NASA ADVISORY COUNCIL
National Aeronautics and Space Administration
Washington, DC 20546
Hon. Harrison H. Schmitt, Chairman

August 17, 2007

The Honorable Michael D. Griffin
Administrator
National Aeronautics and Space Administration
Washington, DC 20546

Dear ~~Dr. Griffin~~ Mike:

One of the primary discussion topics at the NASA Advisory Council meeting on July 19, 2007 was the recommendations from the Biomedical Committee's fact-finding Lunar Biomedical Workshop, held June 27-29, 2007 in Houston, Texas and chaired by Dr. David Longnecker.

Forty-nine biomedical scientists, flight surgeons, NASA program representatives and former astronauts met in Houston to develop an understanding of the strategies and key initiatives that NASA could employ to assure crew health and safety and mission success for the return to the Moon and subsequent human travel to and exploration of Mars. Input from these participants was reviewed and organized by members of the Biomedical Committee, and the Committee's report was presented to the full Council in a public session. Twelve recommendations resulted from the Council deliberations. Enclosed please find the following background information:

1) The twelve formal recommendations that were agreed to by the full Council;
2) Appendix A: The charge that was presented to the fact-finding Workshop participants;
3) Appendix B: A list of attendees from the fact-finding Workshop;
4) Appendix C: An analysis of the Human Research Program portfolio as reviewed by the participants at the fact-finding Workshop.

Note that recommendations B-07-1 through B-07-6 describe a systematic approach to data collection, analysis and archiving that will be required for successful lunar habitation and subsequent human exploration of Mars. The overarching issues involve the physiological response to partial gravity (i.e., 1/6g or 3/8g, vs. zero or 1g), free-space radiation, and crew behavioral health in confined micro-societies for extended durations. Recommendations B-07-07 through B-07-12 describe the application of newly collected and archived data to achieve crew safety and mission success. The Council identified these methodologies as those that should be applied in order to build a successful Lunar Biomedical Research program that will support the Vision for Space Exploration.

Please advise if you have any questions. The Biomedical Committee will receive future updates on the issues contained within these recommendations.

Best Regards,

Harrison H. Schmitt
Chairman

Enclosures

NASA Advisory Council
Council Recommendation
Ad-Hoc Biomedical Committee
Tracking Number B-07-1

Committee name: Ad-Hoc Biomedical Committee

Chair: Dr. David Longnecker

Date of public deliberation: July 19, 2007

Date of transmission: August 17, 2007

Short title of the Recommendation
Define baseline human physiological response to 1/6 Earth's gravity.

Short description of the Recommendation
Define, in the greatest number of individuals feasible, the baseline of human physiological responses to 1/6 Earth's gravity (1/6g) on the lunar surface and compare responses to those obtained in microgravity (µg) and Earth's gravity (1g). In support of this recommendation, improved and coordinated data should be obtained on ISS on a continuous basis as such data will provide a critical background for interpreting and extrapolating data obtained on the Moon.

Major reasons for the Recommendation
Planning a rational approach to crew health and safety requires an understanding of the human "dose response" at partial gravity, which may or may not prevent the deterioration seen in µg. It is essential to determine whether 1/6g exceeds a "gravity threshold" that abates the deterioration in various systems that is observed in µg and if so, to determine individual variability in this abatement. If 1/6 g provides adequate protection from the deterioration of human organ system responses observed in µg, the planning requirements for extended lunar and Martian exploration will be clarified and in many cases simplified. If not, a more conservative approach must be taken and countermeasures protocols will be required for longer lunar stays. In order to obtain dose-response data, it is essential that countermeasures, such as prescribed exercise or medication, not be applied proactively for short duration missions unless specifically required for the protection of crew health.

Current evidence from individuals exposed to microgravity suggests that several physiological systems reach an adaptive limit within 2 - 4 months in most humans, but bone and muscle loss, and possibly other systems such as behavioral health and performance, continue to deteriorate in reduced gravity in most but not all individuals. Maintenance of an adaptive limit requires countermeasures, including exercise. Individual variability is great in both the extent and rate of adaptation. There is a real possibility that 1/6g will reverse or mitigate this adaptive response. Whether it does or not, this information is critical for planning both long term activities on the Moon and on Mars as the major components of the Vision for Space Exploration. It therefore is essential to document baseline individual physiological parameters in 1/6g, beginning with the initial lunar sortie, to define physiological system function prior to application of additional countermeasures (e.g., exercise, medications, personal activities and other prophylactic measures) beyond those that crew engage in regularly by personal preference. Crew preference activities should be identified before flight and each crewmember's baseline

Earth gravity parameters should include the effect of such activities. Execution of this recommendation will require pre- and post-flight data collection, with some data and samples collected during the missions.

Consequences of no action on the Recommendation

Failure to acquire baseline data in 1/6g may add significant cost and time delays to the plan for long term lunar habitation and for Martian exploration. Finally, the results of these partial-gravity experiments also may have application for terrestrial health as well (e.g., in areas such as bone or muscle loss in Earth-based humans), and failure to obtain these baseline data could compromise the application of space-based countermeasure development to the general population.

NASA Advisory Council
Council Recommendation
Ad-Hoc Biomedical Committee
Tracking Number B-07-2

Committee name: Ad-Hoc Biomedical Committee

Chair: Dr. David Longnecker

Date of public deliberation: July 19, 2007

Date of transmission: August 17, 2007

Short title of the Recommendation
Adhere to a rigorous sequential data collection approach during lunar missions, combined with analyses of integrated archived data.

Short description of the Recommendation
Consistent with the recommendations of other clinical and statistical experts (IOM, 2001 and IOM, 2006), the Council recommends a rigorous sequential data collection approach during lunar missions, combined with analyses of integrated archived data, so that such data can be pooled to compensate for the small sample sizes on individual flights and to inform subsequent planning for Mars and beyond.

Major reasons for the Recommendation
Systematic research that recognizes the importance of a rigorous sequential clinical trials approach to data collection and analysis should progress from short duration lunar sortie missions to lengthy lunar outpost activities. Incorporation of mission-related data into common data elements facilitates alignment of observational and experimental results with other physiologic, behavioral, and medical data, and thus a broad-based systems analysis of crew health and performance. Such approaches should be applied during both lunar sortie and outpost missions to facilitate data collection and interpretation of results, including both individual responses and the overall spectrum of "dose-response" relationships between biomedical or behavioral performance and duration in the lunar environment. Sequential analysis, combined with archival data from previous missions (e.g. Apollo, Skylab, Spacelab, Shuttle, ISS and Russian data, if feasible) and ground-based studies will provide the greatest opportunity for proper interpretation of results, hazard identification, and thus planning for risk reduction.

Consequences of no action on the Recommendation
Lack of systematic data collection and integrated analysis will retard or prevent qualitative understanding of the effects of 1/6g on organ systems and crew behavior and performance in the lunar environment, all of which are critical to long term lunar habitation and travel to and exploration of Mars.

NASA Advisory Council
Council Recommendation
Ad-Hoc Biomedical Committee
Tracking Number B-07-3

Committee name: Ad-Hoc Biomedical Committee

Chair: Dr. David Longnecker

Date of public deliberation: July 19, 2007

Date of transmission: August 17, 2007

Short title of the Recommendation
Integrate all relevant clinical, operational and research data into a single encompassing and accessible space flight and bioinformatics database.

Short description of the Recommendation
All clinical, operational and research information and informatics (i.e., genomic, gene expression and proteomic serial data) specifically related to human performance and health during spaceflight, including pre-, intra-, post-flight, and longitudinal medical, behavioral, biological and experimental findings and specimens, should be made accessible to qualified physicians and investigators to inform planning and care for humans before, during and after space flight. Accessibility should be provided through a centralized archive system, consistent with Federal regulations regarding privacy relevant to volunteers for national service, such as astronauts and ground test subjects.

Major reasons for the Recommendation
Current data sources are fragmented and largely inaccessible to a broad base of qualified researchers. Integrated crew medical data, obtained from routine clinical care, including longitudinal care, and from participation of crew and non-crew research subjects, is the most effective way to counter the limitations resulting from small sample sizes and fragmented data sources. Combined databases will enable the characterization of the human adaptation to reduced gravity (Recommendation B-07-1) and will inform crews, clinicians, and investigators of possible long-term health consequences and benefits to space flight. The recommended system would greatly facilitate the development of countermeasures through an enhanced understanding of the biomedical basis of space adaptation that would be provided by the mobilization of a much larger community of qualified experts and researchers than exists currently. Personal medical data that are not related to flight should be excluded from this data base unless specifically waived by the individual, and privacy assurances should be consistent with NASA and other federal regulations. To support this initiative, NASA should leverage relationships with other agencies to fill gaps in our understanding of modern molecular, genomic, proteomic, and metabolic approaches to diagnosing, mitigating and treating human ailments. There are existing, efficient computational and bioinformatics approaches that can facilitate attaining this goal.

Consequences of no action on the Recommendation
The absence of the recommended system impedes effective use of all information sources and relevant research, including retrospective data and relevant non-space medical research findings; full use of all data is essential to address the many risks that confront humans

during and after space exploration and to support the application of relevant space biomedical findings to the improvement of human health in general. Without this system, NASA will miss the greatest opportunity to develop preflight preventative medicine strategies that reduce risk (Recommendation B-07-10), implement personalized medicine for crewmembers (Recommendation B-07-11), and assure that research data are used most effectively.

NASA Advisory Council
Council Recommendation
Ad-Hoc Biomedical Committee
Tracking Number B-07-4

Committee name: Ad-Hoc Biomedical Committee

Chair: Dr. David Longnecker

Date of public deliberation: July 19, 2007

Date of transmission: August 17, 2007

Short title of the Recommendation
Establish a lunar national laboratory during lunar outpost interval.

Short description of the Recommendation
In order to facilitate the collection and analysis of both human and animal data and specimens, the Council recommends establishment of a dedicated laboratory on the Moon for biomedical research during the lunar outpost phase of the VSE. It is further recommended, in this context and in symmetry with the ISS, that this laboratory be designated a "national laboratory" to foster broad agency, academic, commercial and international interest, support, and participation.

Major reasons for the Recommendation
The biological research needed to support long-duration missions will require a laboratory module during the outpost phase of the VSE, one that serves biomedical research and potentially shares resources with the Science Mission Directorate. This laboratory must include research facilities to support non-human research models (e.g., cells, tissues, small mammals etc.) for appropriate time periods approximating the Mars Design Reference Mission. Properly configured, this facility could also support the clinical care of crew through the *in-situ* analysis of laboratory samples, and foster the development and validation of devices to support autonomous health care on exploration missions (Recommendation B-07-9). The national laboratory designation builds on the recent legislative designation of the US component of the ISS as a "national laboratory," and enhances the potential for successful, broad-based research that will enable long-term habitation of the Moon and long-duration missions for the human exploration of Mars. Further, designation as a National Laboratory enables NASA to leverage interaction with other Federal agencies and other private partnerships that may enhance the generation of new knowledge.

Consequences of no action on the Recommendation
Lack of one or more laboratory modules that serve both biomedical care and research and sample preparation for other sciences will 1) prevent efficient use of the lunar experience to prepare for further exploration class missions, 2) compromise some potential aspects of basic medical care, 3) restrict or eliminate acquisition of biological data from non-human research models, and 4) prevent evaluation of potential Mars mission hazards and subsequent validation of related mission risks.

NASA Advisory Council
Council Recommendation
Ad-Hoc Biomedical Committee
Tracking Number B-07-5

Committee name: Ad-Hoc Biomedical Committee

Chair: Dr. David Longnecker

Date of public deliberation: July 19, 2007

Date of transmission: August 17, 2007

Short title of the Recommendation
Supplement limited human data with data from non-human research models to certify crews for 30-month Mars missions.

Short description of the Recommendation
Perform experiments on the Moon with non-human research models to bridge the over two-fold gap between 14 month human experience in microgravity and the proposed 30 month exposure to micro- and partial gravity.

Major reasons for the Recommendation
The human spaceflight record is 438 days (Polyakov). Most long duration missions (ISS and MIR) are approximately 6 months. The Mars Design Reference Mission is 6 months in microgravity transit to Mars, 575 days on Mars at 3/8g, followed by another 6-month transit in microgravity and return to Earth at 1g. In addition, humans have not been exposed to the free-space radiation environment on long duration missions. Experience with analogous duration hypogravity and radiation exposures in non-human research models is scientifically required and ethically necessary before exposing humans to these conditions. Although long term effects of hypogravity and radiation environments have been hypothesized, we have insufficient data to know what we do not know about the effects of these conditions on living systems. Additional ground-based experiments over the next decade have the potential to expand our understanding of the fundamental biological response to the unique characteristics of deep space radiation, but this understanding must be validated by properly designed and compensated lunar experiments in non-human research models, to fully explore possible impacts to the nervous, cardiovascular, immune, and other systems. Research capabilities should include *in situ* analysis, sample return, and a program for specimen sharing with the wider biological community where appropriate. The targets and protocols for these experiments will be clarified by the results of the program recommended in Recommendation B-07-1.

Consequences of no action on the Recommendation
Crew health and safety and the success of long duration missions will be jeopardized without this knowledge, which can only be obtained by exposure of non-human research models, in environments that approximate the planned Mars missions. It is not prudent to send humans on missions of this duration without a reasonable attempt to fill the knowledge gap involving long duration exposure to space.

NASA Advisory Council
Council Recommendation
Ad-Hoc Biomedical Committee
Tracking Number B-07-6

Committee name: Ad-Hoc Biomedical Committee

Chair: Dr. David Longnecker

Date of public deliberation: July 19, 2007

Date of transmission: August 17, 2007

Short title of the Recommendation
Implement research, training and operational protocols that will enhance and maintain the behavioral health of the crew for prolonged intervals (e.g., 2 – 3 years) in the isolated and confined micro-societies that are inherent to extended-duration exploration missions.

Short description of the Recommendation
NASA should undertake an integrated approach to human space adaptation by incorporating a robust behavioral health program in all aspects of research, training, and operations, with the goal of enhancing and maintaining behavioral health of the crew during extended-duration missions. Where possible, both the ISS and realistic ground simulations should also be used as laboratories to study the issues associated with living and performing in isolated and confined micro-societies over 2 – 3 year periods. Additionally, NASA should commission an historical study of leadership, behavioral health and crew performance in previous terrestrial extended-duration exploration activities that involved isolation and confinement.

Major reasons for the Recommendation
Recognizing that a mission to Mars provides a special operational, training, research, motivational, and bonding environment for each crew, continuous team performance and coherence during extended space flight will be essential for mission success. Confined micro-societies, such as those that will populate a lunar outpost or undertake exploration missions to Mars, will be subjected to human stresses rarely seen in other social and physical environments, including current space flight. The dynamics involve all aspects of human behavior, interaction, and performance that comprise the human system, which functions as the overarching system of systems in space flight. Small group dynamics, confinement, isolation, uncertainty (associated with, for example, spacecraft system health and reliability), repetitive routines, pressure to succeed, and limitations of personal space, time, and communication with family or friends all combine to potentially influence human behavior and performance.

There are many examples of successful long term team performances in highly motivated, well-commanded and productive teams, including early sea expeditions, polar explorations and outposts, early Everest expeditions, and other relevant situations. However, experiences from some isolation studies, polar outposts, analog environments and the submarine service indicate that confined micro-societies can be subject to significant stress that requires the development of appropriate countermeasures and preventive approaches. These include leadership techniques, commander and crew selection, real-time monitoring and management of mental health, involving the crew in meaningful and stimulating work,

and the providing opportunities for diversion and relaxation enroute. The historical findings, of which there are many from both successful and unsuccessful exploration teams, can be compared and contrasted with the unique characteristics of space expeditions and contribute much to understanding and preventing adverse behavioral consequences. The recommended study should examine lessons learned about organizational principles, leadership styles, or team performance during isolation and stress. These findings and relevant results should be applied where appropriate.

Consequences of no action on the Recommendation

Again, recognizing that a mission to Mars provides a special operational, training, research, motivational and bonding environment for each crew, with leadership the key component of success, failure to accommodate the potential range of social dynamics of small groups in isolation may lead to detrimental discord among the crew, compromise the mission, and potentially endanger the lives of the crew.

NASA Advisory Council
Council Recommendation
Ad-Hoc Biomedical Committee
Tracking Number B-07-7

Committee name: Ad-Hoc Biomedical Committee

Chair: Dr. David Longnecker

Date of public deliberation: July 19, 2007

Date of transmission: August 17, 2007

Short title of the Recommendation
Involve the crew as colleagues on scientific teams.

Short description of the Recommendation
Identify, train, and support responsible crew as contributing colleagues in biomedical and other research activities.

Major reasons for the Recommendation
Training is essential to all aspects of mission success but, for exploration and research in space, the scientific method requires that trained observers be present to monitor ongoing protocol adherence, assure proper data collection, provide preliminary interpretation of results and advise regarding alternative courses of action when unexpected problems arise. Thus, training for extended distance and duration missions should include a focus on the development of analytic ability and observational experience of crew, to enhance both the quality of data collection and the interpretation of results, and to provide rapid reactions to unforeseen events. This would be accomplished most effectively by engaging the crew not only as subjects for some research protocols, but also as colleagues on both human and non-human research projects. Active engagement of the crew in research will stimulate interest and involvement and enhance the potential for quality data collection. Further, crew will benefit intellectually by a real understanding of the purposes of the research, thus adding an element of diversion from routine that may well enhance crew mental health and overall wellbeing. Thus this appears to be a “win-win” situation for the investigators, the programs, and the crews.

Consequences of no action on the Recommendation
The history of research and exploration shows that failure to implement this recommendation will negate those research efforts that require the collection of complex observational data, informed on-site decisions, or rapid action to save the experiment or to take advantage of an unexpected opportunity. Other research efforts also may well be less successful, as crew interest may erode for tasks that are not well understood or appreciated.

NASA Advisory Council
Council Recommendation
Ad-Hoc Biomedical Committee
Tracking Number B-07-8

Committee name: Ad-Hoc Biomedical Committee

Chair: Dr. David Longnecker

Date of public deliberation: July 19, 2007

Date of transmission: August 17, 2007

Short title of the Recommendation
Enhance the involvement of Human Factors in vehicle and habitat design.

Short description of the Recommendation
In its broadest sense, Human Factors engineering, integrated with crew performance research and past performance analysis, should be fully embedded into all aspects of vehicle and habitat design throughout the course of development and operations, to ensure the effective and efficient integration of the human system within the exploration system of systems.

Major reasons for the Recommendation
Appropriate consideration of human factors in all aspects of architecture design, including vehicle operational responses, displays and controls, habitat, suits and gloves, other garments, food, etc. will enhance performance and minimize preventable injuries or human errors. These considerations have been inadequate on occasion in the past. For example, current suit designs limit crew selection significantly, while current glove designs do not permit facile grasping and frequently lead to overuse injuries of the hands.

Further, because a spacecraft is a mode of transport, an actively flown unit, at least in back-up situations, and a domicile, it is essential that human factors considerations be included in the design from the very first, and throughout the development of the architecture, design, and testing process. There is evidence that humans can adapt to the immediate environment for limited intervals, but evidence also documents that human performance may degrade significantly during prolonged exposures to suboptimal environments, microgravity, inadequate rest, and reduced proficiency training. Prolonged exposures to these factors can be integral components of lunar habitation and Mars exploration. The human must be considered one of the key systems among the system of systems that comprise all operational aspects of the exploration space architecture, from controls and displays and cabin environment through mission duty cycles and operations to interpersonal dynamics and team performance. In the microenvironment of space flight, there is largely no distinction between “professional life” and “personal life”; they are inevitably intertwined into a single “crew life”. Thus expectations for a comfortable environment, reasonable duty cycles, personalized relaxation programs, and flight systems that are ergonomically and functionally “human friendly” will enhance, and may be essential for, overall success.

Consequences of no action on the Recommendation

Inadequate consideration of human factors not only can lead to injuries or human errors but will contribute to low efficiencies in the performance of the human system during exploration activities. Further, current instrument displays and controls may not optimize human-system interactions, particularly after prolonged exposure to micro-gravity, leading to delays or errors that could lead to significant adverse events during entry, decent, landing, and ascent on Mars or on return-to-Earth.

NASA Advisory Council
Council Recommendation
Ad-Hoc Biomedical Committee
Tracking Number B-07-9

Committee name: Ad-Hoc Biomedical Committee

Chair: Dr. David Longnecker

Date of public deliberation: July 19, 2007

Date of transmission: August 17, 2007

Short title of the Recommendation
Enhance the capabilities for autonomous health care during exploration missions.

Short description of the Recommendation
To enhance the capabilities for autonomous health care during exploration missions, both primary and secondary providers of health care should be designated within each crew. Such crew should be trained to manage the spectrum of medical events that have been identified previously, plus other health events that might be anticipated based on flight duration or target environment. Advanced diagnostic, clinical, therapeutic, and telemedicine technologies should be developed to support a robust program of autonomous care during exploration missions.

Major reasons for the Recommendation
The continued development of a systematic approach to autonomous health care is the only option for crew health and mission success on extended duration missions. Emergency return becomes increasingly unlikely as distance from Earth increases (it will be impossible on a Mars mission and severely limited even for many lunar situations). Emergency return from the ISS is currently mandated for toxic exposures, serious burns, and compartment syndromes (e.g., from crush injuries). In the future, some medical emergencies and unanticipated illnesses will need to be managed by medical or surgical (and anesthesia) techniques that should be developed for in-flight use by a trained clinician.

Similarly, a variety of diagnostic techniques, including low mass, low energy body imaging methods, should be developed to allow enhanced on-site diagnosis. These should build on current initiatives, such as the current development of ultrasound as a diagnostic aid, and should encompass the spectrum of initiatives that are being explored by other agencies such as the Department of Defense (low mass Magnetic Resonance Imaging (MRI) techniques) and academia (low mass Positron Emission Tomography (PET) systems). There should be continuous review of potential new diagnostic, clinical, and therapeutic opportunities that will inevitably emerge in these rapidly developing areas. Training is necessary for primary and secondary providers in each crew, as there is evidence from analogous environments (e.g., polar outposts) that the primary clinician may become the patient, not the provider, at any time. Other crew, particularly the commander and deputy commander, should be familiar with the knowledge base and range of capabilities of both primary and secondary providers. The category of potential events should be enhanced by continued review by Earth-based flight surgeons, supplemented by content experts in specific clinical disciplines, to assure that an appropriate spectrum of potential illness or injury is anticipated. It is essential that expected advances in artificially intelligent diagnostic

support, rehearsal and simulation of unanticipated medical procedures, and asynchronous access to remote expertise be incorporated into vehicle and habitat designs and mission planning.

Consequences of no action on the Recommendation

The absence of a systematic approach to autonomous health care for extended exploration missions, while instead relying on crew bravery, initial good health, or anticipated good fortune, could endanger not only the affected person but also the entire crew and the overall mission.

NASA Advisory Council
Council Recommendation
Ad-Hoc Biomedical Committee
Tracking Number B-07-10

Committee name: Ad-Hoc Biomedical Committee

Chair: Dr. David Longnecker

Date of public deliberation: July 19, 2007

Date of transmission: August 17, 2007

Short title of the Recommendation
Use preflight preventive medicine strategies to reduce risk of underlying health problems.

Short description of the Recommendation
Preventive medicine programs should be implemented to the fullest to identify individual health hazards that can be mitigated prospectively and thus maximize the pool of potential crew members, to guide crew selection for long duration missions, to reduce health problems before, during and after the mission, to minimize decrements in crew performance, and to establish and maintain standards for retention and recertification.

Major reasons for the Recommendation
Significant medical findings or events, including findings such as congenital malformations or laboratory abnormalities, and events such as cardiac arrhythmias, dental abscess, back pain, renal stones, and behavioral alterations, can compromise crew performance and impact mission success. Some such conditions can be mitigated once detected, thus maintaining the broadest pool of crew talent possible. Some medical events result from the environment, whereas others result from underlying pathology (i.e., conditions that would manifest on Earth as well) or familial susceptibility. Preventive medicine strategies, such as screening in the broadest sense (cardiovascular, metabolic, endocrine, genetic, behavioral, family history, etc.), combined with appropriate mitigation strategies, can minimize the emergence of medical events during long duration missions. Use of the integrated clinical and research database (Recommendation B-07-3) will foster the effectiveness of this strategy. The development of specific standards for crew health should build on the recently developed NASA Space Flight Health Standards that address fitness for duty, exposure limits and permissible outcome limits. Flight health standards should be continuously reviewed and updated as additional data are accumulated (especially through the process outlined in Recommendations B-07-1, 2 and 3) and either old hazards are eliminated or new ones identified; these data will further inform decision making regarding crew selection for long-duration exploration missions.

Consequences of no action on the Recommendation
Without robust preflight heath screening for individual health hazards, possible mitigation opportunities (if warranted) will be missed, and appropriate selection considerations will be incomplete. Either could increase the risk of decrements in crew performance and the occurrence of incapacitating illness during long-duration exploration mission increases.

NASA Advisory Council
Council Recommendation
Ad-Hoc Biomedical Committee
Tracking Number B-07-11

Committee name: Ad-Hoc Biomedical Committee

Chair: Dr. David Longnecker

Date of public deliberation: July 19, 2007

Date of transmission: August 17, 2007

Short title of the Recommendation
Enhance personalized medicine for crewmembers during exploration missions.

Short description of the Recommendation
NASA should reduce operational risk to long-duration missions by developing a personalized medicine approach to the management of individual responses to the space, lunar, and Martian environments.

Major reasons for the Recommendation
Population-based care of astronauts will be inadequate to support exploration-class missions. As humans participate in longer duration voyages from Earth, the ability to undergo emergency return to earth becomes more remote and difficult and eventually impossible. Personalized medicine, also termed P4 medicine because it encompasses Predictive, Preventive, Personalized and Participatory approaches, focuses on optimal treatment for each individual's medical needs, be they preventive or therapeutic. Most health care authorities see the development of personalized health care as a major opportunity for improved health of the public at large; its value to NASA is even greater than that to the general population, for the individual variations in adaptation or degradation of human systems is remarkable in microgravity. However, individualized care cannot be realized until the basis of the condition is analyzed from the molecular to physiological level. For example, variability in the metabolism of drugs that might be required during long duration exposure to 1/6 g will be a necessary component of effective individualized care. The implementation of the integrated datasets described previously (Recommendation B-07-3) is essential to discover and validate the basis of a condition as a prelude to the P4 approach. It is essential that NASA equip their flight operations personnel and crews with tools for assessment of biomarkers and other types of clinical data (Recommendation B-07-9) that will allow for individualized crewmember health evaluation and individualized use of countermeasures to support crew health during and after prolonged flight. Contingency availability of crew genomic data should be considered in regard to this recommendation, should these data be pertinent to the diagnosis or treatment of an unanticipated medical condition during long duration missions

Consequences of no action on the Recommendation
Failure to provide state-of-the art ability to manage individual health, using both personalized information and archived data, may impair prevention of medical problems as well as treatment of individual crew members and could result in compromise or failure of a mission.

NASA Advisory Council
Council Recommendation
Ad-Hoc Biomedical Committee
Tracking Number B-07-12

Committee name: Ad-Hoc Biomedical Committee

Chair: Dr. David Longnecker

Date of public deliberation: July 19, 2007

Date of transmission: August 17, 2007

Short title of the Recommendation
Use the spacecraft flight systems as simulators to maintain human performance during long duration voyages.

Short description of the Recommendation
Designers of the Constellation and Orion spacecraft should begin to consider ways in which simulation capabilities can be integrated into operational systems in order for crews to maintain proficiency with key future tasks, including but not limited to controlling atmospheric entry, descent, landing and ascent as specifically relevant to missions to and from the Moon and Mars and to Earth-return.

Major reasons for the Recommendation
Prior experience suggests that sensory-motor abnormalities, such as hand-eye coordination, spatial disorientation or even vertigo, could become serious with prolonged exposure to micro-gravity, at least for some individuals. Concern has been expressed by some crew personnel and flight surgeons that chronic exposure to hypo- or microgravity might degrade learned skills for entry, descent, and landing (EDL) a vehicle on a planetary surface, for departing that surface, or for performing necessary medical or maintenance procedures requiring dexterous manipulation. Maintenance of proficiency by realistic on-board simulators is considered mandatory, especially during the long exposures necessary for transit to and from Mars or return from a prolonged lunar outpost mission. Whereas it is likely that the primary system for such critical steps will be automated, it is expected that humans will be essential monitors and back-ups to automated systems, should systems fail or situations arise that might not have been anticipated from prior robotic explorations. Pure computer-based "game" systems alone probably will not be adequate for this proficiency function. As a continuation of pre-flight training, refresher training for the full spectrum of nominal and off-nominal operations will be essential and simulators, ranging from straightforward computer-based desktops to fully immersive, multimodal and reconfigurable flight systems, as appropriate, will be required to maintain crew knowledge and skills.

Consequences of no action on the Recommendation
Without continued ongoing proficiency training, critical piloting, docking or other skills will deteriorate during long duration missions, resulting in potentially serious risks to vehicle, crew and mission.

Appendix A: Agenda and Charter for the Lunar Biomedical Research Workshop.

Agenda

NASA Lunar Biomedical Workshop
South Shore Harbour Resort & Conference Center, League City, TX
June 27-29, 2007

Introduction. This invitation-only meeting will focus on identifying the key lunar research priorities that will foster success of the Vision for Space Exploration. The format will emphasize dialog and discussion among clinicians, scientists, flight crews and NASA project leaders. Initial presentations will provide a background for all participants. Subsequent discussions will take place in round table format, either in plenary sessions or in topic-oriented breakout groups. The meeting will conclude by grouping research opportunities into priority categories that will provide input to the *ad hoc* Biomedical Committee and its parent, the NASA Advisory Council. (The accompanying meeting charter provides additional details.)

June 27, 2007

Plenary Session 0800-1200

0800	Continental Breakfast	
0830	Welcome and Charge to Workshop	*David Longnecker & Harrison Schmitt & Jitendra Joshi*
0845	Lunar Architecture	*Geoff Yoder*
0930	Bioastronautics Risks	*John Charles*
1015	**Break**	
1030	Human Research Program Plan	*Dennis Grounds*
1115	Research Plans for the Moon	*Mark Jernigan*

Lunch 1200-1300

Round Table 1300-1715

1300-1315	Summary Space Studies Board Meeting	*Pawelczyk*
1315-1400	Biomedical research	*Shapiro & Jessup*
1400-1445	Technology development and validation	*Mariella & McCandless*
1445-1530	Autonomous Medical care	*Scott-Conner & Clark*
1530-1545	**Break**	
1545-1630	Habitat and Environment	*Allard & Newman*
1630-1715	Goals for short-term and long-term Lunar missions	*Gernhardt & Satcher*
1730-1830	Evening summary session	*All*

June 28, 2007

Round Table 0800-1145

0800-0900	Experiments necessary for the short missions and long-term lunar missions	*Levine & Meck*
0900-0945	Experiments necessary for Mars transit and surface	*Pawelczyk & Charles*
0945-1000	**Break**	
1000-1100	Additional research considerations (includes input from NIH by Katz)	*Pierson & Loftus*
1100-1145	Resources to achieve research goals	*Young & Jernigan*
1145-1200	Summary and instructions for breakout session	*Longnecker*

Lunch 1200-1300

Breakout Sessions 1300-1650

Group 1.	Prioritization	*Tomko & Becker*
Group 2.	Alignment of experiments with exploration	*Toups & Turner*
Group 3	Identification of challenges to the lunar surface experiment program	*Schmitt & Charles*

June 29, 2007

Round Table 0800-1130

0800-0930	Presentation of the findings from Breakout Sessions	*Drysdale*
0930-1130	Formulation of the list of research and technologies	*Jessup*

Closing Remarks 1130-1145 *David Longnecker*

Lunar Biomedical Research Workshop Info and Charter

Major reasons for the Recommendation:

The Vision for Space Exploration has given rise to an exploration architecture that espouses return to the Moon, establishment of an outpost, use of the lunar environment, and preparation and execution of a Mars exploration mission. There are numerous challenges to human health and performance in this architecture. The NASA Advisory Council (Council) requested that the NASA personnel involved in biomedical research and technology development (R&D) conduct a workshop to compile a list of the R&D that may be conducted on the Moon during short duration stays and the longer outpost missions. From this compilation, the ad hoc Biomedical Committee ("the Committee") of the Council will prepare a set of experiment and technology developments for consideration by the full Council, which provides recommendations to the Administrator. The workshop, which will precede the July Council meeting, will gather information from the participating experts and organizations in and outside of NASA to apprise the Committee of the R&D opportunities on the Moon. There will be no consensus advice provided to the Committee but rather the compilation of the existing plans and new offerings that may arise in the Workshop. The workshop will have representatives from NASA HQ, the Field Centers, the Committee, the Constellation Program and academic institutions. The representatives will be Program level personnel, subject area experts, advisors, astronauts, flight surgeons, scientists, and managers. The meeting will take place June 27-29 in Houston.

Charter:

The Lunar Biomedical Research Workshop is charged with compiling the biomedical experiments and technology developments anticipated during short duration lunar exploration missions and during the long duration outpost operations. The experiments should take advantage of the exploration settings, assess the unique aspects of life in 1/6 *g* and the radiation environment, identify the risks associated with extended stay on the lunar surface to include environmental factors such as regolith and partial gravity, and prepare for the care of humans on exploration class missions beyond the Moon. The R & D should be grounded in the Vision for Space Exploration and aligned with the mission architecture from the Moon through to Mars. The basis for the proposed research should reside in the Human Research Program Plan, the risks catalogued in the Bioastronautics Road Map, and the Standards for Care and Performance advanced by the Human Research Program through the Office of the Chief Medical Officer. The workshop will consider all aspects of human health and habitation and prioritize them into three groups: 1) essential to the Vision, 2) enhances mission success but is not critical, 3) meritorious science opportunity not specifically related to the Vision. The findings will be assembled by the NASA Advisory Council ad-hoc Biomedical Committee, who will report their findings as a public report during the July 17-19 Council meeting.

Participants:

The workshop will have a maximum of 30 participants from NASA and the extramural

science and technical community representing the various disciplines, operations, and support functions necessary for the above task. These individuals will serve as representatives for the larger community and derive their recommendation through consultation with their respective constituencies.

Charge to the Participants:

Participants will review the HRP Program Plan, the risks outlined in the Bioastronautics Roadmap, the Standards for Health and Performance, and proposed list that is in development by the Lunar Architecture Team (LAT). There will be presentations by the LAT and NASA personnel. Participants are urged to comment, affirm, or disagree, and to propose additions and alternatives. The participants will then have group meetings to formulate lists of R&D opportunities, prepare preliminary priority stratification, and select a lead who will present their findings to the entire workshop. Finally the workshop will render a preferred list that is the predominant portfolio of opportunities for R&D on the Moon that serves the entire Vision.

Products:

1) A comprehensive list of experiments and technological developments that need to be done on the Moon in preparation for exploration of the Solar System.

2) A prioritization of the R&D opportunities.

3) A list of non-exploration related R&D opportunities.

Appendix B: Lunar Workshop Participants.

NASA Lunar Biomedical Workshop
South Shore Harbour Conference Center
League City, TX
June 27-29, 2007

FINAL PARTICIPANTS LIST

Allard, Terry, Ph.D., FAA
Becker, Jeanne L, Ph.D., NSBRI
Brady, Joseph V., Ph.D., Bayview Behavioral Biology Research Center
Caiozzo, Vince, Ph.D., UC-Irvine
Carpenter*, Frank E., M.D.
Charles*, John, Ph.D.
Clark, Jonathan B., M.D.
Cohen*, Malcolm, Ph.D.
Collins, Eileen M., USAF (Ret.); Former Astronaut
Drysdale, Alan, Ph.D.
Gernhardt*, Mike, Ph.D.; Former Astronaut
Hauck, Frederick H.,USN (Ret.); Former Astronaut
Jernigan, J. Mark*
Jessup, John, M.D., NIH
Katz, Stephen L, M.D., Ph.D., NIH
Kerwin, Joseph P., M.D.; Former Astronaut
Levine, Benjamin, M.D., UT
Loftus*, David J., M.D., Ph.D., Stanford
Longnecker, David E., M.D.,
Lucid, Shannon*, Ph.D., Former Astronaut
Mariella, Raymond, Ph.D., LLNB
Marshall, Gailen D., M.D., Ph.D., Univ. Mississippi
McCandless, Bruce II, USN(Ret.); Former Astronaut
Meck*, Janice, Ph.D.
Newman, Dava, Ph.D., MIT
Pawelczyk, James, Ph.D., Penn State Univ.; Former Astronaut
Perchonok*, Michele, Ph.D.
Pierson*, Duane, Ph.D.
Potember, Richard, Ph.D., Johns Hopkins Univ.
Scheuring*, Richard A., DO, MS
Schmitt, Harrison, Ph.D., Former Astronaut; NAC
Scott-Conner, Carol EH, M.D., Ph.D., Univ. Iowa
Shapiro, Jay R., M.D., Uniformed Services Univ.
Smith*, Scott, Ph.D.
Tomko*, David, Ph.D.
Toups*, Larry
Trappe, Scott, Ph.D., Ball State Univ.
Turner, Ronald, Ph.D., ANSER
Young, Laurence, Sc.D., MIT

Appendix C: Analysis of the Human Research Program.

1) Studies Essential for Vision: Lunar Sortie Phase

A. Define baseline human response to 1/6 g and compare to micro- and 1 g.
Most systems reach asymptote within 3- 4 months
However, bone loss and behavioral function continue to deteriorate in μg – where is their asymptote?
Define prior to application of countermeasures (esp exercise) other than crew preference activities

B. Drugs – stability in radiation and space environment

C. Radiation effects on crew performance

D. Prevention of injuries
- glove design changes to reduce overuse injuries

E. Lunar Dust – effects on crew health and performance

F. Exercise capacity should be based initially on crewmember preference to establish baseline data regarding adaptation to partial ($1/6^{th}$) g; subsequently then probably as a countermeasure. Possibility of an ergometer (rower) that might also allow limited power storage as well as providing generalized intense loading?

G. Risk reduction through hazard elimination

H. Invest in science and technology to determine the individual differences in susceptibility to risk factors as well as directing crew selection and training and/or to design for the entire spectrum of individual variation.

I. Lunar Dust Exposure as it affects system design to prevent exposure and the effects of oxygen and humidity on dust toxicity

J. Assess novel radioprotectants, possibly through interactions with the Armed Forces Radiological Institute (AFRI)

2) Studies that are helpful but not essential: Lunar Sortie Phase

A. Drug Pharmacokinetics and Pharmacodynamics
i. What is status of Nitza Cintron's studies of saliva for excretion of common drugs and could this be expanded and/or re-explored?

B. Behavioral Issues
- Commander, Program and/or both choose team
- Commander should be trained in behavioral dynamics of team in long term isolation.

C. Definition of Minor Surgery – what equipment is necessary?
3 Chest tube, Burn Care, Abscess

3) Studies Essential for Vision: Lunar Outpost Phase

A. Define baseline human response to chronic exposure to 1/6 g and compare to micro- and 1 g.
Most systems reach asymptote within 3- 4 months
However, bone loss and behavioral function continue to deteriorate in μg – where is their asymptote?
Define prior to application of countermeasures (esp exercise) other than crew preference activities

B. Creation and Designation of a National Lunar Laboratory that is multipurpose and involves biomedical research/use and Sample Triage for other science activities

C. Bone demineralization with countermeasures focused on decreasing renal stone formation
- Vitamin D metabolism as countermeasure
- Alternatively changes to diet and others as Mg Citrate

D. Exercise Capacity, Possible ergometer (Rower) and/or involving crew preference?
- need to quantitate use and performance so assess role of exercise and loading as countermeasure

E. Radiation effects on crew performance

F. Neurovestibular Studies
- Important since requirement for manual back-up on Mars

G. Caloric Intake – monitoring & use as countermeasure

H. Provide leisure activities to support the psychological health of those living on and visiting the Moon

I. Deploy effective in-site and remote health care systems to ensure crew health on the Moon

J. Understand the effects of the lunar environment, in particular partial gravity, on human performance and human factors to understand and promote human productivity in an off-Earth planetary environment

K. Provide safe and enduring habitation systems to protect individuals, equipment, and associated infrastructure
Emplace agriculture systems on the Moon to produce food and plants for lunar operations
Emplace water management and recovery systems in consonance with mission needs to increase life support system closure
Emplace air revitalization systems in consonance with mission needs to increase life support system closure
Emplace waste management systems to handle human and manufactured waste and increase system closure

L. Develop and deploy closed loop life support systems to increase self-sufficiency of future long duration human exploration missions and minimize the impact of humans on the environment

M. Study key plant and bacterial species to evaluate the feasibility of integrating them into life support systems

N. Develop and implement environmental monitoring systems to improve the efficiency of life support systems

O. Understand the effects of the lunar environment, in particular partial gravity, on human performance and human factors to understand and promote human productivity in an off-Earth planetary environment

P. Understand the effects of vehicle, habitat, and EVA suit pressures and oxygen concentrations on human health so as to design mitigation strategies for extended stays

Q. Understand the impact of the lunar environment on terrestrial microbes to understand potential health risks to crews

R. Understand the fundamental biological and physiological effects of the lunar environment on human health and the fundamental biological processes and subsystems upon which health depends to understand the long-term human response to the lunar environment

4) Studies that are helpful but not necessary: Lunar Outpost Phase

A. Research is not necessary to to re-certify for lunar missions

5) Studies that are essential to Vision: Mars

A. Understand the impact of extreme isolation on individual psychological health and group dynamics to ensure the long-term health, safety, and productivity of crews

B. Define baseline human response to 3/8 g and compare to micro- and 1 g.
Most systems reach asymptote within 3- 4 months
However, bone loss and behavioral function continue to deteriorate in μg – where is their asymptote?
Define prior to application of countermeasures (esp exercise) other than crew preference activities

6) Studies that are helpful but not essential to Vision: Mars

A. Study mammalian reproduction in different gravity environments to understand the impact of gravity on reproduction