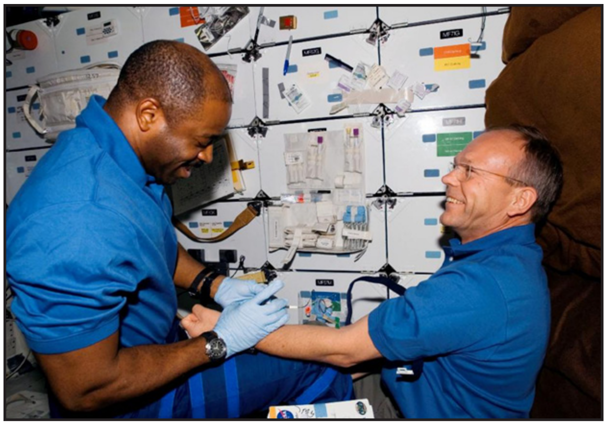
Completion of Integrated Immune Study

In-flight activity for the "Integrated Immune" study was completed, and the study is now in the data analysis phase. The Integrated Immune study was designed to develop and validate an immune system monitoring strategy consistent with requirements and constraints of spaceflight operations. Dysregulation of the immune system has been shown to occur during spaceflight, yet little in-flight data has been generated to assess this clinical problem.

The study assessed the clinical risks resulting from the adverse effects of spaceflight on the human immune system and validated a flight-compatible immune monitoring strategy. A total of 18 short-duration and 17 long-duration crewmembers participated in the study.

Assessments were performed during all stages of flight as part of the investigation, and the final on-orbit samples were collected by the Expedition 31 crew and returned with the landing of Soyuz 29S. All measures of immune cell function required the use of live blood cells. To accomplish this during shuttle missions, in-flight blood samples were collected on the final mission day before landing. During six-month ISS missions, three in-flight blood samples were collected at early, middle, and late times during the mission. However, all blood sampling had to occur immediately before undocking of the return vehicle, so that live blood cells could be returned for ground analysis.

Previous post-flight studies have routinely shown disruption of the immune system, but it was unknown whether this was an in-flight phenomenon. Preliminary data indicates that immune system changes do occur and persist during long-duration spaceflight. This may predict that crews have an increased risk for certain types of adverse health events during deep-space missions. Future NASA studies will determine the nature of in-flight im-



Integrated Immune blood sample collection during Space Shuttle mission STS-122.

A cabin atmosphere that closely matches the EVA suit would allow for new efficiencies like the use of suitports that allow seamless transitions between the vehicle environment and spacesuit. A crewmember enters the suitport (left) and prepares to detach from the craft and conduct his EVA (right).

mune dysregulation and develop countermeasures for these physiological changes.

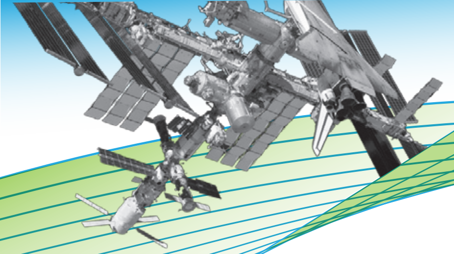
Evaluation of Spacecraft Cabin Atmosphere for Exploration

Extravehicular activities (EVA) are crucial to a manned space exploration program, thus any potential efficiencies or improvements to the EVA process deserve investigation. Previous recommendations from the Exploration Atmosphere Working Group in 2006 were to establish an internal, cabin environment that more closely matched the EVA environment without introducing new risks to the astronauts. The working group recommended using a lower pressure, oxygen-enriched environment of 8 psia and 32% oxygen (8/32) instead of the current Earth-normal environment of 14.7 psia and 21% oxygen on the ISS.

Operating at this lower pressure would decrease EVA preparation time by eliminating most of the oxygen prebreathe activities that are used to reduce the risk of decompression sickness, and would enable the use of a suitport that allows seamless transitions between the vehicle environment and spacesuit. Operating at a lower pressure and within acceptable fire risk means the crew will have less available oxygen, although this is not expected to be a significant risk. This hypoxic atmosphere is considered to be similar to that in Denver, Colorado. However, even at this level of lowered oxygen, there is a need to evaluate the potential physiological risks of adding another stressor to the spaceflight environment.

Because the 8/32 environment does not exist in nature, investigators evaluated human performance concerns associated with altitudes of 6,000 to 10,000 ft. Although this altitude will likely be well tolerated by astronauts, there were significant concerns about potential effects on the central nervous system, including increased intracranial pressure, visual impairment, sensorimotor dysfunction, and oxidative damage. Other concerns were acute altitude sickness, diminished exercise performance, food preparation difficulties, and ensuring quality sleep.

After consulting with experts in engineering, materials, and flammability, investigators were able to make the recommendation to adjust the 8/32 environment to 8.2 psia and 34% oxygen. Although this adjustment seems relatively small, it provides a 14% increase in lung oxygen levels and is expected to reduce the likelihood and consequences of most



of the major physiological concerns. Research is still needed to validate the use of the 8.2/34 environment for both short- and long-term spaceflight.

✦ BONE PORTFOLIO

Study Demonstrates Rapid Assessment of Bone Loss

Bone loss is a major health concern for humans living in the microgravity of space. Finding better ways to monitor bone loss is vital to the success of long-term space exploration missions, and also has significant applications for human health on Earth. Bone might seem unchanging, but it is living tissue that is continuously forming and eroding. In healthy, active people on Earth, these processes are in balance, so there is neither a net gain nor a net loss in bone density. This balance becomes disrupted during spaceflight because Earth's gravity is absent, and a net loss of bone density results.

Arizona State University scientists and NASA have developed a method to assess bone loss by analyzing the isotopes of calcium that are naturally present in urine. Isotopes are variants of an element that differ in their mass. This calcium isotope technique is based on the principle that when bones form, the lighter isotopes of calcium enter bone more readily than the heavier isotopes. Therefore, lighter calcium isotopes are released when bones erode—just as they are during spaceflight-induced bone loss.

Changes in the proportions of light and heavy calcium isotopes can be measured in urine. Subjects do not need to ingest any artificial tracers and are not exposed to any radiation; only a sample is needed.

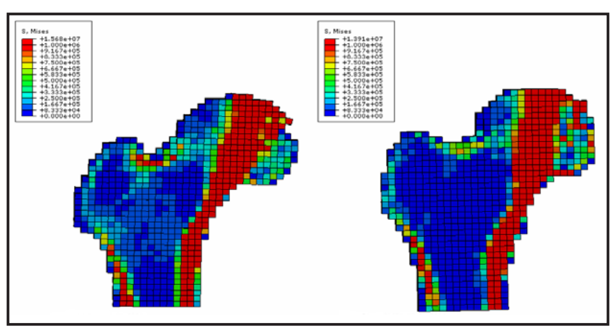
HRP funded a study to examine calcium isotopes in urine from 12 healthy subjects undergoing bed rest for 30 days. Bed rest is often used as an analog to study the effects of spaceflight, including bone loss, on Earth. The study revealed that this bone loss can be detected after as little as one week of bed rest—long before changes in bone density are detectable by conventional x-ray techniques. The isotope method also offers more accuracy than is possible with molecular markers of bone loss.

Although further research is needed, calcium isotope measurements seem poised to assume an important role in monitoring and detecting bone diseases—both in space and on Earth. The findings of this study were published in the journal *Proceedings of the National Academy of Sciences of the United States of America* and can be accessed at http://dx.doi.org/10.1073/pnas.1119587109. This study was also highlighted in the Editor's Choice section in the June 2012 edition of *Science*.

New Technology to Help Detect Early Onset of Osteoporosis in Crewmembers

In order for NASA to determine whether astronauts might develop osteoporosis at an earlier age than the average patient on Earth, investigators will need additional information to describe the skeletal effects of spaceflight on astronauts. With this new information, NASA can apply in-flight countermeasures to mitigate loss of hip strength and direct post-flight rehabilitation to enhance recovery—all to reduce the likelihood of bone fracture later in life.

Recently a panel of osteoporosis experts reviewed astronaut medical and research data, and advised



Finite element modeling can be used to calculate the force required to fracture the hip, based upon the QCT scan. The images represent control (left) and fracture cases (right).

NASA to monitor the hip bones of astronauts after spaceflight to see if any disruptions in bone structure are reversible by two years after return to Earth. If not, these disruptions could combine with changes related to aging and result in osteoporosis, which could cause premature fractures.

The Hip Quantitative Computed Tomography (QCT) study was approved for flight in FY2012 and will provide more information than previous studies and tests, which used dual-energy x-ray absorptiometry (DXA) to measure bone density in astronauts. DXA is currently the clinically accepted measurement to diagnose osteoporosis in the general public. However, in a previous NASA flight study, the DXA method did not detect changes in the structure of the hip bone that occurred during spaceflight, but the changes were accurately detected by QCT.

For the Hip QCT study, investigators will use QCT before and after a mission to detect any changes in hip bone structures resulting from spaceflight. Subjects will also be scanned at one year after flight, and if required, at two years, to monitor the reversibility of those changes. Additionally, data from the QCT scans will be used to generate mathematical models and perform finite element analysis to quantify the force that the hip can resist before fracturing. Recruitment of subjects for the study began in FY2012.

✦ TECHNOLOGY & INFRASTRUCTURE PORTFOLIO

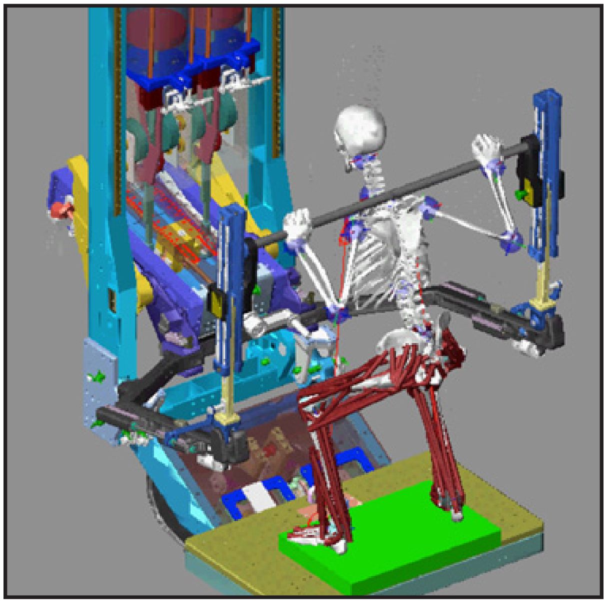
Integrated Computational Models of the ARED Device and Spaceflight Exercises

NASA uses exercise as a countermeasure against bone loss and muscle deconditioning associated with spaceflight. Enhancing countermeasure development by implementing well-validated computational models is one goal of the Digital Astronaut Project (DAP). DAP develops simulations of humans exercising with actual flight hardware or devices that are under consideration for exploration missions.

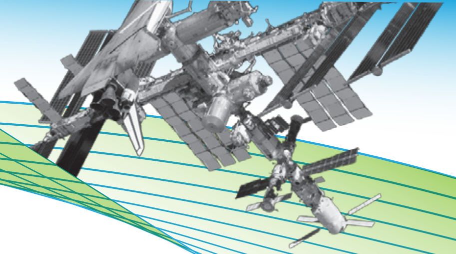
The goal of the simulations are to quantify the following: muscle forces generated when using the exercise device; chronic changes in performance associated with long-duration spaceflight; and bone loading associated with using these exercise devices. This performance data assists exercise scientists in optimizing both the hardware and the exercises themselves to preserve bone and muscle fitness during long-duration missions.

During FY2012, DAP created biomechanical models of subjects performing a normal squat, a one-legged squat, and a deadlift using the Advanced Resistive Exercise Device (ARED). The ARED is part of the ISS exercise system and is used as part of the crew's in-flight exercise regimen. Motion-capture data from subjects performing exercises on a ground-based version of the ARED was used to develop the models.

Additionally, engineers adapted the ARED design drawings to create a software model. DAP then integrated the deadlift and normal squat models with the ARED model to determine forces on the bone at the joints when subjects perform those exercises.



The DAP integrates models of hardware such as the ARED exercise device, with human biomechanical models to simulate performance and deliver data to exercise scientists.



Exploration Medical Capability Element

Overview

Human exploration of the Moon, Mars and other destinations beyond near-Earth orbit will present significant new challenges to crew health. During exploration missions, the crew will need medical capabilities to diagnose and treat injury or disease. Providing capabilities that overcome these challenges requires new health care systems, procedures, and technologies to ensure the safety and success of exploration missions.

The Exploration Medical Capabilities (ExMC) Element develops medical technologies for in-flight diagnosis and treatment as well as data systems to protect patients' private medical data, aid in the diagnosis of medical conditions, and act as repositories of information about relevant NASA life science experiments.

ExMC physicians and scientists develop models to quantify the probability of medical events occurring during a mission. They also define procedures to treat an ill or injured crewmember without access to an emergency room and with limited communications with ground-based personnel for consultation and diagnostic assistance. To read more about the Exploration Medical Capability Element, please visit: http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-exmc.html.

Working Group Refines Dental Concept of Operations for Long-Duration Missions

During long-duration exploration missions, timely evacuation to Earth may not be possible and therefore these missions demand careful planning for medical and dental care. In-flight dental events are a high priority and must be addressed by the onboard medical system, according to the Space Medicine Exploration Medical Conditions List—a document that prioritizes medical conditions most likely to be encountered during exploration missions.

Additionally, the Integrated Medical Model (IMM), a probabilistic risk assessment tool, predicts that dental emergencies will be one of the top five conditions having a negative impact on missions to near-Earth asteroids and to Mars. Dental emergencies may include cavities, filling and crown replacements, and tooth abscess or loss.

To address these dental concerns, a working group was gathered in May 2012 comprised of dental specialists, flight surgeons, astronauts, scientists, and engineers. This working group refined the dental concept of operations and the requirements for dental hardware and training. They recommended enhancements to ground training for crewmembers, including an intensive 2-day hands-on training course in an environment with high patient volume.

An astronaut practices tooth extraction on a model. Dental emergencies are considered one of the top five conditions having a negative impact on long-duration missions.

They also recommended that NASA use advanced screening technologies and additional tools such as longer-lasting dental cement. Future efforts will focus on acquiring necessary technologies for exploration dental care and integrating the dental system into the broader exploration medical system.

In-Flight Blood Analysis Technology for Astronaut Health Monitoring

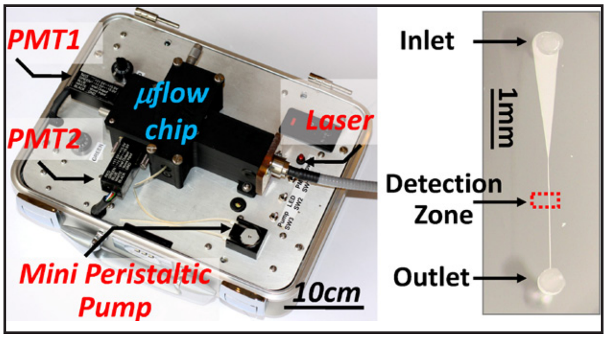
A blood count with white blood cell (WBC) differential is a single test that provides rapid diagnosis for medical conditions such as viral and bacterial infections as well as allergy and autoimmunity. Adding an in-flight blood count capability can address a current gap in monitoring astronauts' health status during spaceflight. ExMC funded the development of a prototype with the aim of providing a portable blood-count instrument that could perform this test.

The instrument was easy to operate and used a disposable microflow cartridge that enabled accurate testing with a minimal amount of sample. Three types of test—WBC count, lymphocyte subtype count and antibody assays, and red blood cell (RBC) and platelet count—were successfully performed with the device.

The WBC count test determines the total count of WBCs and the counts of five WBC subtypes—lymphocytes, monocytes, neutrophils, eosinophils, and basophils. The total WBC count is a rapid indicator of astronauts' general health status. The WBC subtype counts are indicators of more specific conditions. For example, the lymphocyte count is a quantitative indicator of radiation exposure. The dye assays developed for this test have a shelf life of greater than two years, which is optimal for long-duration space missions.

The lymphocyte subtype count and antibody assays provide a detailed evaluation of an astronaut's immune system and the immune disorders associated with spaceflight. This test was conducted on the instrument by using fluorophore-conjugated antibody assays.

The RBC and platelet count test provides a diagnosis of several conditions, including anemia and blood loss. This test uses either an antibody assay or a fluorescent dye assay.



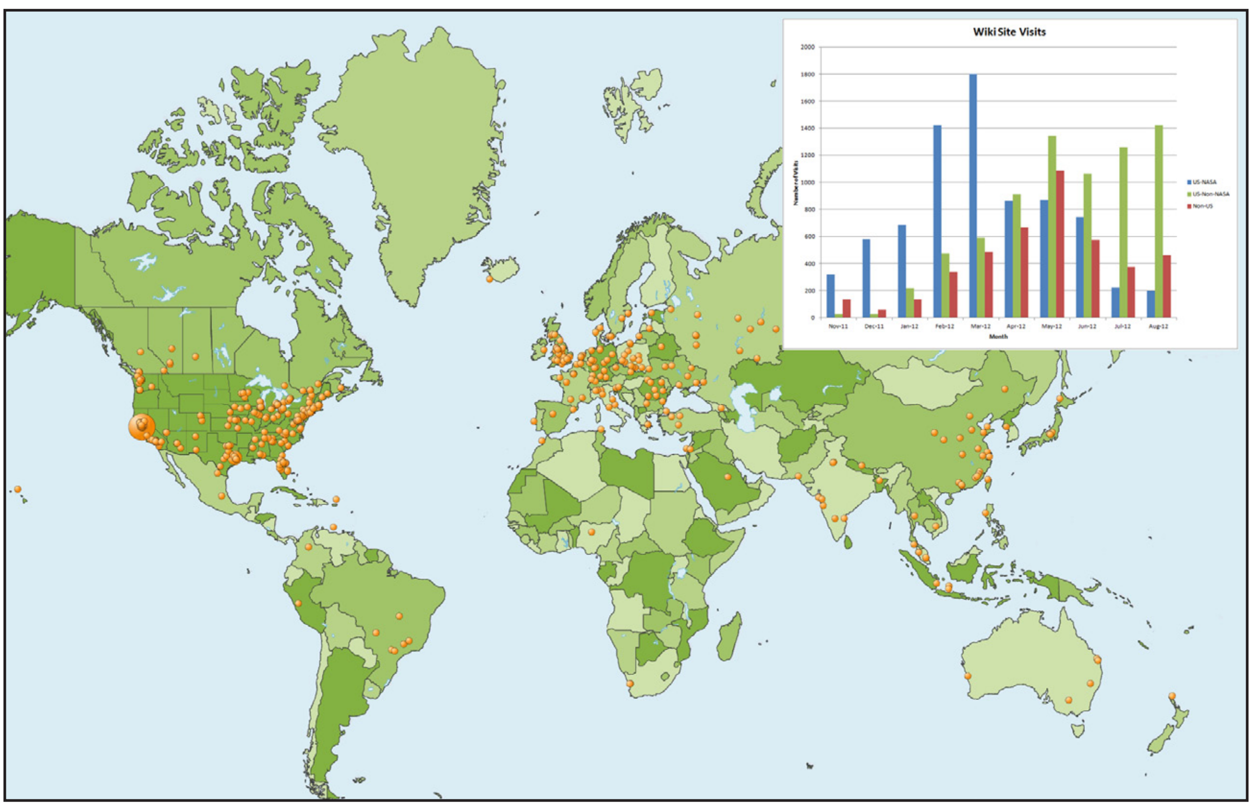
The prototype blood analysis platform provides a small, portable tool for performing fast WBC and RBC counts.

NASA Human Research Wiki Strives to Increase Collaboration Opportunities

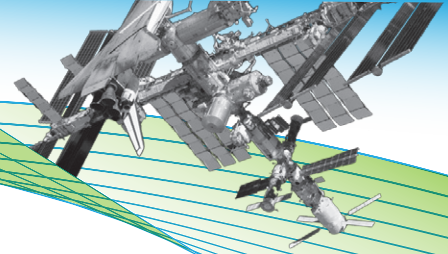
The ExMC has set up a collaborative website for authors, internal and external to NASA, to update and peer-review the evidence base for medical conditions that may occur during spaceflight. The NASA Human Research Wiki stores medical condition evidence and ExMC's gap reports, which identify knowledge or technology that would be needed for diagnosis and treatment of medical conditions. Each medical condition page has a link to the IMM database to retrieve a summary of incidence and outcome information for that condition.

The wiki includes a "read-only" section that is publicly available and a collaboration section that requires access privileges for editing. An editorial board has been established for final approval of the wiki content. Only information approved by this board is displayed in the public section. The wiki currently includes a subset of ExMC's evidence, but will continue to be populated as content is approved.

The NASA Human Research Wiki, accessed at http://humanresearchwiki.jsc.nasa.gov, is just one novel technique being investigated by the HRP to foster collaboration. The wiki continues to draw the attention of the public since its launch last year, and is currently receiving about 2,000 visits a month.



The NASA Human Research Wiki will disseminate ExMC medical evidence and increase collaboration opportunities with subject matter experts. The site attracts about 2,000 international visitors every month. The inset bar chart shows the monthly breakdown of NASA, non-NASA, and non-U.S. visits.



Space Human Factors and Habitability Element

Overview

The Space Human Factors and Habitability (SHFH) Element consists of three main research portfolios: Advanced Environmental Health (AEH), Advanced Food Technology (AFT), and Space Human Factors Engineering (SHFE).

The AEH portfolio focuses on understanding the risk of microbial contamination of the spacecraft and on the development of standards for exposure to potential toxins, such as lunar dust. This portfolio also proposes countermeasures to these risks by making recommendations that relate to requirements for environmental quality, foods, and crew health on spacecraft and space missions.

The AFT portfolio focuses on reducing the mass, volume, and waste of the entire integrated food system to be used in exploration missions, while investigating processing methods to extend the shelf life of food items up to five years. The portfolio also delivers improvements in both the food itself and the technologies for storing and preparing it.

The SHFE portfolio establishes human factors standards and guidelines for interaction of the human system with hardware, software, procedures, and the spacecraft environment. Humans interact with these other entities through "interfaces" such as workstations. SHFE provides validated human models for predicting the effects of interface designs on human performance, methods for measuring performance of humans and the human-system combination, and improved design concepts for advanced crew interfaces and habitability systems. SHFE also facilitates development of tools, metrics, and methodologies for use in implementation, assessment, and validation of standards and requirements. To learn more about SHFH, please visit the public website at: http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-shfh.html

ADVANCED ENVIRONMENTAL HEALTH

The AEH portfolio focuses on the definition and investigation of environmental risks that can adversely affect the safety, health, and performance of the crew, and on technology and activities to mitigate those risks. Specifically, AEH research leads to requirements that influence vehicle design, payload design, flight operations, and food and water quality. Additionally, AEH research incorporates investigations that could directly influence those requirements, including environmental monitoring and remediation techniques.

Current AEH tasks include the establishment of permissible exposure limits (PEL) for lunar dust, investigation of changes in antibiotic sensitivity of microorganisms in response to growth during spaceflight, and changes in the bacteria on and in crewmembers during a mission. Additionally, AEH investigates new microbiological requirements that enable the incorporation of new, advanced monitoring technologies.

Forums to Develop Next-Generation Microbiological Requirements

To decrease the risk to crew health associated with microbial contamination, requirements are developed and imposed on vehicle design and operations. The effectiveness of these requirements is traditionally evaluated by microbiological monitoring, which can occur before, during, or after flight, depending on the type of mission. Current requirements are based on culture-based methodology in which microorganisms are grown on a growth medium and colonies are counted. Use of this technology during spaceflight requires large amounts of crew time and consumables with a short shelf life. Subsequent identification of the organisms requires specialized labor and large equipment, so it has historically been performed on Earth.

For missions beyond low Earth orbit, adequate resources may not be available to use the current methodology. During FY2012, AEH held a series of forums in which microbiology experts reviewed ISS microbial data and recent breakthroughs in technology to provide recommendations for updated requirements. These recommendations include novel vehicle concepts; changes to mission operations; and approaches that use alternative monitoring technologies, such as DNA-based technology, which could lead to smaller, more efficient hardware.

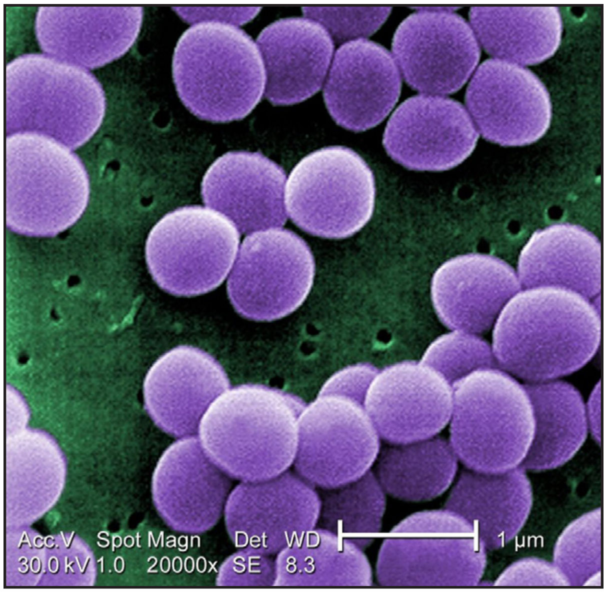
An astronaut collects a potable water sample from the ISS galley in preparation for microbiological monitoring to determine water quality.

The first two forums, discussing microbiological requirements for potable water and spaceflight foods, were completed in FY2012, and the findings are already being used to update current ISS requirements and help in the development of new monitoring hardware. A final forum, which will cover microbiological requirements for spacecraft air and surfaces in the habitable volume, will be held in the spring of 2013. A final comprehensive report compiling recommendations from all forums will be available in the fall of 2013.

Investigations to Understand Changes to the Crew Microbiome

The human body provides a home to trillions of microorganisms. Although they are often thought of in a negative way, many microorganisms are beneficial to their human host by helping the digestive process, providing vitamin K, enhancing the immune system, and shielding against infections. These microbial cells and their genes are called the human microbiome. Understanding how the microbiome changes during spaceflight may provide information that indicates alterations in a crewmember's immune system, the prevalence of beneficial microorganisms, and any increases in the abundance of potentially pathogenic microorganisms. Any of these factors could indicate a greater risk of infectious disease during a mission.

Changes in a spaceflight crewmember's microbiome would not be surprising—crewmembers live in a



Staphylococcus aureus is a bacterium that is often found in the human microbiome and can cause dangerous infections.

stressful, confined environment. Several experiments have demonstrated that aspects of astronauts' immune systems are not functioning as expected. In addition, previous spaceflight experiments have shown that growing, or culturing, microbes during spaceflight can alter their characteristics, including virulence and gene expression.

To better understand the crew microbiome, AEH initiated a new spaceflight experiment led by a renown genomic research firm to characterize the changes occurring in the bacterial and viral microbiome of astronauts. The study focuses on samples collected from specific body sites before, during, and after missions. Fecal samples from the crew will also be evaluated to determine whether changes are occurring in the gastrointestinal (GI) tract. In addition, assays determining alterations in cytokine production and activation of latent viruses will be performed to determine whether changes that correspond to those in the GI tract are occurring in the immune system. Hardware development has been completed and crew selection has begun.

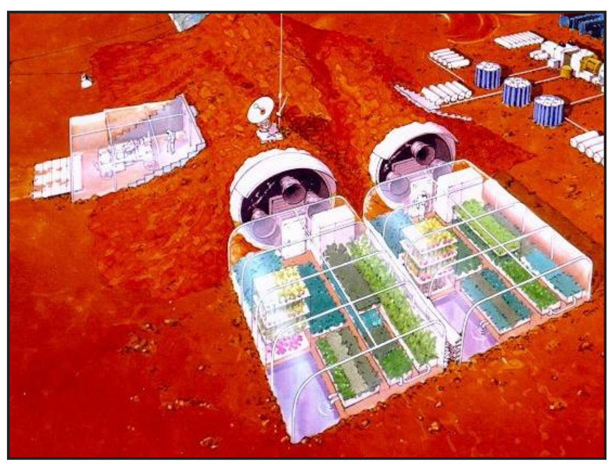
ADVANCED FOOD TECHNOLOGY

The AFT portfolio is responsible for providing crews with a food system that will enable productive human space exploration. The food system must be safe, nutritious, and acceptable to the crew, while efficiently balancing appropriate vehicle resources such as mass, volume, waste, and food preparation time for exploration missions. For exploration missions such as trips to Mars, these requirements necessitate the provisioning of a packaged food system with a shelf life of three to five years. Current ISS food system technologies cannot meet these requirements.

The importance of the food system on a long-duration manned exploration mission should not be underestimated. Food not only provides the nutrients needed for the survival of the astronauts, but also enhances the psychological well-being of the crew by being a familiar element in an unfamiliar and hostile environment.

Study Indicates Mix of Pre-Packaged and Grown Foods is Preferred for Mars

A key habitability question for Mars mission planners is whether to: (1) send prepackaged food provi-



The processing trade study showed that a food system dependent on crops and supplemented with pre-packaged meats offered the best resource utilization for food processing for a crew of six on a 600-day Martian habitat mission.

sions with the crew; (2) grow food plants as part of a bioregenerative, closed environmental system; (3) use a combination of plants and pre-packaged food. During FY2012, the Processing Trade Study devoted to answering that question was completed.

Five food systems were considered. For a 600-day mission on which a crew of six would live in a habitat on a planetary surface, a food system based on greenhouse crop ingredients and supplemented with prepackaged, stabilized meats and dry spices resulted in the lowest resource use by the food-processing subsystem. This food system had both the second-lowest mass and volume shipped, but was third in active crew time.

The advantage of this food system was the low mass of ingredients—relative to a prepackaged food system—and the amount of crew time required that was less than the solely crop-based food systems. The rating of the potential physiological and psychological impacts of the food system such as nutrition, variety, and palatability, did not result in very different food quality index values. Therefore, that rating had negligible impact on the final trade study results.

The results indicated that a food system focused on

Future crew members may spend more time cooking their food, according to the latest research. A recent study determined that a mix of both grown and prepackaged foods is optimal for possible missions to Mars.

minimizing food stowage, with allowance for pre-packaged meat products and minor dry ingredients, is preferred. However, the combination of this data with the resource-utilization calculations for other subsystems, such as biomass production, greenhouse operations, and water, will present the most accurate view of the food-processing cost to mission planners. Future study is needed in galley sanitation, optimization of galley design and cooking operations, and recipe optimization.

Development of Meal Replacement Bars to Reduce Overall Mass of Packaged Food

In an effort to optimize resources, AFT researchers are identifying meal replacement options that would decrease the mass and volume of the food system, as well as decrease the amount of time needed for preparation. Previous work has addressed the need to decrease the mass of the food system and has made recommendations such as reducing the moisture of some of the food items, increasing the nutrient density of the food system, and optimizing food packaging systems.

Two meals—breakfast and lunch—and four categories of food have been assessed for potential replacement. Proposed substitutes include bars and beverages formulated to deliver nutrients equivalent to an average meal on the standard 10-day menu. The categories may be replaced with a bar, beverage, or denser snack alternative.

Thus far, two types of breakfast meal replacement bars have been developed: a Chocolate Peanut Butter bar and a Pumpkin Spice bar. The masses of these bars were 46% and 35%, respectively, lower than the mass of an average breakfast meal, and the bars have been estimated to be nutritionally equivalent. Informal acceptance testing results have shown that, although these bars are palatable, additional work is needed to improve their texture to reduce crumbing.

Future work includes developing beverages for

A researcher prepares chocolate peanut butter bars. These lightweight prototypes are designed for periodic meal substitution on orbit.

breakfast and lunch replacement and identifying or creating substitutions for categories of foods. Formal sensory evaluations and accelerated shelf life testing will be conducted on the final prototypes and substitutions. Mass and cost savings will be calculated to provide an assessment and implementation plan. The study is on track to be completed by 2014.

Forum on Next Generation Microbiological Food Requirements for Spaceflight

The Forum on Next Generation Microbiological Food Requirements for Spaceflight, a collaboration between AEH, AFT, the Space Food Systems Laboratory, and the Microbiology Laboratory, convened a panel of food microbiology experts from academia, government, and industry with two main objectives.

The first objective was to review the current spaceflight protocol, "Microbiological Specification and Testing Procedures for Foods Which Are Not Commercially Sterile." These specifications are maintained to mitigate the risk of foodborne illness in the prepackaged food system, taking into account current food concerns and testing procedures. The panel made 21 recommendations to the specifications, generalized by food category to reflect current industry practices and improve testing sensitivity.

The second objective was to identify testing procedures, risks, and mitigation strategies for next-generation food systems that may include growing and harvesting produce and the inclusion of probiotic bacteria. The panel made 13 recommendations, which included conducting formal risk assessments on all potential food systems for long-duration missions, expanding research into microbiological risks of a bioregenerative system, and investigating new processing technologies. The panel also suggested that probiotics should be provided to the crew, and possible methods for delivery should be investigated.

A report including these recommendations was submitted to the HRP, and discussions are underway on implementing changes to the current prepackaged food system and conducting research and development of next-generation microbiological procedures.

The panel recommended research into (A) the microbial risks of a bioregenerative system; and (B) the inclusion of shelf stable probiotic foods, such as probiotic chocolate.

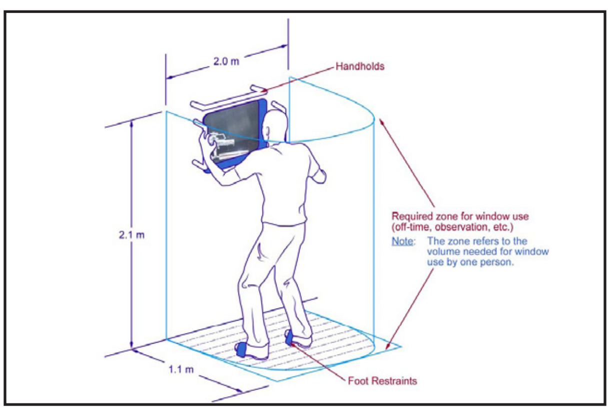
✦ SPACE HUMAN FACTORS ENGINEERING

The SHFE portfolio provides critical answers for the design of the next generation of NASA spaceflight systems. To ensure that humans can perform long-duration missions safely, efficiently, and effectively, SHFE scientists and engineers conduct research and exploratory studies in a variety of settings, from the laboratory to analog environments to spaceflight. They also collect the information needed to verify that a crew's work environment, tools, and system interfaces will support their capabilities and task needs. In a variety of domains, the SHFE team works closely with experts in design and space operations to ensure appropriate and timely solutions to the issues of integrating humans and systems.

Biennial Technical Update of the Human Integration Design Handbook (HIDH)

NASA establishes formal human factor standards for the effective design of spacecraft and habitats. Collectively, these standards are known as the NASA-STD-3001 Space Flight Human-System Standard and are provided in two volumes; Volume 1 covers crew health and Volume 2 defines the habitability and environmental standards.

The Human Integration Design Handbook (HIDH) is a companion document to Volume 2, and contains human-system integration data and lessons learned from previous human spaceflight programs. It is intended to aid interpretation of the requirements in Volume 2, and to provide guidance for vehicle and habitat designers.



The HIDH provides design and background information from research and operational lessons learned. It contains guidance such as the required space for window use and adequate handrail support in a habitat.

During FY2012, the first year of planned biennial updates to the HIDH began. The intent of the update was to add new research findings and information obtained from operations since the HIDH was baselined in 2010. The updates were provided, reviewed, and concurred upon by a team of technical experts—ensuring the content was accurate and of the highest quality.

Significant changes include: the addition of a chapter on vibration, as it relates to human health and performance; updated information on physical and cognitive workload; acoustic noise control planning; occupant protection design; exercise countermeasures; and lighting, habitable volume, and crew interface design.

The revision is expected to be available in early 2013. NASA-STD-3001, Volumes 1 and 2, and the HIDH are publically available documents, and can be found at the following link: http://www.nasa.gov/centers/johnson/slsd/about/divisions/hefd/standards/index.html

Demonstration of Modeling Tool to Evaluate Possible Use of Robotics to Aid Crew

The Man-Machine Integration Design and Analysis System Function Allocation Support Tool (MIDAS –FAST) was developed for the SHFE Portfolio as part of a NASA grant. The tool helps answer the following question: For future space missions, how can partial automation of a robotic arm best help the human operator perform a task?

The tool allows researchers at NASA to compare different robotic systems in terms of their predicted effects on operator and system performance. MIDAS-FAST accepts data about the proposed robotic system, identifying how it implements automation and its reliability. The tool then evaluates particular aspects of operator performance such as focus of visual attention, disorientation, and performance decrements due to poor camera views and control-response incompatibilities. It then provides feedback on predicted operator performance measures such as time to complete tasks, errors made, workload, and situation awareness. Analysts can use the results to compare robotic systems with respect to their predicted effects on performance.

Predictions of the model are being evaluated and refined using data collected during human-in-the-loop studies, including time to complete tasks, errors made, and participant eye movements and fixations. The experiment data is being compared with the MIDAS-FAST model to determine if the model accurately predicts operator performance.

When delivered in FY2013, MIDAS-FAST will be available to NASA researchers and designers for evaluating future robotics for human spaceflight.

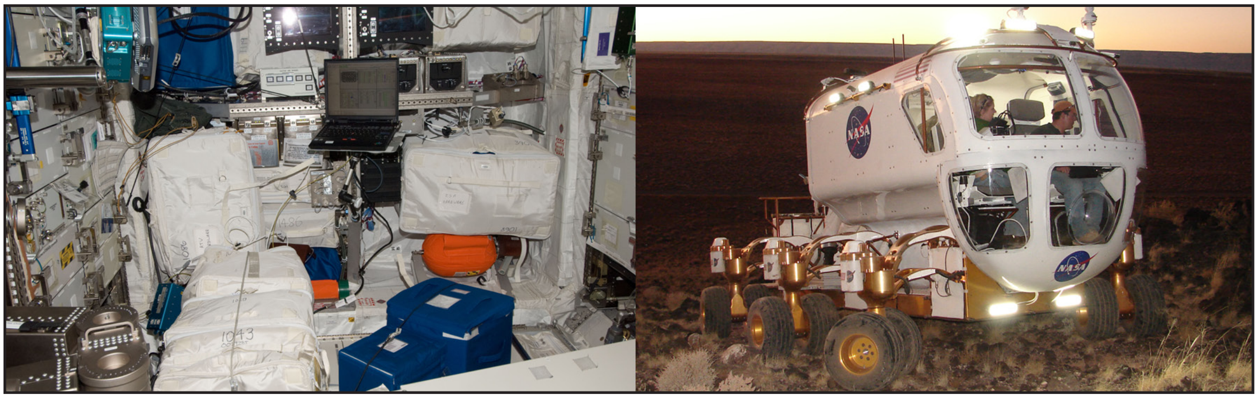
Second Net Habitable Volume (NHV) Workshop for Long-Duration Spaceflight

How big does a spaceship going to Mars need to be? Does its size depend mainly on the number of people inside or how long the journey is? These are some of the questions addressed during the second Net Habitable Volume (NHV) Workshop, held in Houston, Texas in July 2012.

NHV is defined as the functional volume that is accessible to astronauts for living and working. The goal of the workshop was to identify products that could assist designers in determining the minimal NHV of a habitat, and designing and evaluating internal habitat layouts for long-duration space missions. The workshop included experts from the oil and gas industry, the American Bureau of Shipping, the U.S. Navy, the National Institute for Occupational Safety and Health, and NASA.

The main activity during the workshop was the review and revision of a set of draft products for measuring the impact of psychological and human factors on NHV and internal layout. The products developed included a list of behavioral stressors developed during the first NHV workshop; a standardized task list for long-duration missions; a consolidated list of measurements and methods used in previous human factors studies; and a process flow for evaluating the volume of a habitat or vehicle.

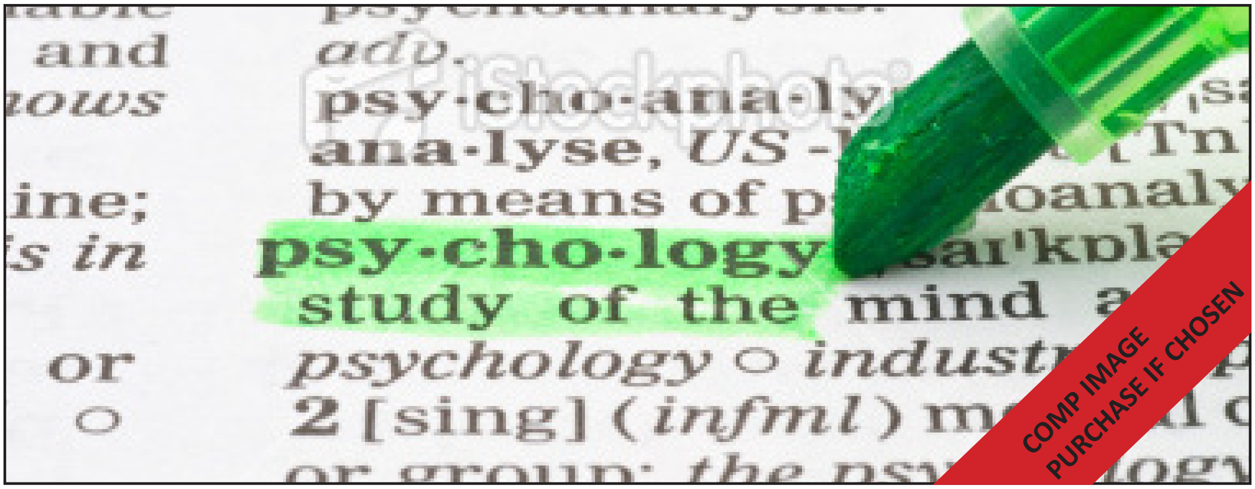
These products will be finalized and published in early FY2013, and will assist in guiding future vehicle and habitat design standards for long-duration missions. An additional outcome of the workshop was a list of NHV-related research topics that should be pursued before long-duration spaceflight begins.



The Net Habitability Volume (NHV) Workshop brings together habitability experts to discuss challenges such as stowage (left). Future smaller vehicles pose even greater NHV challenges, such as the prototype Surface Exploration Vehicle (right).

SHFH

Behavioral Health and Performance Element



Overview

The Behavioral Health and Performance (BHP) Element conducts and supports research to reduce the risk of behavioral and psychiatric conditions. These include performance decrements due to inadequate cooperation and communication within a team and the risk of errors due to fatigue resulting from sleep loss or work overload.

Long-duration missions, beyond low Earth orbit, will require crews to adapt to increasingly autonomous operations in isolated, confined, and extreme environments. Crews are faced with other challenges such as long periods of heavy workload, separation from home, and altered day-night/light cycles. Microgravity, carbon dioxide, and radiation are other factors that may also lead to debilitating neurobehavioral and performance outcomes.

BHP's strategy for addressing its risk reduction research is derived in a systematic manner and driven by operations. Spaceflight analogs and other research environments are carefully assessed to ensure that the individual, team, environment, and mission characteristics fit the research question at hand. To address these concerns, BHP categorizes research into three areas: Behavioral Medicine, Team Risk, and Sleep Risks. The Behavioral Medicine Risk area aims to develop self-assessment tools for early detection and treatment that use unobtrusive and objective measures of mood, cognitive function, and other behavioral reactions to living and working in space. The Team Risk area examines team performance and other team-related outcomes, including crew cohesion and communication, to develop tools and technologies that monitor teams throughout autonomous operations. The Sleep Risk area focuses on countermeasure development, including lighting protocols, medication recommendations, education, and tools that optimize work-rest schedules.

The end result is to provide technologies and tools that will optimize the adaptation of the individual and crew to the space environment, and maintain motivation, cohesion, communication, morale, well-being, and productivity.

To read more about the Behavioral Health and Performance Element, please visit: http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-bhp.html.

Sleep-Wake Actigraphy Study Assessed Crew Sleep for Long-Duration Missions

BHP is making progress in characterizing a major risk factor for spaceflight missions—sleep disruption. Recently, findings from a NASA-funded research study titled "Sleep-Wake Actigraphy Study – Risk

An ISS crewmember enters data for the Sleep-Wake Actigraphy Study. She is wearing (left wrist) an ActiWatch which records movement and is useful in studying sleep.

Characterization and Monitoring Tools for Spaceflight Environments of Shuttle and ISS," were submitted to BHP. The study was completed by world-renowned researchers in the field of sleep medicine from Harvard Medical School and the Brigham and Women's Hospital. This study addresses multiple gaps in both BHP risks and risks related to other Elements in the Human Research Program.

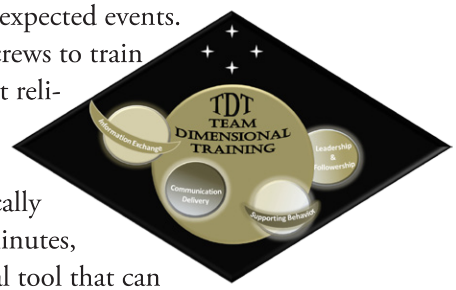
This investigation was the largest study of sleep in spaceflight for both short- and long-duration missions. Data was collected from 21 crewmembers on long-duration ISS missions throughout a total of 3,201 ISS in-flight days. Data was also collected from 64 short-duration astronauts encompassing 26 shuttle (STS) flights and 1,066 STS in-flight days. Results indicated that astronauts obtain insufficient sleep during both STS and ISS missions. Furthermore, findings suggest that astronauts face significant chronic sleep debt, even three months before launch, and that their sleep restriction is sustained throughout spaceflight even when they use sleep-promoting medications.

Previous ground-based research indicates that chronic sleep loss, similar to that observed in the current study, decreases performance. These findings highlight the need for effective countermeasures to promote sleep and thereby enhance wakefulness during flight. The results of this study have informed both the research and operations communities and generated interest in transitioning these procedures from research to spaceflight operations.

Flight Controllers Participate in Team Dimensional Training as Baseline Group

Team Dimensional Training (TDT) is a method of guiding teams through a process of self-correction after a simulated or actual performance event. In previous studies with U.S. Navy submarine crews, the TDT debrief method significantly reduced team errors relative to those occurring after a more traditional instructor-led debrief. Five instructional components contribute uniquely to this outcome. First, the discussion is organized around a model of effective teamwork. Second, a balanced amount of time is spent reviewing positive and negative performance. Third, a facilitator helps to maintain a positive learning climate. Fourth, team members contribute unique insights and observations. And finally, the goals for improvement are process-oriented rather than outcome-oriented.

The TDT method is uniquely suited for long-duration missions for multiple reasons. The process is not specific to a particular type of task or performance event; therefore, crews can use TDT to learn and adapt after unexpected events. It can be used by crews to train themselves without reliance on assistance from others. A TDT debrief typically lasts only 30-40 minutes, thus it is a practical tool that can be built into a crew's schedule to promote continuous learning. Finally, TDT has been used to debrief



distributed teams that are part of a multi-team system. Therefore, coordination between ground flight controllers and long-duration crewmembers can be facilitated using the same strategy.

In FY2012, flight directors at Johnson Space Center were trained to use TDT methods for multi-team simulation exercises. To date, 13 flight controllers have participated as a "baseline" group that will be compared to an "experimental" group. Researchers are expecting to show that the benefits of using TDT extend to individual learning by accelerating the rate at which flight controllers certify for a position within Mission Control.

This study serves as an operational analog for testing and validating the TDT debrief protocol, which may lead to adoption by JSC's Mission Operations Directorate and Astronaut Office for use in long duration exploration-class missions and ISS missions, if appropriate.

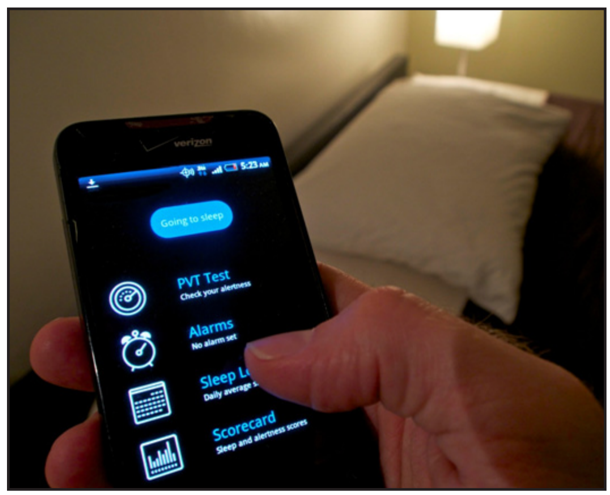
Tool Helps Measure Fatigue of Astronauts in Space and Truck Drivers on Earth

Scientists supported by NASA and the NSBRI, and led by a prominent principal investigator from the University of Pennsylvania, have developed a rapid, reliable test, called the Brief Psychomotor Vigilance Test (PVT), that objectively measures processes involving alertness, vigilance, and reaction time.

The Brief PVT was developed and tested extensively in mission analog settings, including four NASA Extreme Environment Mission Operations (NEEMO) missions in an undersea laboratory, at the Haughton Impact Crater in the high Arctic, and in the Russian Mars 520-Day Mission Simulation. Currently, it is in use by the ISS crew to evaluate the effects of fatigue and common stressors such as long duty hours, chronically restricted sleep, and shifts in sleep and work schedules.

With the support of the NSBRI Industry Forum, Pulsar Informatics, Inc. has adapted this technology originally developed for space missions to help improve safety on U.S. highways by objectively measuring fatigue in truck drivers. In 2011, Pulsar Informatics received an NSBRI Space Medicine and Related Technologies Commercialization Assistance Program grant to develop a smartphone application, based on the Brief PVT, that will be used to assess fatigue in long-haul commercial truck drivers. Pulsar has partnered with an industry-leading company in trucking safety, to field-test the technology as part of a Department of Transportation funded study.

Pulsar Informatics has made a demonstration version of the NSBRI-sponsored app called SleepFIT available as a free download on the Android Marketplace,



A demonstration version of the SleepFIT app is available as a free download for Android phones. The app allows users to monitor their alertness and understand how sleep patterns affect performance.

enabling anyone with an Android phone to monitor their alertness and understand how their sleep patterns affect their performance.
https://play.google.com/store/apps/details?id=com.pulsarinformatics.SleepFit

Flight Analogs

Overview

Before new technologies are tested during flight, they are developed and refined using ground-based studies and flight analog environments. An analog is a scenario or environment with similar characteristics to the spaceflight environment. Example analog environments include head-down-tilt bed rest, undersea habitats, and Antarctic outposts.

The Flight Analogs Project assists HRP researchers by characterizing current and potential analogs, evaluating their relevance and similarity to spaceflight conditions, and matching the characteristics of analogs to requirements for research. The Project maintains an Analog Implementation Plan that matches investigators in the HRP Integrated Research Plan to a potential analog mission over a 5-year window. This 5-year plan is updated as analog missions are identified and utilized across NASA.

Ground-based analogs utilized during FY2012 included a NASA Extreme Environment Mission Operations (NEEMO) mission at the National Oceanic and Atmospheric Administration's Aquarius facility in Florida, research stations, and expeditions in Antarctica.

Analog Characteristics	FARU - UTMB	NEEMO	Devon Island / HMP	Antarctica	Desert RATS	Human Related Chamber Complex
Environment/Terrain External to Habitat						
Desert (may include Arctic desert)			●	●	●	
Island			●			
Ice sheet				●		
Sub-ocean		●				
Other	●					●
Extreme Environment Features						
Hypoxia						●
Hyperbaric						●
Atypical day length			●	●		
High humidity		●				
High temperature					●	
Low temperature			●	●	●	●
Characteristics						
Confinement within habitat	●			●		●
Crew hierarchy (Commander, etc.)		●				
Microgravity simulation (0g)	●	●				
Lunar gravity simulation (1/6g)	●	●				
Mars gravity simulation (3/8g)		●				
Difficult or limited logistics		●	●	●		
Isolation from outside world		●	●	●		●
Limited local infrastructure		●	●		●	
Remote communications			●	●		●
Autonomous operations		●	●	●		●
Autonomous care or "telemedicine"		●	●	●		
Moon/Mars field or EVA activities		●	●		●	
Lunar surface simulation			●		●	
Martian surface simulation			●		●	

NASA bed rest studies are conducted at the Flight Analogs Research Unit (FARU), a dedicated facility located at the University of Texas Medical Branch (UTMB). In FY2012, NASA conducted two integrated bed rest campaigns.

Two New HRP-Sponsored Studies Evaluated During NEEMO 16 Mission

NEEMO mission 16 was conducted June 11-22, 2012, with a crew of four aquanauts representing NASA, the Japanese Aerospace Exploration Agency, the European Space Agency, and Cornell University. During the mission, two HRP investigations were conducted. One investigation, sponsored by the HRP Space Human Factors and Habitability (SHFH) Element, evaluated real-time crew input and human factors and habitability data collected by video cameras. The second investigation, which was conducted by the HRP Behavioral Health and Performance (BHP) Element, examined how interdependent teams interact and perform when delays occur in communication between mission control personnel and crewmembers.

The SHFH team asked NEEMO 16 crewmembers to evaluate potential tools and methods for reporting near-real-time observations about habitability and human factors issues in their environment. The crewmembers used an iOS-based Space Habitability Observation Reporting Tool (iSHORT) on an iPad to submit media-enhanced reports about issues

In addition to the typical textual-based reports, the iSHORT app (above) allows the user to record video and still photos to help document habitability concerns. The iSHORT tool running on an iPad was assessed during NEEMO 16.

affecting their performance and comfort during the mission. Crewmembers also used small head-worn video cameras to give walk-through tours of the habitat and to capture commentary while they performed certain tasks. Researchers evaluated the iSHORT reports and videos from crewmembers to determine whether these tools and methods have potential as a means to capture valuable information about habitability during future spaceflight operations. In light of the quality of data gathered using iSHORT and the positive feedback from study participants, the SHFH team plans to transition iSHORT to flight operations on the International Space Station.

The NEEMO 16 Crew gathers in front of the hatch to the Aquarius undersea laboratory on June 11, 2012 for the start of the NEEMO 16 mission.

The BHP team examined the impact of communication delays on individual and team performance. Four NEEMO habitat crewmembers and three

A NEEMO participant adjusts his over-the-ear camera in preparation for a walk-through tour of the Aquarius habitat.

NEEMO mission control personnel completed three highly critical and unfamiliar tasks, one with no delay in communication between the habitat and mission control, one with a 5-minute delay, and one with a 10-minute delay. These delays represented intervals that will occur during a mission to Mars or to a near-Earth object.

The NEEMO crew also participated in a simulated emergency scenario under the various communication-delay conditions. Results from this study will help structure an upcoming study to examine the impact of communication delays on performance and crew well-being in the environment of low Earth orbit, using the ISS as a Mars transit analog.

Bed Rest Campaign 17 to Assess the Effectiveness of Compression Garments to Prevent Orthostatic Intolerance

Campaign 17 used the 6-degree, head-down tilt bed rest model to simulate cardiovascular changes that occur during spaceflight. One of these changes is reduction in the volume of blood plasma in the body, which can lead to orthostatic intolerance, or lightheadedness and fainting. The study tested whether a three-piece, custom-fit compression garment prevented orthostatic intolerance after 14 days of bed rest. In addition, a schedule for progressive removal of this garment was studied to facilitate re-adaptation to a vertical posture after bed rest.

A total of 16 subjects were divided into two groups for the campaign. The first group, a control group, wore the chest-high garment for a portion of the day that they got up from bed (BR+0). The garment was removed after testing and the subject completed the re-adaptation process without compression garments. A second group, the experimental group, wore the chest-high garment for the entire first day out of bed and wore thigh-high garments for the next three days—thus gradually reducing compression over multiple days.

Results of this study indicated that wearing compression garments on BR+0 alleviated orthostatic intolerance. Garments may be used on subsequent days when needed to assist with re-adaptation. Due to the positive results in this campaign, they will be tested in an upcoming flight study to assess their usefulness in re-adaptation to gravity.

In addition to the compression garment study, a investigation of ocular health was conducted during this campaign. Recent findings of changes in astronauts' vision as a result of spaceflight prompted ocular monitoring of bed rest subjects. A suite of vi-

An Optical Coherence Tomography (OCT) scan is performed on a subject during Campaign 17 to determine if bed rest is a relevant analog for vision studies.

Bed rest studies provide a ground-based analog for investigations on the physiological effects of microgravity. Campaign 11 subjects were confined to bed for 70 consecutive days of 6-degree, head-down tilt bed rest.

sion tests were used to confirm that 6-degree, head-down tilt bed rest did not produce negative effects. This data will be used to further characterize the bed rest model as a ground-based analog for future vision studies.

Bed Rest Campaign 11 Studied Exercise and Testosterone as Countermeasures

Campaign 11 is an ongoing study and examines the effects of 70 days of 6-degree, head-down tilt bed rest on physical function as well as countermeasures to these effects. Four investigations are integrated in this study complement. One study identified the key physiological factors that contribute to changes in performance by using a set of functional task tests that are representative of critical mission tasks for planetary operations.

A second study examined the ability of an integrated resistive and aerobic training (iRAT) program to mitigate the negative effects of long-duration head-down tilt bed rest.

A third study expanded upon the iRAT program by introducing a dose of testosterone to enhance the effectiveness of exercise in preserving muscle and bone structure during long-duration bed rest.

Results of these studies will help researchers to optimize exercise countermeasures—with or without testosterone supplementation—and determine their effects on both physical and physiologic functioning after long-duration bed rest.

A fourth study reviewed the relationship between smell acuity and nasal congestion that result from 6-degree, head-down tilt bed rest and how it affects food acceptability and menu boredom.

Overview

The Human Research Program supports a number of education and outreach initiatives across multiple HRP Elements and NASA centers. The HRP Education and Outreach (HRPEO) Project is committed to using NASA's expertise in space research and exploration to assist K–12 educators in science, technology, engineering, and mathematics (STEM). Additionally, the HRP Elements help support other outreach initiatives including research internships, post-doctoral programs, and summer institutes for interns.

HRP Education and Outreach Project

The HRPEO had a successful year of content development, educator professional development, outreach, and collaboration with new and established professional partners. In FY2012, a Space Act Agreement (SAA) was signed with Laying the Foundation (LTF). LTF equips teachers with resources to prepare students for Advanced Placement-level coursework and coursework for students preparing to enter fields related to science, technology, engineering, and mathematics. The partnership highlights HRPEO education content in teacher training, classroom-ready materials, and web-based resources to improve the quality of math and science instruction in middle and high schools.

Educational content development in FY2012 included collaboration with Special Olympics and The Resource Center of Jamestown, NY. The goal was to modify activities and materials from the Train Like an Astronaut (TLA) program to make them useful to those with disabilities.

The Exploring Space Through Math & Science (ESTM/S), Math and Science @Work (MS@W), and 21st Century Explorer (21C) projects teamed with Texas Instruments (TI) to design, develop, and beta-test new educational content as part of an SAA that was renewed in 2012. Content was released on the NASA website, and TI tracked over 28,000 downloads on their website. HRPEO conducted workshops covering initiatives for the ESTM/S, MS@W, TLA, and Mission X projects, and received positive feedback from participants.

HRPEO is currently working to refresh the 21C elementary activities with a redesign of the website, and new middle school content is under development. Also, a radiation iBook pilot project, in collaboration with Ames Research Center and Marshall Space Flight Center, will be completed by FY2013.

The HRPEO has further developed the Displays and Demonstrations Outreach projects, which are composed of hands-on, interactive hardware displays, backdrops, static displays, videos, and lithographs.

Science teachers are often looking for new and engaging in-class activities. HRPEO is working with LTF to provide STEM focused pre-AP activities.

The 9th annual NASA Space Radiation Summer School participants stand outside the NSRL at Brookhaven in Long Island, New York.

Each display includes processes and instructions for training other HRP groups to manage the displays and expand the HRPEO Research to Outreach objectives.

To learn more about HRPEO please visit: http://www.nasa.gov/exploration/humanresearch/education.

9TH Annual NASA Space Radiation Summer School

The Space Radiation Element, in support of developing the next generation of radiobiology researchers interested in space, selected 17 students from more than 50 applicants to attend the 9th annual NASA Space Radiation Summer School held at Brookhaven National Laboratory in June 2012. Participants included domestic and foreign graduate students and postdoctoral fellows, as well as faculty in biology and physics.

The integrated curriculum of radiation biology, radiation chemistry, and physics culminated in hands-on, accelerator-based experiments. More than 30 faculty members in biology and physics from leading universities and national laboratories, many of whom are actively engaged in NASA space radiation research, lectured on their areas of expertise.

Students Evaluate Ease-of-Use for Tablet Computing in Microgravity

A Space Human Factors Engineering (SHFE) team worked with undergraduate students from the University of Illinois at Urbana/Champagne as part of the Systems Engineering Educational Discovery (SEED) Program. This program, sponsored by NASA's Microgravity University Program, allows NASA researchers to identify projects of interest to be paired with student research teams.

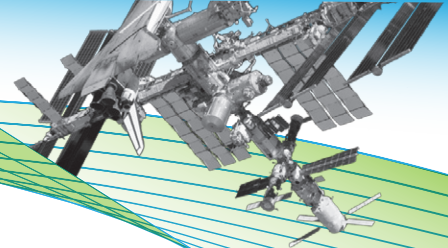
The SHFE team submitted a proposal requesting students to perform a usability evaluation of a tablet computer in a microgravity environment, including a focus on mounting of hardware during use. The student team designed an experiment to evaluate pieces of hardware used to mount an iPad on the user's arm or torso. Students selected off-the-shelf software and developed custom software to provide tests of user performance. They compared performance in microgravity to performance in 1-*g*, and also compared performance with different hardware mounts.

Analysis indicated that participants did not perform as well on any of the tasks in microgravity as they did in 1-*g*, and comparisons of hardware setups indicated that different hardware setups held advan-

Participants use torso-mounted and arm-mounted iPads to perform tasks during microgravity segments of parabolic flight as part of the SEED program.

tages for different types of tasks. For example, participants typed faster when using the torso mount, but they performed better on hand-eye coordination tests using the arm mount. The team made the following recommendations: provide large buttons within software for use in microgravity, expect human performance to be slower and less accurate in microgravity, and provide hardware to mount iPads when typing is required.

After the flight study, the students participated in numerous outreach activities, working with media outlets to publicize their efforts, explaining their work to potential engineering students, and meeting with the community at open-house events. In addition to providing an opportunity for students to benefit from the experience of designing and implementing an experiment during parabolic flight, this project provided NASA the opportunity to gain insight into tablet use in microgravity.



Future Plans for Fiscal Year 2013

New International Science Office to Optimize Human Research Across ISS International Partners

With the completion of the ISS, the focus has shifted from space station assembly to utilization of the ISS's unique environment to enhance our knowledge for future space exploration. Significant advances are expected from onboard research by the planned end of the ISS Program in 2020. To optimize research throughout the end of the program, a focus on international cooperation is necessary and will enhance human research across all ISS partners.

In FY 2012, HRP was asked to lead the ISS Expert Working Group Human Health Management Team—also known as Team 5. Team 5 was formed to develop a common understanding across ISS International Partners (IPs) on the priority of human health and performance risks, particularly those for which ISS research is essential. Team 5 is expected to establish an approach for tracking international efforts on ISS to obtain the data necessary to better understand and mitigate the risks associated with long-duration spaceflight.

Additionally, a one year mission (ISS-12) with one U.S. and one Russian crewmember in residence on the ISS is planned to begin in 2015 by NASA and the Russian Federation Space Agency. It is expected that a joint human research program, with participation by the International Partners will be planned and executed to maximize the scientific return of this flight. The HRP International Science Office (ISO) was established at JSC and will oversee this joint U.S. and Russian program.

To assist with this new multi-national management initiative and enhance limited ISS resources, the ISO will place particular emphasis on the efficient use of IP resources and will coordinate and oversee the execution of Team 5 and joint ISS-12 activities. The ISO will be responsible for coordinating and integrating HRP and other IP assets into an international research portfolio. Their intent is to increase the availability of medical and science data among IPs, standardize and share research hardware when possible, and increase test subject availability.

New Study to Determine the Long-Term Risk of Atherosclerosis from Spaceflight

Long-duration missions will expose astronauts to increased risk of oxidative and inflammatory damage.

Future Plans for Fiscal Year 2013

Oxidative stress and inflammation may result from a variety of sources, including radiation, psychological stress, reduced physical activity, altered nutritional status, and exposure to oxygen-rich environments, such as during extravehicular activity. An increase in oxidative damage and inflammation accelerates the development of atherosclerosis, and thus could be a long-term health concern for astronauts.

Determining if biomarkers of oxidative and inflammatory stress are elevated with spaceflight is the purpose of the study, "Defining the Relationship between Biomarkers of Oxidative and Inflammatory Stress and the Risk for Atherosclerosis in Astronauts during and after Long-Duration Space Flight" which was selected for flight in March 2012.

Additionally, the study will determine if indices of increased atherosclerosis risk are present before, during, and after long-duration spaceflight, and if biomarkers of oxidative and inflammatory stress are related to indices of atherosclerosis risk in ISS astronauts.

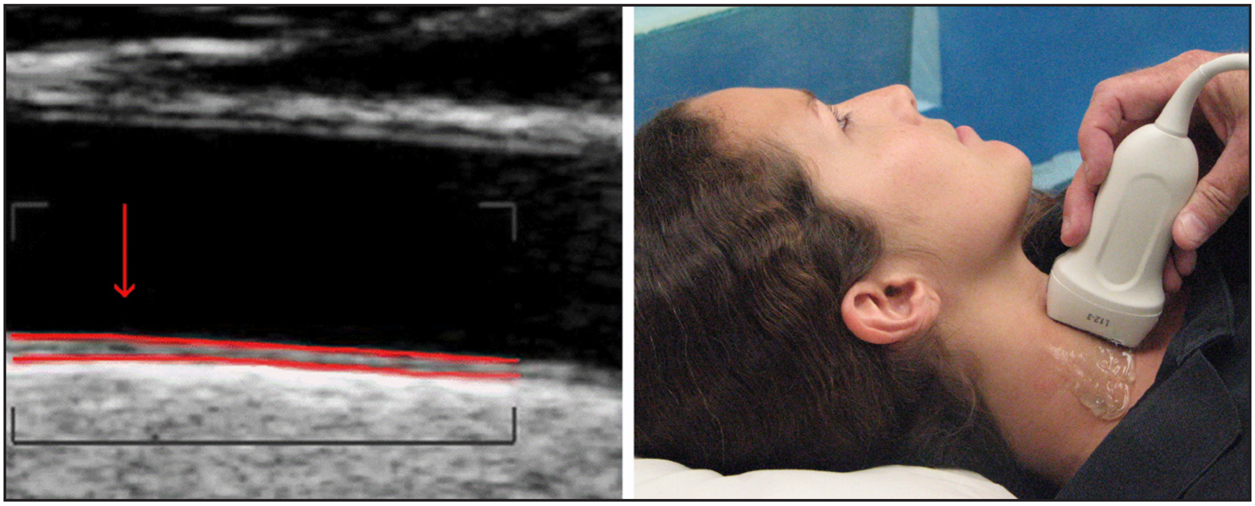
To meet the objectives of the study, 12 astronauts will be studied before, during, and up to five years after ISS missions. Levels of oxidative and inflammatory stress biomarkers, some of which were previously shown to be elevated with spaceflight, will be measured in blood and urine samples.

Increased carotid artery wall thickness and decreased brachial artery function—measured using standard clinical ultrasound—are well-established indices of atherosclerosis risk. Therefore, arterial structure will be assessed using measures of carotid artery wall thickness and arterial function will be measured in the brachial artery.

This is the first study proposed to assess the risk for atherosclerosis using biochemical, structural, and functional measures before, during, immediately after, and up to five years after spaceflight. The first astronaut volunteer began training in late FY2012, and the first baseline data collection session for this study was performed in early FY2013.

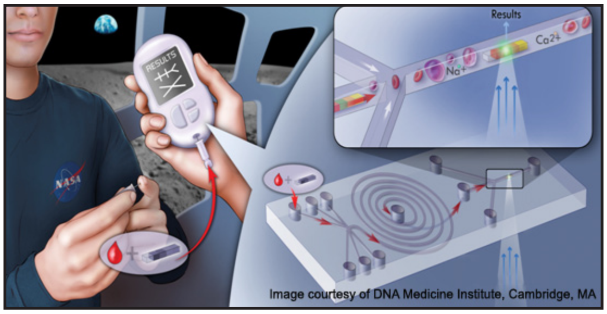
New Handheld, Point-of-Care Laboratory Analysis Tools to be Demonstrated

Biological samples are collected from ISS crewmembers for later return to Earth and analysis in HRP laboratories to gain a broader understanding of physiological changes that occur during



A new study will use ultrasound (right) to measure carotid artery wall thickness (left) to determine long term risk of artherosclerosis due to spaceflight.

Future Plans for Fiscal Year 2013



In FY2013, several in-flight laboratory analysis candidate technologies will be demonstrated like the one depicted above.

spaceflight. With the retirement of the Space Shuttle, biological sample return from the ISS will be challenging because of limited space on returning vehicles. Additionally, the long durations of future exploration-class missions will make sample return impractical.

The In-Flight Laboratory Analysis effort seeks to develop a handheld, diagnostic platform, which can analyze potentially hundreds of analytes from a fingerstick of blood. It would also provide fast, on-the-spot test results for display to the crewmember, and storage or downlink to flight surgeons on the ground.

In FY2012 requirements and contracts with vendors were established to develop the capability to perform in-flight assays for high-priority biomedical research. Candidate technologies will be demonstrated at NASA Johnson Space Center in FY2013 as part of an activity to identify the most promising candidate(s) for development of flight hardware. Future work includes demonstration of broader assay capability and flight certification for an on-orbit technology demonstration on the ISS in 2016.

Rather than relying on ground-based analysis, in-flight laboratory analysis would provide a point-of-care assessment for the biomedical research community. This technology is not only relevant to spaceflight, but also has wide-ranging applications on Earth—from disaster sites, to military field operations, to the doctor's office.

Enhanced Crew Performance Through Lighting and Schedule Optimization

Spaceflight exposes crewmembers to frequently changing light-dark cycles that can disrupt the body's internal circadian cycle and sleep-wake schedule. This disruption can result in poor sleep and reduced performance. Other environmental disturbances found in spaceflight such noise, temperature, and microgravity can further exacerbate cognitive deficits and increase the risk of fatigue-related accidents and injuries.

The National Space Biomedical Research Institute (NSBRI) is using an integrated approach to address the effects of the spaceflight environment on performance by using multi-discipline studies that incorporate schedule optimization, novel lighting systems, and single-wavelength light dosing.

Light can be used as a countermeasure to disruptions in the sleep-wake and circadian cycles, and it plays a key role in multiple aspects of human health, such as vision, alertness, hormonal regulation, and control of biological rhythms. Light exposure is an effective, safe, non-pharmacological countermeasure for deficits in cognition related to circadian rhythm disruption and fatigue.

NSBRI researchers are studying the combined effects of a highly challenging workload and sleep reductions on performance and sleep need.

Future Plans for Fiscal Year 2013

Investigators have shown that short-wavelength light in the blue/green range can be used as a countermeasure to enhance alertness during spaceflight. Researchers are working to validate a solid-state blue light system and determine the most effective wavelengths and intensities of light. This research will lead to countermeasures to help reduce disruption of sleep and other biological rhythms which are common during spaceflight.

Crew performance and alertness are also adversely affected by slam-shifting and frequently changing sleep-wake cycles. Therefore, NSBRI researchers have developed a scheduling strategy based on mathematical models for prediction and countermeasure design. This research uses data collected from wrist-worn activity and light monitors and is loaded into modeling software to provide specific reports which help tailor the design of countermeasures for each individual's circadian and sleep characteristics.

In FY2013, NSBRI researchers will continue to build on the lighting and scheduling studies to optimize the effectiveness of a blue-wavelength, solid-state light source for ISS and future exploration missions. Their research will test the effectiveness of using both short- and long-duration exposures to light as a countermeasure for decreased performance caused by sleep disruption. Their experimental and modeling research will have direct Earth-based applications for workers on early-rising, night, or rotating schedules, as well as for people experiencing jet lag.

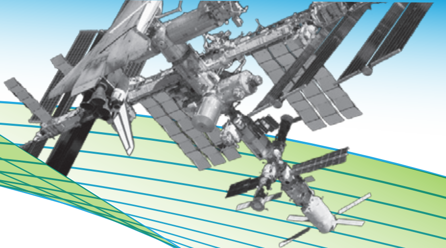
Next-Generation Crew Exercise System to be Prototyped and Demonstrated on ISS

The Advanced Exercise Concepts (AEC) effort within the HHC Element is overseeing the development of a next-generation crew exercise system for demonstration on the ISS. The long-term goal is to provide a crew exercise system for exploration missions.

The AEC will perform trade studies on current and state-of-the-art exercise technology and protocols for effective maintenance of cardiovascular and musculoskeletal health of crewmembers exposed to hypogravity. They will also develop system requirements derived from optimized and validated physiological requirements established by the Exercise Physiology and Performance Portfolio.

Once the trade studies are completed, the AEC will

The developmental flow an exercise hardware concept takes begins with computational modeling of human-machine interactions. It then progresses through standardized ground testing, parabolic flight testing, and finally demonstrations on the ISS.



develop a standard set of criteria for tests and evaluations and finally select a candidate technology to be prototyped. Researchers will then work to validate the prototype exercise devices in ground laboratory and space analog environments such as parabolic flight sessions. Finally, AEC researchers will design, build, test, and flight-certify the selected exercise system.

The advanced exercise system will be demonstrated on board the ISS with an integrated exercise protocol. The AEC project team will support operations and final reporting for demonstration of the integrated system technology, and toward the end of the decade will support eventual development and deployment of the exercise system for evaluation on future exploration missions based on known Design Reference Missions.

Collection of ISS Countermeasures to be Evaluated as an Integrated Suite

As NASA nears the scheduled end of the ISS Program in 2020, the HHC is planning a test of an integrated countermeasures suite on the station. HHC has previously tested many individual countermeasures intended to counteract the detrimental effects of spaceflight. Past evaluations included exercise protocols to prevent losses to the cardiovascular and musculoskeletal systems and pharmaceuticals that decrease the risk of kidney stone formation. Special diets ensure that crewmembers have the nutrition necessary to perform critical mission tasks, and training protocols are being evaluated to overcome the sensorimotor deficits seen on landing.

These physiological countermeasures are currently in different states of development. Some are just beginning trials in bed rest studies, while others are being used in spaceflight operations. HHC plans to take advantage of the ISS's characteristics as a unique test bed to combine all currently available countermeasures into a complement to be tested on individual crewmembers. Researchers will use NASA Standard 3001 as the "measuring stick" for determining if the combination of all countermeasures developed to date can successfully protect crewmembers during all phases of flight and ensure their ability to perform mission tasks.

Packaging Research to Increase Food Shelf Life for Long-Duration Missions

For long-duration space exploration missions, the packaged food system is required to maintain its quality or shelf life for five years. However, many of the current space menu items do not maintain acceptability or nutritive value beyond three years. The study, "Integration of Product, Package, Process, and Environment: A Food System Optimization" seeks to optimize shelf life for the space food system through product recipe adjustments, application of new packaging, and processing technologies, and modified storage conditions.

Currently in its second year of a four-year project, the study characterized the Martian climate as a possible opportunity for ultra-cold food storage. Although clear evidence supports lowering temperature as a means to slow down chemical changes in food, studies indicate that storing canned fruit in a pouch at -80°C resulted in reduced fruit firmness immediately, through irreversible ice damage. However, when 3.5-year-old pressure-assisted, thermostabilized (PATS) fruit were compared with equally aged fruit in a pouch, the PATS process resulted in fruit with better color and firmer texture.

In the next two years, other foods such as soups, vegetables, and meats will be used to evaluate cold storage temperatures, food-processing technologies, and a new packaging design using a non-foil, high-barrier packaging film. Color, texture, and sensory analysis will continue to be the main measures for determining product quality over time. Additionally, microscopic evaluation will commence in FY2013 for some of the remaining fruit samples, as well as vegetables and starch sauces, to better gauge the

Future Plans for Fiscal Year 2013

A photo comparison of various fruits stored for 3.5 years. The PATS fruits (bottom row) showed better color and firmness compared to the retort-pouch stored fruits (top row).

mechanisms that occur at a microscopic level.

At study conclusion, the team will deliver requirements for formulation guidelines, food processes, packaging, and storage conditions which will achieve a prepackaged space food system with a five-year shelf life for the various food categories.

Assessing the Impact of Communication Delay on Team Behavior and Performance

Future exploration missions to near-Earth asteroids and Mars will require changes in procedures and communication between crew and ground control personnel because of communication delays and associated technical difficulties. Delays lasting for up to 20 minutes could prohibit mission control from providing critical information to the crew. However, few studies have observed teams in autonomous contexts that represent long-duration space missions with high fidelity.

To that end, principal investigators from the Behavioral Health and Performance Element and the University of Southern California will conduct a study during ISS Increment 35/36 to examine the impact of a communication delay on individual and team behavior and performance.

Study participants will complete one specific research task per day, four days a week, lasting four weeks. During two of the four weeks, these tasks will be completed under conditions of no communication delay between the ISS and ground control. The remaining two weeks, these or similar tasks will be completed under conditions of a 50-second one way delay. The tasks to be performed by the crew vary along the dimensions of novelty and criticality.

After each task is completed, participants will complete questionnaires on communication quality, autonomy, individual and team performance, and well-being. Audio will be recorded during each task to obtain objective data. This study will provide a better understanding of how delays in communication affect individual and team performance and what countermeasures, if any, would best mitigate the risks associated with such delays.

Flight controllers communicate in near-real time with ISS crewmembers. A 20-minute delay—as would be experienced during missions to Mars—poses a significant risk to crew performance. An on-orbit study will use ISS crewmembers to simulate the delays and seek methods to overcome the impacts.

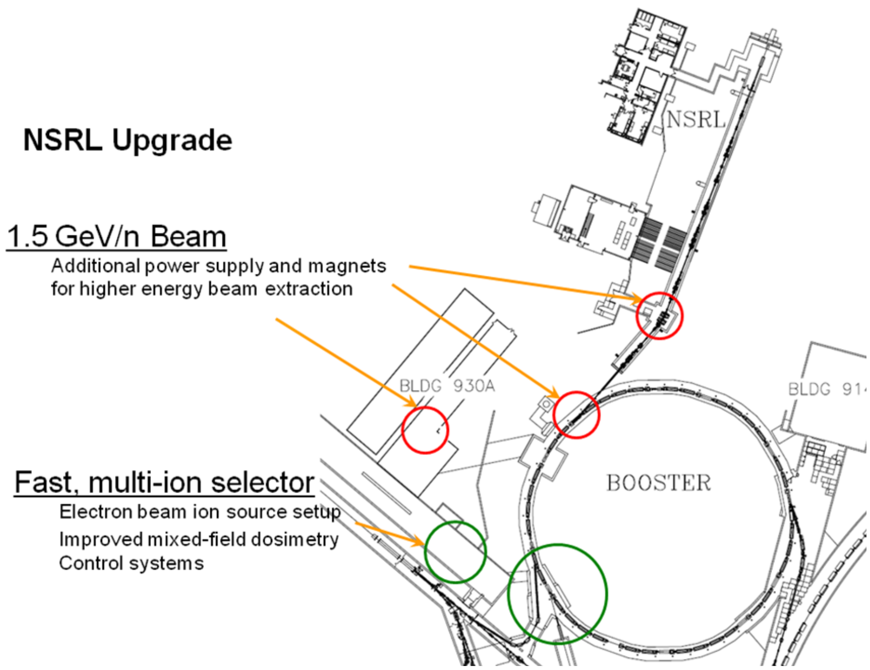
Upgrades at NASA Space Radiation Laboratory Decrease Set-Up Time

The NASA Space Radiation Laboratory (NSRL) at Brookhaven National Laboratory is one of the few places in the world that can simulate the harsh cosmic- and solar-radiation environment found in space. Ground-based research in radiobiology, shielding, and dosimetry is conducted at the NSRL using beams of high-energy protons and heavy ions to predict and mitigate risks to astronaut health from radiation. However, the NSRL has a limitation in its range of heavy ions relative to thick shielding configurations as well as in its capability to perform efficient mixed-field studies. Planned upgrades to the magnets, power supply, mixed-field dosimetry, and control systems will allow rapid switching of P, He, O, Si, Fe, and other important ions over multiple energies to provide a full galactic cosmic ray simulation capability.

The increase in heavy ion energies from ~1.0 GeV/nucleon to 1.5 GeV/nucleon will increase the range of heavy ions, or average distance traveled in material before stopping, by up to 70%. The increased range makes possible improved simulation of galactic cosmic radiation, including generated neutrons and other secondary particles for thick shield configurations. This capability provides an experimental test bed for the surface of Mars, which has relatively thick atmospheric shielding, as well as for the combined shielding thicknesses of spacecraft plus human tissue. In addition to facilitating mixed-field studies, the new laser ion source needed to rapidly switch between ion beams will significantly increase the number of different ions available to researchers on a given day, thus greatly improving efficiency and schedule flexibility.

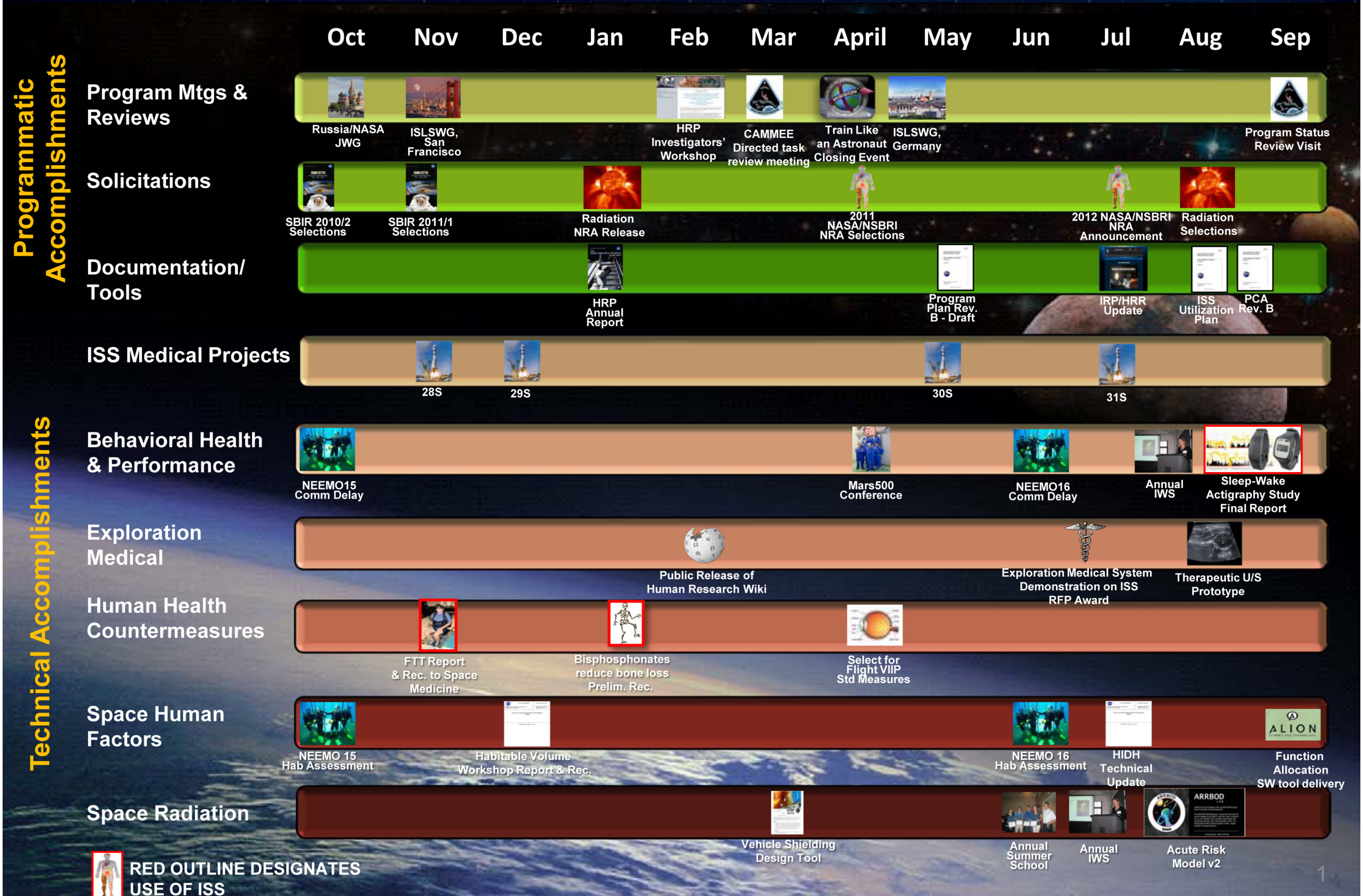
Current space radiation research is largely focused on quantifying space radiation risks and their mechanisms as well as reducing uncertainties in risk-projection models. Continued research progress and advancements are required to evaluate biological countermeasures (BCM) to determine their effectiveness in mitigating health risks from chronic radiation exposures. Therefore, future plans include increasing the focus of space radiation research on the identification and testing of promising BCMs.

Evaluation of BCMs will require testing a large number of agents, drug dosages, radiation types, and exposures for identified radiation-induced risks. The new, mixed-field capability will reduce the cost of BCM testing by allowing multiple radiation types and exposures to be tested in a much shorter period than before. The estimate of a ten-year period needed to test BCMs is based on these new capabilities.



HRP Fiscal Year At A Glance

FY12



Human Research Program

2012 Fiscal Year Annual Report

National Aeronautics and Space Administration
Johnson Space Center
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Houston, Texas 77058
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