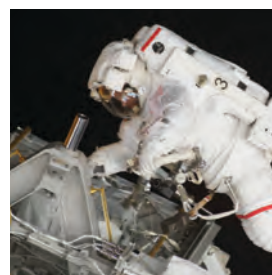
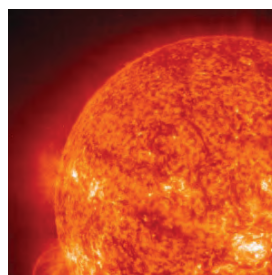
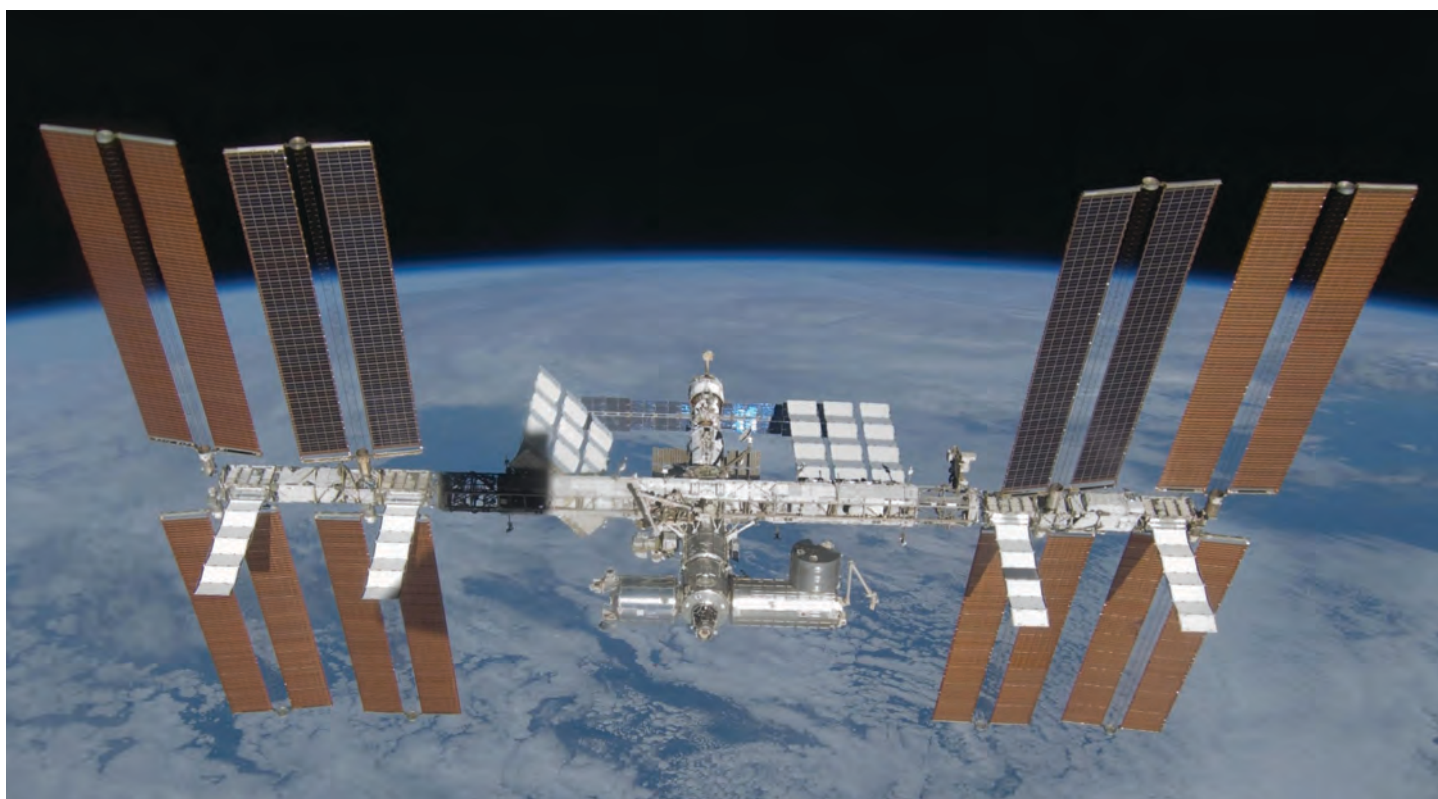


INTERNATIONAL SPACE MEDICINE SUMMIT III EXECUTIVE SUMMARY



JAMES A. BAKER III
INSTITUTE FOR
PUBLIC POLICY
RICE UNIVERSITY



BCM
Baylor College of Medicine



JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY
RICE UNIVERSITY

INTERNATIONAL SPACE MEDICINE SUMMIT III

MAY 14-17, 2009

EXECUTIVE SUMMARY

FEBRUARY 2010

International Space Medicine Summit III

THIS SUMMARY WAS WRITTEN BY PARTICIPANTS OF A JOINT CONFERENCE ORGANIZED BY THE JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY AND BAYLOR COLLEGE OF MEDICINE. THE VIEWS EXPRESSED IN THIS SUMMARY ARE THOSE OF THE INDIVIDUAL PARTICIPANT(S) AND DO NOT NECESSARILY REPRESENT THE VIEWS OF THE JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY OR BAYLOR COLLEGE OF MEDICINE.

© 2010 BY THE JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY OF RICE UNIVERSITY

THIS MATERIAL MAY BE QUOTED OR REPRODUCED WITHOUT PRIOR
PERMISSION, PROVIDED APPROPRIATE CREDIT IS GIVEN TO THE
JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY.

Organizing Partners

James A. Baker III Institute for Public Policy, Rice University

The mission of the Baker Institute is to help bridge the gap between the theory and practice of public policy by drawing together experts from academia, government, media, business, and nongovernmental organizations. By involving policymakers and scholars, as well as students (tomorrow's policymakers and scholars), the institute seeks to improve the debate on selected public policy issues and to make a difference in the formulation, implementation, and evaluation of public policy, both domestic and international. The Baker Institute is an integral part of Rice University, one of the nation's most distinguished institutions of higher education. The efforts of Baker Institute fellows and affiliated Rice faculty focus on several ongoing research projects, details of which can be found on the institute's Web site, <http://bakerinstitute.org>.

Baylor College of Medicine

Baylor College of Medicine is committed to being a national leader in advancing human health through the integration of patient care, research, education, and community service. The college pursues this mission by promoting patient care of the highest standard, advancing basic and clinical biomedical research, sustaining educational excellence, and fostering public awareness of health and the prevention of disease. Since its founding in 1900, Baylor has grown into an internationally respected medical and research institution. Baylor offers patient care services through several of its Texas Medical Center affiliate hospitals and clinics, with more than 152,000 inpatient admissions and 2.2 million outpatient visits annually. The college has more than 70 research and patient-care centers and units. More information can be found on the school's Web site at <http://www.bcm.edu>.

Acknowledgments

We are grateful to the Friedkin Family, the Alkek and Williams Foundation, and the Allbritton-Alford Trust for their generous support of the International Space Medicine Summit. Because of their support, the International Space Medicine Summit was successful and has provided a foundation for future collaborations.

Table of Contents

Preface

Introduction

Day One: May 15, 2009

Welcome, Introductions, Opening Remarks

NASA Celebrates 10th anniversary of International Space Station

Panel 1 — ISS Utilization: Lessons Learned and Achievements

Luncheon: Overview of Chinese Space Program — Past, Present, Future

Panel II — Research Opportunities for Countermeasure Development

Panel III — Analog Environments: Human Performance

Reception and Dinner — Keynote Address

Day Two: May 16, 2009

Mars 500 to Exploration

Novel Technology Presentations

Panel IV — Commercial and Industrial Opportunities

Luncheon: NASA Celebrates 40th Anniversary of Apollo 10 — Preparation for Lunar Landing

Panel V — Education Needs and Career Opportunities

Reception and Dinner — Space Medicine: Principles and Practice

Day Three: May 17, 2009

Discussion Groups

Group A: Cooperative Research Opportunities during Space Station and Lunar Missions

Group B: Suggestions for Analog/Ground-based Collaborative Research

Group C: Education Needs and Career Opportunities

Appendix A: Program

Appendix B: List of participants

Appendix C: Discussion groups

Appendix D: Summary of ISMS III findings, unsolved problems, recommendations

Preface

The first International Space Medicine Summit was held in 2007 with the intent of bringing together leading physicians, space biomedical scientists and researchers, engineers, and astronauts and cosmonauts from the world's space-faring nations. High-level discussions focused on the research needed to prevent and/or mitigate the medical and biomedical challenges associated with long-duration space flight, as well as the issues that affect the nations' capabilities to accomplish that research. The 2007 and 2008 conferences were quite successful in attempting to achieve these goals, providing a forum that encouraged open discussion of the issues and challenges faced by the various researchers and spacefarers. The first two summits and the 2009 summit, which is the focus of this report, were co-sponsored by The James A. Baker III Institute for Public Policy and Baylor College of Medicine.

The intent of the third summit, International Space Medicine Summit 2009, was similar to the previous two meetings, with an additional focus on lessons to be learned from the analog environments of Devon Island, the Antarctic, and NASA's Extreme Environment Mission Operations (NEEMO). Scientists wanted information that could help advance successful human space exploration and protect the health and well-being of the flight crews before, during, and after long-duration missions in space. A secondary objective was to enhance life on Earth by applying the resultant advances in human knowledge and technology acquired through living and working in space. A third objective was to discuss how the space program, and specifically space medicine, could contribute to inspiring young students to pursue careers in science, medicine, and engineering.

The participating organizations included the Australian Antarctic Division (AAD), the China Astronaut Research and Training Center (CARTC), The Canadian Space Agency (CSA), the European Space Agency (ESA), the German Aerospace Center (DLR), the Henry Ford Hospital System (HFHS), the Russian Institute for Biomedical Problems (IBMP), the Japanese Aerospace Exploration Agency (JAXA), the Massachusetts Institute of Technology (MIT), Moscow State University, the National Aeronautics and Space Administration (NASA), the National Institutes of Health (NIH), the National Space Biomedical Research Institute (NSBRI), the Russian

International Space Medicine Summit III

Academy of Sciences National Research Centre, and the Russian Federal Space Agency (ROSCOSMOS).

DAY 1: MAY 15, 2009

Welcome, Introduction, and Opening Remarks

The 2009 International Space Medicine Summit (ISMS), co-sponsored by Rice University and Baylor College of Medicine, convened Friday, May 15, 2009, at 8:30 a.m. at Rice University's James A. Baker III Institute for Public Policy on the Rice University campus. *(See Appendices A, B, C, and D for the program, list of participants, discussion groups, and recommendations, observations, unsolved problems, commentaries, and opportunities respectively.)*

The Honorable Edward P. Djerejian, founding director of the Baker Institute, former U.S. Ambassador to Israel, former U.S. Ambassador to the Syrian Arab Republic, and former U.S. Assistant Secretary of State for Near Eastern Affairs, welcomed the participants to the third International Space Medicine Summit, and made the following opening remarks. They are provided here as presented:

“I would like to welcome you all to the James A. Baker III Institute for Public Policy, and to Rice University, for the International Space Medicine Summit—an event that we are truly proud to co-sponsor with the Baylor College of Medicine. For many of you, this is your third International Space Medicine Summit, and we are delighted to have you back. I particularly want to welcome our international participants who have come a long way to be with us, and especially our new attendees from China. We are very pleased to have you with us, and we hope that this will be the first of many future visits to the Baker Institute.

The Summit has proven to be a forum very much in keeping with the goals of this institute—an event committed to intellectual excellence that bridges the divide between the world of action and ideas, and it accomplishes this on an international scale. Look around, and you will see leading physicians, space biomedical scientists, engineers, researchers,

International Space Medicine Summit III

astronauts, and cosmonauts from all over the world. We have gathered to discuss, freely and openly, the medical and biomedical challenges of long-duration space flights—as well as the issues facing our ongoing and future joint activities in space.

I am also pleased to see that this year's summit addresses the education of our young people—and the importance of developing a new generation of engineers and scientists that will take us to new horizons.

This past November, we celebrated the 10th anniversary of the International Space Station, the largest spacecraft ever built. The orbital assembly of the space station began with the launch from Kazakhstan of its first component, Zarya, on November 20, 1998. A few weeks later, the space shuttle Endeavour carried aloft the Unity module. The space shuttle crew—which included a Russian cosmonaut—joined Unity and Zarya together in space, in what marked the beginning of a long and fruitful international collaboration.

Ten years later, the station's mass had expanded to more than 627,000 pounds, and its interior volume is more than 25,000 cubic feet—comparable to the size of a five-bedroom house. Some 167 individuals, representing 14 countries, have been to the space station, where they have eaten approximately 19,000 meals. Now, that's an impressive number, but I am not too sure about how many Michelin stars their meals would get.

When it is completed next year, the space station will represent the largest international cooperative technological project in history. That's quite an accomplishment. Its completion, however, comes at a time of great uncertainty in the United States' space program. The U.S. space shuttle, scheduled to make its last flight in 2010, is an essential element in the construction and operation of the space station because of its large up-mass and down-mass cargo capability.

In a Baker Institute report earlier this year, senior fellows Neal Lane and George Abbey, and Rice lecturer John Muratore, called for enhancing support for the space station. They recommended establishing a clear rationale for the station based on continued international

International Space Medicine Summit III

cooperation, the peaceful uses of space, and scientific research. The Baker Institute report also proposed that the space shuttle program be extended to 2015 in order to sustain the space station. Additionally, any efforts to explore Mars should be restructured to include international partners—building on our relationships from the space station.

I'm happy to note that, last week, the White House ordered a complete outside review of NASA's manned space program. An independent panel will look at the design of the new spacecraft to replace the space shuttle and go to the moon—as well as the five-year gap between the shuttle's current proposed retirement and the new moon vehicles. The review will also look at extending NASA's use of the International Space Station beyond 2016. I am hopeful that this planned review will bring a sense of direction to our program—a direction that will continue to support and enhance international cooperation. So meetings such as this summit can go a long way to further that cooperation. I have been very impressed by the previous two meetings and the openness and the quality of the discussions. I am looking forward to a summit that will continue to set the standard for such deliberations. Again, I want to welcome all of you and wish you a very successful session. Thank you very much.”

George Abbey, the Baker Botts senior fellow in Space Policy at the James A. Baker III Institute for Public Policy at Rice University, and Bobby R. Alford, chancellor of Baylor College of Medicine and chairman of the Board of Directors and CEO of the National Space Biomedical Research Institute, welcomed the participants to the summit and underscored their significant international presence. Both encouraged the participants to talk freely and to take advantage of the most powerful aspect of the summit, which is to share ideas, promote collaboration, cooperation, and coordination of space life science research, and to communicate, expand on and discuss lessons learned.

NASA Celebrates the 10th Anniversary of the International Space Station

Jeffrey R. Davis opened by commenting that it was his honor to introduce the moderator of the panel, William H. Gerstenmaier, Associate Administrator, NASA Space Operations Mission Directorate.

Davis chronicled Gerstenmaier's career, noting that he began working at NASA in 1977 in what was then called the NASA Lewis Research Center. By 1995, Gerstenmaier was the Shuttle-Mir Program operation manager, serving as the primary interface to the Russian space agency for operational issues. Gerstenmaier became the manager of space shuttle program integration in 1998, and by 2002, he had been named the manager of the International Space Station (ISS) program.

Davis observed that in Gerstenmaier's current position gives him oversight of both the International Space Station and the space shuttle programs. Gerstenmaier, who received a Bachelor of Science degree in aeronautical engineering from Purdue University in 1977 and a Master of Science degree in engineering from the University of Toledo in 1981, is a fellow of the American Institute of Aeronautics and Astronautics.

Gerstenmaier began by commenting how lucky they were to have such a distinguished panel of individuals with a "good variety" of ISS experience, including astronauts, cosmonauts, and operations personnel, which would make it interesting to hear their perspectives.

Gerstenmaier noted that the ISS had been through "many fits and starts"; many technical and political problems; and, many discussions in the process of getting the ISS put together. Somehow, through all the turmoil and all the tribulations, "the thing that kept us moving forward was the humans working together as a team, and realizing the potential of the space station."

In that same spirit, Gerstenmaier said he thought it was appropriate to look back on those 10 years, but not to dwell on them. "What got us here was that future of what we could do with the space station. As we learn from the lessons of the past, we should project them into the future

and figure out how to use that experience as effectively as possible because the ISS offers ‘tremendous opportunities’ in the areas of medicine, engineering, and operations. The space station can be a ‘true test bed’ as we go beyond the low Earth orbit.”

When those who were there from the beginning saw images of the ISS hardware from its earliest incarnation, he said, it brought memories to mind such as “the simple meals,” the time when Columbia occurred, and “it was very tough keeping space station crew during those time frames without the shuttle, when it went away.” But again, he said, that was good experience, and it would allow us, during the next period when the shuttle retires, to operate the space station in an effective manner.

Gerstenmaier called on panelists J. “Milt” Heflin, Leroy Chiao, C. Michael Foale, Boris V. Morukov, Jean-Loup Chretien, Vladimir G. Titov, and James S. Voss to present their reflections with respect to their experiences with the ISS.

Heflin, noting that he served as chief of the flight director office during the beginning of the buildup of the ISS, described the space station as a “zero-gravity United Nations” that works much better than the one on the ground. Heflin said its great legacy consisted of all that was done technically to build it, as well as what the international space-faring partners had learned in the process of blending the “people culture and the space culture” of each country in doing the job.

Chiao said his experience on the ISS, on Expedition 10, taught him a great deal about living and working in that unique environment over a long period of time, especially from the “much different” biomedical perspective. He said it is clear that the space station is the next step to going on to longer-duration missions, not only from the perspective of operations and science, but also the hardware aspect. The learning experience involved in building the ISS would contribute toward the construction of more robust spacecraft on future missions, including those to the moon and Mars. Having learned from his own experience, training, and working with those from other space-faring nations, Chiao agreed with Heflin that the space station’s most valuable legacy would be the global experience that proved “we can all come together as a mini-U.N.”

Foale described the ISS partnership as the second-greatest achievement of the last century, after the Apollo program. He predicted that the ISS would continue to be a “very sustainable” project in the future because of the vast interest that multiple countries have in maintaining the Station with their partners in a strong international collaboration, “the glue that keeps it going.” Building on this ISS lesson of interdependency, Foale suggested that the most important point for future long-term missions would be to have a common safe haven between the Earth and moon, perhaps at the L-1 point, with the docking adaptors to allow each nation to save the other if necessary, as “insurance” on certain mission phases on the way out or the way back.

Foale described an impending physics experiment involving the installation of an alpha-magnetic spectrometer on the ISS that will measure high-energy particles coming from the universe. He noted that the experiment will involve 150 scientists from 18 different nations, including China and Taiwan, working together. Foale pointed out that the spectrometer will allow us to learn more about the radiation threat to humans living beyond the protection of Earth’s geomagnetic field, and to learn more about fundamental physics, using the space station as an observation platform.

Morukov recalled the period from September 8-20, 2000, when he was one of two Russian Space Agency members of the international STS-106 crew on Space Shuttle Atlantis, which was assigned the considerable task of preparing the station for the arrival of the first permanent crew. Morukov said that he was part of a crew of “laborers” who unloaded 6,600 pounds of supplies and installed batteries, power converters, and other fundamental equipment.

Morukov said, “We called our crew ‘the Brigade of Construction Workers,’ who just entered the new house to finish it up and prepare it for the inhabitants who would live there later.” Since then, the “house” they built has played host to representatives of many countries.

“I think the most important result of this activity is that we are learning to work together,” Morukov said. “We are listening to each other. We are finding some ways out of some difficult situations that sometimes happen on the Station. It is most important that all the sides support each other.”

Morukov commented that he recently had received good news with respect to the results of a Biorisk experiment completed in 2008, involving the exposure of biological objects to radiation in open space outside the ISS for more than 1.5 years. Morukov said the subject of interplanetary transport of life also is being explored in a new series of experiments called Expose-R.

Morukov said that he believed that the Mars mission would represent all of humanity, and all of us will need to integrate our resources: material, intellectual, and technological. “I think this goal will be achieved,” he concluded.

In lauding the “spectacular accomplishment that is the space station,” Chretien focused on the evolution of the concept of international space cooperation into reality, as well as the realization of his dream to fly in space.

“This international realization, mostly of course American and Russian, is shining over our heads, and I hope it’s shining for many more years,” he said, calling the ISS a “fantastic accomplishment.”

Chretien reflected also on the time in 1977 when, as a young French test pilot, he was at NASA’s Johnson Space Center (JSC) in Houston, doing some test flights and dreaming of going to space one day. “Unhappily, France failed in the first selection of astronauts going to join ESA and the Spacelab program,” Chretien recalled. “Of course, I was quite frustrated, quite sad. That was at a time when many objects were shining over our heads, and in this country, you had just finished the Apollo program that was such a dream for many of us.”

In 1979, when the Soviet Union offered France the opportunity to fly a cosmonaut on board a joint Soviet-French space flight, the offer was accepted. Chretien was named the following year as one of two French finalists who would go to Russia for training, and “then I started my space career,” Chretien recalled, adding that this was his “initiation to international cooperation.” In 1981, he was named research cosmonaut on the crew of the Soyuz T-6 mission, launched in 1982.

In 1984, Chretien returned to JSC for mission training as a backup astronaut on space shuttle, and “at this time, there was no word of international cooperation,” he said. Chretien said he had just visited the Soviet system, where the “be first and fight” concept still prevailed, “and here, we had the mockup of the Freedom Space Station, which was already a fantastic project, but there was no cooperation—just Spacelab.”

But step by step, with one foot in one country and the other in another country, Chretien said, “I had the feeling that international cooperation was on its way.” Finally, after his second space flight as a research cosmonaut and further spacecraft pilot training in Moscow, he received a call from Abbey, who worked for NASA at the time.

“That was when the International Space Station program was being put on the table,” Chretien said. “I really was very happy to be given a chance to participate in that forum, and to move to this country for 15 years and finish my career as an American astronaut.” After obtaining joint citizenship, he remained at NASA as a U.S. astronaut for the last years of his career.

“Thanks a lot. I hope I helped in this cooperation,” Chretien concluded.

Voss shared with the group how, during the previous weekend, he watched the ISS fly over, and thought of the three crew members up there and the scientific experiments they were doing. He thought in particular of how things can be done in the ISS laboratory that can’t be done anywhere else, and how he had always been so enthusiastic about participating in that unique and ongoing scientific exploration.

Voss harked back to his experience on the ISS with Expedition 2 in March 2001. He recalled that he had two crewmates, Yury Usachev and Susan Helms, and the three of them “really believed in doing science.” Fortunately, they were able to do some. They conducted a total of 17 experiments, including 16 involving human research. One of those experiments involved an aspect that is important in long-duration space flight: that of bone mass loss. He said they also had a phantom torso, which was of significant scientific value in looking at the effects of radiation on human beings.

One experiment struck Voss as having special value in future long-duration missions. It concerned the crew's interactions with one another and with the ground crew. Voss, who spent a total of 163 days on the space station, noted that going into space, especially for a long period of time, is unique with respect to the prospect of working with people who may be from different cultures, and who may have different ideas of what's important. Being able to work together as a team is most important, he noted. Voss said he couldn't imagine what it would be like to work on Mars, when "we absolutely must be able to work together for long periods of time."

"We do a lot of looking at the hardware on the space station, and looking at how it will be better prepared" for future long-term missions. Voss said it was equally important for us to continue to look at the human beings, and make sure they will be able to function properly and will return in good condition when they come back. Voss added that he hoped his medical colleagues will continue to sponsor and do research and take care of the human component of space flight, as well.

"When I watched the space station fly over, I thought what a fantastic scientific resource it is. I hope we will continue to use it to gather information and maximize its scientific benefits to us in the long run."

Titov, like Morukov, recalled that as the multicultural crews started working together, they developed their own special language, and an important part of that process was the cooperation that ensued. Titov described the ISS as "a grand experiment" and "a product of international cooperation."

Titov wore a broad grin as he told the summit participants that he was looking at Charles Bolden in the audience, who was smiling at him, which made Titov remember how in 1992, he arrived in the Houston area for the first time (for training at JSC as one of the two Russian cosmonaut candidates for the impending STS-60 Space Shuttle mission, the first joint Russian-American venture of its kind). Titov remembered that he couldn't hear the Russian language spoken anywhere in Clear Lake, the Houston suburb where JSC is located. Moreover, he said "Charlie was thinking: 'Who are those Red cosmonauts from another planet?'"

Titov said further that “What is important is cooperation, and the cooperation started coming together as we started working together and we developed a special language, as Boris (Morukov) told us.”

Titov recalled how happy he was when the first module was launched for the ISS, when “even the skeptics were cheering.” He further remarked that the activity on the Shuttle-Mir Program united the efforts of the astronauts and cosmonauts in space with the efforts of those on the ground, including scientists and engineers. That, in itself, was a “grand experiment.”

“What do we have in orbit right now?” Titov asked. “We have a great, large station that is a product of international cooperation.” He noted that soon, a double crew of six people aboard the ISS would be able to fully devote themselves to science, which he said was the initial ideal of space station. “Finally, we are going to have a full scientific laboratory.”

After Titov’s remarks, Gerstenmaier opened the floor to questions and comments.

Dave Williams asked if it would be of value for all of the agencies representing the space-faring nations of the world to come together and articulate their long-term vision for future space exploration, to help focus the national priorities during changing economic times and anchor those programs for the future.

Gerstenmaier responded that this might not have been done in a formal sense, as Williams was suggesting. However, Gerstenmaier said, “Each country had its own objectives of what they wanted to accomplish for station, and then, through all these tough times, we figured out a way to achieve our goals.”

Gerstenmaier said he very clearly remembered a meeting one Saturday, years ago, in which he and all the international partners “had to decide on a series of assembly flights that wasn’t optimum for anybody.” He recalled that it was “not good from the U.S. perspective, and I wasn’t allowed to even talk about the other sequences.” His Russian colleagues had a different

sequence, and his European colleagues had another sequence. “We were all defending our own individual pieces,” he said.

“Finally, my Russian colleague said, ‘You know, we will never get this done, but we’re going to have to rise above our nationalistic interests and figure out what is the right answer for the International Space Station,’” Gerstenmaier recalled. “I thought, ‘Man, what a profound statement that was!’” So at that point, I said, ‘OK, let’s throw away our badges, let’s throw away our nationalities, and let’s figure out what the right thing to do is, so we can go forward to our politicians and our countries and represent what we’re going to do, and go forward.’”

Gerstenmaier said they couldn’t do it that day, at the end of which he presented “the decree from the NASA side.” But he said “they all looked so hurt,” he arranged to meet with everyone individually the next day, Sunday. “On Monday, we all got together and we agreed to a plan and then we took it forward to our politicians. So we didn’t have a big formal plan, but we sure had our own individual goals up front, and were able to compromise our nationalistic interests to achieve where we are on station.”

Williams then suggested that there might be value in a shared agreement in which the space-faring nations defined objectives for the next 50 years. Gerstenmaier agreed, saying the space station serves as a demonstration of “what you can do with cooperation.” He said that “we should leverage off the station” and use it “as we go forward with space exploration toward the larger goals you describe.”

Following up on Williams’ idea, Bolden of the NSBRI (who was named NASA Administrator after this conference took place) noted that the scientific community uses decadal surveys, which he had learned are “like Moses bringing the tablets down from the mountains—it’s like the law,” and it works for them. Bolden said that several people were wondering if it wouldn’t be wise to have the human space flight community to design an international decadal survey—if not for the “short horizon” for space flight of 10 years, perhaps a survey encompassing a longer period of time. The survey would formalize an international agreement and state that “these are the goals we want to achieve” within a certain time frame. That would mean that “everybody is speaking

the same language” going forward, based on the record of the international agreement that was made at a certain point in time. Right now, Bolden said, “everything is ad hoc” but, “at some point, we’re going to have to formalize this stuff, or we’re never going to get there.”

Given that “we can’t agree, even in the U.S., whether we should go to Mars or the moon,” Foale suggested that “we should go for the minimum goals that people can agree on” in Bolden’s concept of an international agreement with a set time frame.

Walter Cunningham, of the NSBRI User Panel, recommended that individual countries should not be limited by the international agreement—that, with the large set of goals that are the products of international agreement, individual space-faring nations should be permitted to pursue their own national subsets of goals, as long as they fit into the master plan. Foale agreed.

Laurence Young, said the scientific community had, in fact, been doing decadal surveys in human life sciences of the sort that Bolden had suggested. Young said that every 10 years, the National Research Council, through its Biological and Life Sciences Committee, has studied future directions for life sciences in space, but the problem was that “it takes two to have a conversation.” He said that the scientific community has regularly written what facilities and experiments take priority. “Then, when it comes to spending money,” Young said, “the operational constraints take over.” As an example, he cited the absence on the ISS of the centrifuge accommodation module—the animal centrifuge—that one decadal survey had indicated was the most important apparatus needed. Somehow, Young said, “those surveys do not seem to be given the attention, or have the strength, as those of our colleagues in the astronomy community.”

Another summit participant asked what made the ISS unique; specifically, what was its unique contribution? Voss cited its value as a scientific laboratory in a unique environment, while Foale said it could be a way station in the future.

Joseph Kerwin, a former astronaut and now a member of the NSBRI User Panel, commented, “The crowning accomplishments of the ISS have not yet been achieved.” He recommended that

they build on the lessons learned from Skylab's successful life sciences program. Specifically, Kerwin suggested that if a campaign were mounted for an expedition that involved all the appropriate resources and a dedicated crew focusing on countermeasures, physiological mechanisms, and medical care, "we'd be a lot closer to being ready for those planetary expeditions, and we would crown the ISS with a real success."

Julie Robinson of NASA commented: "We've never had this capability, this extent of scientific equipment, to address so many different kinds of scientific questions, available with this number of crew, for this long duration in space." She said ISS provides three elements that are needed to conduct research on the ground: capable labs, the ability to do experiments over many years, and interactive feedback so that those conducting the experiments can adapt to the unexpected and conduct appropriate follow-up investigations, meaning "we can do science the way it needs to be done."

Jeffrey Hoffman, a former astronaut who now teaches at MIT, wondered whether the completion of the ISS construction might signal a good time to consider a suggestion from several years ago: for a nongovernmental entity to manage the scientific operations on the ISS. Gerstenmaier responded that it might be difficult for an NGO to operate it because the station is a very diverse, complex, and multidisciplinary operation.

Gerstenmaier then summarized the reflections and comments by noting that panelists had discussed ISS achievements in culture, language, sustainability, food, and engineering design—things that had been accomplished before in individual countries, but never as an international community. Moreover, he noted that the goals were achieved in an "unbelievably tough" environment where no mistakes could be made. He observed that the technical challenge of operating in space had led to cultural and communications breakthroughs. Gerstenmaier recalled an experience in which he was attempting to communicate with a Russian colleague about an issue involving orbital mechanics. When he discerned that the interpreter wasn't properly translating his words, he wrote out the mathematical equation for orbital mechanics and gave it to the Russian, who immediately understood. Thus, he noted that cultural issues had to be worked out by the astronauts and cosmonauts, who developed a common language.

Gerstenmaier cited other major achievements of the ISS: The participants had learned to live in space as an international community; forged lasting international friendships; learned a great deal about engineering; and learned how to work together as a control center, “which is new,” he said, noting that a series of foreign countries’ control centers had been added to those of the United States and Russia.

From the science standpoint, Gerstenmaier noted Morukov’s reference to Biorisk experiment, a study examining the effects of space on biological samples on the outside of the space station, which he described as “very promising.” Gerstenmaier added that scientists were learning that salmonella mutates more rapidly in space, and it was believed that a vaccine might be developed based on the samples returned from the ISS. Gerstenmaier also said scientists were taking unique aspects of the space station and “using that test environment to drive out different results that change our theories” about bacteria and viruses, which could be applied to situations on Earth.

Gerstenmaier further described the ISS as a “truly unique platform,” and raised the question of how that platform would be used in the future, given the “very small window” in which to do it. “We aren’t going to get all the perfect equipment up there, but we should look at what’s on board the space station today,” he said, describing the “whole variety” of scientific equipment currently on the ISS as “a very well-outfitted research lab.”

“It may not be perfect, but the challenge to us is: how can we use that equipment the way it is in space station—not have to fly something else up new, but use that equipment to push science in the next direction,” Gerstenmaier said. “That’s our challenge as we move forward,” he concluded, thanking all the panelists and other participants.

Panel I — ISS Utilization: Achievements and Lessons Learned

Panel I members included Valeri V. Bogomolov, IBMP; Shanguang Chen, CARTC; Volker R. Damann, ESA; Smith L. Johnston, NASA; Donald R. Pettit, NASA; Vladimir G. Titov, Mir; Dave Williams, CSA.

Moderator J.M. “Milt” Heflin opened with a comment that he was going to try something a little different. Instead of letting each panel member speak, he invited audience participants to think of questions they would like to ask the panelists.

Heflin said he wanted to offer the group one question to ponder. He said in his opinion, the six-man crew operations would be the biggest challenge in the near term, including the health and well-being of the crew. “How are we going to find a way to operate, doubling the size of the crew and maintaining all the creature comforts, and so on and so forth?” he asked. Heflin opened the floor to questions from the audience, noting that the participants had a great deal of experience in space and flight operations.

Bonnie Dunbar asked the first question. She asked if “our representatives from China would speak about their space medicine program.” Panel member Shanguang Chen noted that he would discuss the Chinese space program at noon, but said he would provide a few introductory remarks. At present, Chen said, they were doing work on the near-Earth orbit flight, so the Chinese space medicine program at the moment is focused on countermeasures in short-term flight. The next step will pay more attention to the long-duration flight.

Addressing the topic of “lessons learned,” Dunbar asked panel members what research is being conducted on the ISS that is translational to fractional gravity, in looking at long periods of time in one-sixth gravity on the moon or one-third g on Mars, with respect to all the human physiological changes that would be involved. Panelist Dave Williams responded that much of the work on the ISS is zero- g -specific, but in terms of translating that beyond lower-Earth orbit, there will be zero- g transit times, so it would be relevant for those times.

Williams suggested looking at the ISS work in the context of exploration-enabling research: asking questions relative to one-sixth g in terms of such issues as osteoporosis, radiation exposure, and nutritional balance; conducting those experiments on the ISS and planning for those to continue in a partial-gravitational environment, “wherever that might be.”

Panelist Smith L. Johnston commented that he had spent a lot of time in the g transitions, “when we go to zero g and when we come back.” “It doesn’t get any worse from 1 g to zero g, from zero g to 1g,” he said. “So if we can do a good job there on landing, and put the parameters, put the metrics there to measure how well we’re doing, when we go to the moon, and go to Mars, we should be able to do a fairly good job there.”

Williams noted that transition is a really interesting phenomenon. He said there is a huge opportunity to study the physiological transition between g states. Understanding the phenomenon of adaptive change would help us to become destination-independent, he said.

Panelist Donald Pettit added that “the transition from microgravity to Earth can be done in a way where you can be surrounded by doctors and technicians willing to snip little pieces off your body for the sake of science.” He remarked that “we have an under-sampled system.” For example, he said, “We might do a blood take a couple hours after landing, then a blood take a week later, and there’s huge transients that occur. Maybe we ought to be on semi-continuous blood takes.”

Pettit noted that “when you go from Earth into space, we don’t have the facilities to do these really detailed biochemical analyses. We do when we come back to Earth, and I think that being a lab rat is part of what it means to be a crew member. There is much to be pried from the souls of people who come back from space, particularly when you arrive on Earth and you have access to all the kinds of medical research facilities that are available.”

Speaking through an interpreter, Valeri Bogomolov commented that during the past 10 years of working together, we created a great potential of cooperation. He said we have a huge volume of materials that can be used in the area of human safety in space. He noted that we adhere to international requirements for human health; we have joint standards and joint requirements on the acceptable environment for humans in space.

Now, Bogomolov said, we are talking about a six-crew situation on board the station. The experience that we have so far, the integrated capabilities of both medical personnel on the

ground and on the station, will no longer be applicable, because we are talking now about segment-by-segment medical support of their crew members using only national resources. Bogomolov commented that the integrated system no longer exists. The experience so far is being rejected, and “I think this is negative and incorrect,” he said. He cited the use of separate on-board physical exercise equipment and separate food intake for the different national crews on the station, instead of integrated resources. Bogomolov said he believed the position of the program administration was wrong. Up to now, the engine of station assembly and science was the scientific and medical research. Right now, “we are making a step back,” he said. However, he thought the mistake probably would be corrected in the future.

On a positive note, Bogomolov said, “We have more scientific equipment and resources and capabilities now on the ISS than ever before, but we do not have common science programs—we only have national programs. Integration of the resources of the ISS is important.” He commented that if the station is going to be broken into national parts, “we will not be talking about joint missions to the moon and further.” “Only by bringing the resources together—medical staff, scientists, engineers—only then can we achieve the goals we have.”

“Excellent, excellent comments, concerns,” said Heflin, asking panelists what could be done about the issues Bogomolov had addressed.

Volker Damann of the ESA said that Bogomolov was right. “We are at a point where we have to fear that we are breaking the station apart into national elements.” However, Damann said he wasn’t as worried as Bogomolov. He said he was confident we are on a good track and the team would get back together. Damann commented that, especially from the medical domain, it would be a worst-case scenario if we set up borders and limitations and didn’t share all the resources we all have. He said it is true that different space agencies are pursuing certain avenues and interests, and there may be political pressures. “I fully believe the only way we can progress in space and in space medicine is by true international collaboration.” He said he felt that we are on the right track.

Heflin said in his experience, “Folks at the working level get along great.” He felt the problem was at higher levels of organizations.

Audience participant Walter Cunningham said he wanted to return to the topic of the research focus in regard to zero gravity and long duration flights. He said he thought the proper focus was on zero gravity, and he would not want to see an effort to reproduce all the previous experiments we have done in zero gravity in one-sixth g or one-third g. The focus, he said, is properly on long duration and the transitions in long-duration missions.

Williams added that he thought it would behoove all the space-faring nations of the world to share the information stemming from the data that astronauts are collecting while they are doing an experiment.

In response to a question from an audience participant about scientific sampling over long-duration flights, Pettit commented that a crew is typically enthusiastic about doing an experiment if they understand why they are doing it. The more crew members know in terms of “why we need to do this, what the value of it is, the more the crew understands the fundamental basis of these experiments, the greater enthusiasm I think you’ll find they have for periodically sticking themselves with pins and needles.”

Johnston commented that one of the biggest values of the ISS is that, “We’re actually living there day to day.” Johnston cited an example of a space medicine problem not only for astronauts in orbit, but flight controllers on the ground: getting sufficient sleep in the time available on a busy, long-duration mission. Johnston said measures had been instituted such as ground testing programs for medications that would enable the user to get maximum sleep during the available time. Another measure involves watches that accurately measure the amount of time the wearer sleeps.

Johnston said that recently, a subgroup of a multinational panel had been instituted to study the subject with flight controllers, astronauts, cosmonauts, and flight surgeons. The group is an example of what can be done to generate a cooperative international response to a problem that

everyone has a need to solve, he added. This subject is also relevant, he said, to the general population and to the aviation community concerned about, for instance, cases of pilot fatigue that might cause a plane to go down.

Williams commented that for all the space agencies of the world, no one take chances flying in space; instead risks are managed. To manage risk means we need to make data-driven decisions. However, sometimes more opportunities are necessary to obtain life sciences data. Williams strongly encouraged the audience to think about ways of integrating science, and to “challenge ourselves” to get access to the data needed to make the appropriate risk-management decisions.

Pettit said that in data archiving, there are “heaps of data” from the ISS, but he asked how to correlate it. He said there is a “shroud” of medical privacy that seems to hinder researchers from getting access to some of the data. He noted that due to the small subject number (e.g., $n = 2$) in some space medicine studies, there is the potential for recognition of a particular crew member. From a crew perspective, it is important to recognize the benefit of the medical data.

Audience participant Dennis J. Grounds said, “Of course, we have been aware of the need to balance privacy of individuals, which is guaranteed under the Privacy Act of 1974, with the need to access the data for legitimate uses for a very long time.” In the last few years, “we have been on a campaign to make sure that as much non-attributable data can be put into the public places as possible.” Also, processes are now in place and available for formal requesting of data, even if it is attributable, for legitimate causes, for need-to-know, and some requests have been granted. But there will always be a need to protect privacy under the law.

Charles F. Bolden Jr. commented: “Data for the experimenters is important. Data for the guinea pig is critical. I’ll say the same thing I’ve been saying since 1980. A data point of 1 is a data point. We are never going to have n ’s of 1,000 in the space program So you experimenters have got to be willing to share your data with us and let us know what a data point of 2 says. It’s a preliminary assessment, but it’s based on all the data we have. And I think you’re talking around what the crew members are interested in. We’re interested in: What did you learn?”

Audience member Jeffrey Davis said a Human System Risk Board, which he co-chairs with Grounds, had been formed in the past year to address the issue of risk management. The board is comprised of “all our technical decision makers.” Davis said the board had a good database that serves as a knowledge capture tool to take a snapshot of the risks at a certain point in time that will be accessible in the future. He mentioned that there had been “just a couple” of cases of some eye changes on orbit on long-duration flight, which they had never seen before. By virtue of having this risk forum and sharing the data, “we are already convening a summit” to address the problem. So progress is being made on how data are handled.

Smith Johnston commented that he had been given permission to disclose information concerning an n of 1, of a female crew member who had been in space for two long-duration periods. She had much less bone loss on the first mission where she was doing a renal stone experiment and taking potassium citrate. That may be a simple countermeasure for retarding bone loss. He offered this as an example of a situation where “you sit down with all the researchers and pull that together in a debrief” that can make a difference down the road.

Audience participant Richard Scheuring said ISS data that would be translational to partial-g environments include sleep issues as well as EVA suit issues. He said he saw immediate benefits regarding the crew work-day requirement and related sleep needs using the ISS paradigm to the Constellation mission.

Audience participant Amy Kronenberg asked Davis whether only NASA data was handled by his risk board. He responded that the one-year-old board started within JSC then began tying other centers and other federal agencies together, and now “we think we can enable that to be an international board” to share experiences and data. Kronenberg said she was asking with respect to the point that had been raised “by our Russian colleague” about different prescriptions being used by different agencies for their representatives in space as a way to learn how effective they are, and to harmonize them to make it easier for the crew to integrate the information that comes back from those risk boards. Heflin asked, “How do we solve that?”

Bogomolov cited as an accomplishment the fact that “we have a fairly good understanding of the risks inherent in long-duration flight and in the course of crew member operations.” In the upcoming stage starting in 2011, when the orbiter will no longer be flying, we will have a few years when the crews are only going to be delivered and returned with Soyuz vehicles that are also designated as emergency rescue vehicles. Mitigation of medical risks is related primarily to the sufficiency of medical resources on board to monitor and maintain crew health, while the second prerequisite is appropriate management of the process. He stated that when he expressed concern regarding the diversity of the per-segment support, he proceeded primarily from his concern that there will be increased medical risk related to psychology, related to the fact that the crews on orbit sometimes find themselves in unequal circumstances with respect to resources. So if there is a lot of science hardware on board, there is still risk with respect to the delivery or return of research results since Soyuz has limited capability in that regard. Bogomolov said a poll of the scientific community evaluating this situation might be useful with respect to prospective corrections related to this segment-wise support and responsibility.

In response to a question as to the most important space medicine problems with respect to future missions such as Mars, Williams cited, first, the acquisition of data to understand how our terrestrial treatment paradigms and diagnostic protocols work in a microgravitational environment, where the pathophysiology of disease may be different; and, second, to better evaluate pharmacological efficacy in space in a microgravitational environment. He cited “huge opportunities” to start doing research on those issues in a microgravity and partial-gravity environment. Another huge challenge is the issue of inventory management to support a six-person crew on a three-year mission to Mars.

Smith Johnston noted that we’ve already gone to the moon. But to go to the moon, live there and colonize for a six-month mission—which he feels is necessary before thinking about going to Mars—radiation is one of the bigger problems and more tools are needed to monitor the crew for that risk. The issue of genetic susceptibility is of interest in this regard, in potentially enhancing knowledge of individual risk susceptibilities.

Volker Damann commented that “as a space physician,” he wondered how we will select space physicians in the future; how we will make them aware of all the issues that come along; how will the profession change; whether space physicians will fly in space; and how will we provide information to the physician in the spacecraft or on the moon.

Chen commented that, although China has not been an ISS participant, the ISS had had many achievements over the past 10 years. He noted that the space station has set a very good example for international cooperation. From now on, Chen said “we should start to think about creating a platform for more nations and people to participate in this kind of cooperation.”

Panelist Vladimir Titov said through an interpreter that the information he had heard about separation, and the trend toward segment-wise support with respect to re-supply, material contributions, and other planes of separation, gave him the idea that “someone wanted to introduce a political virus” on board the space station. “What would the outcome for psychology be?”

“Let’s imagine a crew of six would split into two or three crews,” Titov said. “We are going back to a cold war of sorts.” He had never seen anything that would separate us. Titov cited what he called the positive political component of the situation: the Soyuz Apollo program. That, he said, was a great political undertaking that helped us get where we are now, to talk and exchange opinions. He added that the managers that are running the space station are smart and talented, and he thought that common sense would prevail. He did not have an understanding of how we can separate the station crew into several crews, and he would be very much against this idea of separation.

Cunningham told Titov that he agreed, it would be nice to keep politics out of it, but maybe we can try to keep it out of the medical aspects and the science. Cunningham addressed Johnston’s earlier comment about genetic susceptibilities, commenting that he thought that “genome profiles are useless for flight crews, and let’s say in fact are used to determine who goes and who doesn’t go.” We can’t afford to have politically correct solutions—for example, someone saying “we don’t want to impose it on them.” It’s knowledge that has to be used, especially for something

like going to Mars. Johnston noted that someone could not be denied health insurance based on their gene profile, based on current law.

“Flying to Mars is more important than the health insurance,” Cunningham responded.

In response to a question about the most significant advances in space life sciences research over the past 10 years, Johnston cited exercise countermeasures, the ability to do in-flight analysis (e.g., bone turnover markers), diagnostic tools like ultrasound and radiation-monitoring capabilities, increased knowledge about neurovestibular issues, and related awareness of the need for more such research pertaining to ballistic re-entry. Williams noted that the repertoire of countermeasures had been individualized to the crew members, which enabled monitoring and intervention.

Bolden asked the panel if there was one thing that could be identified as an individual achievement from space that would be valuable to people on Earth. Williams cited the spinoff from space robotics into surgery.

In response to a question from Heflin about obtaining more budgetary funding given such significant achievements, Williams said that the problem is that “we have not shared the story” with members of Congress. He suggested that if one were to talk to an unsupportive member of Congress who asked him to identify “one good thing” about the space program, that congressional member would be surprised to hear that the United States is now a leader in the multibillion-dollar industry of creating surgical robotics. “We have to share the story,” Williams urged those assembled.

An audience participant asked how important it is to do animal experimentation on the ISS. Another participant said there still is a capability for rodents in space, and a mission to send mice to the ISS was scheduled for August. Inessa Kozlovskaya of IBMP noted that Russia started an animal experimentation program in 1973. “We had all species on board, including monkeys” and the program was successful until it was ended, she recalled. “But it has re-started now,” with flying mice and rats, and she was sure that in the future they would again fly monkeys. “And

everybody is welcome.” Kozlovskaya noted that medical science always had developed based on animal studies, and it was “very wrong” that there was a loss of interest for awhile that stopped such studies in space. Audience participant Laurence Young remarked that we didn’t stop doing animal experiments in space due to lack of interest—there was a “huge” interest in it. What we lost is the money, he said.

Dunbar asked, as we proceed to build a base on the moon in 90- to 180-day sorties with the knowledge that in the long-duration microgravity environment there is the issue of osteoporosis and bone loss, how do you know what protocol to use for a mitigating approach in one-sixth gravity—or do you learn as you go?

Williams said we should go before the 50th anniversary of Apollo and acquire the data while we’re there. Dunbar responded that, in that case, we need to plan it now, and asked where the assessment would be done. Johnston said: “You do the best you can in zero g, you figure out what you can do in one-sixth g”—which may be “amazing”—and “then that will translate to Mars.”

Thomas Lang from UCSF, and team leader of the NSBRI, suggested this might be a good opportunity for a NASA program manager to talk about one of the one-sixth g bed-rest analogs that are currently being carried out, as well as the animal work. Grounds said that “there is a major initiative to get some predictive power on bone loss,” both combined with the deconditioning of bed rest. He observed that bed rest can be used to simulate zero g with a head-down configuration. “We are currently trying to configure bed rest to give a one-sixth gravity influence on the systems, particularly bone and muscle.” It’s a difficult problem because you get a little different response from the cardiovascular system than you do from bone. Grounds said “they are working through those problems now.”

Grounds also stated that, “If we are successful, then we will be able to do a series of deconditioning studies that simulate one-sixth g. It would give you some predictive value about which countermeasures are effective.” Noting that this is just a prediction, he said the real truth will come from measuring the crew returning from lunar and increasing duration missions.

Another effort is underway to capture all the information in models that would explain something about the mechanisms—the digital astronaut models. A third aspect is trying to predict the work component and force components of EVA with respect to how much loading the body gets.

Bogomolov commented through an interpreter that when gravity is one-sixth g, it will be necessary to implement some countermeasures that will have to be defined. As to the length of the mission, he said he believed past long-duration missions on the Soyuz and Mir station have proven that keeping bone mass is possible, and one can lower the loss of minerals by using countermeasures.

Kevin Fong of University College London, asked about the risk paradigm with respect to space medicine: “Looking back now, do you think that the approach to space medicine risk on the space station, now that you’ve had 10 years of it, was excessively risk-averse, accepted too much risk, was just right, or all of the above?”

“Just right,” Williams and Johnston both responded.

Heflin ended the panel discussion by commenting on the need to take what exists across the entire international community and find ways to come to common ground. One issue of disparity is sleep shifting, he said, challenging the international space community to find solutions.

Luncheon

Speaker: **Shanguang Chen, Director, Astronaut Center of China**

Overview of the Chinese Space Program — Past, Present, Future

Leroy Chiao introduced Shanguang Chen, director of the Astronaut Center of China (ACC) by first talking about China’s role in space. When Chinese astronaut Yang Liwei was launched into space aboard the Shenzhou-5 spacecraft in October 2003, China became the third nation in the world to launch an astronaut into space. Chiao said he met Chen in April 2006 on a visit to China, at which time Chen extended an invitation to him to tour the Astronaut Center of China

(ACC). The following September, he accepted Chen's invitation and became the first American allowed to enter the facility. He was "very impressed" by the facility's up-to-date technology, noting that the street signs in the compound were in both English and Chinese, which "hints at their openness to thinking globally."

Chen, who has been the ACC Director since 2003, provided an account of the development of his country's manned space program. Chen's remarks are provided here as presented:

"After China was unsuccessful in attempting a manned space flight in the '70s, the program resurfaced in the late '80s under a long-term scientific initiative called Project 863, from which emanated Project 921. In making the transition from high-altitude to suborbital flights, China focused on the 'human-centered concept.'

In January 1992, a special meeting, which included China's top scientists, was held in Beijing to discuss the possibility of a manned space program. It was concluded that such a program was both possible and necessary to boost the country's confidence and technological capabilities.

In August 1992, a team comprised of top aerospace scientists delivered a report on the results of their study on the development of the program.

On September 21, 1992, Chinese leadership gave the go-ahead for the national manned space program known as Project 921. Its goals were to: master space flight technology; conduct space observation and other scientific research; develop a space transportation vehicle; and, acquire experience for a future permanent space station.

On November 20, 1999, the first unmanned experimental spacecraft, named Shenzhou I, was launched from Jiuquan. After orbiting the Earth 14 times in 21 hours and 11 minutes, the re-entry capsule of the spacecraft returned to the Earth and landed in the landing site as scheduled, marking the first milestone in the program.

On January 9, 2001, the Shenzhou II flight expanded vehicle capabilities. Over five dozen experiments were carried out within various segments of the unpiloted vessel. After its week-long mission, the craft's descent section touched down in Inner Mongolia on January 16. Shenzhou II's forward orbital module was left in space, and was maneuvered several times over a six-month period.

On March 25, 2002, Shenzhou III carried into space instrumented mannequins and a variety of experiments. A recoverable re-entry module parachuted into the grasslands of Inner Mongolia on April 1. The orbital module circled the Earth and finally plunged into the atmosphere in November.

On December 29, 2002, Shenzhou IV orbited Earth, "signaling all clear for China's first space traveler to be launched in 2003." China's first manned space flight, Shenzhou V, was launched on October 15, 2003, aimed solely at the safe launching and return of the spaceship which carried one crew member, Dr. Yang Liwei. The mission was conservative in terms of the flight time as well as the fact that the craft carried only one crew member, although it was designed to accommodate up to three astronauts. Its success meant that China became the third country in the world to develop independently a manned space flight.

When Shenzhou VI was launched October 12, 2005, it became China's second manned spaceflight; its two crew members spent 5 days in low Earth orbit. Crew members were able to change out of their spacesuits and enter the orbital module to conduct scientific experiments for the first time.

Shenzhou VII, carrying three crew members, was launched September 25, 2008, and two days later, an extravehicular activity (EVA) involving a 20-minute space walk, was carried out by Zhai Zhigang, wearing a Chinese-developed "Feitian" space suit. A miniature satellite was released, and a solid lubricant exposure experiment was conducted during the mission."

In preparing for that mission, the first challenge, Chen said, was to develop an EVA spacesuit. This process benefitted from international cooperation—particularly that of Russia. The second challenge was the EVA crew selection and training, which included a vestibular function test, and training under pressure and in a pool. Challenge three was to monitor and support the health of the crew, including issues such as space motion and decompression sickness. Chen reported that traditional Chinese medicine and theory were used in countermeasures. The fourth challenge consisted of medical and ergonomic evaluation tests.

Chen stated that the ACC had developed a space medico-engineering discipline which was used in meeting these challenges. Space flight studies were conducted on the human body to ensure the safety, health, and efficiency of crew members. The ACC established a system for astronaut selection and training and developed a simulator for astronaut training exercises. The ACC mastered the technologies required to design, manufacture, and test the products of spacecraft environment control and life support systems, space suit engineering, space medical monitoring instruments, space food engineering, and other related technologies.

Chen noted that breakthroughs were achieved in developing life support systems. An experimental cabin simulator was built to perform a long-duration proof test. Effective ergonomic systems were developed. The physiological effects of weightlessness and countermeasures were studied, and a series of ground-based gravity simulation facilities were established.

Chinese space medical engineering went from ground-based studies to space-based experiments. More importantly, China has trained a new generation of talent in space medico-engineering.

According to the three-step strategy outlined in China's space program, the success of Shenzhou VII announced the onset of the second step, in which China will achieve a breakthrough in space rendezvous and docking technology and launch a space laboratory.

“The Chinese manned space mission and our space medico-engineering discipline face the challenges of the transition from short-term space mission and space flight to medium- or long-term space flight,” he said. Not only do the rendezvous and docking training project and astronaut selection strategy need to be established, but space emergency techniques and remote clinical diagnosis and treatment capabilities also need to be developed. The products manufactured for space flight support will also need to tolerate long-life demands and high-level reliability tests. Many experiments will be conducted by humans in space, and appropriate orbital countermeasures will be developed.

In summary, Chen said: “So no doubt, space medico-engineering will be enriched and developed, and have more application in ongoing manned space missions. At the same time, the development of space medico-engineering will help the accomplishments of the manned space mission and will promote the development of manned space technology.”

“We also hope that we will establish cooperation with many countries, and make some contributions to the world’s manned space exploration.”

Audience participant Valery Morgun noted that in the early ‘90s, China sent two specialists to train as cosmonauts at Star City, Russia. He asked how that experience was used. Chen replied that he thought the Russian training experience had been helpful in the selection and establishment of Chinese training systems.

Chen was asked by another audience participant to describe the traditional Chinese medicine that he said was used to treat space motion sickness, and how well it worked. Chen responded that the Chinese actually use a combination of Chinese and Western medicine, as the two systems can work efficiently. He said the results could be seen from the six Chinese astronauts’ behavior in space flight as well as their recovery after returning to Earth.

Panel II — Research Opportunities for Countermeasure Development

Panelists included Volker R. Damann, ESA; Scott A. Dulchavsky, HFHS; C. Michael Foale, NASA; Dennis J. Grounds, NASA; Inessa Kozlovskaya, IBMP; Valery Morgun, ROSCOSMOS; Boris V. Morukov, IBMP; Jeffrey P. Sutton, NSBRI; Fei Wang, NIH; Lin-jie Wang, ACC; Laurence R. Young, MIT.

Moderator Filippo Castrucci commented that in his position as a flight surgeon, he felt that in order to maintain the health of the crew members, we need to get enough knowledge about countermeasures, and he had been working in this area. That morning, a lot of information about countermeasures already had been shared, commenting, “We are on the right way on this.”

Castrucci then announced that there were two guests: Paul Christopher Levetzow from the Russian Academy of Medical Science, and Olga Shimbireva, from the Reconstructive and Microsurgery Department of the B.V. Petrovskiy National Research Centre of Surgery, Russian Academy of Medical Science, who would make brief presentations.

Castrucci commented that in his position as ESA crew medical support flight surgeon, he often has been asked by crew members about maintaining their health in flight. He cited three major issues: bone loss, radiation exposure, and loss of aerobic capacity. He asked Morgun to provide insight from his perspective about the most critical medical limits that, so far, are not allowing us to leave Earth’s orbit.

Morgun stated through an interpreter that the priority is the provision of health for astronauts and cosmonauts. It is our task to train him or her well so that everything will be OK. We have to monitor his or her health, learn from the crews, and provide for rehabilitation. In our ISS program, he said, we have formed two committees on medical operations and space medicine that cover all these effects.

As to perspectives on future flights, Morgun said he believed that we are going to continue our efforts and beyond that, develop new medical standards. “That is a very clear task.” A second

task for future flights is to develop psychological training activities. The third task is the support and monitoring of health of crew members, and countermeasures and medicine as treatment in case of trauma or illness. The fourth item is rehab after completion of a space flight.

Morgun said in order to fulfill these things, we need to continue the work of the past 10 years on the ISS, and prior to that, in the Shuttle Mir program and the Mir station. This experience should be used in planning all the activities that have to do with maintenance of health in space. We have a lot of hope for the medical research that is new that has been started at IBMP: The new experience that is Mars 500. This scientific experiment probably will provide some great data that can be used for the development of new standards and support, and in planning future space health maintenance and treatment.

Castrucci then asked Damann to comment on the challenge of conducting research on the development of medical countermeasures in such small numbers of subjects, while respecting the individual's fundamental right to privacy.

Acknowledging the “fine line we have to walk,” Damann underscored the importance of the flight surgeon relationship with the astronauts, noting “we are the representatives” of their medical interests. He noted that the Multilateral Space Medicine Board had been established as a platform where such medical issues could be discussed, and where needs could be identified with respect to health questions scientists could try to answer.

Also, Damann said, a number of commercial space flight participants had more or less agreed to make their stories public, which would be helpful to science. In addition, data-sharing agreements had recently been prepared in which astronauts could voluntarily share some of their information for the benefit of future life science research, emphasizing that this should not be made a requirement. Damann said there was no easy answer on how to progress in the future. He was open to any good ideas anyone might have to offer.

Kozlovskaya eloquently advocated the integration of countermeasure systems on board. She noted that the Russian and American systems use different protocols. They have different

exercises, and different principles on which they stand. She proposed that the systems be compared and integrated, using the best points of each. We have to integrate our science on board. We need a joint system of evaluation.

Kozlovskaya said that the Russian system is about 80 percent dedicated to treadmill exercise, while the American system is dedicated to resistive exercise. “What is good?” she asked. An international scientific board of specialists should be created, and this board should select the priorities and the approaches; for example, deciding who should do a particular experiment. It is absolutely necessary. Without it, we still may have some “brilliant experiment” on board, but without being linked to all the other things, there will be no understanding of what is really going on.

Morukov, speaking through an interpreter concurred, saying doctors and lead investigators should work together and create a standardized battery of tests and investigations that would reflect the primary changes in the human body post-flight, which would help evaluate the functional reserves an astronaut has after flight.

Morukov was optimistic about future long-duration flights due to the experience of numerous Russian crew members who spent more than six months in space. An apparently paradoxical trend was found wherein the longer a person stays on board, the better shape in which he returns, which Morukov said was “confirmation that we have a good countermeasure system.” In an extra-long flight in the future, it now will be a question of whether the crew member does his or her best to follow the recommendations, and does the physical exercise that was recommended.

With regard to the issue of bone tissue loss, Morukov said that it turns out a cosmonaut lost the same amount of mineral density in his second flight as he lost in his first shorter flight, which demonstrated that if a person does his best, the system that we have is effective. The system needs to be improved and customized to the individual. Different people have different capabilities, and previous flight experience is important as well. However, the existing system is a basis for planetary countermeasures.

Morukov said interplanetary flight has a certain degree of uniqueness. There is a different level and a different spectrum of radiation. We need to target that spectrum and study the systems, which we are doing on the ISS. We need to study the systems which are most prone to this factor. This factor is going to be very important on planetary surfaces, such as the moon and Mars, because Mars is practically devoid of a magnetic field. Therefore, the issue of prevention in this regard, for both engineering measures and medications, is of paramount importance for people to be able to go outside low Earth orbits, and for people to be able to go to other planets over long periods of time.

Morukov commented that another factor to keep in mind will be the psychological effects of long-duration flight, and there needs to be a system of psychological countermeasures.

Further, Morukov said that within the Mars 500 project, there will be a unique investigation studying the effects of radiation on primates. Parallel experiments will assess the effects of various types of radiation on biological subjects. A similar experiment in one of his labs took a year to figure out a way to simulate the modified radiation background with regard to strength and spectrum encountered in space.

Foale then described how his knowledge, selection, and application of useful countermeasures progressed and evolved with his space flights. He said his overall health condition was worse after his 4.5-month stay on the Mir station than after his subsequent 6 months on the ISS. After Mir, he had less neck strength and more bone loss in his trochanter than after his later, longer-duration ISS flight. Foale attributed that in part to his lack of full participation in all of the on-board protocols prescribed, and the fact that the exercise equipment on the ISS was not the same as it is now. However, he also said he believed the Russian post-flight rehabilitation approach of long mountain walks was very beneficial. After the ISS, he did a great deal of high-altitude hiking, and recovered his strength much more quickly. Also, by using the rubber Thera-Band countermeasures while on the ISS, he was able to avoid replicating his post-Mir neck problems.

Asked to discuss the potential for use of artificial gravity countermeasures, Lawrence Young delineated three factors that should be known before pushing ahead with short-radius

centrifugation: whether it is effective, tolerable, and practical. He cited a large international study that he co-led which involved deconditioning individuals for 21 days in 6-degree head-down bed-rest. Half the subjects had 1 hour of centrifugation each day. A physiological assessment at the end of the study revealed that they had greatly reduced loss of muscle mass, as well as improved strength, stamina, and cardiovascular findings. However, the researchers could not find a significant difference in bone loss between the centrifuged and noncentrifuged subjects. The centrifuge system appeared to be both effective and tolerable. He suggested that the question of practicality remained to be examined from an engineering perspective.

Asked to comment, Lin-jie Wang said it would not be practical to have such a high-load machine inside the cabin of China's spacecraft. She also pointed out that China takes a whole-system perspective of the body rather than addressing just one system.

Levetzow announced that the Russian Academy of Medical Science was initiating a new International Institute for Nanohealth in Space Research, which hoped to work in collaboration with other partners to address key challenges to the global population. Focuses identified for future studies include issues related to: health, energy, novel materials development, and the environment. The Institute will also have a student exchange program.

Shimbireva then enumerated the many different types of surgery that are being performed within the Petrovskiy National Research Centre of Surgery, a branch of the Russian Academy of Medical Sciences. Shimbireva said that the Centre is looking for development of collaborative research in various surgical procedures.

Jeffrey Sutton suggested that in going forward with new health countermeasure protocols for long-duration missions, first there should be "an interface between users and the scientific community," to prioritize what should be done. Second, this should be an international effort. There should be a formal mechanism by which this should take place. Third, Sutton noted this needs to be done now because there is "some urgency to this," as the ISS was moving into full utilization mode and it takes time to put together multidisciplinary experiments. He observed further that there was a "brain trust" within that very room.

Audience participant Dennis Grounds, in response to a question from Castrucci about the hardware that needs to be used in flight with respect to experiments on the Station in the future, said we should remind ourselves of what we have: “a fairly robust set of biomedical hardware” now on board the ISS. Further, we have international sharing agreements, particularly with our European partners, to share equipment within the laboratories. He noted we have cooperation with our Russian partners regarding how we look at pre- and post-flight testing.

However, Grounds said he would echo Morukov’s and Kozlovskaya’s earlier comments about the value of devising standardized testing, particularly pre-and post-flight, and countermeasures in flight. He also agreed with Morukov about the difficulties, but noted that steps are in place within the international countermeasure working group as a venue to continue that conversation. After the end of the shuttle program, the logistics system will not be as robust. The shuttle provides a lot of down-mass that will no longer be in place. Grounds said he agreed with Sutton that time is running short, and there is a sense of urgency in trying to maximize the available time.

Grounds also cited multiple focal health-related areas for “this magnificent machine” in the future, such as: the importance of making maximal use of the ISS exercise hardware, including the new treadmill; making maximum use of the measures on returning crews; adding countermeasures with respect to muscle mass; measuring body responses to reentering gravitational fields; determining how trabecular bone changes and how reversible it may be over time; understanding changes in the heart, such as size; evaluating countermeasures to maintain muscle strength in flight; and, accurately monitoring the immune system in orbit in the future.

Grounds said other areas of ISS interest in the future are: behavioral health issues in providing self-assessment and self-help tools to the crew for long-duration missions; the medical technology that will be used in confined spaces with small amounts of logistics on flight; the need to improve and augment terrestrial medical technology; the ability to concentrate oxygen out of the atmosphere for ventilation; the ability to generate infusion fluids from potable water; radiation-related work in terms of the testing of dosimetry in orbit; and, finally, further testing in the area of nutrition for the dosing of vitamin D.

In response to a question about new medical technology of use on future long-term missions, Dulchavsky cited new, lightweight ultrasound and imaging technology that, coupled with short-term training, could help a non-physician crew member to evaluate and address sudden medical concerns; for example, appendicitis symptoms. Dulchavsky said he was “very optimistic” about the ability of a well-trained non-physician crew member to do most of the things that he does in his hospital—maybe not exactly in the same way, but “good enough to keep a crew member healthy.”

Fei Wang commented that the NIH’s focus was human health on Earth, and that her agency could contribute to countermeasures used in space. She noted that the NIH would be helpful in that regard because of the knowledge built up on Earth; for example, what had been learned by way of productive results in exercise and nutrition could be employed as exercise and nutritional countermeasures in space.

Fei Wang further noted that the NIH recently issued a funding announcement with respect to the fact that her agency is going to send cellular and molecular-based research into space with NASA’s help. She said she asked when she heard that: “Why not human?” The answer was that “NASA already has a human research program.” So, “we would like to be complementary.” She was sure that what had been learned from the achievements in the human research program would benefit NIH scientists.

Fei Wang also said that the purpose at the NIH is to try to use the unique ISS resource to conduct experiments, and hopefully what will be learned will bring benefits to human health on Earth. She asked if the participants could imagine that if, years later, some of the NIH experiments done on board the ISS would have a huge human health impact. That would provide very positive feedback for the ISS existence. The unique aspect of the ISS to the NIH is that the Station is a discovery platform. Hopefully, whatever is learned from scientific discovery on the Station will benefit human health on Earth and also that of astronauts in space.

Panel III — Analog Environments: Human Performance (including Antarctic Telecast)

Panel III members included Oliver Angerer, ESA; Jeff Ayton, AAD; Michael L. Gernhardt, NASA; Valery Morgun, ROSCOSMOS; Pascal Lee, NASA; Yinghui Li, ACC; Christian A. Otto, CSA Consultant; Marcum L. “Marc” Reagan, NASA

Moderator and former astronaut Dave Williams introduced Jeff Ayton, chief medical officer of the Australian Antarctic Division (AAD), saying that Ayton would open his presentation with a live telecast from an Australian research station in the Antarctic, where it was then 2:30 a.m.

Ayton provided an informational backdrop for the impending telecast, saying that emergency medical physician Dr. Glenn Browning would be speaking from Mawson Station, one of three research bases on the Antarctic continent that are managed by the AAD, along with a sub-Antarctic base on Macquarie Island. “Our neighbors are the Chinese, the Russians, the French, and the Japanese, and this last summer, we assisted all in medical endeavors and logistic endeavors,” Ayton noted.

Speaking from Mawson Station on the telecast, during which he demonstrated the use of a new ultrasound technology protocol that was being tested, Browning said he was the only physician at Mawson Station where 16 expeditionists were spending the winter. Generally, there was no opportunity for anyone to leave or enter for 9 months over the winter there, where outside temperatures averaged minus 20 degrees, with winds of 20-30 knots.

With the assistance of a team member serving as a “patient,” Browning showed the use of a pre-programmed, laptop-size machine, a probe, and simplified flip-chart instructions. Browning used the probe to scan through the “patient’s” tissues to his bladder to provide images on the laptop screen.

The new technology package was designed to enable an inexperienced, minimally trained operator to collect high-quality images that could be transmitted from a remote venue to a specialist located elsewhere for interpretation and diagnosis. The compact, lightweight

ultrasound equipment is of interest not only because of its application for use in remote communities like this Antarctic station, but also with regard to its potential as part of medical equipment to be taken on long-duration space missions.

In response to a question from Williams, Browning said he felt his Antarctic station provided an excellent analog for a long-term space mission, above all because of its “absolute remoteness.” “You’ve got a very real population of people in a potentially very dangerous environment, isolated for a long period of time, where, if there’s a problem, you’ve got to sort it out down here.”

Back at the summit conference, Ayton presented his own ultrasonography demonstration, displaying on a screen a three-dimensional image of a liver scan sample provided by GE in Australia, to show “what we hope to have at the end of the research project” at the end of the year. Ayton described the project as a collaborative study, involving GE and Royal Perth Hospital in Australia, using an untested approach in the Antarctic of volume ultrasound. He thought that this new approach helped him, as the chief medical officer, to make the right calls and decisions in the support of his doctors in making a diagnosis. It also enabled him to send off a block of data to an expert for further analysis in evaluating and, hopefully, excluding some uncommon medical problem that would be cause for concern sufficient to prompt a decision on whether and how to evacuate a patient.

At the request of moderator Williams, all of the panelists then identified themselves and their analog environments. Ayton, who began, added to his earlier comments by noting that Australia’s Antarctic Division has a long history of doing research there, and has had a cooperative agreement with NASA since 1993.

Next, Oliver Angerer, ESA Human Exploration Science Coordinator, said research directed at space application was under way with French and Italian scientists operating Concordia Research Station in the Antarctic, including technology testing and validation, as well as medical monitoring of a group overwintering at that station.

Michael L. Gernhardt, of NASA-JSC, said he was project manager of the Lunar Rover Project and the leader of a new team, Exploration Analogs, in Mission Development. Gernhardt described tests of the rover on the lunar-like terrain at Lava Point, Arizona. He also discussed a CSA-sponsored project in British Columbia's Pavilion Lake, where freshwater microbialites exist in the context of a rare, ancient underwater rock whose growth may offer lessons about the evolution of life on other planets.

NASA planetary scientist and Mars Institute chairman Pascal Lee said for the past 12 years he had focused on Devon Island, a Mars analog in the High Arctic. In 1997, Lee initiated the NASA Haughton-Mars project, a scientific study of the Haughton impact structure and surrounding terrain on Devon Island. Lee said an analog site serves four functions: first, to learn about parallels such as the site's geology or microbiology; second, to test systems, strategies, ideas, and technologies; third, to train; and, fourth, to engage others.

Yinghui Li of the CARTC commented that Chinese herbal medicine had proven effective in the cardiovascular arena in the results of a 6-day bed-rest experiment of 24 volunteers.

Christian Otto, a remote medicine physician and researcher with CSA, cited his analog experiences at the South Pole, Mount Everest, and Devon Island. Otto said he felt there was concurrence on the panel regarding the value of specific aspects of different analogs, and their use in preparing crews for different types of training, thus avoiding significant costs in trying to accomplish similar work in space. Otto cited five key areas of analogs to consider in making comparisons: first, physical and environmental factors (e.g., similarity to lunar/Mars fidelity); second, mission characteristics (e.g., duration, relevance); third, human resources (leadership, crew size, composition); four, station characteristics (confinement, habital volume); and, five, medical care autonomy.

Marcum "Marc" Reagan, of NASA-JSC, said he had been involved since 2000 with the NEEMO project, a collaboration using NOAA's undersea research habitat, the Aquarius Underwater Laboratory, for analog missions. He said four-person crews, accompanied by two NOAA aquanauts, went on 6- to 18-day missions at NEEMO, near Key Largo.

Williams, who noted that he had participated in two underwater analog missions, asked for a moment of silence to mark the recent death of 36-year-old Dewey Smith during a Navy-NOAA mission at Aquarius, an event which underscored the risks as well as the strong bonds of friendship formed by those in space exploration pursuits.

Otto was asked by a summit participant to comment on the things that he felt should be considered for a Mars mission based on all of his Antarctic experience. Otto said BHP (behavioral health and performance) factors are critical. After dealing with the issues of zero gravity and its effects on the physiological system, the psychological factors of such a long-duration mission are “showstoppers,” based on what he had observed in individuals who had spent a long period of time in the Antarctic.

Responding to a request by another participant to define isolation, Ayton suggested consideration of the components of minimal communications and remoteness in “real, absolute isolation” without the possibility of evacuation over a long duration under hazardous circumstances. To these, Otto added confinement in environmental and social monotony. When asked later what proportion of analog health events is psychological in the Australian Antarctic, Ayton said about 4 percent.

Summit participant Rick Scheuring, NASA Constellation medical operations flight surgeon, voiced enthusiasm about the usefulness of the learning experience he had had in a lunar module medical contingency simulation on Devon Island. Scheuring then described difficulties he had encountered in the past in obtaining funding to use NEEMO to validate a number of engineering requirements for Constellation, as the Key Largo-based project was viewed as “somewhat of a boondoggle.”

Scheuring asked panelists for recommendations on how to get the analogs’ operational message across to nonoperational people who had not done field work. Williams asked Reagan to comment, joking, “Marc, I mean Key Largo—it’s 85, 90 degrees, sunny every day, and you’re scuba diving.” “I would say that’s probably one of the biggest things that’s hindered the NEEMO project—just the perception that ‘How could this be worth anything when it’s 85 degrees and

you're scuba diving every day?" Reagan responded wryly, adding that he didn't know what the answer was to the question. He suspected that all the panelists "share the same frustration" due to misunderstanding of analogs. He said he worked 12- to 14-hour days the week before, during, and after a NEEMO mission that he described as stressful and intensive.

Acknowledging that it is harder to "sell" a proposal if the objective is diffuse or the place sounds exotic, Gernhardt recommended specificity in presenting the hypotheses that would be tested. In response to a question about budgetary constraints, Gernhardt acknowledged that the money is not available to keep all the analogs operating at a high level. The approach we are taking is to focus on specific years on specific environments. However, Gernhardt said there was a "huge" potential for international funding.

"As we go to the Moon, we need to fashion astronauts into instruments of discovery," Gernhardt said, noting that currently, astronauts' missions are "very scripted." Astronauts needed to be converted into "field operational scientists" who would work on all aspects of the integrated science process on missions. Doing that now in analogs will offer astronauts the opportunity to see the big picture.

Another summit participant asked why—"if we're lucky" and we go back to the Moon in 15 years and to Mars in 20 years—all this work needs to be done now. Gernhardt responded that if we can do all of the work that needs to be done in analogs now, we can understand how we will want to operate. The purpose of analogs is to objectively analyze issues and use the data to make informed decisions. Otto interjected that, in fact, he wondered whether there was enough time for this planning process. "We're not early," Otto and Gernhardt emphasized.

In conclusion, Williams said panelists had come to the consensus that analogs are valuable. In light of all that had been discussed, he posed three closing questions for all to consider in the future. First, how can we increase the amount of international collaboration in analogs? Second, how can we get the appropriate funding for analogs to support the breadth of analog research studies?

Williams raised the possibility of creating what he called the “science of opportunity” in asking his final question, which was multi-tiered: Do we have the opportunity to openly discuss the benefits and disadvantages of the different analogs, and create the opportunity for peer-reviewed science to exist, which can provide a base of published research that can be tapped in implementing plans for new project payloads?

Reception and Dinner

Keynote address: The Honorable James A. Baker, III, honorary chair, James A. Baker III Institute for Public Policy, Rice University; former U.S. Secretary of State; former U.S. Secretary of the Treasury.

The Honorable Edward P. Djerejian, the Baker Institute’s founding director, welcomed the participants to the dinner, commenting: “Today’s deliberations were superb. And I think this is truly a unique conference that holds a lot of potential for future work for all of us.”

“It’s really my honor and privilege tonight to introduce our distinguished speaker for tonight’s dinner. He is a person that you all know, so I’m going to make a very brief introduction. Our speaker has run five presidential campaigns. He has been twice White House Chief of Staff. He was the 67th Secretary of the Treasury of the United States; the 61st Secretary of State. He is the author of two books: “The Politics of Diplomacy”; and, another book whose title is “Work Hard, Study. . .and Keep Out of Politics!” which his family told him, which he simply did not follow; but, his most important title to me is that he is the honorary chair of the Baker Institute at Rice University.”

In preliminary remarks, the Honorable James A. Baker complimented Djerejian for the “remarkable job” he had performed at the Baker Institute over the past 15 years. “This type of event is evidence of that. “We are very proud to be co-hosting this event with Baylor College of Medicine. These two fine institutions have developed a partnership that we hope will continue to broaden and deepen.”

Baker said that the Space Policy Program, which has long been a critical component of the Baker Institute's research agenda, had been "very ably" directed by George Abbey, whom Baker described as "extraordinarily effective, with a true passion for space." Baker said that George Abbey and Dr. Bobby Alford, "the very talented Chancellor of Baylor College of Medicine"—as well as Baker's personal otolaryngologist—were owed "an immense debt of gratitude for their unstinting efforts in organizing this conference." He then delivered the following address which is provided here as presented:

"This summit brings together leading physicians, space biomedical scientists, engineers, cosmonauts and astronauts from the space-faring nations to discuss the medical challenges that humans experience during long durations of space flight. I particularly want to welcome our Chinese colleagues who are attending this summit for the very first time. Their presence here will broaden our perspectives and will enrich our conclusions. Of course, there are going to be many questions about the future of space exploration, but one thing I think is for sure: China will play an important part in it.

Now, ladies and gentlemen, let me begin with just a little bit of history. Some of you are young enough that you may not remember all of this. A year and a half ago, the Baker Institute celebrated the 50th anniversary of one of the most significant events of the past century. That was the flight of the first manmade satellite, the Soviet Union's Sputnik I, in October 1957.

That flight actually was a turning point in the cold war. It startled the world, and it honestly alarmed the United States, which had until then believed itself the world's leader in space technology and in missile development. The surprise Sputnik launch and the failure of the first two United States satellite launch attempts provided a much-needed wakeup call to U.S. policymakers and our citizens alike. The crisis spurred a number of American initiatives, including the National Aeronautics and Space Act, which was signed into law by President Eisenhower in July 1958. This legislation created NASA, the civilian agency responsible for guiding the nation into the space age. The Soviet Union followed the triumphant flight of

Sputnik with other successful space missions that culminated when Yuri Gagarin became the first man in space in April of 1961.

Three months later, the space race was on in full swing when President Kennedy challenged our nation to send a man to the Moon and to return him safely back to Earth by the end of the decade. By February 1962, the United States had achieved its first manned orbital flight when Mercury astronaut John Glenn circled the earth. Fulfilling President Kennedy's challenge to reach the moon, I think, clearly established the United States as the world's then-unquestioned technological leader. In a little more than 7 1/2 years after President Kennedy's 1961 speech, the Apollo program had become one of man's greatest achievements when Apollo 8 orbited the moon. The following year, Apollo 11 landed on the lunar surface.

The Apollo program captivated the imaginations of young Americans, and inspired them to become scientists and mathematicians and engineers. They became a brain trust that has fueled our countries' technological progress ever since. Now, despite its importance for all of mankind, the Apollo program was really an American program.

I stress this because the early years of man's space exploration were to a very large extent driven by the Cold War. While other factors were important, not least the abiding human desire to explore the universe, U.S.-Soviet rivalry was clearly decisive in giving urgency to the efforts in both countries. Would man have reached the moon but for the Cold War? In my view, probably, but almost certainly not by 1969, a mere 12 years after Sputnik. As our nation's last Cold War Secretary of State, it is really quite heartwarming to me to note that that Cold War ended now almost 19 years ago and, thankfully, it ended with a whimper rather than with the nuclear bang that so many had feared.

The end of the Cold War gave rise to a new geopolitical climate. That new geopolitical climate has opened up vast areas for international cooperation. Today's manned space efforts, I think, reflect this new reality. This very evening, the International Space Station is orbiting Earth, thanks to technology and machines provided by the United States, Europe,

Japan, Russia and Canada. As I speak, American and Japanese astronauts are flying together with a Russian cosmonaut. And control centers in the United States, Canada, Europe, Japan and Russia, as well as tracking facilities in Australia, are working together to conduct research and to operate the station.

I don't know about you, ladies and gentleman, but I think the International Space Station is as incredible a political achievement as it is a scientific one. When it is completed, the space station will represent the largest international cooperative technology project in the history of mankind. U.S-Russian collaboration has been a critical part of this success. When then-Russian President Putin visited the Baker Institute in November 2002, he said, 'Particularly great here are the potentialities of the scientific community.' Therefore, joint Russian-American research and development, in our view here at the Baker Institute, has very great prospects. And the two countries' cooperation on the space station helps nurture an atmosphere of mutual respect. We can only hope that this will serve bilateral relations well into the future.

Predictably, I think, the U.S.-Russian partnership has recently had its share of difficulties, just as I think all major endeavors of similar complexity probably do. But the strength and the durability of the U.S.-Russian space partnership has been demonstrated in times of crisis. In the wake of the tragic space shuttle Columbia accident, for instance, NASA officials were only able to maintain their operations on the space station through the outstanding support provided by their Russian colleagues and the Soyuz and Progress spacecraft. So the bottom line is clear: International cooperation is indeed critical to the future of manned space travel. So Russo-U.S. cooperation will obviously be crucial. But so will cooperation with China, Japan, the EU, and indeed, all countries committed to the peaceful exploration of space.

And this summit is dedicated to broadening and deepening that cooperation in ways that advance knowledge and inspire the human imagination.

Forty-seven years ago, President Kennedy visited this university, and he gave a historic speech about space exploration. Right here in Rice's football stadium, not far from where

we sit, he spoke of our exploration of the universe. ‘We set sail on this new sea,’ Kennedy said, ‘because there is new knowledge to be gained and new rights to be won, and they must be won and used for the progress of all people. There is no strife, no prejudice, no national conflict in outer space as yet. Its hazards are hostile to all of us. Its conquest deserves the best of all mankind. And its opportunity for peaceful cooperation may never come again.’

Now, ladies and gentlemen, I cannot hope to match President Kennedy’s eloquence. But I do believe that it is important for us to recall the huge stakes, not just for the countries represented here today, but for all of mankind, in forging a common approach to discovering a universe whose wonders we have but just begun to explore.”

DAY 2: MAY 16, 2009

Mars 500 to Exploration

Boris V. Morukov, cosmonaut and deputy director, Institute for Biomedical Problems (on behalf of Igor B. Ushakov, IBMP general director)

George Abbey introduced speaker Boris Morukov, noting that Morukov would discuss the then-current 105-day Mars simulation study at the Institute of Biomedical Problems (IBMP), of which Morukov is deputy director. His remarks are provided here as presented:

“In recent years, the attention of humanity is directed more and more toward the distant universe. One of the first places to study is planet Mars, a planet which is somewhat similar to Earth, and the place of development of the solar system. We are attracted by the capability of understanding the history of the development of the solar system, the development of life, and possibly the history of domination of life. Lately, distant studies of Mars’ surface have taken over.

However, I think that people will never give up the idea of visiting the planet, in which case, the effectiveness of the research and the analysis of the results are going to be at a much higher level.

Humans are the primary priority of an eventual Martian mission. The human is also the most vulnerable link in the chain in implementing a Martian mission.

The basic difference of an orbital flight and an interplanetary one is in the fact that once we leave low-Earth orbit, we are unable to replenish any resources that we require for the subsequent mission and for crew life support. In an orbital mission, resupply is possible.

It is not possible either to obtain assistance from the ground, and it is not possible to get back to Earth, which is an additional psychological factor that will affect humans.

In a low-Earth orbit flight, the control function is largely dependent on the control center on the ground support services, which not only monitor continuously all the systems, but also in most cases control the vehicle by commanding it remotely.

In an interplanetary mission, these functions will mostly fall to the crew. The crew should be able to manage itself, to control on its own, which will include independence with respect to decision-making, including independent resolution of possible contingencies, which will also include self-monitoring, including health monitoring and psychological status as well as performance.

For an interplanetary flight, what you would find is a change in communication, reducing the volume, and experiencing a lack of data transmission which in a Martian orbit or closer in to Mars could be as long as 30 minutes, in which case voice communications are not possible. The only interchange that is possible is an electronic interchange between the crew and ground support.

Landing a manned vehicle on an unknown planet is something that is completely new and previously unexplored by manned space flight, as is operation on board on the surface of the planet and in the Martian orbit. The crew will find it very difficult, because the crew remaining in orbit will have to work much harder and cover for the rest of the crew which are on the ground, and they will also need to coordinate with the controllers back on Earth.

Essentially, these are the unique features of a Martian mission that we concentrate on in the Mars 500 project. This is a project that started four years ago. Initially, it needed to be justified, and rationale needed to be provided for engaging in a project like that. At that particular moment in time, we needed to justify it to ROSCOSMOS. We were able to do that. ROSCOSMOS is the primary customer for this activity.

Subsequently, we needed to upgrade our ground medical and engineering facilities. We needed to establish new modules. Right now, there is a set of five modules that includes a habitation module, which is the primary location where the crew is going to be spending most of their time. There is a medical and research module. There is a storage module, although it is not purely storage, because in addition to housing all of the foodstuffs and all of the other resources for the crew to sustain themselves, we have a greenhouse, as well as a workout room, and some medical equipment. This set of modules also includes a module which is designed for a Mars landing. And the final component which is part of the vehicle is a module that simulates the Martian surface, which has been introduced recently. I can talk to you of the engineering properties of the vehicle if you're interested in more detail.

The crew that is currently isolated on the simulated vehicle is a crew for a 105-day experiment, and we will not be able to simulate a complete Martian mission, of course, from the duration standpoint. Our concept is that we are going to simulate a target-oriented ISS flight of 105 days which reproduces some peculiarities of the Martian mission. This experiment was preceded by two verification experiments of 14 days each, which mostly verified the life support system for the crew. Every time we introduced a new module, the vehicle configuration changed, and we needed to verify the new configuration.

We split the 105-day mission into three series of 35 days each. In each of the series, we were attempting to keep to the following constraints: stringent isolation, which is mostly related to the fact that the crew has no communications capability which is currently available to the ISS crew, and that was previously available to our test subjects in similar experiments of even greater duration. For example, there is no way to use a phone; the crew does not have internet access; limitations have been imposed on interchanges with the support team. We have introduced a rule that the crew will initiate communications, and the support team is supposed to respond or provide a tag-up or provide information; i.e., the crew will be the lead in setting up interchanges with the support team.

All of the resources that are required for crew life support are already on board the simulated vehicle, including mostly food, clothing, life support components, sanitation and personal hygiene items, things related to medical support, and medical treatment. Everything is inside the simulated vehicle, and the crew is supposed to use these resources on their own. This is a test, as far as we are concerned, of the correctness of the utilization standards for groups and individuals for this period of time.

Their independence is also supported by the fact that the crew is expected to find resolutions to any situations that arise in the course of the experiment. They do not have any access to technical or medical assistance from the ground, which can be provided, but only under exceptional circumstances when there is risk to human health or risk to some equipment that is unrecoverable, which may arise in the course of the experiment.

The final 35-day stretch is going to be characterized by the communications mode which is accepted in the Martian orbit, which will probably be confined to two or three packet messages from the crew to the support team, and back to the support team from the crew.

One other objective of this final stretch is to introduce the module that simulates a Martian lander, such that: the crew is able to verify all of its systems in an integrated manner together with the primary module. The crew is to evaluate its human engineering properties; and, the crew is to perform a number of activities which will be novel for the crew and

which the crew is going to be notified of electronically in the course of the experiment after launch.

As for the selection and training of the crew, the crew is a six-person crew: four Russian crew members and two European Space Agency crew members. The crew has the following functional positions: we have a crew commander; a flight engineer; a crew surgeon; and, three researchers. The experiment has a very heavy research program. There are over 70 projects that are being implemented in the course of the experiment, mostly, as expected, psychological investigations. The objective in the training is to distribute the responsibility for these experiments out to the crew members, and we have defined clearly who is responsible for each specific experiment, who is assisting, and who is supposed to be monitoring the state of health if required.

But in the planning of these activities, the crew was heavily involved, because they have the initiative, and we just assisted in apportioning the responsibilities in an efficient manner. It should be noted that most of the investigations are multifaceted investigations, and it is difficult for a psychological experiment to find someone that would be happy with just a questionnaire. There is some recording of physiological parameters and some biochemical parameters, which may provide insight into the condition of the body and the psychological and emotional stress. These are integrated investigations and we had to combine research proposals in certain instances to avoid duplication and save some time.

At this moment in time, we are close to the midpoint in the 105-day experiment. The transition to stand-alone operations was very difficult for both the crew and the investigators because, frequently, the crew members requested things that we did not want them to request, or we didn't want to provide in the way of additional information or resources. On the other hand, when the investigators through the video—because it's very well provisioned with video—to see that the crews are not doing the right thing, the researchers are tempted to intervene and they are saying that 'On station, we are able to contact them and tell them to adjust their activities.' But we have to hold them back, because the crew is out there somewhere away from Earth. That means he or she has to be on their own, and you can

correct the procedure once you get the results back. So over a month, we have minimized the activity on either side.

We were lucky because we have a very good crew. I think that we should mention the professional qualities which have been demonstrated by members of the crew, and we have to speak about their personal character traits that we wanted and we found.

In addition to being healthy and professional, they have to be very creative for an experiment like that, and for an interplanetary mission, even more so. They need the ability to digest new information, to learn as they go along because very frequently procedures change, new objectives arise, and crew members have to play off their sheet of music without ever having practiced. Motivation is very important. Motivation coupled with conviction that a personal contribution is required to succeed. It is also very important that the person be critical toward his or her conduct. They need to be responsible. They need to take on responsibility for the consequences of their actions.

Also, it is very important that they be able to get along with the rest of the crew. They need to measure their actions and their emotions by the actions and emotions of the rest of the crew and, if required, be able to subjugate their desires to overall objectives. We would like to see them tolerant toward one another. We would like to see them behaving naturally, because it's difficult to play a part for a very long time. In a critical situation, a person is always him- or herself. We also require a nonaggressive sense of humor.

The crew includes two cosmonauts: one is a researcher and a commander working at our institute and one flight engineer is an Energia person. We also have a practicing physician on the crew, a very good one. We have a physical exercise specialist on the crew as well. And as far as our European colleagues are concerned, they do a very good job; they fit in well with the crew. One is a civilian pilot, a commanding officer of an Airbus 320, a French person; the other is an engineering officer that has some experience in Afghanistan. They are working very well. They are very responsible, and we are very happy with the way they are doing.

The primary objective right now is to get together a crew for the 520-day experiment which would mimic the current crew that we have and its properties. I would like to say right off the bat that we are writing a program for the 520-day experiment with little past experience with the crew in this current experiment. We have made a call for the crew. The European Space Agency is also providing us with some candidates.

It is very important to have an overall concept for this mission. The changes in communications which we introduced in the 105-day experiment overnight after day 70, which is what we are going to do, we expect to do gradually in the longer experiment at a time when you would expect this to occur in a real Martian mission where this delay lengthens over time. It is quite clear that the first 70 days, the delay is not going to be significant and will not affect the crew to any serious degree; however, it will grow exponentially after that point in time and it will grow in importance.

It is a major problem for us to apportion the various functions to the crew members and to identify the crew members that are going to land on the surface of Mars. We would like to get a virtual model of the Mars landing. You know that we do have this in our experiment, and on the station. This is a research program which is called the Pilot. Here we investigate the skills of a pilot for docking and undocking operations and also in some complex environment. We would like to get a virtual model of such dynamic operations for landing on Mars surface.

Activities on Mars surface are actually an ongoing project, and we have some activities done by Moscow Aviation Institute in preparation for that. Also, the Moscow State University is involved. They have the virtual module for Mars surface already, and they have a proposal to use prototypes of Martian rovers. Also, it is possible that probing of landing site can be done by using flying means like aerostats and other vehicles because the crew cannot walk away far. You need to know which direction to take, and you need to know what exactly you are looking for. That's why it is important to start at least to develop a system that will use automated means where a person will be supporting such systems, will be getting information and analyzing the situation. Later on, this data can be used for some specific

paths where a man, a woman, would take part. Later on some sampling can be taken of the ground, of other items, and then we will already know which place they will be investigating, and where exactly they will be taking the data from.

Of course, this is a huge project. It is good that we have some room for creativity here. On the other hand, we have a deficit of time. One experiment is ongoing right now. The other one is going to be started in September. In September, we are going to start working with the crew. Right now we are in the preparation phase. In the beginning of next year, we will start the experiment with 520 days' duration. We are convinced that we are on good schedule, and what we are doing is timely. This is the principle that we adhere to at our Institute. Prior to jumping into a huge project, we have to do preparation work on the ground. This is what we were doing prior to long-duration flight. We had a 970 bed-rest experiment in the past. At that time, we were developing countermeasures not only for long-duration flights, but also for Martian projects. Those countermeasures that were developed at that time can be applicable. Also, prior to introducing females to space, we had a bed-rest experiment using a female subject. In 1967, a long time ago, it was one of the most unique confinement isolation experiments, where we used biological systems of life support.

Such ground preparation work will give you the initial data base to move along, also to create medical support systems for a human being to be away for such a long time.

I believe that when this project is completed, we will have more questions than answers, although right now, many scientists think that we have received some interesting results. But this is a research project. This is a project that is needed to make sure we will make minimum mistakes when we work on specific planning and programs. That's why we will not spare our efforts. Thank you very much."

In the ensuing question-and-answer session, a participant asked Morukov what could motivate people to voluntarily shut themselves up for 520 days, saying that was "almost like volunteering to go to prison for a year and a half."

Identifying himself as a cosmonaut who had associated with other cosmonauts all his life, Morukov said that kind of motivation was a character trait of many of his friends, who enjoyed activities like diving and going to the mountains for a long time. Such individuals had to be healthy, curious people, willing to learn something new. The confinement aspect of the experiment was not a punishment. Two of the people involved were actively collecting data for their own science projects during their confinement, so that was their motivation. “Of course, they have a lot of support, especially in Europe, where a lot of attention is being paid to their science programs. Another motivation trait is that ‘they have to test themselves’ and that was what they were doing in this experiment. Sometimes I am surprised, myself, but you can find people like that.”

Christian Otto asked Morukov whether there were any objective monitoring procedures to evaluate crew members’ behavior, noting that he had observed “a slow deterioration in psychological status” and a “loss of objectivity” over time in crews spending long-duration assignments in the Antarctic, and that they had trouble recognizing and self-monitoring that phenomenon. Otto also remarked that if ongoing data involving measurements like voice analysis, heart-rate variability, and facial recognition were relayed to the ground, objective observers on the ground could analyze it and respond by suggesting timely countermeasures.

Morukov responded that a multifaceted psychological evaluation was used, and individual qualities of crew members were observed as well. He stated that there was an awareness that in space, “sooner or later, we will observe some psychological changes” in people; that behavior would change in terms of interactions between crew members, as well as between the crew and the support crew on the ground. Morukov said that the psychological and emotional sphere is the subject of observation. Also, several of the experiments are devoted to sleep. In addition, every day for four hours, one of the crew members is on guard, and is supposed to report to the support group if necessary. He is supposed to watch the system in general. So the research is comprehensive. Of the 70 experiments on board, 30 are psychological. Three of them are American projects.

Bobby Alford thanked Morukov for his excellent presentation, saying it was an outstanding project.

Novel Technology Presentations

Cheng Chi Lee, UTHSC professor of biochemistry and molecular biology

James M. Tour, Rice University professor of chemistry and computer science

Bobby Alford told summit participants in his introductory comments that “Today, we have something a little unusual for the summit. There are two novel presentations to make that fit into the category of interesting, relevant new discoveries. One was brought to our attention by Dr. Tom Caskey, who is a professor at the University of Texas and a very well-known geneticist. It is from one of his former students who is now also a professor at the University of Texas, Dr. Cheng Chi Lee who is going to talk about the induction of a hypometabolic state in mammals.” Lee’s report is abridged as presented:

Professor Lee opened his presentation by showing a slide from the movie “Star Trek” entitled “Suspended Animation?” to raise the topic, saying that he thought that if we could achieve this process, the trip to Mars would be greatly simplified. Lee provided context for his ensuing discussion by explaining that he had interests in circadian rhythms as well as the process of metabolic control.

Lee said that when an Alpine marmot enters the state of hibernation, its core body temperature drops rapidly, as well as the amount of oxygen consumption. Lee explained that about 6-7 years ago, when he began thinking of his project on the induction of a hypometabolic state in mammals, he wanted to find a gene that could be used as a marker to find the molecular basis for how those aspects of the hibernation process work.

Lee said he and his team began by looking at a non-hibernating animal, as he felt that if he could find it in a non-hibernating animal, perhaps he could do the same thing, and find usefulness for it, in the human being. Choosing the mouse as a model, the team kept one in

constant darkness, while the other was kept on a light-dark cycle. Then they took the livers and ran microarray analysis tests of gene expression, to see whether they could find differentially expressed genes.

They found a gene for murine procolipase, which produces an enzyme whose role is to break down dietary fat into fatty acids—a gene which is strictly expressed in the pancreas and stomach, Lee noted. Since this gene had, instead, been found in the liver in the microarray analysis tests, Li said he initially thought there was some mistake. So he and his team ran another method of analysis.

Lee and his team then posed the question: Is the gene expressed in the liver in the light-dark cycle? They found that the answer was no, in the light/dark-cycle mice they tested.

However, in mice kept in constant darkness, it was expressed in the liver and in all the peripheral tissue except for the brain and kidneys. Lee alluded to observations during work related to a Zhang et al publication in Nature in 2006 (Nature 439: 340-343, 2006.)

Lee and his team then asked the question: What is the signal that regulates this gene expression? The team found elevated levels of 5-prime adenosine monophosphate, or 5'-AMP, which Lee defined as the breakdown of ATP (adenosine-5'-triphosphate), in the blood of the mice kept in constant darkness compared to those on a light-dark cycle.

Lee's team then injected a synthetic version of 5'-AMP into the mice on light-dark cycles at room temperature, and found that the gene for procolipase was induced “everywhere” in the tissues. The gene was not expressed in saline-injected mice. Therefore, this had to be the correct molecule, Lee said. Injection of the synthetic substance was found to induce torpor, as well, in the mice on the light-dark cycle.

During that time, Lee said, his postdoc remarked to him that, when he used his fingers to pick up the mice that had been injected with synthetic 5'-AMP at a room temperature of 15 degrees C, they felt cold. Lee asked him to take their temperature, and was very surprised to

hear the findings of a 10-degree difference, which underscored how dramatically their bodies had cooled after the injection.

At this point in his presentation, Lee showed a video clip with the overlying question: “Can we put non-hibernators into suspended animation?” which depicted a gloved hand picking up the limp bodies of the mice that had been injected with synthetic 5’-AMP, to show they were in a deep hypothermic state. The mice had had no anesthesia and were not comatose, he said, noting that it could be discerned that they were moving slightly.

Further tests were done, involving an array of physiological measurements including heart and breathing rates and oxygen consumption. Lee said the data showed that these rates all slowed. First, there was a slowdown in oxygen consumption, followed by a drop in core body temperature.

“What is critical is the temperature of the room,” he said, showing a data chart. “If you keep it warm, the animal comes up very quickly. If you keep it cool, it stays down pretty long – in this case, up to about 9 hours.” You can’t stop the animal from coming out of its torpor by giving more AMP, which would be lethal, he said.

The challenge, Lee said, was: how can we make this state of suspended animation last much longer? Lee said he conducted an entire metabolic analysis of the blood of the animals in further tests. Lee said he was making “considerable progress” with the metabolite cocktail he is working on at this time. He showed a chart that indicated experimental mice were injected first with synthetic 5’-AMP, and subsequently injected periodically with the metabolite cocktail, which significantly extended the hypothermic state—up to 24 hours—at which point the mice were brought out of their state by increasing the room temperature.

“I am very hopeful that we can extend this process” beyond 24 hours, he said, adding that for a mouse, that was “enormous.” Lee said he believed it would be “a lot easier” to do this, using the same technique, in a larger animal.

Lee commented that he had conducted experiments using 5'-AMP in a dog and a monkey, to show that it was not only applicable to the mouse, and it worked in both of those cases.

Alford thanked Lee for bringing his new discovery to Summit participants.

Alford then introduced the next presentation, to be given by James M. Tour, professor of chemistry and computer science at Rice University. Alford reminded the summit participants that Tour spoke to the group at the 2008 Summit during the Solar Radiation Risks for Lunar Operations Panel.

Tour discussed findings of his research group from studies in mice of an oral dosage of a drug designed to be taken within a half-hour of radiation exposure. He began by noting that a long series of tests were done from 1959 to the early to mid 1970s on protectants and mitigators for the effects of radiation exposure. Tour's presentation is provided as presented:

"It's interesting that this topic is being reinvestigated not just because of space travel, but more so because of the effects of what might happen here on Earth due to terrorist attacks – what might happen if a nuclear action were to go off in a city and you had a million people exposed, or soon to be exposed. Is there something that could be done to protect or mitigate the effects of this?"

Tour said his research group had looked at some experiments that involved nanometer—sized particles delivering different agents intravenously, intraperitoneally, and orally. If there were a radiation event on Earth, and a large number of people—for example, 1 million—were exposed, it would be impossible to use the mode of IV administration. The only viable mode would be to provide an oral dosage to massive numbers of people under such circumstances.

To that end, the Department of Defense had studied a mode of distribution in which dosages would be made available in supermarkets, where people could get the dosage and take it immediately. That scenario was envisioned because in the event of an impending radiation

exposure, people could not get to doctors' offices or hospitals. Moreover, it would not be feasible to recommend that an individual should take the dose if he felt ill because everybody will be feeling sick—everybody will want this dosage for themselves and their families.

Even if it were not a mitigator that could work after exposure, an oral dosage that would work before exposure could be effective in a place where there is a large radiation exposure. That's because radiation travels as a plume in a large vector, and people could have "minutes to days" in which they would know that inescapable radiation was coming their way.

Houstonians had seen that it was almost impossible to get out of the city with several days' warning that a major hurricane was coming. The city highways were frozen in traffic gridlock as Hurricane Rita was approaching in 2005. Even when the infrastructure is working, it would be impossible for large numbers of people to exit a large city on short notice.

Tour and his research group, along with two scientists from The University of Texas M.D. Anderson Cancer Center, used a traditional study of crypts in mouse jejunum to look at the effects of radiation on the stem cells in the crypts. This assay has been used since the 1970s, and was developed in collaboration with M.D. Anderson. In looking at the effects of radiation, his team generally doses a mouse with 12 gray of radiation, a fatal dosage. Typically, the mouse would die from that dosage in a few weeks.

Tour and his team studied the effects for 3.5 days after the radiation exposure. Then they counted the crypts in a slice of jejunum. Usually, there are about 150-160 crypts in a normal mouse. Since the stem cells generate the cells that line the villi, once the stem cells in the crypts are gone, what happens is death by GI syndrome. The main source of death would be the bacterial infections that occur without the layer that normally covers the small intestine. So, the question arises: Can we protect that layer?

Tour and his team have found a drug that, when a single dose is administered 30 minutes before a radiation event, results in the retention of more than two-thirds of the crypts in the jejunum in their mouse model. If there is no treatment, generally only 10 percent of the 150-160 crypts remain.

Compounds not unlike this, and quite related, were studied in mice back in the '60s, but further studies found that they didn't translate to larger mammals.

Currently, Tour is finding that, because he is looking at a community which is potentially much larger than that going on space travel, he can leverage funding from agencies such as the DOD and NIH and other agencies that would want to protect large numbers of people to attack this problem.

Tour raised the question: Do we have something that would move this effect into larger mammals? He would like to work on a number of compounds, but the funding is in the form of only small bursts of support.

As an example, Tour cited a grant that initially was supposed to provide funding for the limited time period of 12 months. Then, when they got the grant, the grantor asked if he could cut back the timeline to 6 months, because they wanted a solution. They finally agreed on 9 months. When that ran out, Tour said we were making very good headway with this oral dose that was able to protect two-thirds of the crypts. That was typical of the funding issue, in that a fast solution was sought. Many of you know there's no easy solution to this.

I think we're showing we're within reach, and if we reinvestigate something that's been investigated 40 years ago, I think we can solve this problem. We have nanometer-size delivery vehicles, we have nanometer-size particles that can go in, and things that can sequester far more radicals.

I think we are within reach of finding an oral cure to this threat, or at least a protection if not a mitigator as well, by studying a series of strong radical traps that could be administered.

In fact, many of the compounds he and his team are studying are so nontoxic, people could take a daily dose day after day with no effects.

Many of them actually are compounds that have been known on Earth for a long time, and have been looked at in other studies. So people could, indeed, take large amounts over a long period of time.

Alford thanked Tour for his outstanding and encouraging research presentation.

Panel IV — Commercial and Industrial Opportunities

Panel IV members included Jeanne L. Becker, NSBRI; Robert J. Benkowski, MicroMed; George “Bud” Brainard, NSBRI; George P. Noon, TMH; Neal R. Pellis, NASA; Kenneth S. Reightler, Jr.; Babs R. Soller, NASA; James M. Tour, Rice

Bobby Alford introduced Panel IV moderator, Col. Brewster H. Shaw Jr. (USAF, retired), a former astronaut who is now vice president and general manager of space exploration for Integrated Defense Systems at The Boeing Co.

Shaw said in his opening remarks that “we’re gathering at a pretty exciting time for space-based and travel-related, enabling research. If all goes as planned this month, we’ll have six crew members on the International Space Station living full-time in orbit, conducting scientific research in the unique environment that only this engineering marvel can offer. At present, the ISS is our only option for long-term, human-tended research in space.

Recently, Shaw noted, a shuttle crew delivered and installed the last major piece of U.S.-provided hardware to the station, a Boeing-built power module that enabled the station to reach its full power capability and support science investigations on board, noting that his company is NASA’s prime contractor for the ISS.

Shaw told the participants that the ISS supports a variety of pure and applied research for the United States and our international partners. It also plays a critical role in support of U.S. space exploration policy by aligning scientific research to support exploration objectives, including medical countermeasures for long-term human space travel and for the development of enabling technologies. Moreover, the ISS demonstrates the value of human involvement in space exploration, to accurately assess unforeseen events and properly address them to maintain overall mission objectives.

Currently, there are 19 research facilities on board the ISS: nine sponsored by NASA, eight by ESA, and two by JAXA. When the international assembly is complete, the ISS will have 24 facilities.

In the years since permanent human presence began aboard the ISS, expedition crews have conducted some 155 integrated investigations serving over 600 scientists globally. Shaw noted that the 2005 NASA Authorization Act designated the U.S. segment of the ISS as a National Laboratory, and directed NASA to develop a plan to increase the use of the ISS by other federal entities and the private sector. As the nation's newest National Laboratory, the ISS will further strengthen relationships among NASA, other federal entities, and private-sector leaders in the pursuit of national priorities for the advancement of science, technology, engineering and mathematics.

Shaw stated that it is in concert with the theme of this panel that enticing commercial companies to execute medical sciences research on space platforms represents a tremendous opportunity to advance the global well-being of the human species. However, we Yankees have been a little bit inconsistent in our approach, he said, noting that we designed and built the ISS with a model of utilization in mind. Then, with the advent of the Vision for Space Exploration, much of the science that had been planned for years to be conducted on the ISS was cancelled by the agency. Then the U.S. declared it a National Laboratory, and encouraged other agencies and the private sector to become involved in research. What followed on the heels of that is the retirement of the space shuttle, the main logistics carrier for ISS utilization.

In light of all this, Shaw posed this question to the panel: “Given that we have this logistics problem, where we’re going to be dependent on Russian, European, and Japanese logistics carriers for the foreseeable future, with limited up-mass and no down-mass capability, what is the greatest barrier to commercial utilization of the ISS for medical sciences research and development?”

The moderator then introduced panelist Jeanne L. Becker, noting that in her current capacity as chief science officer of Astrogenetix, Becker is part of the research team developing a vaccine for *Salmonella enterica*. “This initiative partners industry with academia and government for the development of a commercial product, and serves as a pathfinder mission to validate the use of the ISS as a National Laboratory for commercial research and development after assembly is complete.”

Becker is also vice president and institute associate director of the NSBRI, as well as associate professor of OB-GYN and Surgery at Baylor College of Medicine. Her project stemmed from some excellent fundamental science that was one of the lucky payloads that got to fly on the shuttle. A couple of years ago, a finding was made that when salmonella is allowed to grow in space, it becomes more virulent. That was validated first by growing the organisms, bringing them back down, and injecting them into mice. Becker stated that Dr. Cheryl Nickerson did that work and subsequently published it in *PNAS*. That prompted the investigative community as a whole to stand up and take notice of the capability of microbes in the environment of microgravity.

“A group of us got together and decided that if we could figure out the reason behind the increased virulence, we could potentially create an attenuated vaccine,” Becker said. “In other words, use the novel platform of microgravity to uncover what was involved in the virulence, target that, potentially eliminate that target, and then create a vaccine that could be used for on-Earth application. So we really are using microgravity as a tool for new discovery.”

Next, they enlisted some excellent investigators in this field, led by principal investigator Tim Hammond, Ph.D.; located an organization with extensive experience in flying cell culture work

to provide hardware; found a commercial industry sponsor that was willing to fund the work; and a small, privately held venture called Astrogenetics was born. Astrogenetix is part of Astrotech, which was formerly known as SPACEHAB.

Becker said they put together their first payload in March 2008. “What we did was create several strains of knockouts of Salmonella bacteria. We brought in Alejandro Aballay from Duke University, who is an expert in this field. We set up an interesting in situ microgravity virulence assay and knocked out certain genes that were known to affect virulence in the organism. We used *C. elegans*, a small worm, as our ‘canary in the mine.’ The worm eats bacteria as its normal food. It will eat Salmonella. And if it eats Salmonella that have increased virulence, the worm will die. So there, you have your assay.”

“It’s a 48-hour assay, and it’s contained in little canisters that have replicates of test tubes in them,” Becker explained. “It’s turned on by a simple crank of the crew. It’s a little can that houses eight test tubes. The organisms are in each little compartment within the test tube. So one crank will mix the bacteria and the *C. elegans* together. They’re allowed to hang out for 48 hours. An additional crank compresses it into the third compartment, which is a fixative, and the experiment is over, and is returned.”

Becker said they were incredibly lucky and “we nailed one of the genes on the first try.” Now, she said, they have a target. “When the gene was taken away, the virulence effect went away. So that’s what we’re pursuing.”

“We have now flown five payloads, and we’ve validated this.”

“We have formed a very serious effort to develop a vaccine. We are now going ahead with developing our investigational review board qualifications and putting together an investigational new drug, IND application that will be submitted to the FDA, based on this work, to go forward with human-based trials. That will be conducted at the V.A. Hospital at Duke in Durham.”

In addition, Becker said that the company has flown two payloads of methicillin-resistant *Staphylococcus aureus* (MRSA) and other medically relevant organisms that cause a lot of human disease. The goal for this work is to use a similar approach with the other organisms to understand what is involved in the increased virulence, and to use that knowledge as a target to create a therapeutic.

Becker noted that “the station is a real platform for new discovery. Some very good fundamental science has now turned into a potential product, and led to a company forming around it. This is an example of why we are a pathfinder mission for validation of the ISS National Lab; for R&D for commercial purposes; and, for excellent, good science that potentially can turn into commercial products.

Shaw then introduced Robert Benkowski, chief operating officer of Micromed Cardiovascular Technologies, whom Shaw described as instrumental in the development of the DeBakey ventricular assist device, which uses space shuttle technology to pump blood through the body. Micromed manufactures the pump, which Shaw described as “one of NASA’s most successful technology transfer stories.”

According to Benkowski, “There is a huge spectrum of technology that is developed for space missions that can be commercialized and provide use right away. In my experience, there’s a little bit of a gap between what’s invented for these missions and commercialization of it on earth.” He cited a few examples of NASA-developed technology that had been successfully commercialized—Mylar, the car airbag switch, cordless power tools, the DeBakey blood pump—and suggested there were many more such success stories that needed to be transferred to commercial use.

Benkowski said “we need to do a better job” of making NASA-developed technology available commercially. He urged those who develop a product for space to talk to their technology transfer office to see if the technology could be commercialized through that office. He encouraged everyone to join local biotechnology groups to see if any commercial technology being developed independently could be brought into the space program.

Shaw then introduced the third speaker, George “Bud” Brainard, professor of Neurology and Pharmacology at Jefferson Medical College of Thomas Jefferson University, to discuss insights from spacecraft lighting investigations and their applicability to commercial lighting technologies.

Brainard described a recent, relatively rapid translation of basic science into applied science in his area of study. Between 2000 and 2008, Brainard reported that a variety of laboratories, including his own, discovered that the human eye contains two discrete sensory systems: first, the visual system, which is experienced at the level of consciousness and has a peak of 555 nanometers; and second, a nonvisual system that takes place below the level of consciousness, which has a peak of 480 nanometers—“the blue part of the spectrum.” That fundamental biology was discovered and elucidated with support from the NSBRI. The space application stemmed from the fact that “we would like to have a nonpharmaceutical intervention for disruption of sleep, disruption of circadian rhythms.”

Brainard noted that last year, JSC Behavioral Health and Performance sponsored a test involving the Phoenix (Mars) Lander ground crew, using blue light-emitting-diode (LED) solid-state light as the nonpharmaceutical countermeasure, and the data are being worked up now. Apollo Lighting of Utah, the industrial partner, provided the light units in that combined industry-NASA project.

“Ultimately, we wanted an in-flight lighting countermeasure—something that can address the defined risk of human performance failure due to sleep and circadian disruption. Toward this end, we have a larger industrial partner, Philips Lighting, which has designed and created prototype lamps that are deeply enriched in the blue; they give a white-appearing light, but a lot of energy in the blue range.” Phillips has provided the lamps to the NSBRI-sponsored program, while Apollo Lighting has provided the blue LED lights as well as the white-appearing LED lights that are deeply enriched in the blue range.

Brainard commented that in the past year, Kennedy Space Center, working with Bionetics Corp., developed the first prototype solid-state lamp, which was installed on the ISS, where astronauts

have found its light “acceptable for the purpose of supporting astronaut vision on the station. Ultimately, there is a move afoot to replace all of the lights on station with solid-state.”

The new lighting mode’s advantages for NASA are that it has less up-mass; it consumes less energy; it produces less heat; it has a longer life span; and its “tremendous bonus” being nontoxic, compared to the station’s current fluorescent system, which contains the mercury toxin. “Orion and (lunar lander) Altair are looking at solid-state lighting for the future of all those vehicles and those habitats.”

Besides that space application, there was a commercial application that was manifested in two places. When the new biology was elucidated, light therapy companies were “the first commercial entities that jumped on it,” Brainard said. Those companies produced light units involving blue-enriched and overtly blue products for people suffering from winter depression and circadian disorders, and they had a large volume of sales.

Brainard predicted that in 10-20 years, the bigger industry of general lighting will have switched over almost entirely to solid-state lighting technology, which he described as “very versatile and powerful, and just as attractive” as the current white-appearing, incandescent, fluorescent lighting, which Brainard called “dinosaurs,”

“So we are looking at a revolution in both general lighting and architecture here on Earth. Large companies like Phillips are investing both for space applications and also because it will have tremendous impact and would become a multibillion-dollar industry on Earth. First, the move to solid-state lighting will penetrate operations that are continuous and run 24 hours a day, such as hospitals, manufacturing and the military. Ultimately, solid-state technology will penetrate all of lighting.”

“So it’s an exciting moment, and the space station is going to be one of the lead installations in terms of this theme.”

Shaw then introduced George P. Noon, whom he described as professor of Surgery and chief of the Division of Transplant Surgery and Assist Devices in the Michael E. DeBakey Department of Surgery at Baylor College of Medicine; executive director of the Multiorgan Transplant Program at The Methodist Hospital; co-director of Methodist's Vascular Diagnostic Laboratory; and a surgical associate of the late Dr. Michael E. DeBakey for more than 40 years.

Noon noted that his primary interests have been in heart failure, in heart failure surgery, and in the development of assist devices in total heart replacement. DeBakey, his longtime colleague, pioneered the development of heart pumps in the early 1960s, when DeBakey obtained NIH funding to support the research.

In 1966, DeBakey performed the first successful implant of a ventricular assist device (VAD), which had been developed through the program on which they had been working. The patient's failing heart was supported for 7 days by the device, after which she recovered, the device was removed, and she was able to leave The Methodist Hospital.

For some time, the clinical application of heart pumps was not very active until the 1980s, when specific protocols were developed to use pumps primarily as a bridge to transplant and then removed. "The devices we were working on were primarily pulsatile devices," Noon recalled. "They were large, and they were cumbersome, but they served the purpose."

After working with these for some time, they wanted a much smaller VAD. They decided to go to NASA for technological help, because they thought "they're the ones who should have the expertise with the things we're looking for in a pump," citing "durability, reliability, size, and power requirements—all things they've been looking for with application to space."

So it came to be that in 1988, DeBakey and Noon began working on their idea for a novel VAD with the help of NASA engineer David Saucier, on whom they had performed heart transplant surgery not long beforehand. Saucier arranged for the doctors to meet with several NASA officials.

“We went out with all our devices and asked if they were interested,” Noon recalled. “We said, ‘We have some of the same problems you have in space. We have a hostile environment: we work in the human body, especially blood, which is very fragile.’ We gave them our pump requirements, and they were able to do it without much problem.”

The first incarnation was not a complete success, however. After the doctors put blood through it, the device destroyed all the red blood cells in 1 minute. Finally, a continuous—flow pump was developed that was found to work as desired.

“In 1998, 10 years after we first started the pump, we finished our development and our trials with animals, and we were ready to go to implants in people,” Noon said. They received clearance to do that in Europe and performed the first implant in Berlin, and the next in Vienna.

Another aspect of the development of the continuous-flow pump that was analogous to space was that, although they knew from experience that this device would work well over the short term, no one knew what the long-term effects would be with respect to the pump’s lack of a pulse. Fortunately, their experience using this pump in patients has been very positive; the doctors are able to resuscitate them, rehabilitate them, and “actually get them back to normal activities.”

Noon said he also found it interesting that when patients needed a replacement for a pulsatile pump, they told the doctors that they didn’t want a similar device. Those pumps, Noon said, started falling apart about a year to a year and a half after they were put into patients for destination therapy, i.e., to remain in the body beyond the 60-90 days when used as a bridge to a transplant. Therefore, he said, “we had to go to a nonpulsatile, continuous-flow pump.”

Furthermore, Noon said when the doctors asked patients with a pulsatile pump, and patients who had switched from pulsatile to continuous-flow, which type they would have preferred from the beginning, the patients always said they would have chosen the continuous-flow. Noon noted that the continuous-flow pump, which was much smaller and didn’t make any noise, was “much more patient-friendly” than the pulsatile model.

Another aspect with space industry parallels, Noon said, was that “we’ll be starting implants in China in the near future,” and added that they had done an implant of their continuous-flow pump in Russia in 2002. At that point, he opened a cardboard box and took out a small device attached to a length of plastic tubing. “So now, you can see this is the device that we developed with our NASA engineers, which is totally implantable, compared to this device,” he said, holding up a significantly larger, pulsatile device, “that we were stuck with before we had this.”

In conclusion, Noon said, “We are very pleased with what we were able to develop with NASA technology, and pleased that we were able to bring it to the patient population and be very successful in its use.”

Brewster then introduced Neal R. Pellis, , whom he identified as the JSC-headquarters NASA senior scientist for spaceflight sciences “who oversees all of the medical, health, and biotechnology issues associated with human space flight, including research to counteract the effects of space travel.”

Pellis said he wanted to address the topic of technologies that have been developed that are quite unique in many respects, and certainly unique because they emerged from the space program. “The first one that gets a lot of attention is a device that is sometimes called a space bioreactor,” Pellis said, describing it as “a horizontally rotating cylinder about the size of a Campbell’s Soup can.”

“It was conceived somewhere in the late 1970s that there ought to be something in the way of some kind of a system to keep cells in suspension so that we could do cell biology experiments in space, and keep them in suspension until you get through the launch profile.” Out of that grew a number of different devices, a lot of which are really just paper on the shelf and numbers for patents. So I won’t talk too much about those.

“But it resulted in this one system, the horizontally rotating cylinder that I spoke to you about, and the unique aspect of that cylinder is, when it’s completely filled with water, it behaves very differently than you might expect. Particles, cells, whatever you want to say, that are slightly

more dense than water, when this rotates slowly, become suspended, and they remain suspended.”

“Interestingly, if you could ride one of those particles, you’d find out that you were actually falling at terminal velocity in that fluid for most of the time that you were within that rotational paradigm.” Pellis said “that gave them the system that could actually meet some of the requirements that they were talking about. The unexpected side of that history is that it really resulted in a technological development that gave us a lot of advantages.”

“We wanted to study cells in space, and the reason for that is that cells, just like they are for biomedical research on the ground here, are models for many different kinds of systems in the body-models for disease and whatever. So that was the first reason,” Pellis said.

“The second is, I think, that we try to understand how terrestrial life adapts to the microgravity environment, to the radiation that’s there, the whole space experience. Some of this can be done at the cellular level. And some things that may not even be quite as ethical in human beings, we can do to cells. We can put them in a radiation beam; we can do all kinds of nasty things to them, and watch how they behave and how they respond to it. That’s the reason for doing it.”

Pellis commented that “the one thing that we had to do was to be able to take the technology as we understood it on the ground and begin to translate that into what goes on in space, and also translate it into equipment that we can use in space in parallel.”

“We did develop a system that is actually a space-designed bioreactor system which has its own, interestingly, pulsatile heart, and it has a lung system for it to be able to get good gas transfer. We can keep cells alive and functioning for a long time in that system.” Pellis went on to describe the outcomes of what they saw with the ground-based development of the technology.

“The first thing that we found is that the cells didn’t die. The surprising thing is that a lot of cells that we grow from the human body are what we call anchorage-dependent—they like to hang onto something ... and they don’t die. In fact, what they do is, they get together with each other. ... So it became a very good system for that.”

Moreover, Pellis said, they found that “things that we observed with this system had parallels with what we were observing in cell culture in space. So, it became a cell culture analog system. This is extremely valuable in designing experiments for space study. You can refine experiments much more readily using a good analog system, and do a much better experiment in space.” The outcome of that ground-based study was a “myriad” of different kinds of cells; probably more than 70 different kinds of cells were grown in the system.

Pellis stated that “it became a test platform for understanding a number of factors, one of which is that physical forces do, in fact, impact life systems all the way from bacteria to us.”

The value came out on the ground-based side “when we realized that tissues, or cells, when they reassemble, begin to morph back into a lot of the morphology they had as an existing tissue before they had been dissociated. It became a tool in tissue morphogenesis.”

Pellis noted that tissue morphogenesis work is done for several reasons, framing these in the form of rhetorical questions: Can we make models of human disease? Can we make models that we can use in drug-testing venues? Can we make more robust models that will allow us to understand better how two different types of tissues interface with each other? “For instance, in neoplastic disease, as tumors progress and metastasize, there is a participation from the normal cell component, so it (the system) gave us a platform to do that.”

“Can you make tissues for transplantation?” he asked further, responding that he thought there was a possibility: “Obviously, if you can conduct fairly high-fidelity tissue morphogenesis, there’s the opportunity to do that.” Pellis said some researchers working in type-1 diabetes have an interest in the possibility of the system “to make islet cell assemblies with other participating cells, to be able to implant into type-1 diabetic kids.”

Pellis reported that the technology for the system ended up being transferred out to a manufacturing company that, as of January 2008, had sold more than 25,000 units worldwide, of which NASA owns about 30. So “we are not the customer here. Actually, it was the scientific community outside that realized what the potential is for this kind of technology and what you might be able to do.”

“In fact, I could extend it one step further. Dr Becker told you about what they observed in some of the bacteria. The initial observations that suggested that might happen in space were actually conducted in this rotating analog system.”

More than 200 primary publications on the system have appeared to date in peer-reviewed journals, plus about 30 patents within NASA and “probably at least an equal number on the outside for various adaptations of the technology. It’s had a good ride, so to speak, and I think the ride is actually just beginning.”

Pellis said he thinks there’ll be “another good 10 or 15 years” before this is supplanted by some other super-technology.

“So, what we know from this is that we get pictures of changes in gene expression that might occur in space, and we’ve seen some things matched in microgravity, like cellular locomotion is lost in this device and it’s also lost as well in microgravity. Their ability to walk in space is not as good as ours despite the suits that we have.”

Shaw then introduced Babs Soller, professor of Anesthesiology at the University of Massachusetts Medical School, where she develops medical applications of near-infrared spectroscopy. Shaw asked Soller to share her experience working to found a company for medical sales of a device she developed. Shaw noted that Soller, who is funded by the NSBRI, is developing a portable, noninvasive device to measure the effectiveness of exercise and other countermeasures on muscle atrophy in space, a device that also has potential applications for emergency medicine care of critically ill patients, and on the battlefield.

Soller opened her presentation by adding that she was also privileged to be the team leader of the NSBRI Smart Medical Systems Team, a group of eight university investigators who are developing medical technology required for long-duration space flights. Soller noted that the day before, summit participants heard there is a need to get more medical and scientific data while the astronauts are in flight.

Soller commented that “this is exactly the problem that the members of the Smart Medical Systems Team are addressing in their technology development. As a team, we are each

developing unique technologies that are noninvasive, easy to use by being highly automated, and provide continuous real-time information on a number of important medical parameters. They'll provide both medical as well as scientific data for use by the astronauts and flight surgeons."

Half of the investigators in Soller's group are funded by the DOD, and 75 percent have ties to industry. "This provides significant benefits, in that the technology we are developing specifically addresses both the needs of the military as well as the needs of NASA. As such, we are also able to bring advanced technology to remote areas of the United States as well as the rest of world, and we are able to bring advanced technologies for trauma care out of the hospital and into ambulances, where they are more likely to save lives and reduce complications."

"One thing about developing new technologies is that it requires a lot of money," Soller said, noting that engineering and scientific expertise, and clinical trials are also needed in order to gain regulatory approval. Soller said the military will not allow new medical devices without FDA regulatory approval to be used in the military near the battlefield. "One of the dilemmas we all face in developing this technology is getting that money that is required to bring this technology out of our research labs for use not only by NASA, but the civilian population. This money, you would hope, would be available from the industrial sector. But in the medical device business, what we find is that medical device companies do not invest in university technologies. They rarely license patents out of universities. Instead, they like to buy companies ... successful companies."

"So really, the only way to get that funding from industry is to be able to start a company and raise the money to get a product into the market." Echoing Becker's earlier comment about spending her nights and weekends working on her company, Soller said she had been doing the same for the past year, trying to raise venture capital for her company.

"Raising venture capital money is a very competitive process. The venture capital investor that I've been working with tells me they see five to eight proposals a day, and over the year, they're going to invest in six companies. So it's actually harder to raise venture capital money than to get money from the NIH."

Soller said she had found that “you have to be very unique; you have to have a product that has a large commercial potential in order to get their attention.” She discovered that the space program’s product requirements have enabled her to build a “very exciting” product with multiple benefits for not only the users, but the investors.

Soller explained that her goal was to build a noninvasive sensor for use in the spacesuit, which would measure the wearer’s metabolic rate on the surface of the moon during lunar EVA. The product will be very inexpensive, which means high cost margins for the company, but it will be very robust and use very little power. The space program’s requirements—small size, light weight and low power usage—translate into “a very attractive medical product, and one that has a very good economic return for the investors.”

Commenting on the amount of funding required, Soller said she was very grateful for the support she received from the NSBRI and the military. However, it requires “twice that total funding” to get this product to market. But when she does, “that’s a four-X return to NSBRI and their investment in this technology, and what they get in return, and what NASA gets in return, is a validated product and also, one that has a significant impact for people here on Earth.”

Soller raised two concerns that she believes “this community as a whole needs to address,” based on her experience: “This is a wonderful academic-federal government industry partnership, but from the academic perspective, most academic institutions are not well versed in technology transfer to all industries; and, in particular, there is little knowledge of the medical device industry. So technology transfer transactions that understand and respect the economics of medical devices are difficult. There is also a tremendous issue around conflict of interest at all levels – again, something else that probably needs to be addressed.”

“I think this is a great model for developing medical technology that has applicability in space as well as for the military and for the civilian population on Earth,” noting that three of her Smart Medical Systems Team colleagues also had started companies. “It’s a great testament to the NSBRI for supporting these projects at their critical time, when they can attract significant funding from the investment community.”

Shaw then introduced Capt. Kenneth Reightler Jr. (U.S. Navy, retired), a former astronaut who piloted two space shuttle missions: STS-48, the first shuttle flight in support of Mission to Planet Earth, which deployed the Upper Atmosphere Research Satellite; and STS-60, which was the first joint U.S.-Russian space shuttle mission, the first flight of the Wake Shield Facility, and the second flight of the Space Habitation Module (Spacehab-2). Shaw said Reightler now is vice president of NASA program integration for Lockheed Martin Space Systems, which is developing the Orion crew exploration vehicle for the next-generation Constellation program.

Reightler said, as it appeared he was representing the perspective of the large-industry partner, he wanted to provide some background on that, as well as his thoughts on the commercial direction. He said he had two opportunities to work on two very different missions that demonstrated the value of having a transportation system—the shuttle—which is “incredibly flexible and very capable,” and able to accomplish far more than originally conceived by its designers.

First, Reightler said that the STS-48 Mission to Planet Earth was “the precursor for where we are today with our earth resources missions, our earth science activities.” Second, STS-60, the second flight of SPACEHAB, introduced the world of doing things on a commercial basis, as well as the problems involved in doing commercial-government activities where the only customer is the government, which has represented an ongoing set of challenges.

Reightler cited the STS-60 Wake Shield facility as a “tremendous example” of combining the strength of academia with government to explore the unique aspect of being in space, using the microgravity environment to achieve “astounding results.” As STS-60 was the first joint U.S.-Russian shuttle mission, it also demonstrated the value of international cooperation in working with different countries. Reightler said it set the stage for what followed on Mir and on the ISS, and showed the value of not only the political uses of space, but also, of international cooperation in space.

Reightler said that his space shuttle experience and management jobs, including chief of the astronaut office space station branch and mission support branch, provided him with a good

understanding of the system, to see how a new system was developed, and to appreciate the value of the relationships that he had built.

After he was asked to join Lockheed Martin in 1995, he became the program manager for several large programs, including engineering prime contracts at JSC. Lockheed became involved in a number of space, life and earth sciences missions. The company designed and built Mission Control Center (which it continues to operate) in Houston. Reightler subsequently became head of Lockheed's services business. Then, with the win of the Orion/crew exploration vehicle contract in 2006, he transitioned from services to development. Based on this broad-spectrum experience, Reightler said he has a broad industry perspective.

“How do you do business with NASA? When you talk about industry, that's really what it's all about. How do you turn a relationship with a government agency into a moneymaking proposition?” He cited several points. First, services are getting “very hard for big businesses to do. There is a very aggressive socioeconomic goal process that NASA is undertaking. Second, there is an organizational conflict of interest which Dr. Soller cited earlier, that is something we need to continuously deal with. How do you provide the services on a vehicle you are also designing and building?”

Reightler also cited the issue of constant competition, turnover, or “churn,” in dealing with the cultures associated with those companies, and making the changes that are required. He said there is a “significant impact to the work force” in doing that.

Next, he said, the U.S. government is “looking hard” at the whole issue of large-scale systems integration. “When the chief executive officer of the United States, the President, the commander in chief, points to one of your programs that's a large-scale integrated program and he points to it as an example of a process run amok, you know it's going to be a bad day.” He stated further that he didn't think increasing government involvement would be helpful, nor would a fixed-price contract resolve a problem that was driven by “not knowing what you want to build when you let the contract to begin with.” Industry's response would be self-protective and risk-minimizing, which would increase costs more.

Next, Reightler said, NASA is trying to strategically rebuild its technical capability, and in doing so, and managing programs to accomplish that, “the result is that the programs are less efficient, taking longer, and are stretching timelines and budgets.”

“I think the U.S. is still pushing very hard on that holy grail of cheaper access to space. When we have a commercial approach to doing business, and yet, the only customer is the U.S. government, I question how truly commercial that process, or that result, is.”

Reightler also said he believes the government is trying to work in a more collaborative process, noting that was the case with Lockheed’s work on Orion. However, NASA budget cuts impact the industry work force, and not just for the short term. He cited an example where NASA cut the budget for nonhuman life sciences work that Lockheed had at NASA Ames. Those programs continued at a much lower population, and the cuts came in Lockheed’s local work force. Lockheed tried to find jobs for those highly skilled individuals elsewhere in its business, but the result is that those people are now gone. “The long experience they had in plant and animal research is now gone. When the funding comes back someday, which I certainly hope it will, those people won’t come back, because they’re doing other jobs that are very satisfying in other parts of our industry. Their expertise will not return.”

In conclusion, Reightler reiterated his earlier theme of building flexibility into next-generation spacecraft so they can do “more than what we’re thinking about today.” The ambitious Moon mission requirements for which Orion was designed enabled it to be incredibly capable in low-Earth orbit as well and we’re spending a lot of our investment money looking at other missions that Orion can do to support science and other areas in the future.

Shaw re-introduced an earlier speaker at the summit, Rice University professor James M. Tour, , who on the current panel would discuss evolving U.S. export regulation. Shaw described Tour as a synthetic organic chemist and nanotechnology expert who had won a Space Act Award from NASA, and who had developed NanoKids video programs to teach children about nanotechnology. Shaw said Tour would discuss evolving export regulation, based on his service on a related advisory board to the Department of Commerce.

Tour greeted them by saying “hello” first in Russian and then in Chinese, following in English with: “Welcome to Rice.” Tour said he would present an overview of some of the work he has been doing serving on the Commerce Department’s Emerging Technology Board to revise our current laws.

Tour remarked that “there was a real frustration when Rice brought in a team of attorneys from the outside to assess what the laws are and try to come into compliance.” He began by providing background. There was an outcry from a number of institutions, he said, because it “would hamstring the work that they are trying to do.”

Tour said he would read the Deemed Export Requirement rule and define it. “It’s not giving something to somebody. It’s telling somebody something. This is what we do in the university all the time,” he explained as a prelude. “Of particular concern to them are people from certain countries; to be specific, some of the countries that are at the top of the list are Russia and China: what is communicated? If we go by the rule, there may be assessed to be many violations that took place in this meeting over the last day and a half.” He said he would read the rule, show what the problem is, and why we need some changes in it.

“Deemed export means release or transfer of technology that has dual use to a foreign national in the U.S. Release or transfer: That’s like a professor instructing a student. Of technology means know-how; not a physical thing ... that has dual use: military and civilian. To a foreign national: that does not include a green card holder who happens to be in the United States.”

“So what I teach to my Chinese or to my Russian students that is not already in the literature, in print, is deemed a deemed export, and that is illegal. That’s why we need some laws changed,” Tour explained. His Commerce Department committee has been given a zero-based approach, meaning they aren’t trying to modify existing law; “we start with a clean slate and say, ‘How do the laws have to change?’”

“Personally, I think the deemed export law is absolutely ridiculous in an academic setting, for sure, and could be ridiculous in many industrial settings as well.” Tour then stated that he would

read some facts about what had taken place since the law had come into effect, which spanned a time period of about a decade.

Tour commented 99 percent of the exclusions—meaning when a company had written to request an exclusion from the rule—had been granted, of the “tens of thousands” of such requests. “The 0.5 percent not granted were almost always granted after there was a small clarification.”

“Sixty percent of the deemed export control licenses have been requested by just four companies in the United States,” which led him to speculate that “probably Lockheed and Boeing are pretty good at doing this sort of thing.” Furthermore, “Zero percent of the deemed export control licenses have been requested by universities.”

Tour said he asked a Commerce Department representative: “Why do you figure no universities have requested this?” and she responded, “I assume they are all in compliance.”

In the past 5 years, a total of 120 cases of deemed export control violations have been checked by the Commerce Department Enforcement Office. Of those 120, a total of 19 people in 17 cases were noted for penalties, while several others led to letters of warning, but no penalty.

The average penalty was about \$20,000. One of the penalties was \$800,000 and a 2-year prison term, but that was particularly egregious, he said; none of the other cases involved any prison time. None of the 17 cases involved a university, but two of the 220 cases that were originally screened did involve a university.

Tour then asked, “Does this expensive machine of the Deemed Export Control Office warrant continuation, where the few cases of technology that were transferred were far less damaging to the U.S. economy than the restriction of free flow?” He said the Department of Commerce view is: “We’re losing technology. You tell this international student, they go away, they go to their home country and develop it, and then they clean our clocks when it comes to the development of the technology.”

In contrast, Tour said his feeling is: “If my student can take something I’ve told him or her and go back to their home country, and start an operation and beat me out on it, God bless them. Let them do it; it means we haven’t been as innovative, as entrepreneurial, and we haven’t done this. Let it at least be developed.”

Moreover, Tour noted that, of the 33 nations who work with the United States to coordinate export control, none have deemed export control laws.

Not only are there problems trying to comply with Commerce Department regulations; there are problems stemming from differing departmental definitions. Tour stated that he thought all of the problems at Rice could be mitigated by having all the postdocs come under the shelter of class, under the rule’s research exclusion. The problem, Tour said, is that the State Department differs with the Commerce Department on what a research exclusion is. The State Department says “if it’s published, it’s excluded” from restrictions, while the Department of Commerce says its interpretation of the exclusion is “if the intent is to publish.” As for the latter interpretation, this means that “I could be taught by a Russian student, but not tell the other Russian student about it.”

Tour provided another example of what he called “silliness in interpretation” relating to certain items on the restricted list—in this case, carbon nanotubes. “We make carbon nanotubes at Rice ... they’ve been commercialized. Carbon nanotubes are made all over the world.” Tour recalled that in the early ‘90s, he developed a procedure for making C60 that would reduce the cost by at least two orders of magnitude, as he stated in his patent application. Six months after the patent came through and the paper was published, Tour was approached by a Russian businessman who asked him if he’d like to buy C60 at an extremely low cost. When Tour asked him if he was using Tour’s process to sell him back the very things he had patented, the Russian responded: “You know, Jim, my English is not so good.”

Despite their worldwide proliferation, carbon nanotubes are on the restricted list, and that means “I can’t even ship it to a colleague in the United States who isn’t a green card holder, even though he or she may be a professor.” The explanation for carbon nanotubes’ presence on the

list, he related, is: “They say that they have a very strong modulus, of stiffness, higher than any carbon fiber.” However, Tour asked rhetorically, “You want to try to bend a benzene ring and tell me how stiff that is? You can’t say a single molecule is a fiber.”

Further, Tour said that “if we were to observe the rules in totality,” even red wine would be restricted because of certain transparency and absorption attributes that don’t meet the stated requirements for materials considered legally acceptable for export.

Tour remarked that he and other academics on his Commerce Department committee are pushing for change; specifically, they plan to come up with an algorithm that could be used with new technologies, to determine if they “should really be protected, or could it make our lives a lot easier by having many of these things taken off the ITAR (International Traffic in Arms Regulations) list and the deemed export control list. “

Further, Tour stated that he and his colleagues want technologies to go back through this process “every few years” to see whether they should still be protected or have become ubiquitous. “We have to have good, free exchange of knowledge. Without this, and particularly in an academic environment, we’re going to hamper ourselves tremendously. These are some of the things that need to be covered so that we are able to keep the free flow of information going and lower some of the barriers, because it’s hurting our economy, and not helping it,” Tour summed up in concluding his presentation.

“We feel your pain,” Shaw told Tour. “Both the space shuttle and the space station are considered defense articles. Therefore, under the auspices of the State Department and ITAR, Boeing trains 160,000 people every year on export compliance, which Shaw called “a very hot topic.”

At this point, Shaw opened the floor to questions.

Alluding to Brainard’s presentation on LED lighting for the ISS, JAXA flight surgeon Kaz Shimada noted that the white LED light was invented years ago in Japan by Dr. Shuji Nakamura,

now on the faculty of University of California-Santa Barbara. Shimada further noted that researchers in Japan had developed photocatalytic paint with air-cleaning properties that have been found useful on building exteriors there. Shimada commented that the newer Japanese technology development of visible-light-driven photocatalysts might offer a technique that could be useful for the ISS. Brainard praised the many manifestations of Japanese leadership in novel lighting technology, saying that it would not only benefit the space program, but would broadly impact programs domestically all over the world.

Shimada raised a logistics question regarding the return of tissue from bioreactor experiments on the ISS in the future, asking panelists whether it might be possible to develop a small recovery vehicle to bring back live tissue samples in a timely manner, or whether there should be a move toward on-board analysis. Pellis commented that it would be much cheaper to develop in situ analytical equipment on board to send back data, instead of sending specimens back aboard a vehicle. Becker said she knew of some capabilities under development with respect to such a vehicle, including one that SPACEHAB has, and added that she expected more such capabilities would come on line.

NSBRI scientist David Watson asked panelists if it was considered important to further downstream commercial development of vaccines in order to have animal capability on board the ISS. Becker responded that it was. In fact, she said, the animal work that has been conducted on the shuttle was done with the sponsorship of Procter & Gamble for therapeutic development, so “this is a critical need.”

Padraig Moloney, who identified himself as a Rice University student who was formerly with NASA JSC, asked panelists whether they thought NASA does a good job at tech transfer. Benkowski, of MicroMed, cited two obstacles to tech transfer from NASA: first, “finding out what NASA has,” due to the sheer breadth of its technology, and figuring out where and how to get the information to get the tech out; and, second, “negotiating the license agreement,” particularly if negotiating an exclusive license. Benkowski said “it took MicroMed a year to negotiate an exclusive license, which was vital. Once you get past that, the cooperation you get from NASA is astounding.” He said MicroMed had access to the expertise of a number of key

NASA scientists even after the company was formed and the technology was commercialized, and the partnership was excellent.

Moloney asked whether panelists thought NASA does a good job in allowing small companies to collaborate with their scientists on new technology. Soller responded, “It’s evolving and it’s improving ... there is definitely an effort involved in merging the portfolios, both from the small company as well as university investigators, and NASA internal investigators.”

In conclusion, Shaw thanked the panelists for their “very informative comments and observations.”

Luncheon — NASA Celebrates the 40th Anniversary of Apollo 10

Preparation for Lunar Landing

Glynn S. Lunney, Apollo 10 Flight Director, NASA

In his introductory comments, George Abbey observed that the following Monday, May 18, 2009, would be the 40th anniversary of Apollo 10. “So 40 years ago today, we were in the prelaunch phase for Apollo 10, getting ready to go to the Moon,” setting the stage for the film they would see, which documented the events of that historic point in time. Abbey commented that following the film, there would be a presentation by Glynn Lunney, who had served as lead flight director for the Apollo 10 mission. The style of the dated documentary film transported its viewers into the frame of mind of the observers of the actual events at that time.

The film, entitled “APOLLO 10: To Sort Out the Unknowns,” opened with a perspective of the huge Apollo 10 rocket on the launch pad as the narrator intoned the words: “May 18, 1969. We were almost ready. Man had orbited the Moon once. Man had test-flown the lunar module, the lunar landing craft, in Earth orbit once. But before we would commit man to a lunar landing, there were still a number of things to be worked out. This was the mission of Apollo 10 – in the words of its commander, Thomas P. Stafford, ‘to sort out all the unknowns and pave the way for a lunar landing.’”

As the camera followed the three astronauts toward the rocket, the narrator noted that this was “a veteran crew.” The commander, Tom Stafford, had flown on Gemini 6 and 9; lunar module pilot Eugene A. Cernan had flown with Stafford on Gemini 9; and command module pilot John W. Young had flown on Gemini 3 and 10. “They would face problems on Apollo 10, problems that would be solved on Apollo 11. Most would be minor, but they would be solved,” said the narrator. He went on:

“Stafford. Young. Cernan. They brought to their mission enthusiasm, dedication, responsibility—even amazement. And through the means of color television, they took us with them as they played their part in man’s greatest adventure.” The Apollo 10 flight was the first mission to be equipped with color television capability, sending live color broadcasts to those on the ground who had that novel capability in their own homes, three years after NBC-TV adopted an all-color schedule.

On the ground, the countdown began: “We are go for a mission to the Moon at this time. Tom Stafford reports they are go. We’re coming up on the 20-second mark. T minus 20 seconds and counting. . .” At liftoff, a thunderous roar was heard as the Apollo rocket soared into the sky, trailing a huge plume of smoke, as NASA flight controllers on the ground raised binoculars to their eyes to track its progress.

“What a ride, man, what a ride!” an astronaut’s voice is heard to exclaim over the airwaves from Apollo.

The report from the ground, calmly confirming “Good ignition on the second stage,” was met by further enthusiastic responses from Apollo, including an astronaut’s exclamation: “Just like old times! It’s beautiful out there!” As the film of the Apollo 10 journey progressed, the astronauts’ unabashedly euphoric descriptions of the wonders that they were seeing of the moon and Earth, from their extraordinary vantage point, were peppered with similar superlatives, like “fantastic” and “magnificent.”

After the checkout in orbit, the ensuing translunar injection resulted in a “perfect burn” of the S-IVB engine to send Apollo 10 on its way to the moon, the narrator said. The command module, dubbed “Charlie Brown” after the “Peanuts” cartoon character, separated from the S-IVB and turned around to dock with the lunar module, “Snoopy.” During the docking, the first problem occurred when astronauts found that the Mylar containing the insulation on the spacecraft hatch had broken; this would be fixed for Apollo 11, the narrator noted.

After reaching lunar orbit, Young stayed behind in the command module when the lunar module containing Stafford and Cernan undocked and headed for the moon, riding out a brief, unexpected gyration due to a malfunction that, as the narrator again noted, would be fixed for Apollo 11. The lunar module came to within about 8 miles of its surface, and Stafford described the landing site in the Sea of Tranquility that was selected for Apollo 11. “Snoopy” then rose from the moon and rejoined “Charlie Brown.”

At the end of the film, an undeniably impressive view of the face of the moon is shown as a voice is heard to say: “How much we’re going to progress in the future is left to your imagination. But if we harness our energies and keep our perspectives right, the goals are unlimited.”

Abbey then introduced the Apollo 10 flight director, Glynn Lunney, noting that Lunney “started with NASA when NASA was formed” in 1958. Abbey said Lunney worked on the Mercury program; was a flight director during the Gemini and Apollo programs; served as manager of the successful Apollo-Soyuz Test Project in 1975; and became manager of the shuttle program in 1981. Abbey stated that in 1985, Lunney left NASA to join Rockwell for a successful career there. In 1990, after working for Rockwell in California, Lunney returned to Houston as president of the Rockwell Space Operations Company, which provided support for flight operations at JSC. Five years later, Lunney became vice president of the United Space Alliance’s spaceflight operations in Houston, finally retiring from the company in 1999.

In his opening remarks, Lunney commented that the picture of the Saturn V rocket made him consider that if anyone viewing the film hadn't been to a manned space launch, he would encourage them to see one: "It's a powerful feeling."

Lunney went on to provide his special perspective, as an insider, into what summit participants had just seen of the Apollo 10 journey in the documentary film. First, Lunney said that although observers of the film couldn't tell, the Saturn V rocket ride was a rough one for the crew. "They really were rocking and rolling in the cabin during that flight" to the point where the crew was concerned about it, particularly during the translunar injection burn that put them on their way to the moon.

Lunney noted that the crew members weren't able to see the moon as they approached it, as it was "dark the whole time." That was not planned, but it was "probably a very good thing." If the astronauts had been able to watch the moon getting bigger out their window, and realize they were targeted for 60 miles behind it, "they probably wouldn't have believed it. But they didn't see it, so they didn't worry about it."

In all, Apollo 10 was a "great flight," Lunney said, citing just one problem: There was no time for flight controllers like Lunney to savor the experience, because so many flights were stacked up at one time in that period—generally about 2 months apart. For example, Apollo 11 was sitting on the launch pad when Apollo 10 came back. "We had so many great flights in those days. . . By the time you got off the console at the control center, it was time to get ready for the next flight."

Looking back on the flight, hearing others describing it from their perspectives, it's surprising to Lunney how many things happened in the totality of the experience that some individuals knew about, and others didn't at the time. "It reminds me that history really is in the eyes of the beholder," he said. "It depends on your perspective."

Lunney said his own perspective came from working on all the flights in the Houston control center for about 10 years, when “I had the best job in the whole world. It was a grand time.”

From his “knothole” on the Apollo program, Lunney saw a number of reasons why the mission was successful. The first was motivation. “People were very highly motivated to do well on the program. They viewed it as a national imperative, and one in which the country did not want to fail.” A sense of national urgency emanated from the moon-directed imperative laid out by President John F. Kennedy in 1961. “It pervaded everything that we did.”

Given that attitude, one of the primary things that made Apollo work was the hardware provided by the contractors and government engineering teams, which was “extremely good” and reliable. In contrast, the Mercury and Gemini spacecraft, a generation earlier than Apollo, had a number of mechanical problems. Additionally, “we were blessed with the leadership we had. We all aspired to model our behavior and actions after the leaders that we saw.”

Further, the earlier missions—particularly those of Gemini, which provided “confidence and boldness” for an ensuing series of short precursor flights to landing—yielded many learning experiences that helped build toward the Apollo 11 success.

For example, “the reason we were able to go at the pace we did” was due in great part to all the work of the Gemini planning team, who tied that in with the flight control team that guided the astronaut. The aggregate of the experience of testing brought about a lot of bonding; for example, when Gemini astronauts had to struggle with flooded fuel cells while accomplishing all their mission objectives. That brought the team together to the point where, by the time they all got out of Gemini, they were confident about doing things like using then-new digital equipment, steering the ship, and doing EVAs.

Even after all of these important experiences, Apollo “would demand a great deal from us.” On Apollo 9, the lunar module became available, and rendezvous testing was done between the two ships in Earth orbit. The Apollo 10 decision-making process involved looking at a number of factors, like the fact that the lunar module had not been flown in lunar orbit, and it had only been flown one time when manned. Also, the lunar module was “a little on the heavy side.”

Further, “masscons,” or concentrations of lunar masses that were local gravitational anomalies, had been found to perturb the lunar orbit. More knowledge was sought to determine how they might affect navigation and the goal of landing the craft as close as possible to the targeted site on the moon, to improve the odds of conducting the scientific excursions and the explorations that they wanted to do. So for those reasons—primarily the fact that the lunar module was a little heavy—Apollo 11 was planned.

In the process, “we young Turks would argue with the boss, saying, ‘As long as we’re going to go that far, why don’t you let us land?’ The adults won the conversation.” Therefore, in four manned flights, “we did everything we could” to make sure everything was properly tested and prepared, so that all was in readiness for Apollo 11.

In conclusion, Lunney said he enjoys revisiting the experience: “Looking back, it has the color of gold.”

Abbey opened the floor to questions, and astronaut Dave Williams asked the first. “The achievements over a 10-year period in the ‘60s were truly remarkable. Nowadays, we’re looking at leaving lower-Earth orbit and going back to the Moon and on to Mars. Our risk-management strategy today seems to be very process-intensive. I wonder if you can comment on the leadership and the willingness to accept risk and the unknown challenges of space flight—how you approached that back in the ‘60s relative to today, where sometimes we need procedures to go and change a light bulb on the space station.”

“It is true that it appears to be that way today,” Lunney responded. He said he knew many people in the space program today, including his youngest son, a flight director in the control center, as well as individuals in the Constellation office who were planning for the next mission. “I have to tell you, they are an admirable group of people,” Lunney said, adding that he had a lot of confidence in them. “But I will grant you, they are constrained.” He noted how different times are today. “In our time, we had a clear goal of wanting to get to the Moon and back in the ‘60s—in the ‘decadus,’ as the president (President John F. Kennedy) said in his Massachusetts accent. We probably could have stretched that to mean 1970 with a little interpretation. Nevertheless, we felt we had a real urgency associated with the program. Today, there’s not that sense of urgency; it’s not an imperative. It’s an important thing to do, but people don’t feel like it is the most important thing to do, and we don’t have to get it done by any particular date. These days, we are more prone to nitpick, review, legalize a lot of things... in our day, people would get on with it. Now, it takes review by management.” Lunney said some of that is a reflection of the world in which NASA now lives, “especially as reflected in the conservatism” in Washington.

“So I am afraid these honorable, smart, tough guys have got a tough road, tougher than we had, in a sense, and are struggling with it,” Lunney said. He expressed the thought that it would not change “any time soon.”

Lawrence Young, Apollo Program professor of Astronautics and Health Sciences at MIT, commented: “So much of the success of Apollo is attributable to training and simulation. As we look ahead now, to returning to the Moon, there is a question as to whether it is still appropriate to go through, for example, a new equivalent of the lunar training vehicle, with its benefits and also with its risks.” Lunney asked if Young were talking about a trainer that was an actual flying machine, and he said he was.

Lunney recalled, “We had a flying machine, and I’m embarrassed to tell you, but it looked like a metal bed frame. In fact, two guys had to eject out of it, one of them being Neil Armstrong. But all the crew were very adamant that that kind of training was essential to landing on the Moon.” Lunney said he was aware of the current debate over whether the system could get by without a training vehicle, and said he suspected they’d “end up with something new.” Young asked

further: “In your opinion, going back to Apollo, it was worth the risk?” Lunney said he thought it was.

Marcelo Vazquez, NSBRI senior scientist for space radiation and exploration, asked Lunney about the perception at Mission Control of the radiation risk at the time of Apollo. Lunney recalled that “it was a real environmental concern—we recognized we had to do all we could to protect against it.” He said there was an early warning system set up with respect to a potential solar flare, and there were dosimeters on board, as well as other equipment. “We were fortunate in that the missions were relatively limited in duration, unlike the flights of today.”

Apollo 7 astronaut Walter Cunningham, now of the NSBRI User Panel, raised a question about Apollo 8, the first manned venture to the Moon. Cunningham recalled that before the flight, concerns were aired in the media about break-off phenomena and being out of touch with Earth, although none of the flight crews had such concerns. “But as time went on, I came to the conclusion that it was a big decision for management and flight directors. They weren’t the ones doing it. We never gave a thought to it. They were having to commit somebody to going out of Earth’s gravitational attraction for the first time. Was that a factor in the thinking at the time?”

Lunney responded that he thought “it probably was an environmental factor, but I don’t think we knew what else to do. Fortunately, we were in our 20s, or barely out of them, so we were not inclined to wring our hands a lot or spend a lot of time ... unnecessarily worrying about it. We recognized it, but it was time to get on with it.”

Cunningham commented that he felt the decisions that flight directors and flight controllers had to make, which affected people’s lives, were far more difficult than “just doing it yourself.” Lunney returned Cunningham’s compliment in his response that many other people have to make such decisions: “You served in the Marines—you know what officers have to do in that environment.”

Former astronaut Jeff Hoffman, now a professor of aerospace engineering at MIT, commented: “It is amazing to realize what the average age of Mission Control was in those days.” He asked

whether the fact that people in these jobs are older today might present an impediment to risk-taking in the decisions that need to be made.

Lunney said that, based on what he had heard from people currently in those jobs, there didn't seem to be a problem with that. Then Lunney noted another significant difference in Mission Control between the '60s and the present day: today, women generally comprise about half the people in the Control Center, which Lunney thought upgraded the once all-male team. Furthermore, "we have a lot more brainpower."

"I think the people today are just as good in terms of attitude, and probably better in terms of preparation and the tools they have to do their jobs compared to what we had in our day. We were, as I tell my son, iron men, but we had these rickety wooden ships," Lunney said. "They have great things today to help them."

Abbey expressed his thanks to Glenn Lunney and concluded the session.

Panel V — Education Needs and Career Opportunities

Panel V members included Ludmila B. Buravkova, IBMP; Bonnie J. Dunbar, Washington State Aerospace College; Kevin Fong, University College London; Jeffrey A. Hoffman, MIT; Barbara Morgan, NASA; Michael Simpson, International Space University; William A. Thomson, NSBRI; and Aleksandra "Sasha" Titova, GCTC

In the wake of Glenn Lunney's presentation, Panel V moderator Karl Doetsch, chairman of the board of Athena Global, exclaimed with admiration: "That's a pretty tough act to follow, isn't it!" Doetsch said Lunney's description of the Apollo era, and its contrasts to the present-day space program, served as "a very good introduction" to his panel because it "shows how programs do change with time and we have to adapt with it, and how education is an important part of it." Doetsch emphasized another contrast: today, a total of 44 nations own or operate satellites; whereas, in the Apollo era, only a handful of nations were involved.

Moreover, Doetsch observed that many people in the first generation of the space program have become eligible to retire in the private sector and government. Because of that, “there will be a need in space-faring nations with a longer history to replenish those resources.” Hence, Doetsch said, we need to address a number of issues with respect to: education; attracting young people to the field; stimulating opportunities; and, determining what is needed to do so. Doetsch said he was pleased that a panel representing a cross-section of backgrounds, nations, and universities would discuss these issues.

First, Doetsch introduced IBMP Scientific Secretary Ludmila B. Buravkova, D.Sc. Buravkova presented an education model that she felt was optimal. Buravkova noted that she is chief of the postgraduate department in the IBMP as well as a professor at Moscow State University. The IBMP has a special agreement with two faculty members of Moscow State University and two technical universities “so we could teach students and we could involve the students in our projects. We try to draw the attention of students to problems of space medicine. Then we try to involve them in participation in real projects and real investigations. Then we make a choice as employer. In my mind, it is an optimal situation.”

Buravkova said that when they place an announcement of postgraduate education in the field of space medicine or physiology on their Web site, “many students visit our institute to understand more about the possibility of investigation and, of course, the possibility of a job.” Each year, she said, the IBMP invites 10 to 15 postgraduate students to the institute for special three-year courses. The young scientists start their Ph.D. education, “and at same time, they start their job in our institute” on a temporary contract. She said this is a good way for students to understand not only the investigation itself, but their responsibilities for the results and mistakes in a project, and their teamwork skills, by participating in a real investigation. She added that it is very important to have international cooperation in education at this time.

Second, Doetsch introduced former astronaut Bonnie Dunbar, now president of Washington State Aerospace College. Dunbar emphasized the importance of inspiration in attracting young people to the space field.

Dunbar noted that she is president of the Museum of Flight in Seattle, where the focus is on “how we inspire K-12 youth to take the appropriate amount of science and mathematics in school” so they can go into college and take subjects, such as engineering, science, and medicine, that are needed in space. She recalled that during the time she spent working as assistant director to NASA JSC for university research, she observed that many universities were “struggling” to find qualified engineering students.

“It starts first with that inspiration as to what gets (students) into science and engineering,” said Dunbar, citing the components of supportive teachers and parents, as well as teachers who can teach these subjects properly.

This is not a new issue, Dunbar noted. National Science Foundation indicators in 1987 showed declines in engineering enrollment. She pointed to the pivotal 2007 report, “Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,” written by a committee created by the National Academies. The “Gathering Storm” report authors expressed deep concern that the scientific and technological building blocks critical to the nation’s economic leadership were eroding at a time when many other nations were gathering strength in those areas. They also presented a series of proposed solutions aimed at resolving the problem.

Dunbar said the Museum of Flight has “the largest K-12 program of any aerospace museum in the nation, including the Smithsonian.” The 16 educators on staff reach 120,000 youth in the state of Washington every year, and have vans that can reach Indian reservations in distant areas.

“We work directly with the schools,” she said, noting all the instructional material they provide aligns with state academic standards. Dunbar noted that one of the museum’s most successful programs had “migrated from Texas,” where it was known as the Texas Aerospace Scholars, and was started by George Abbey, for whom she had worked years ago. Dunbar said the Museum of Flight entered into an agreement with NASA to bring the program to Washington.

The Washington Aerospace Scholars program provides the opportunity to juniors from high schools throughout the state to take 10 NASA-designed, on-line, academic lessons in Mars exploration. Museum officials then select 160 students to come to the museum during the summer. There, the students break into groups of 40 and work with scientists and engineers to design a mission to Mars. Dunbar said the purpose of the program is to “introduce the vocabulary” of science and engineering to qualified youths who were choosing careers outside those fields, and “to show that they could be involved.” The students have provided feedback indicating how excited they were to have had this opportunity. Dunbar said the program, now in its fourth year, is making a difference; the museum is tracking program graduates, and they are now entering universities in Washington State in those academic areas.

“We have all found the problem in North America and Europe,” and “we have all found point solutions,” Dunbar said. The challenge now is finding inspiration, as well as a high level of national direction. “I am here because of one funded program during Apollo called the National Defense Education Act, which sent me to college with a full grant loan to study engineering. I was inspired by Sputnik and by President Kennedy speaking at this university in 1962, shown on a black-and-white television we were able to borrow.”

Doetsch then introduced the third speaker Kevin Fong, commenting, “Kevin, you represent a nation that has been powerful in space, but hasn’t supported human flight very much of late.”

“Yes,” Fong responded, “the U.K. is infamous for being the only G8 nation that doesn’t support a national program of astronautics.” Fong addressed the summit participants at large in saying that they all were aware that “my mission is to get this country to reengage,” and he’d been “at it for 10 years now.” But Fong said some things had changed from the position of Margaret Thatcher’s government, when the policy was “we will never engage in human space flight,” to a position now where the government is saying, “we understand there are arguments to support this, and it’s not a question of if, but when and how.”

Fong identified himself as a specialist in anesthesiology and critical care medicine and senior lecturer in physiology at University College London, adding that he runs the only course in the

U.K. on space medicine and extreme environment physiology. “Two messages I continue to sell: education, and terrestrial benefits through knowledge transfer.”

“We need to imprint on kids and society, as well, the value of science—what it can do at its best. We need public support that turns into federal funds—at least, in my country.” However, in the U.K., Fong said he continues to hear the question: “Why should we support human space flight when it creates opportunities for only a few people in a very narrow spectrum?”

The answer, Fong said, is that “it does have the opportunity to inspire” many people on a much broader level; for example, to attract students to the field of science. To illustrate his point, he said, “Of the tens of thousands of people who watch the Olympics, very few of them are going to carry themselves down a 100-meter track in less than 10 seconds—but a lot more will try to get fit.” Fong added that he, like Dunbar, had had the benefit of inspiration: he said he had been “propelled by my earliest memory of the Apollo-Soyuz test project,” and, that having been a first-generation immigrant in his country, he was “very grateful” for that inspiration.

The fourth speaker Doetsch introduced was former astronaut Jeffrey Hoffman, now a professor in the Department of Aeronautics and Astronautics at MIT.

Hoffman said that based on his experience with students, he thought “the best motivation we could give them is the ability to reach out and touch space, through getting involved in projects that they can see are happening in space.” He cited an experience in the fall of 2003, when he and a colleague were deciding what topic to choose for an impending graduate student project design class. They thought it would be a good idea to have the class look at lunar and Mars exploration, and they posted that subject announcement. In January 2004, President Bush made his announcement about the goals of his new Vision for Space Exploration, and when the students came in for class shortly thereafter, “the excitement was electric” because “this was not just a paper study,” said Hoffman.

Hoffman said it is important to do everything possible in the political and economic sphere to stimulate the supply of another generation of scientists and engineers who will carry the space

exploration program forward, while taking into account “cyclical factors” such as the fact that currently, “there is a lot of uncertainty about the whole employment situation” as well as “the irregularity of funding for research projects, particularly the life sciences.”

Further, Hoffman said, between one-third and one-half of the MIT graduate student population is comprised of non-U.S. citizens, “many of whom would like to stay” in this country, but feel they probably won’t be able to get a job.

The fifth speaker was former astronaut Barbara Morgan, who was a teacher before she went into space and is now with Boise State University, Doetsch said.

Morgan presented three points emphasizing the educational significance of space-related activities and participation. First, she said, a group of Boise State students recently flew in NASA’s Microgravity University and the experience “opened up whole new opportunities,” especially for the many in the group who were first in their families to go to college. Second, Morgan said that teachers need the same hands-on opportunities, as they would go back and relate these experiences to their students. Third, Morgan said she believed that if teachers from all space-faring nations could have an opportunity to collaborate on space-related work, “it would do amazing things” for all of their educational programs.

The sixth speaker, Michael Simpson, president of the International Space University, said he was receiving “record applications from around the world from people who want to participate in the space sector,” all tied to a sense that space is “both an inspiration and a set of solutions,” and that “you can do a lot of things in a lot of different places.” He said the university had a 10 percent annual increase in applications over each of the prior 6 years until the current year, which has had a 35-40 percent increase. One area of opportunity that comes up regularly in the applications is space life science, which Simpson predicted would be a growth area in the future, in part because of the emerging personal space flight business.

Simpson stressed the need for an “intergenerational partnership,” as “we need to invest not just money, but time and enthusiasm” to get the message out, to help the next generation to see beyond today’s horizon.

Seventh on the panel to speak was William A. Thomson, professor and director of the Center for Educational Outreach at Baylor College of Medicine, and NSBRI team leader. For the last 30 years, Thomson noted, we have recognized there has been a waning interest in science and mathematics, coupled with concern about the quality of teachers at all levels. “We’re concerned about the public’s lack of interest in science at all, not just the space program.” The problem of trying to replace the current generation of educators and scientists is challenging, complex and not well understood.

Thomson noted that the children of Generation X, who are now entering universities, are quite different from their parents. “They don’t want to be scientists; they don’t want to be educators—they want things now.” By and large, he said, they don’t want to do the types of work we do, or work as hard as we do.

Thomson likened the problematical situation to a river where “you can get big footprints of activities” in the places where the river runs wide. As examples, Thomson said the NSBRI partners with the media in activities, writes curriculum materials, and builds Web sites the contents of which reaches “millions of people.” Where the river narrows, he said, the NSBRI has established graduate programs; Thomson stated that NSBRI helped establish the bioastronautics program at MIT and the space life sciences program at Texas A&M University. “These are systemic changes where there have been deliberate investments of our dollars” as stewards of money provided by NASA and the federal government. Thomson said data show that these efforts are working.

If he had the opportunity to talk to NASA leadership, Thomson said, he would recommend three things: first, use the ISS as an opportunity for collaboration in education; second, use NASA’s technology to exploit the social and web-based media, including Twitter and Facebook, which are ubiquitous among young people; and, third, develop pathway programs that work with

minority-serving institutions and the best colleges and universities in the country, to increase the access of underrepresented citizens to science and medicine.

Thomson illustrated his first point about the ISS representing an “extraordinary education opportunity” by describing the tremendous amount of media-fueled public interest in a spider that was lost aboard the ISS in November 2008 from an experiment that had involved a fellow faculty member with NSBRI funding. “More inquiries came in to us about the lost spider... than we ever had before. So use the space station as an international opportunity for collaboration in partnership not only for science and political considerations, but also for education.”

With respect to his second point on the widespread use of social and web-based media Thomson suggested, “Let’s exploit the media with well-designed studies to see what works and what doesn’t; for example, we don’t know if web-based education is equivalent to didactic education.”

With respect to pathway programs for minority students, Thomson observed, “At Baylor College of Medicine, through the leadership of Dr. Alford and others, we established B.S.-M.D. programs with minority-serving institutions, where students who are hispanic and black, who never would have had an opportunity to access a medical education, now do so.” Such a program identifies these students in high school, provides them with academic and social support, and places them in summer laboratory programs. “You are growing your own scientists and doctors for the future,” he said. “That can be done, and it doesn’t cost that much money to do so.”

“The last thing I’d say (to NASA leadership) is: ‘Let’s exploit your skills in technology and our skills in education, and demonstrate to the nation that stuff like this can work,’” Thomson stated in conclusion.

Aleksandra Titova, the eighth and final speaker on Panel V, said she represented the Yuri A. Gagarin Cosmonauts Training Center (GCTC) in Star City, Russia, where “we started an outreach program 10 years ago” aimed at helping to prepare children to select their careers. The basic theme is career familiarization. “The idea for the program at GCTC occurred to me because of the things that I saw in Houston. I must say ‘Thank you very much, George Abbey, for

allowing me to touch this wonderful project.” This year, she said, “we have had 600 children from all over Russia participating in our project. All the children were very interested in what was going on at the GCTC. It was very important for the children to touch the activities, to talk to the people who do the work, and partake of the influence and authority of these mentors in selecting the correct path through life.”

Titova said teen-agers who had participated in the program had gone to Bauman Technical University (Bauman Moscow State Technical University) which offers degrees in various engineering fields and applied sciences and had come back to the GCTC to work as instructors. In conclusion, Titova said she would like to establish a children’s inter-cosmos program to enable the Russian children to interact with children from other nations and share science projects.

“We are now at the point where we can really interact and use the expertise of the panelists, who have displayed so many aspects of the education field,” Doetsch announced, asking three student participants if they had questions for the panelists.

Rice postgraduate student Padraig Moloney addressed Dunbar and Fong in noting that he was the first generation of his family to have the privilege of graduating from college, and even to attend high school. “I have had the bigger privilege of being the sole foreign NASA civil servant at JSC for the past decade,” Moloney said. He noted that he was the only person in his undergraduate class at MIT to go to NASA, adding that most people in his class went into “finance, Wall Street, and information technology.”

Moloney said his NASA experience had been “fantastic” from an educational point of view; the highlights had been mentoring 20 Texas Aerospace Scholars and teaching nanotechnology to Houston-area high school students. The experience also brought out “how bored I can become when there is basically no demand, time, funding or willingness” for low-TRL advanced technologies” at either JSC or Ames, adding that there was a “big disconnect there.”

Ronke Olabisi, who identified herself as a graduate student in her last few months at Rice, said it seemed as if most of the focus was on children K through 12. She asked what could be done to motivate students in their college years. Jeffrey Hoffman said if the space station were properly utilized to give college students a chance to participate in experiments, the excitement it would generate would be tremendous. Hoffman commented that Bill Gerstenmaier of NASA had said he'd support it, except for the fact he had no money to support it. Doetsch asked if Hoffman knew of any programs that would enable that, and Hoffman responded, "Not yet." Bonnie Dunbar recalled that such programs existed with Skylab and the shuttle, and they needed to be revisited because "they worked very well." They were cut for budgetary and funding reasons.

Jacob Berlin, who said he was also a postdoc at Rice University, commented, "Events like this are truly inspiring." One of the key problems that he perceived was the communication of "exciting problems." He asked panelists the question: "What is the grand challenge of space?" He also wanted to know how to motivate students beyond high school, and how to encourage the message distribution and simplification of such problematical questions "for all of us."

Simpson said the greatest motivating tool for him, as a student, was to ask questions that engaged the students. He agreed that "we need to be willing to share questions (with students.) The things we don't know are really motivating."

Fong addressed the question of the "grand challenge," qualifying his response by saying he could only speak for how his own government perceived it: "They tend to look at the science, the excellence of science, and the theme that has emerged for them is the astrobiological context. They feel that understanding the nature and origin of life and the universe, and its likely ubiquity, is probably one of the biggest challenges that science technology faces in this new century."

"I think I do agree with that," Fong added, raising the question of the combination of means—human and nonhuman—that would address this challenge. "I think that half that, maybe more than half that, can be addressed by robotic and automated platforms. I think that the detailed prospecting of the inner solar system, and particularly of the surfaces of the Moon and Mars, probably can only be done in the foreseeable future by human-tended outposts."

Noting that NASA “still” issues grants, Neal Pellis suggested that one way to engage younger students would be to make it a condition that “they have to have a partner school that addresses an education theme in reference to their flight experiment.” Pellis also pointed out that the ISS National Laboratory exists because of a congressional directive to bring research on the ISS to a level that is equivalent to the other national laboratories, like Oak Ridge. Pellis said NASA has created partnerships with federal agencies like the NIH, the Agriculture Department, and others interested in participating in a National Laboratory segment of the ISS.

Charles F. Bolden Jr., of the NSBRI board, keying off the Rice student’s question about educational opportunities for college students, asked what panelists thought about “consideration of collaboration between the Department of Education, NASA, other federal agencies, and commercial startup space companies.”

“You know, a sounding rocket is a sounding rocket is a sounding rocket,” said Bolden. “SpaceShipOne is a big sounding rocket. Does it make any sense to try to involve them as a part of this family of organizations that we use to try to provide educational opportunities, not just for kids in secondary and elementary schools, but for students in colleges?”

Bolden cited the example of a group of University of California students who formed a rocket club, which “has grown immensely.” Bolden said the students now have contacted the Scaled Composites company “right up the road from them at Mojave,” and “some of them serve as interns” at Scaled Composites.

“What I fear is that we get insular when we think about NASA as the only opportunity for inspiration in terms of space exploration,” Bolden commented. “I think we’ve got to open up the mold a little bit and do some collaboration.”

Thomson concurred, as did Simpson, who said his university has a couple of agreements with startup companies on work that has evoked “tremendous excitement” from students. Simpson urged NASA to “be a partner,” because the NASA and ESA brands “add a real cachet of being at

the frontier.” Dunbar agreed that “we need that kind of partnership” because while NASA is a great brand, “there really are not that many resources coming down from NASA.”

Former astronaut Walter Cunningham, now of the NSBRI User Panel, interjected an observation with respect to earlier comments about the current dearth of candidates in science and other “high-achieving areas” of education: “We reap what we sow. Most people would agree that we’ve been going through a dumbing-down of education—you know, ‘Leave no one behind’ in the classroom, and ‘Don’t fail anyone, it’s bad on their self-esteem,’” Cunningham said. He also stated that this problem had to be addressed at the beginning of the pipeline, at K-12. “We need to demand and get more out of our students and teachers. We need to encourage our students to take risks, because the corollary to risk is failure. We’ve got to get away from this simpleminded stuff of nobody failing and nobody getting left behind. They have to learn that you have to put out the effort to do it. Is there anything you can do in that area?—because you’re going to get the benefit later from it.”

Simpson cited an experience earlier in his university career with a successful program called Kids at Risk, which targeted children, starting with fourth-graders, in an upstate New York community in which the parents had had no college education and in some cases, no high school education—where the children were “just not making it through the pipeline at all.” According to the program’s federal reviewers, one of the things that made it work was that the program ensured there was a network at home to help the teacher get the message across that “working hard wasn’t just nonsense,” said Simpson. “It also made the parent an ally.” At the end of the year, the children in the program “passed the same statewide regents exams that their peers were passing, and that their predecessors had been failing.” Moreover, as the children grew, “so did their parents,” Simpson said, noting that some parents went on to obtain their G.E.D., while a number went on to college.

Responding to the question of student inspiration, Richard Scheuring said “Let me give you a view from the trenches. In addition to my day job as one of the Constellation flight surgeons at NASA, I teach a lot.” He and others at NASA teach in their free time, at night, and on weekends. “We love what we do, but ... we need the freedom to do that. We’re crunched with the very few

civil servants that we have to actually do the job because we have so many things going on. You know, this is one of our mission statements for NASA, that we do education outreach. I think this should be just as much a part of our daily job that we do this, for those of us who are inclined and have the passion to do that.”

Analogs like Pavilion Lake and NEEMO provide a “perfect opportunity” for educating young people of all ages, stated Dave Williams, adding that he thought Charles Bolden was right: “We can look at these private-sector launch opportunities and get educational components there. But by the same token, we need to put funding into supporting the analog sites.” Williams said the CSA would provide \$25,000 to send students to these sites.

“In the next 3 to 4 years, access to suborbital flight will occur every day,” audience participant James Vanderploeg noted. “There will be several thousand people flying every year. With each of those flights, there will be access for small experiments to be done. My question for the panel is: how do we prime that pathway for students to recognize those opportunities and take advantage of what is coming in terms of commercial daily space flight opportunities?”

Hoffman responded, “I think NASA historically has done a pretty good job making parabolic flight opportunities available to students. However, all of this costs money. That’s the big problem we always run into. The model is there. We know how to do it, if we can afford it.”

Laurence Young of MIT urged summit participants to support by example the identification of space life science as its own discipline, commenting: “We do have a challenge, and that is having these bright young people, who want to get involved in the sort of research that we know is necessary, identify themselves as members of the space life science discipline rather than as individuals in the sub-disciplines who attend their own meetings.”

Audience participant Adrian Perachio, of UTMB-Galveston’s Graduate School of Biomedical Sciences and the NSBRI Board of Scientific Counselors, provided an example of the supportive role that could be played by medical schools. He noted that for years, UTMB has offered space life science courses taught by JSC personnel. “With the opening of the flight analog facility

several years ago, we thought it was also important to acquaint medical students with some of challenges that flight surgeons face, in supporting the program,” adding that such a course was added to the medical school curriculum.

Amy Kronenberg, of the NSBRI External Advisory Council, commented with respect to inspiring young people. “My experience is that you can’t start too young, and it doesn’t take much, and hands-on is what you need. If you get the 5-year-olds engaged, they remember.”

Kevin Fong noted that he had been teaching a university-level space medicine course for a decade in the U.K. While the medical students may think they’re learning about “astronauts and polar explorers and mountaineers,” Fong said, “they actually are learning basic physiology principles that would be extremely useful to them in practicing medicine.”

Another audience participant asked the discussants not to forget the importance of educational opportunities to graduate students and senior scientists, citing his favorable experience in a NASA space radiation summer school at Brookhaven National Laboratory.

Returning to the topic of youth in control in the Apollo era, Rice University professor James Tour conjectured that “magical things” would happen if a “lean and mean young team” under age 35 were assigned to work on a specific problem at NASA, working with minimal oversight “under the protection of older people.” Hoffman commented that NASA from time to time has special projects to which NASA engineers are assigned, which constitutes for them the intrinsic reward for doing the job.

Abbey urged summit participants to read the National Academies’ “Gathering Storm” report to which Bonnie Dunbar referred with respect to inspiring the interest of young people in science and related educational subjects. “The problem really gets back to much younger children,” Abbey said. “If you look at the city of Houston, we have the third-largest school district in the United States of America. We graduate less than 50 percent of the students from high school. In the state of Texas, we graduate less than 50 percent of the students from our high schools, let alone go on to college. We need to address the problem at a much younger age. We also need to

ensure that we give the background to the teachers so they can get young people interested in science and mathematics and engineering. Further, we need to look at how we can incentivize teachers, and pay them the money we should pay them, and recognize the responsibilities and the duties they have. This problem is not just the issues we've been talking about here today. It's a massive problem, and it's going to take us all working very hard to try and solve it."

Gilbert Castro of the NSBRI External Advisory Council said he wanted to make a point with reference to the story that Williams had said needs to be told about the space program, in order to engender support and stimulate interest. Castro said he worked with public schools which have a "portrait of a graduate." Of the requisite traits, academic skills comprise only 10 percent; the other 90 percent involve "professionalism and interpersonal skills" that cannot be measured. Castro commented that the story associated with international space medicine includes all the latter skills that teachers are trying to impart to their students, and that should be included when telling the story.

"I have to do a little defense of NASA here," interjected another audience participant who did not identify herself. "NASA has tried really hard to inspire students in stem education. They've tried everything under the sun in K-12." At the college level, she noted, "we've talked about parabolic flight"; in addition, about 400 undergraduate students were expected to be working as summer interns, most of whom would be funded by NASA. She said all of the scientists she had worked with on life sciences missions went into classrooms to inspire students with parallel projects.

She agreed with Abbey regarding the magnitude of the education problem, saying: "NASA is trying its best, given the resources and the fact that our primary business isn't education. We all have to do it. Every university in this country is trying to work K-12 because it's such an enormous American problem. We are all working on it, and it's going to take a lot of effort from a lot of people." She emphasized that NASA funds K-12 education, as well as undergraduates and senior design projects through the Space Grant Consortium, and she recommended that summit participants check out the NASA education website showing all of its programs. She also said she thought NASA would be "well served by working with the Department of Education"—

a point with which Hoffman concurred. Based on his experience with K-12 constraints as director of the Massachusetts Space Grant Consortium at MIT, he said, “I get the sense there seems to be a bureaucratic sensitivity between NASA and the DOE. Your remark that these need to be coordinated is right on the mark.”

In conclusion, moderator Doetsch said an idea had sprung to mind while listening to all of the comments during the session. Doetsch proposed “a service that could be well-fulfilled by a group like this”—to collect these ideas in a structured way, and coordinate with an education department, industry, or agency like NASA in preparing a document enumerating all of the suggestions for improvement.

Reception and Dinner Presentation

Space Medicine: Principles and Practice

James D. “J.D.” Polk, D.O., Chief of Space Medicine, NASA-JSC

Bobby Alford introduced speaker James D. Polk, telling the summit participants: “We are very honored to have a very distinguished speaker and very important person, who is chief of Space Medicine at Johnson Space Center, Dr. J. D. Polk. I think you’ll enjoy what he has to say about space medicine.”

In his presentation, Polk described how NASA utilizes aggressive preventive-medicine practices, novel devices, transportation planning guideposts, and progressive protocols in engineering optimal health outcomes for astronauts and developing space technology that eventually will cascade to use on Earth.

“What I want to talk about is how you strategically plan for space missions, especially exploration missions,” Polk began. “Where do you start? The first thing that you have to do is pay attention to history. We had to bring folks back, because you lose corporate knowledge. We brought the Apollo folks back; we brought the Skylab folks back.” He explained that it is valuable to talk to those “who’ve already been there and done that,”

given the gaps between what may be “politically correct” documentation and what actually happened.

The budget has to be carefully considered, Polk said, noting that sometimes, plans made with high hopes and related expenses may be curtailed with changes in administrations.

“You also have to define the concept of operations,” he said, explaining that means knowing “what you’re going to do when you get there” and planning for contingencies. For example, Polk said if someone would be driving a rover into a ravine, “thoughts of trauma spring into my head,” qualifying the comment by explaining that he was an ER and trauma doctor. In addition, he said, it is important to define the levels of care.

In deciding which items to fly, Polk considers six tenets: mass, power, volume, time, money, and risk. Sometimes, he noted, colleagues in the medical profession will ask Polk a question like “Aren’t you going to fly an MRI to the moon?” Using the tenets as guideposts, the answer would be “no,” Polk said, adding: “Right now, I’m lucky to get food, water, clothing, and a small medical kit on board.”

One major space transportation constraint relates to rocket fuel costs. “The astronauts all know it takes 27 pounds of fuel for every pound that I fly,” Polk remarked. “It costs me \$20,000 per pound, currently, to get to lower-Earth orbit,” and more to get to the lunar orbit. “So you have to be a little picky, when it costs that much to fly a pound of material, as to what pound you’re going to fly.”

Planning for space flights in the early years was a different procedure than that of the present day, partly due to lack of experience; the fact that “we didn’t share a lot with other countries, and vice versa.” “We selected from a very specific group of individuals” and the flights were shorter, said Polk.

Today, “we don’t select just the hardened fighter pilot” to be an astronaut, Polk said, adding that the average age is now 46, compared to 36 in the Apollo era. Missions are longer. There

is multinational sharing and learning, and medical kits, equipment and exercise hardware are provided by multiple nations.

Polk noted that he takes for granted his friendships with colleagues from other space-faring countries, including fellow summit participants Filippo Castrucci and Boris Morukov. Such international relationships were built from years of working together as partners, a “very foreign” concept in the Apollo era, he said. Polk displayed a slide reading “TRUST: Despite the years of training, the millions of dollars, and the miracles of modern science, it still comes down to whether you trust the Russian guy will let you back in the airlock.”

“It took a lot of trust for us to convert to ISS operations,” Polk commented.

Today, Polk said, “preventive medicine is 90 percent of what we do” as flight surgeons, continually monitoring the astronauts’ health, looking for problems and fixing them. Polk said people in Congress have asked him: “If somebody’s got afib (atrial fibrillation), why don’t you just get a new astronaut?” Given the multimillion-dollar investment in that astronaut’s training, “it’s better to get the afib ablated and fly that person than it is to hire a new person and train them,” he explained.

“If you’ve had a kidney stone, you need not apply to the astronaut corps,” Polk said. “But if we’ve spent \$16 million training you, and you have a kidney stone, we’re not kicking you out, we’re keeping you.”

In astronauts’ exams, “it’s amazing what you find,” he said, “because we’re looking for things that typically, your family doctor won’t look for.” Random MRIs and other “limb- and lifesaving” tests are performed on astronauts heading for the ISS that aren’t routinely done on asymptomatic patients by their family doctors, because any anomalies must be caught and fixed before flight. Polk said they’d found pituitary adenomas and other things that would have caused significant sequelae, had the astronaut gone into orbit and experienced issues.

“We have taken preventive medicine to a very offensive level in trying to reduce risk in the astronaut corps,” said Polk, citing another discrepancy: “We probably put people on statins much faster than your family doctor would.” Where most physicians treat a male patient with a PSA (prostate-specific antigen) at a level of 4, Polk said, “we treat it on the level of rise” at a particular rate over a year. “We picked up three prostate carcinomas in doing that,” he noted.

Polk displayed a graphic illustrating the process of “Practicing Offensive Preventive Medicine” at NASA, starting with screening standards; preventive medical care, like statins and A-1 Milano HDL therapy, related to fitness for duty; medical requirements, using bioaeronautics research and medical studies to evaluate current therapies and predict future problems; and finally, “operational success,” with the result for exploration medicine of “reduced coronary risk to less than 1 percent,” and reduced volumes of medications and hardware.

Polk cited five main initiatives at NASA: quality, consistency, patient information data flow, occupational health surveillance, and focused operational research and development. He noted that 50 percent of the care of astronauts assigned to the ISS is outside the United States, as they’re training elsewhere; hence, NASA wants to ensure that the astronauts receive the same type of care off-site as in Houston, and that up-to-date health information is accessible to the treating physician.

Also in practice today at NASA, he said, is a new “lifetime surveillance of health” preventive-care program that uses age-based protocols, including tests to prevent diseases for which an astronaut is known to be at risk because he is flying in space.

Polk showed a slide entitled: “Institute of Medicine Report: ‘To Err is Human,’” with an “Impact of Error” list stating “44,000-98,000 annual deaths occur as a result of errors” and “medical errors are the leading cause, followed by surgical errors and complications.”

NASA's astronaut clinic uses the Lean Six Sigma methodology to prevent problems through a focus on providing consistent, high-quality care, said Polk. He cited NASA's medical application of Lean Six Sigma principles to clinical practice guidelines, care managers, selection standards, vehicle-specific standards, and fitness for duty standards. Addressing the first application, Polk said his 16 flight surgeons were treating things "16 different ways" years ago. Today, he said, they all provide care under clinical practice guidelines that set minimum levels of treatment in a mode of standardized care that doesn't limit their autonomy.

For example, if a patient is found to have a cholesterol LDL reading of a certain number, there is a corresponding minimum that the flight surgeon is obliged to do under the current guidelines, he said. After the new guidelines were put in place, it was found that "the astronauts were placed on statins much sooner than if we left the physicians to their own devices," and that "we were decreasing soft plaque due to cholesterol and other risk factors," said Polk.

They also standardized electronic medical record usage, so they could access records from Russia and elsewhere, "and that helped greatly." Polk said.

The new approach has resulted in reductions in health-related risks, as well as substantial cost savings to NASA. Polk offered an example by estimating the cost of flying an automated external defibrillator (AED) at about \$10 million, accounting for purchase price, fuel cost, crew training, flight certification, and other factors. Polk explained that if he could eliminate the need to carry an AED on board, by standardizing care and ensuring that the coronary disease risk was less than 1 percent, he would have just saved NASA that \$10 million expense.

NASA also uses novel technology to reduce risk and expense, Polk said, citing a closed-circuit ventilator with an oxygen concentrator. The device takes the oxygen out of the atmosphere, concentrates it, and gives it to the patient, he explained. The device was evaluated with respect to the fact that "we can't have O₂ going greater than 28 percent" in a

medical procedure, in order to avoid a fire risk in a spacecraft. If he were to intubate and ventilate a patient on a spacecraft, and a large portion of the oxygen went into the cabin, the fire risk would be increased, Polk explained.

The new closed-circuit ventilator was tested on 20 patients at the University of Cincinnati to get FDA approval, he said. “We also wrote a computer algorithm that weaned the patient from the vent,” which was found to dramatically reduce the use of oxygen, Polk said, adding that the new device and mode saved the Constellation program “millions of dollars” in heavy equipment that didn’t need to be carried on board.

Another piece of novel technology that Polk described was the CPOD, a device “about the size of my Blackberry” that monitors and transmits the wearer’s vital signs. The CPOD was designed to make it easier to monitor astronauts as they moved about in space, eliminating the need to hook them up to a number of wires that would tether them to equipment.

When Polk dons a CPOD, its Bluetooth can transmit his data to a read-out at the top of his helmet, and he can transmit that data to Houston; “We proved that on Devon Island,” he noted. Illustrating the breadth of the CPOD’s advantages, Polk said that when he flew as chief flight surgeon on Metro Life Flight before joining NASA, he had a 10-pound pack that served the same purpose that the small, lightweight CPOD serves today. This type of technology, and attendant thought processes, eventually will cascade into everyday medical practice, he said, adding that it sometimes can take as long as 12 years to do so.

Polk raised the question: “Where do we start planning for exploration on the medical side?” He then broke it down into the component questions: “What are the risks? What are the medical diagnoses unique to spaceflight or the astronaut population? What is the mitigation strategy?”

Polk displayed a graphic showing how NASA looks at risk: Risk (expected loss per unit time or activity) equals severity (loss per loss event) times probability (loss event per unit time or activity.)

Polk stated that the long-duration lunar and Mars missions will have “unique aspects,” the most important of which will be the reversal of the existing life-limb mission paradigm. As an example, he said, right now, if an astronaut incurs a corneal infection that worsens on orbit on the ISS, “we’re not going to make that astronaut sacrifice an eye, we’ll bring the person down.” However, if an astronaut gets a corneal abrasion on Mars, “we can’t abandon the mission because of that,” he said.

Another difference will involve physician training: “When you become an astronaut, you work on astronaut stuff, you don’t necessarily see patients and keep your clinical skills up. But for an exploration mission, you’re going to have to,” said Polk. Additionally, that physician will have to “know everything,” on the order of the traditional family-practice doctors who were trained in the ’50s and ’60s to do everything.

Polk noted there is a difference between a standard of care and a level of care. He has been asked whether he could do prophylactic surgery, like taking out someone’s gall bladder on the moon or Mars. While that might be possible, he noted that things can go awry in surgery, so he prefers not to start planning for doing such procedures in those venues.

The crews are going to have to be autonomous, which means they must be able to cope medically with 20-minute one-way communication. A consultant will be available, but not for emergent care. The medical officer must have the proper training to provide the majority of medical care; a consultant will be available, but not for emergent care.

“We’re going to have to leverage our past experience, as well as analogs,” and will have to do “pretty good forecasting,” using an array of tools including a Delphi technique. Polk stated that on long-duration missions, there will be “unique psychological and psychiatric issues, as well.”

On the side of preparedness, Polk stated that “physiologically, we have a good model for how to get to Mars.” He noted it takes 6 months to get to Mars, and “we have an analog for that” in the ISS. “We can do long-duration lunar missions which give us one-sixth g, so any

countermeasure that works in one-sixth g is going to work in one-third g,” Polk said before opening the floor to questions.

Charles F. Bolden Jr., of the NSBRI board, asked the first question: “I was happy to see you’re using electronic medical records, but have you been able to break the code yet in getting the astronauts to trust you to access the electronic medical records from their civilian physicians, so you really do have an accurate record?”

“That’s a tough one, because we use so many different consultants,” Polk responded. He noted that the issue “has more to do with the hospital side, than with our patients.” He said The Mayo Clinic and the Cleveland Clinic “allow us to access their records, easily.” However, “if we go to Methodist downtown, we don’t have access to those folks.”

Moreover, “there are so many different EMRs, with different languages that don’t speak to each other, it’s difficult for medicine as a whole,” Polk said. “If you’re seen at Clear Lake Regional and then go to St John’s, the two don’t speak to each other electronically. So we’ll see how we get there. At least from NASA’s standpoint, all the medical/clinical care that our folks are going to receive, regardless of where they’re at—whether that’s going to be Star City, White Sands, JSC, or KSC—we’ll be able to get to that electronic medical record.”

Polk said that was extremely helpful to researchers as well, because previously 50 percent of that information was not being captured in EMRs, “so we didn’t know how many incidences of X we had.”

Another difficulty was that “because of medical confidentiality, I’m the only group at NASA that can’t boast of my successes,” Polk said. He explained that he couldn’t identify individual astronauts with respect to “great saves that wouldn’t have been picked up otherwise” in terms of morbidity and mortality. “So the astronaut corps themselves probably have no idea of all the things we’ve taken care of. That, to some respect, doesn’t allow us that warmer relationship with the astronaut corps.”

The second question came from an unidentified audience participant who asked Polk to expand on his point about the “unique psychological issues” of long-duration missions.

“There are things you don’t expect,” Polk responded, noting that “psychological support techniques can present a double-edged sword.” For example, “crews love the IP phone; they get to touch base with home.” That can be a plus, but it can have negative effects as well, especially in conjunction with the receipt of negative communication like a child’s bad grade.

Further, “more and more, for Constellation missions, group dynamics will come into play,” Polk said, explaining that “compatibility plays into the selection” of crew members on long-duration missions. While “we want a type-A, gung-ho” personality for short shuttle missions, “that doesn’t necessarily play very well for long-duration ISS or exploration missions.”

George Noon, a Baylor College of Medicine professor of Surgery, asked Polk whether NASA offers psychological training to family members, in the same way it is provided to astronauts, to prepare them for a mission “to avoid some of the things you were just talking about.”

“We do, but probably not enough,” Polk responded. “Especially as we get into Constellation missions, we’re going to need to do more, in my opinion. When it was only a military paradigm, back in the Apollo and the early days, those folks were married to military wives who were used to deployments, used to moving every two years, used to the hardship of military life. It’s a little bit different now with folks who are not necessarily military coming into NASA, and all of a sudden their spouse is spending six months in Russia.” The fallout from the astronaut’s training and related moves “is hard on the family.”

Another audience participant commented that different vulnerabilities had been found among subjects in a number of experiments, and among patients in medicine in general, which had led to the evolution of personalized medicine. “We’d love to know what those are, so we can mitigate, prevent, and target countermeasures,” he said, asking Polk to comment on the approach of identifying differential vulnerabilities.

Polk responded with a timely example: the impending introduction in his clinic of a diagnostic and monitoring test for atherosclerosis that uses NASA-based technology. As background, Polk reiterated his earlier comment that U.S. doctors generally gear statin treatment toward a particular LDL number. However, after working with cardiovascular experts throughout the country, Polk said that “in the next month and half, we’re going to start carotid intima-media thickness (CIMT) ultrasounds in our clinic” for use as a screening technique in the early detection, monitoring and management of atherosclerosis.

Polk said that because individuals build plaque at different LDL numbers, “rather than picking an arbitrary number, we’re now going to focus it and aim it at what number those (individual) folks are laying down soft plaque. So if we see an increase in soft plaque, we’re going to manage our statins based on what we see on the CIMTs, not necessarily based on an arbitrary number that we pluck out. Then we’re going to try to carry those in our clinical practice guidelines to make those tailored toward each patient in other venues, beyond cardiovascular.”

“That’s a thought process in preventive medicine that will eventually cascade down to medical practice, that NASA is ahead of the curve on,” Polk said, commenting that many people focus on “Velcro and Tang” as NASA-derived contributions to everyday life. “How do you put that down so that folks know that came from the space program?”

DAY 3: MAY 17, 2009

Discussion Groups: Summary Reports

Group A: Cooperative Research Opportunities during Space Station and Lunar Missions

Team Leader: **Jeffrey Sutton**

Jeffrey Sutton, NSBRI president and director, provided the summary report representing Group A’s discussion. Before presenting the report, Sutton noted that this was a preliminary draft; that the group’s research emphasis was on operational research; and that the group had international representation.

Group A discussions had a recurring theme of “cutting across national interests and focusing on science and the development of medical countermeasures in future technologies,” Sutton noted.

He summed up his group’s report by enumerating a number of points:

- “I think there really was general agreement that there is a need to expand the current medical evaluation platform that exists to incorporate a standard protocol for research measures. This needs to be internationally agreed upon, and it needs to be enacted and implemented soon.” This was envisioned as a standard platform of tests of physiological measures. This objective is “a rather urgent matter.”

- “There was recognition that there is good baseline dateline collection in field tests, but they are not standardized in the same way that the medical evaluations are,” Sutton explained. This point raised the recurrent theme that “there is a need to break down some of the silos that have developed among the nations in terms of what is being evaluated and how it’s being evaluated.”

- “There have been quite a number of expeditions on the ISS that have now taken place with very important medical data, and it’s time to review what is known on the ISS missions, both from a medical standpoint and also from a research standpoint.”

- “It is desirable to have crew involvement internationally in the research enterprise, and that consent be shared internationally.”

- With respect to the ISS, “as the number of crew members increases, there will be an increased need for the use of common resources and equipment,” Sutton said, adding that most of what was emphasized concerned medical resources. “Not every nation needs to fly a medical kit and resources for contingencies. From a planning standpoint aboard the ISS, the resources need to be used by all the crews.”

- “There is a need for universal protocols for countermeasures, and for consistent reporting on the use of these countermeasures.”
- Again with respect to increasing crew size, there is a need “to organize and structure crew activities, the complexity of tasks that are going on, to best utilize not only crew time but the resources that exist upon station,” Sutton reported, “and then, in this context, also be aware of off-nominal events and contingencies that take place.”
- “There is a need for an inclusive international joint working group pertaining to research,” said Sutton, adding that one-third to one-half of Group A’s discussion time was spent on this point. “There already is ISSWG, but the Russians are not part of that.” Further, this joint working group “needs to be established in a timely way.”

“My sense was that there really is a desire for the leaders in the various countries, who are responsible for the research enterprises, to sit around a table together and really discuss the priorities: what is needed, and how to cooperate and collaborate even better than we already do,” Sutton said. “There are lessons learned about how to do this: the med ops folks have a good head start from previous enterprises such as Skylab. But now we have added the complexity of multiple nations.” Further, “there was clear recognition this can’t only occur at a high level. The work of this prospective group needs to get down to the subgroup level and have the discipline groups from the various nations discuss the particulars. This must be an inclusive enterprise, to address the multinational stakeholders, the partners, the operational people, the crew, the physicians, the basic and translational researchers and the commercial participants.”

“Specifically, this joint working group needs to emphasize the research and data acquisition that will be focused on answers,” Sutton reported. The consensus was that the proposed group must target “enabling risk reduction, and also, solidifying some of the engineering design requirements and technology development.”

“There was no question everyone liked the idea of the international crews and investigators interacting together in an intellectual environment, planning the research, conducting, sharing the results,” Sutton emphasized. “Of course, in many successful missions, the crew have been the P.I.s and the co-P.I.s on the investigations. So it was really felt that part of the charge of the joint working group was to facilitate and ensure that this does happen.” This related to the group’s recurring theme of cutting across national interests and focusing on science and the development of medical countermeasures, he said.

- Finally, it was considered “critically important” to address some of the international questions concerning the transitions in gravity, “and with respect to lunar ops, the fundamental question concerns the differences in physiological systems at one-sixth g versus zero g.” Sutton reported.

At the culmination of the lengthy question-and-answer period that ensued, Summit participants achieved a significant goal in agreeing that they had reached a consensus, based on a motion made Bobby Alford.

Alford broached his call to action early in the Q&A discussion by commenting: “It seems to me that, having seen the development of the International Space Station as it has occurred, that it truly does represent a multinational effort.” He noted that participants at each of the three International Space Medicine Summits manifested common agreement as to the need for “the four Cs”: communication, cooperation, coordination, and collaboration. Alford suggested that having reached this position of accord, Summit III participants should “take the next step” and agree that “we have a position that, from our point of vantage, are committed to trying to make this truly an international model for how nations can cooperate.”

After numerous comments, questions, and additional input, the group reached formal consensus, acknowledged by George Abbey at the podium, on the following motion, which Alford was asked to express:

“As a group of leading biomedical scientists, physicians, engineers, and other participants at the third International Space Medicine Summit, we feel that it is very important for our governments and our countries to get behind the International Space Station: to promote collaboration and cooperation at all levels; and, to the greatest extent possible, magnify and enhance the work that we all have envisioned and are trying to accomplish in order to be able to ensure safe long-duration human space flight, and to do other things that will be of great benefit to all the people on Earth.”

Alford noted that, having reached this acknowledgment of their unanimity on this issue, they could all, as individuals, do what they could to implement the resolution in their own venues, as many participants had recommended after he initially made his suggestion.

ISMS participants reached this point after an extensive process of asking Sutton questions and making further suggestions about his Group A summary recommendations. The theme that the international participants enthusiastically voiced throughout this period, at the close of the conference, was the need to take action and maintain the momentum in various respects after the summit ended, when they would break apart and return to their respective laboratories, offices, and countries.

The first question after Sutton’s presentation came from former astronaut Joseph P. Kerwin, , of the NSBRI User Panel, who asked whether the proposed international joint working group would be the entity that would conduct the major review of ISS medical data that comprised another point on Group A’s list of recommendations.

Sutton acknowledged that was one way of doing it, although “my personal interpretation was that these two activities could proceed on an urgent basis in parallel.” He observed that it will take some work for the proposed group to come up with a charter and its operations, “whereas the data exist now, and there’s already a critical mass of the international community with expertise. I could see that going ahead in the immediate short term.”

“And would that group then, after reviewing the medical data and determining what currently is known, proceed to determine what else is needed that could be accomplished on the ISS, and begin to shape a project?” Kerwin asked.

Sutton responded in the affirmative, but reiterated: “The main point I want to emphasize is that I don’t think it’s sequential. These two activities need to launch out. I think there are individuals who participated in this summit who are the leaders. I think it behooves us to determine, among this community, how we go forward. The critical mass exists here.” Kerwin responded that he shared Sutton’s sense that “there’s some urgency in this. We have to get on with it, if we’re going to make an impact on the station.”

Former astronaut Walter Cunningham, also of the NSBRI User Panel, asked whether thought was given to how to keep such an international working group “as objective as possible,” to keep politics out of the agenda.

“Whenever the discussion moved toward the political arena, the brakes were immediately put on,” Sutton responded. “There was a real emphasis on leaving the politics aside” and transcending that with a focus on medicine and science, which Sutton believed would be mirrored in the proposed international working group. He said the group would focus on “what is the best science to be done, going forward,” rather than who would do it.

Because of the group’s emphasis on operational research, Neal Pellis, PhD, NASA chief scientist for space life sciences and a Group A member, asked whether there was “something we should say with regard to the basic research opportunity,” especially with regard to gravitational forces, or whether that would be taken up in another venue.

Sutton responded that the international working group for science would be charged with taking up the issue, as it would address all forms of research.

Alford said he agreed with Neal Pellis that ISS research should include basic science work as well as primarily translational work. He observed that many questions need to be answered for

long-term human space flight, and “I don’t think any doors need to be closed.” Alford also said he thought there was a need to take action and move forward.

The theme of taking action in the form of a summit consensus was pursued and expanded upon by numerous ISMS participants until the end of the session, when Alford was asked to make a formal motion with the final wording of the proposed consensus, and it was finally achieved.

Sutton emphatically agreed with Alford on the need to take action, saying that with the close of the third ISMS, “this is where the work begins.” Sutton then volunteered to “help with the next step” and be part of the proposed international joint working group, to develop a position paper and work with the international community to “move out and move forward,” observing that “many of the stakeholders were in this room” at the ISMS III sessions.

Then Charles F. Bolden Jr. proposed that ISMS III participants take the Summit model back to their own communities and share it with their colleagues and others at every opportunity, saying, “Here’s what I’ve seen, and it works.” He said if everyone described their experience with the international model, “things will change.”

Bolden elaborated on the international nature of the experience that the Summit provided its participants in recounting what he called “the most interesting experience in my life”: “the experience in preparation for working on the STS-60.” Bolden told the story of how George Abbey, who then was with NASA, had overcome Bolden’s strong objections and persuaded him to command the first U.S.-Russian joint shuttle mission, which launched in 1994.

“When Mr. Abbey called me, I was at NASA headquarters, and he said, ‘I want you to come down to Houston and fly again.’ I said, ‘OK,’” Bolden recalled. “I asked him what mission. He said it was STS-60. I said, ‘Isn’t that the Russian mission?’ He said ‘Yes.’ I said, ‘George, get real. I’m a Marine. I’ve spent my entire life learning how to kill those guys. I don’t want to have anything to do with that.’”

After Bolden refused the Russian mission in no uncertain terms, Abbey recommended, in so many words, that he “settle down,” and then told him: “Sergei Krikalev and Vladimir Titov are going to be in town tomorrow night. Why don’t you at least have dinner with them before you make up your mind?” Bolden agreed to the dinner, which changed his mind.

“STS-60 turned out to be my last mission, but it also turned out to be the one that taught me the most, and gave me the most personal gratification, next to being with the Marines,” said Bolden.

Bolden told Summit participants that he shared the story about his perspective-altering meeting with the Russians to explain why he felt that “we really need to go back to our individual communities and talk about this experience and this model, and I think things will change.” He suggested they should all work individually to broadcast this issue as a “committee of one.”

Following up on the issue of group consensus, Alford commented, “One country cannot do this alone. That is the key issue in many ways. But together, we can do almost anything.” Alford suggested that if there were no real opposition, “we can accept that as a consensus.” Sutton responded that he fully agreed, and that this was a discussion point in Group A, that there was consensus.

Valery Bogomolov of the IBMP said: “I would like to propose that the findings of the Summit be brought to the management of the agencies of the partners, and also be presented in the program office of the ISS. This will become a significant step for the realization of the goals of the positions that we have defined here, (presented) by Dr. Sutton.”

Another participant volunteered his services to Sutton to further the cause, and suggested that the group needed a timescale for their agenda, to keep the momentum going and to “facilitate the utilization of the facilities we have.”

CARTA director Shanguang Chen commented that he quite agreed with the point of view that had been expressed by Sutton in his presentation. He noted that the third summit constituted the first time for a Chinese delegation to attend that type of meeting, and voiced his thanks to the

ISMS organizers for giving them the opportunity to speak and to listen at the conference. “We feel that the ISMS is quite a success,” said Chen, adding that the Chinese delegation hoped to be given the opportunity to attend future meetings.

“International cooperation in the future is very important,” Chen said. He noted how he had described in his presentation China’s development of its own space program, and he thought the program would need international support in the future. He said that during the implementation of its space program, China had developed better cooperation with “a lot of countries,” such as Russia and countries in Europe. Chen then noted that this was the first time he had been in the United States since 1998. “It’s a little long, but I think it’s not too late,” Chen said.

Chen said he had noticed during the summit that many people said they thought we should have an international platform and standards, and some research in the future in wider fields, and commented: “I quite agree with this point of view.”

“Chinese experts also will devote their wisdom and efforts to enrich such kinds of cooperation with the experts from other (parts of the) world, and also make some suggestions to the government, to notice that,” Chen said in conclusion.

Inessa Kozlovskaya of the IBMP and who had been a member of Group A, complimented Sutton on his summary of the group’s discussion, saying it provided a clear and promising path to success in the future. She emphasized that the priorities and representation of the prospective international working group should include both medicine and science, including basic science. As she had been speaking in Russian, Sutton responded in kind by saying “thank you” in Russian, and said he fully agreed.

Alford suggested that it was time to determine whether the group was ready to put the consensus issue on the table. He was asked to articulate the proposed consensus, which was as follows: “As a group of leading biomedical scientists, physicians, engineers, and other participants at the third International Space Medicine Summit, we feel that it is very important for our governments and our countries to get behind the International Space Station; to promote the collaboration and the

cooperation at all levels; and to the greatest extent possible, magnify and enhance the work that we all have envisioned and are trying to accomplish in order to be able to ensure safe long-duration human space flight, and to do other things that will be of great benefit to all the people on Earth.”

Alford noted that, after acknowledging their unanimity on this issue, all ISMS III participants should, as individuals, do what they could to implement the resolution in their own venues as many participants had recommended.

Group A member Richard Scheuring, said he wanted to bring out a point that a number of members had felt strongly about: the concern that in establishing a new international working group, “we don’t create a control or review board monster,” adding another bureaucratic layer that would further bog down an already cumbersome scientific research process.

Filippo Castrucci commented that those on the working level had demonstrated a common commitment and record of unified achievement over the years on the ISS, and that in moving forward, “continuity is key” in the pursuit of a firm 5- or 10-year plan for the future.

JAXA flight surgeon Kaz Shimada said he thought the summit provided the best forum to determine the appropriate space research, so rather than start a new international working group, “why not the summit?”

At this point, Abbey took the podium to ask participants if they were in consensus on Alford’s motion, and as there were no objections, he said they would consider that there was a consensus.

Group B: Suggestions for Analog/Ground-Based Collaborative Research

Team Leader: Lauren Leveton, NASA Manager, Behavioral Health and Performance Element

Group B leader Lauren Leveton provided the summary of discussions and the recommendations of her group, which focused on analogs.

Each member of Group B had a unique experience with an individual analog, and each member represented one of a wide variety of disciplines, including radiation, behavioral health, surgery, emergency medicine, bone loss, and other areas, she said. The group also represented a broad variety of nations.

In its discussions, Group B found that some analogs already have “considerable” international participation, like Devon Island’s Haughton Mars Project, where ESA, Canada, and the United States are regular participants, and the Antarctica, where there are 56 nation-participants and a total of 70 research stations. Leveton said the IBMP’s Mars 500 project has international participation, including Russia, ESA, and Italy. The United States participated in the 105-day study because it fell under the umbrella of ISS planning, but cannot participate in the 520-day Mars simulation study due to certain provisions of the Iran Nonproliferation Act of 2000, she said. In contrast, some analogs, like Desert RATS and NEEMO, currently have minimal international participation.

Moreover, Leveton stated that analogs have different characteristics with respect to the environments they simulate, citing the NEEMO underwater laboratory as an excellent space exploration analog. Some analogs are “great in terms of real estate,” citing the Haughton-Mars project at Devon Island, which has lunar-like terrain.

Leveton then read the Group B consensus statement: “Space analogs fill a critical gap in keeping humans safe, healthy and productive for human space flight. They are a necessary component of our space exploration strategy. Analogs are going to provide a venue for translational research so that we can transition science for operationally relevant products and deliverables that we need in order to have long-duration, safe and productive space flight. We know there is no one end-all and be-all that fulfills all our needs. We need to be much more systematic and much more integrative in how we utilize the various analogs for reducing human space exploration risks. We believe that international collaboration is the opportunity to provide us both the systematic assessments that we need and the integrative quality of the work.”

Group B divided analogs into two categories: operational and experimental. The operational type is a field setting which is more apt to test the feasibility of tools, technology and protocols than an experimental analog, which primarily involves laboratory studies in a much more controlled environment, where large databases can be obtained. Laboratory studies at this time are more conducive to standardized processes, which Leveton said is really a goal for both types of analogs. Operational analogs are important for what they provide in terms of training for mission crews, medical requirements, and ground operations.

Leveton commented that analog users become aware of a flow process from the laboratory setting into analog environments, with different kinds of fidelities. That flow process needs to be “transparent to everybody,” and might be defined and elucidated in the future, as that would help bring a systematic and integrative nature to how analogs are used.

Some of the challenges of analogs are: the costs, which could be addressed through international cooperation in addressing common issues; perception, relative to their image and credibility; and, the fact that, as far as Group B could determine, there is no forum to discuss our use of analogs – so “this is one of the first ones,” Leveton said, asking: “How can you collaborate if you don’t have the opportunities to discuss it?” Also, contrary to any misconception of an analog as a “boondoggle,” the work done on analogs is “very critical” for exploration missions, and the analog itself represents a microcosm of the international community.

In terms of international coordination, Leveton stated that the ISS Medical Project is an excellent model, adding that Mars 500 and Antarctica also are good models. Group B thought there was a need to be more systematic in the use of analogs, and therefore, a need to find out how each analog provides the appropriate fidelity.

Leveton pointed out that the value of analogs is that they provide training, mission objectives, a timeline, ground control support, and an excellent opportunity to test and validate hardware, technology and tools. They also provide an educational venue that should be exploited.

Group B made the following recommendations:

- Characterize the pros and cons of all the different space analogs.
- Catalog all the analogs in an international inventory.
- Define a systematic process for the optimal use of analogs.
- Review and vet how we select the work we do on analogs; how we select an analog; how we prioritize what will be done on the analogs. “We need to assess both the science and the operational feasibility,” she said.
- Establish international oversight for prioritizing and selecting all the studies that go on in the different analogs.
- Leverage current international collaborations.
- Make educational outreach a priority.

The group thought joint RFPs or RFAs with the international communities would be a possible option, and intergovernmental agreements for utilization in some of the areas where there are current barriers, e.g., the aforementioned Mars 500 legal issue.

“We need integration teams to vector all the different requirements for the different analogs. We need to develop cost-sharing plans with our international partners to help defray some of the costs of analog research. We need data-sharing plans and agreements, and we not only need to share the data, but we need to share it regularly, at least annually.”

Leveton expressed the view that a lot of information that comes out of analogs doesn’t get communicated in a way that’s accessible to everyone.

Group B thought it would be a good idea to encourage the participation of teachers and students in analog activities through the Internet. Each analog has its own unfolding story, with educationally enriching information that could be mined through collaboration. Group B members also felt that it was important for an educational component to be tied into the implementation of the work being done on the analogs, which would become part of the standard operational procedure.

- Convene an annual International Analog Workshop.
- Establish an International Space Analog Network.
- Create a road map for international participation in the different analogs.
- Involve all the stakeholders, including the NSBRI, all the international partners, and commercial partners. Develop guidance in a system for doing this.
- Learn from our current experience with analogs as an international community, to ensure that the knowledge and experience of our analog research is presented on a regular basis.

After Leveton opened the floor to questions, JAXA flight surgeon Kaz Shimada noted that there are many different research stations in the Antarctic and asked whether there was a forum representing all of them. Shimada also asked if there was a way they could be contacted as a group.

Jeff Ayton of the AAD responded to that question, identifying himself as deputy chief officer of the Scientific Committee on Antarctic Research (SCAR) Life Sciences' Expert Group of Human Biology Medicine.

“We have that forum,” Ayton said, adding that the organization met once every two years, and once each year in an intersession. “The Expert Group has in its constitution the opportunity to translate Antarctic work to other extreme environments, so you would be welcome to engage with that group.”

“The Scientific Committee is part of the International Council of Scientific Unions, the umbrella group, and it is tasked from the Antarctic Treaty to answer scientific questions,” Ayton noted. He said the group published papers in peer-review journals, and also had a Web site called Medical Antarctica, which was being revisited, but that in the interim, he could be contacted through the email address that he had provided.

Another participant praised the idea Leveton had aired regarding the prospect of joint international RFAs. “Those of us who have been involved in peer review for NASA would

always get excited about doing some sort of an international solicitation,” he said, explaining that they felt that having international reviewers on a panel increased the quality of the reviews, led to less duplication of research, and “allows us to know what’s going on elsewhere.”

On the same topic, Oliver Angerer of the ESA, who had been a member of Group B, raised the specter of what he felt was a major challenge to the type of international collaboration that had been described as an aim, noting that each partner has different research goals and approaches. “NASA at this point in time is extremely operationally oriented. In Europe, we are basically the exact opposite; we have a very strong focus on fundamental science,” Angerer observed. He added that the Russians have a “fairly balanced” approach, while each of the other countries had their own priorities. “That is what makes coming to a coherent road map so difficult, and maybe even unrealistic from these initiatives,” he suggested.

Angerer said he agreed that the goals that the group had described were “something we need to strive for,” “but at the same time, we need to be realistic in what we expect.”

Leveton agreed that Angerer had a valid point, and said “it’s important for us to be sensitive and aware of that.” However, Leveton said she thought the plan could be crafted “so it will work for everybody, so that all of their ends could be realized.”

Group C: Education Needs and Career Opportunities

Team Leader, **Ludmila Buravkova**, IBMP Scientific Secretary

Speaking through an interpreter, IBMP Scientific Secretary Ludmila Buravkova, opened her presentation of Group C’s summary findings by noting theirs had been a “very unusual and active session.” She expressed her gratitude to all the participants, especially the panelists, who were very active in discussing the general issues, and offered special thanks to Karl Doetsch for helping to specifically articulate the group’s outcomes.

Buravkova said the group divided the problematic issues into three sections: child education, college student training, and postgraduate education. The key prerequisite was to examine each educational level from the standpoint of international cooperation, she said.

“The most time and the most passion,” she said, was spent discussing K-12 education, parents’ education, and the ability to use all of the space sciences, including life sciences, to motivate children and improve the quality of their education, to engage them in being interested in finding out about their environment. Everyone agreed this endeavor should utilize all possible means available to the national space agencies, governments, ministries of education, and foundations.

Group C members agreed that “we should do our best to support the enthusiasts,” the volunteers and the activists who work in this area, and involve their environment, including the individual involvement of people working for agencies and taking part in space research. “In many cases, this activity is on a voluntary basis, and we are thankful to these people, and we should support them with everything we’ve got,” Buravkova emphasized.

When Group C proceeded to college students’ education, “we may not have had a lot of euphoria here,” Buravkova noted. Participants shared the capabilities and the approaches being used in the course of college students’ education. Buravkova said she was at least confident that the initiatives being undertaken by the various countries, universities and colleges, both medical and technical, are “very timely and very good and very correct.”

There are universities that have set up chairs and electives in space medicine, life support, gravitational biology, biotechnology, and fundamental research that “are on the right track she said. Group C concentrated on involving students in actual projects and on international student exchanges, and on supporting student research. “I think we must get support, and appeal both to the national space agencies and the various foundations” Buravkova said. In Europe and Russia, there are ways that are continuing to be developed to exchange students, and there are government-sponsored foundations supporting this exchange. “It turns out that it is very difficult to exchange students between the U.S. and Russia,” Buravkova said, “although Russia frequently receives U.S. exchange students supported by the various foundations.”

Group C participants expressed concern about the employment prospects of new graduates: “Everyone agreed we should not lose the talents and the motivated young people from the new generation that would like to work in space exploration.”

When the group reached the level of graduate education, Buravkova was “very surprised that the discussion died down.” The opinion was expressed that this stage is “very customized,” that it is essentially up to the postgraduate students and their research advisers. However, she said, it should be noted that this is the final stage in knowledge transfer, and this is joint research by different generations of researchers, “which is a very important step” that could be very singular.

The approaches in the various countries for granting access to young researchers to space platforms are very different, noting that Europe and NASA have youth projects, and Moscow builds separate satellites for young researchers. “But all of the participants remarked that access for young researchers to space platforms, including the ISS, should be maximized to implement the ideas of this new generation of researchers.”

Therefore, in providing the draft of its findings and recommendations, Group C opened with the following statement, Buravkova said, speaking English from here onward:

“The International Space Station is available as an international, accessible, and inspiring tool for all levels of education in many countries to foster international cooperation.”

Buravkova said the group then provided its findings and recommendations for the three educational levels:

Age group K-12:

Finding: There is an urgent need for more information and active training opportunities for teachers, museums and science centers to effectively address space and its benefits: national security, exploration, and competitiveness.

Recommendations:

- Increase visibility of the information and training jobs and their importance to senior management for national space and education authorities as a systemic program regarding science and technology teaching.
- Expand outreach opportunities. Use space center resources and personnel for outreach in schools, museums and newsletters.
- Establish national competition with top prizes which, where appropriate, would involve projects and flight opportunities.
- Establish living international best-practices education documents for teaching this community.

University level:

Finding: The number of aerospace programs at universities is sufficient at this time, but could need expansion in the future. By and large, the program content is matched to the needs of the employment sector, but needs more hands-on opportunities outside the university. There is an insufficient number of students for the broader needs of SS&T for future demands and for the aerospace sector in three to four years. There is a potential short-term challenge for job opportunities in aerospace, but mostly in the longer term.

Recommendations:

- Universities should work closely with employers to match needs.
- More cooperative activities and exchanges between universities should be encouraged.
- More short-term internship need for students in the work force; more hands-on experience.
- More close disciplinary training.
- International project opportunities at the university level on the ISS for all partners.

In the ensuing question-and-answer period, Charles F. Bolden Jr., of the NSBRI board of directors, asked the first question: “In response to Dr. Alford’s question in the first group about ‘Do we want to do something?’ I would recommend that we make those findings and recommendations available to every single one of us to take back to wherever we’re going, and

to take it to your state legislators and international governments. And if you'll give me a copy right now, I'm going to put it in my pocket and take it with me tomorrow, so at least I'll leave one thing where I'm going." His request was greeted with a round of applause by summit participants.

Bonnie Dunbar, president of The Museum of Flight, said she seconded Bolden's recommendation, adding that it would be very helpful to her to promote that "if it came out under the heading of the summit as a finding and a recommendation on an international level," that she could take forward.

Jeffrey Hoffman of MIT offered another suggestion for implementation: that in the pragmatic organization of student ISS projects, "it's extremely important to take advantage of the hardware that's already up there" that would fit the time frame of the average student's course of study. He reminded participants that "one problem we noted for getting students involved with the ISS is the long amount of time it typically takes for getting something (new) flown."

Following on that comment, George Abbey drew the group's attention to "a good example of a program that made use of existing systems on board shuttle, and can be used on station": Sally Ride's EarthKAM program, which Abbey said was established at the elementary-school level "in a number of places around the country and internationally."

Another suggestion in that category was offered by Marcelo Vazquez, NSBRI senior space scientist in exploration and radiation, who recommended the use of analogs as an intermediate solution to fit into the short period of time available in a student's career.

That idea was seconded by a participant who underscored analogs' appeal in engaging students' interest, as well as their public relations appeal to the public on an international level. Moreover, he cited the ability to implement students' experiments on analogs in what he called a very quick time frame—"a matter of months"—without having to pass through all the boards and procedures involved in normal space flight.

Buravkova said she “absolutely” agreed with the idea to use the analogs, noting that it still takes some time to prepare for these types of programs. She noted that the IBMP laboratory had organized a time-effective school program that gives students lead time to prepare their experiment proposals, as well as a time-saving way of sharing relevant information with the public through the media.

Laurence Young of MIT lauded Buravkova’s presentation, commenting that from the perspective of an individual at a university with a bioastronautics graduate program, her summary would be very helpful in such tight economic times to bring back to the universities, “to present the need seen by a group like this for our graduates.” Young also said they all believed in the importance of bringing down international barriers in providing students the access they needed to get the hands-on education they needed.

“We have to look at how we’re going to use the ISS differently from the kind of payload mentality that we had when we ran shuttle experiments all the time,” suggested Neal Pellis, of NASA. Pellis said he had a graph showing an 11-year span from the inception of a grant to “what I call the LPU, the least publishable unit.” Careful planning of ISS experiments could collapse that down to 4 years, he said. “We have to consider the fact that if we wisely use the opportunity to send multiple specimens and do multiple experiments, with even variations in each iteration of the experiment, there are accommodations that can take care of that. . . . So not all is lost with trying to do something within the time constant of a graduate student’s career.”

Another group participant made a suggestion for the creation of an international website or portal that would facilitate the access of young students and teachers to a comprehensive pool containing all the resources that provide science, engineering and space-related information.

Kevin Fong of University College London issued a note of caution in the estimation of how hard it would be, in terms of the requirements for resources and coordinated action, to attain “the single most important delivery item that you can have in the end—how to have a demonstrable impact upon K-12 and beyond, attitudes to science, and science and culture.” Fong said he was encouraged to hear “how important people think this (outreach) is,” but the same statement had

been made at meetings he had attended “across the pond” for 10 years, and he had yet to see any actual, concerted effort “to try to gain an objective view to see if we’re doing any good, or if not, to steer it in a way that will.”

“In fact, I can’t quite agree with you,” Buravkova responded through an interpreter. She cited the example of an IBMP greenhouse experiment in which, over a long period of time, visiting schoolchildren prepared experiments with the help of the specialists; made measurements in their school on how their plants were growing; and shared the data with the crew on board. “It was an impressive experience for the children,” she said.

Buravkova said that she would encourage Fong to visit the IBMP research facility to show how specific medical developments are being applied in the field of countermeasures and are being used in the clinic, in a hospital in Moscow. Observing that “it all takes time,” Buravkova said she felt that everyone present would like to expedite the time to see changes after the inception of an idea, and that she thought that the people gathered at the meeting did what they could, but time was required in that process.

At this, the conclusion of the session as well as the summit, Alford took the podium.

“I think everyone can agree it’s been a busy 3 days and nights,” he said. “There’s been an enormous amount of information exchanged and experiences expressed, and I think a lot of very productive recommendations have been made. George Abbey and I want to thank each and every one of you for taking the time to come to this summit. I also want to ask if you would please express our appreciation to your universities and organizations for your being here, and how much we appreciate your being here.”

Alford strongly encouraged everyone to complete the evaluation forms for each day of the Summit conference: “It gives us real pause for thought, based on the scores,” he explained.

“We want to thank all of the various agencies and entities that have helped us develop this program,” Alford said. “In particular, I want to express my deep appreciation to (IBMP) General

International Space Medicine Summit III

Director (Igor) Ushakov and to his team, and to Inessa Kozlovskaya for talking with me on the phone, and with the others who helped us to shape and make this a worthwhile experience for everybody.” He asked Abbey if he would like to comment further.

“I would just like to echo what Bobby has said: We greatly appreciate your taking the time to come to the summit and contribute to the discussions. I think we’ve had some very good discussions over these 3 days, and obviously, some very good recommendations. Bobby and I will deal with those recommendations, and try to get those out to you, so you all will have copies of them. I think we appreciate the consensus that we reached earlier this morning, and I think we will certainly take that forward as best Bobby and I can, to see if we can enhance our international cooperation and make it happen as best we can. I think it is important to maximize the return we can get from the Space Station and bring in international partners and countries that can contribute and make it a better program.”

In closing, Abbey said he hoped all the participants had enjoyed the last three days, because “we’ve certainly enjoyed being here with you.”

Appendix A: International Space Medicine Summit 2009 Agenda

THURSDAY—MAY 14, 2009

1800 Opening Reception/Registration for Invitees

FRIDAY—MAY 15, 2009

0800 **CONTINENTAL BREAKFAST and Registration for Invitees**

0830 **Welcome, Introductions, and Opening Remarks**

Ambassador Edward P. Djerejian, Janice and Robert McNair Director of Public Policy,
The Baker Institute, Rice University

Orientation: George W.S. Abbey, Baker Botts Senior Fellow for Space Policy
James A. Baker III Institute for Public Policy, Rice University
Bobby R. Alford, Chancellor, Baylor College of Medicine
Chairman of the Board and CEO, National Space Biomedical
Research Institute (NSBRI)

0845- **NASA Celebrates the 10th Anniversary of the International Space Station**

0945 Introduction: Jeffrey R. Davis

Moderator: William H. Gerstenmaier, NASA Associate Administrator,
Space Operations Mission Directorate

Reflections: Leroy Chiao
Jean-Loup Chretien
Michael Foale
James M. Heflin
Boris V. Morukov
Vladimir G. Titov
James S. Voss

Topics:

- Expectations
- Outcomes
- Scientific Discoveries and Results—ISS

0945- **Panel I: ISS Utilization: Lessons Learned and Achievements**

1145 Moderator: James M. Heflin

Panelists: Valery V. Bogomolov, IBMP
Shanguang Chen, ACC
Volker Damann, ESA
Smith L. Johnston, NASA
Donald R. Pettit, NASA
Vladimir G. Titov, MIR
Dave Williams, CSA

Topics:

- Benefits of ISS National Laboratory: Platform for research, commercial venues, international visitors
- Research Opportunities Coordination: Columbus, Destiny, Kibo, Zvezda, Tranquility
- Results from ISS
- Six-man Crew Operations
- Translational research considerations for the Moon and Mars

Discussion, Questions and Responses

Summation

1145-
1300

LUNCHEON

Introduction: Leroy Chiao, Astronaut

Title: *Overview of Chinese Space Program: Past, Present, Future*

Speaker: Shanguang Chen, Director, China Astronaut Research and Training Center

Discussion

1300-
1500

Panel II: ISS Research Opportunities for Countermeasure Development

Moderator: Filippo Castrucci, ESA Crew Medical Support Office

Panelists: Volker R. Damann, ESA
Scott A. Dulchavsky, HFHS
Michael Foale, NASA
Dennis Grounds, NASA
Inessa Kozlovskaya, IBMP
Valery Morgun, Roscosmos
Boris V. Morukov, IBMP
Jeffrey P. Sutton, NSBRI
Fei Wang, NIH
Lin-jie Wang, ACC
Laurence R. Young, MIT

Topics:

- Artificial gravity 1/6 G, 1/3 G, 1 G
- Human Research Program (HRP) Priorities for research
- NIH/NASA Agreement: Cooperation in Space-Related Health Research
- Science that can only be conducted in Space
- What needs to be done

Discussion, Questions and Responses

Summation

1500-
1730

Panel III: Analog Environments: Human Performance

(To include Antarctic Telecast)

Moderator: Dave Williams, Astronaut

Panelists: Oliver Angerer, ESA
Jeff Ayton, AAD
Michael L. Gernhardt, NASA
Valery Morgun, Roscosmos
Pascal Lee, NASA
Yinghui Li, ACC
Christian Otto, Can
Marcum L. Reagan, NASA

Topics:

- Antarctic
- Desert RATS (Research and Technology Studies)
- Devon Island
- EVA requirements, suits, and rovers
- Medical Support Requirements
- NEEMO
- 105 Day Isolation Study
- Systems Support

Discussion, Questions and Responses

Summation

International Space Medicine Summit III

1800

RECEPTION and DINNER *

Introduction: Ambassador Edward Djerejian
Keynote Speaker: Former Secretary of State the Honorable James A. Baker, III
Honorary Chair, Baker Institute for Public Policy

*** Doctors Orchestra of Houston Ensemble**

SATURDAY—MAY 16, 2009

0800

CONTINENTAL BREAKFAST

0830-

Introduction: Bobby R. Alford

0915

Title: ***Mars 500 to Exploration***

Speaker: Boris V. Morukov, Deputy Director, Cosmonaut,
Institute For Biomedical Problems—On behalf of Igor B. Ushakov,
General Director, Institute for Biomedical Problems

0915-

Novel Technology Presentations

0945

Cheng Chi Lee
James M. Tour

0945-

Panel IV: Commercial and Industrial Opportunities

1145

Moderator: Brewster H. Shaw

Panelists: Jeanne Becker
Robert J. Benkowski
George “Bud” Brainard
George P. Noon
Neal R. Pellis
Kenneth S. Reightler, Jr.
Babs R. Soller
James M. Tour

Topics:

- ☐ Bioreactors
- ☐ Export Policy
- ☐ Medical Devices
- ☐ Radiation Protection
- ☐ Technology Requirements
- ☐ Technology Transfer
- ☐ Vaccine Development

Discussion, Questions and Responses

1145-

LUNCHEON NASA Celebrates the 40th Anniversary of Apollo 10

1330

Introduction: George W.S. Abbey, Baker Institute

Title: ***Preparation for Lunar Landing***

Reflections: Glynn S. Lunney, NASA, Apollo 10 Flight Director

Discussion, Questions and Responses

1330-

Panel V: Education Needs and Career Opportunities

1530

Moderator: Karl Doetsch, Athena Global

Panelists: Ludmila B. Buravkova
Bonnie J. Dunbar
Kevin Fong
Jeffrey Hoffman
Barbara Morgan
Michael Simpson
William Thomson
Aleksandra “Sasha” Titova

International Space Medicine Summit III

Students: Jacob Berlin, Ashley Leonard, Padraig Moloney, Ronke Olabisi

Topics:

- ☐ Career Opportunities and Future Needs of the Space Program
- ☐ Pathways for Success
- ☐ Student Accomplishments
- ☐ Student Perspectives

Discussion, Questions and Responses

Summation

1530-
1730

Discussion Groups

Group A. Cooperative Research Opportunities During Space Station and Lunar Missions

Team Leader: Jeffrey P. Sutton

Team Members: Assignments to be distributed

Group B. Suggestions for Analog/Ground Based Collaborative Research

Team Leader: Lauren Leveton

Team Members: Assignments to be distributed

Group C. Education Needs and Career Opportunities

Team Leader: Ludmila Buravkova

Team Members: Assignments to be distributed

Discussion, Questions and Responses

1800

RECEPTION and DINNER

Introduction: Bobby R. Alford

Title: *Space Medicine: Principles and Practice*

Speaker: James D. Polk, NASA Space Medicine Chief

SUNDAY—MAY 17, 2009

0830-
0900

CONTINENTAL BREAKFAST

0900-
1145

Discussion Group Reports

Group A. Cooperative Research Opportunities During Space Station and Lunar Missions

Group B. Suggestions for Analog/Ground Based Collaborative Research

Group C. Education Needs and Career Opportunities

Discussion, Questions, Responses and Recommendations

Summation

1200

CLOSING

Appendix B: International Space Medicine Summit III Attendance

Invitee	Institution	Other	Contact
George W.S. Abbey	Baker Institute, Rice University		gabbey@rice.edu
George W.S. Abbey, Jr.	British Consulate, Vice Consul, Aerospace, Homeland Security		george.abbey@fco.gov.uk
James V. Abbey	Texas/UK Collaborative Swansea University		j.v.abbey@swansea.uk
May G. Akrawi, PhD	British Consulate Science and Technology Consul		may.akrawi@fco.gov.uk
Bobby R. Alford, MD	Baylor College of Medicine/NSBRI		balford@bcm.edu
Colonel John R. Allen, PhD	NASA Program Executive, Crew Health and Safety		john.r.allen@nasa.gov
Oliver Angerer, PhD	ESA Human Exploration Science Coordinator		oliver.angerer@esa.int
Jeff Ayton, MD	Chief Medical Officer Polar Medicine Unit Australian Antarctic Div		Jeff.Ayton@aad.gov.au
Ellen S. Baker, MD	NASA, NSBRI User Panel	Astronaut	ellen.s.baker@nasa.gov
Secretary James A. Baker, III	Baker Institute, Rice University		via George Abbey
Jeanne L. Becker, PhD	NSBRI Vice President and Associate Director		jbecker@bcm.edu
Antonio Belli, MD	University of Southampton, Neurosurgeon		a.belli@southampton.ac.uk
Michaela D. Benda	NASA		michaela.d.benda@nasa.gov
Robert J. Benkowski	COO MicroMed Cardiovascular Technologies		rbenkowski@micromedcv.com
Jacob Berlin, PhD	Rice University Postdoctoral Associate (Tour Lab)		jmb8@rice.edu
Jacob J. Bloomberg, PhD	NSBRI Associate Team Leader NASA Human Research Program		jacob.j.bloomberg@nasa.gov
Susan A. Bloomfield, PhD	NSBRI Associate Team Leader		sbloom@tamu.edu
Valery V. Bogomolov, MD, PhD	IBMP RAS Deputy Director for Science of the SSC of RF		vbogomolov@ibmp.ru
Maj. Gen. Charles F. Bolden, Jr.	NSBRI Board of Directors	Astronaut	jackandpanther@earthlink.net
Eugenia "Genie" Bopp	Wyle Laboratories Vice President		ebopp@wylehou.com
Joseph V. Brady, PhD	NSBRI Associate Team Leader		JVb@jhmi.edu
George "Bud" Brainard, PhD	NSBRI Team Leader		george.brainard@jefferson.edu
Timothy J. Broderick, MD	NSBRI External Advisory Council		timothy.broderick@uc.edu
Jay C. Buckey, MD	NASA Dartmouth University	Astronaut	jay.buckey@dartmouth.edu
Ludmila B. Buravkova, DSc	IBMP Scientific Secretary		buravkova@ibmp.ru
C. Thomas Caskey, MD	University of Texas Houston, Professor		c.thomas.caskey@uth.tmc.edu
Gilbert A. Castro, PhD	NSBRI External Advisory Council		gcastro@comcast.net
Filippo Castrucci, MD	ESA Crew Medical Support Office Flight Surgeon		filippo.castrucci@esa.int
Franklin Chang-Diaz, PhD	AdAstraRocket	Astronaut	Franklin@adastrarocket.com
John B. Charles, PhD	NASA Program Scientist, Human Research Program China Astronaut Research and Training Center		john.b.charles@nasa.gov
Shanguang Chen, PhD	Director		tigerescg@163.com
Leroy Chiao, PhD	NSBRI User Panel	Astronaut	leroychiao@gmail.com
Brig. General Jean-Loup Chretien	Tietronix/Safetronix President, Founder	Astronaut	jchretie@tietronix.com
Jonathan B. Clark, MD	NSBRI Space Medicine Advisor NSBRI User Panel		jclark1@bcm.edu
Barbara J. Corbin	NASA Deputy Manager, Human Research Program		barbara.j.corbin@nasa.gov
Francis A. Cucinotta, PhD	NASA Chief Scientist Radiation Program, HRP		francis.a.cucinotta@nasa.gov
Walter Cunningham	NSBRI User Panel	Astronaut	walt@waltercunningham.com
Clifford C. Dacso, MD	The Methodist Hospital's Abrahamson Center		Cdacso@tmhs.org
Volker R. Damann, MD	ESA Head, Crew Medical Support Office		volker.damann@esa.int
Richard W. Danielson, PhD	BCM/NASA		richard.w.danielson@nasa.gov
Jeffrey R. Davis, MD	NASA Space Life Sciences Director		jeffrey.r.davis@jsc.nasa.gov
David F. Dinges, PhD	NSBRI Team Leader		dinges@mail.med.upenn.edu
Ambassador Edward P. Djerejian	Baker Institute, Rice University		pmedlin@rice.edu
Julie Do	NSBRI		jdo@bcm.edu
Karl Doetsch, PhD	Athena Global, Chairman of the Board		doetsch@telus.net
Dorit Donoviel, PhD	NSBRI Senior Researcher		donoviel@bcm.edu
Scott A. Dulchavsky, MD, PhD	Henry Ford Hospital		sdulcha1@hfhs.org

International Space Medicine Summit III

Bonnie J. Dunbar, PhD	Washington State Aerospace Scholars President and CEO	Astronaut	Bdunbar@museumofflight.org
JM "Mike" Duncan, MD	NASA Deputy Chief Medical Officer, Space Life Sciences		james.m.duncan@nasa.gov
Marybeth A. Edeen	NASA National Lab Manager - ISS Program		marybeth.a.edeen@nasa.gov
Earl W. Ferguson, MD, PhD	NSBRI External Advisory Council		ewferguson@SunBMT.com
Edna Fiedler, PhD	NSBRI Senior Scientist		efiedler@bcm.edu
C. Michael Foale, PhD	NASA	Astronaut	michael.c.foale@nasa.gov
Kevin Fong, BSC, MBBS	University College London		kevinfong@gmail.com
Michael L. Gernhardt, PhD	NASA	Astronaut	michael.l.gernhardt@nasa.gov
William H. Gerstenmaier	NASA Associate Administrator, Space Operations Mission Directorate		william.h.gerstenmaier@nasa.gov
Rupert Gerzer, MD	DLR, Director Institute of Aerospace Medicine		rupert.gerzer@dlr.de
David A. Green, PhD	Kings College London, Reader Human Geography		david.a.green@kcl.ac.uk
Dennis J. Grounds,	NASA Manager Human Research Program		dennis.j.grounds@nasa.gov
Judith Hayes	NASA Deputy Chief Human Adaptation, HRP		judith.hayes-1@nasa.gov
Dennis R. Headon, PhD	Director, Texas/United Kingdom Collaborative Rice University		headon@rice.edu
James M. "Milt" Hefflin	NASA Chief, Flight Director Office		via George Abbey
David C. Hilmers, MD	NSBRI User Panel	Astronaut	dchilmer@texaschildrenshospital.org
Jeffrey A. Hoffman, PhD	MIT Aeronautics and Astronautics	Astronaut	jhoffma1@mit.edu
Antony S. Jeevarajan, PhD	NASA, Deputy Chief, Habitability and Environmental Factors		antony.s.jeevarajan@nasa.gov
Smith L. Johnston, MD	NASA Flight Surgeon		smith.l.johnston@nasa.gov
Jeffrey A. Jones, MD	NASA Constellation Lead Surgeon		jeffrey.a.jones@nasa.gov
Thomas D. Jones, PhD	NSBRI User Panel	Astronaut	skywalking@comcast.net
Sheryl L. Kelly	Boeing Space Exploration, Chief of Staff		via Brewster Shaw
Ann R. Kennedy, DSc	NSBRI Team Leader		akennedy@mail.med.upenn.edu
Joseph P. Kerwin, MD	NASA (retired) NSBRI User Panel	Astronaut	medinaut@pdq.net
Elizabeth Klerman, PhD, MD	NSBRI Associate Team Leader		ebklerman@hms.harvard.edu
Inessa Kozlovskaya, MD, DSc	IBMP Professor, Head of the Department		ikozlovs@mail.ru
Amy Kronenberg, ScD	NSBRI External Advisory Council		a_kronenberg@jbl.gov
Craig E. Kundrot, PhD	NASA Deputy Program Scientist, Human Research Program		craig.e.kundrot@nasa.gov
Helen W. Lane, PhD	NASA Chief Nutritionist		helen.w.lane@nasa.gov
Thomas F. Lang, PhD	NSBRI Team Leader, UCSF Professor Radiology/Biomed Imagin		Thomas.Lang@radiology.ucsf.edu
Cheng Chi Lee, PhD	UTHSC-Houston, Professor Biochemistry/Molecular Biology		cheng.chi.lee@uth.tmc.edu
	NASA Ames Research Center, Mars Institute		
Pascal Lee, PhD	Chairman		pascal.lee@marsinstitute.net
Ashley Leonard	Rice University student		ashley.d.leonard@rice.edu
Lauren B. Leveton, PhD	NASA Manger Behavioral Health and Performance, HRP		lauren.b.leveton@nasa.gov
Paul Christopher Levetzow, PhD			
Yinghui Li, PhD	Hamburg University Professor		paul.levetzow@gmail.com
Richard M. Linnehan, PhD	Astronaut Center of China (POC: Jason Lu)		yinghuid@vip.sina.com
Charles W. Lloyd, PhD	NSBRI User Panel		riclin109@yahoo.com
James P. Locke, MD	NASA Physiological Countermeasures Manager, HRP		charles.w.lloyd@nasa.gov
	NASA		james.p.locke@nasa.gov
Mattias Loebe, MD, PhD	BCM Associate Professor of Pediatrics and Critical Care		mloebe@bcm.edu
John M. Lounge	Boeing		john.m.lounge@boeing.com
Yaofeng "Jason" Lu	ACC Foreign Affairs Rep Main Point of Contact for China		sfaacc@163.com
Glynn Lunney	NASA		via George Abbey
Marlene Y. MacLeish, EdD	NSBRI Team Leader		mmacleish@msm.edu
Kathryn S. Major	NSBRI		major@bcm.edu
Saralyn Mark, MD	NASA Senior Medical Advisor Office of Women's Health		saralyn.mark@nasa.gov
Robert Marchbanks, PhD	University of Southampton		r.marchbanks@southampton.ac.uk
Helen Matushevskaya, PhD	Moscow State University Lomonosov, Economics Professor		mathelen@gmail.com
Padraig Moloney	Rice University student		padraig@padraigmoloney.com
Barbara Morgan	NASA retired/now at Boise State University	Astronaut	barbaramorgan@boisestate.edu

International Space Medicine Summit III

Valery Morgun, MD	Russian Federal Space Agency [FAX: 1.256.961.6418]		morgun@mcc.rsa.ru
Boris V. Morukov, MD, PhD	IBMP Deputy Director	Cosmonaut	morukov@imbp.ru
George P. Noon, MD	Baylor College of Medicine, Professor of Surgery		gnoon@bcm.edu
Col Bryan D. O'Connor	NASA Chief Safety and Mission Assurance	Astronaut	bryan.oconnor@nasa.gov
Ronke M. Olabisi, PhD	Rice Engineering, NSBRI Postdoctorate Fellow		ronke@rice.edu
Charles M. Oman, PhD	NSBRI Team Leader		coman@mit.edu
Christian A. Otto, MD	CSA Consultant, ER Physician		christianotto@hotmail.com
Nigel Packham, PhD	NASA Constellation Human Space Flight		nigel.packham1@jsc.nasa.gov
Neal R. Pellis, PhD	NASA Chief Scientist Space Life Sciences		neal.r.pellis@jsc.nasa.gov
Adrian A. Perachio, PhD	NSBRI Board of Scientific Counselors		aperachi@utmb.edu
Donald R. Pettit, PhD	NASA	Astronaut	donald.r.pettit@nasa.gov
James D. "JD" Polk, DO	NASA Space Medicine Chief NSBRI User Panel		james.d.polk@nasa.gov
Yi-Xian Qin, PhD	NSBRI Associate Team Leader		yi-xian.qin@sunysb.edu
Marcum L. Reagan	NASA STL Office Lead, ISS Capcom (for Bill Todd)		marcum.l.reagan@nasa.gov
Patricia Reiff, PhD	Rice University's Space Institute		reiff@rice.edu
Captain Kenneth S. Reightler, Jr.	(USN retired) Lockheed Martin Space Systems	Astronaut	ken.reightler@lcmo.com
Judith L. Robinson, PhD	NASA Associate Director Space Life Sciences JSP		judith.l.robinson@nasa.gov
Julie A. Robinson, PhD	NASA, International Space Station Program Scientist		julie.a.robinson@nasa.gov
Merri J. Sanchez, PhD	NASA Liaison to US AFSPC and NORTHCOM		merri.j.sanchez@nasa.gov
Igor A. Savelev, PhD	Wyle/NASA/NSBRI International Liaison		igor.a.savelev@nasa.gov
Charles "Chuck" Sawin, PhD	NASA (retired) Wyle Laboratories		ssawin@aol.com
Richard "Rick" Scheuring, DO	NASA Constellation Med Ops Flight Surgeon/NSBRI User Panel (USAF retired) Boeing Vice President & Gen Mgr		richard.a.scheuring@nasa.gov
Col. Brewster H. Shaw	Space Explor	Astronaut	brewster.h.shaw@boeing.com
Kaz Shimada, MD, PhD	JAXA Flight Surgeon, Medical Operations		shimada.kazuhito@jaxa.jp
Olga Shimbireva, MD, PhD	Russian Academy of Sciences National Research Centre		shimbireva@list.ru
Michael Simpson, PhD	International Space University President		simpson@isu.isunet.edu
Walter Sipes, PhD	NASA Chief Operational Psychology, Beha Health & Perform		walter.sipes-1@nasa.gov
Babs R. Soller, PhD	NSBRI Team Leader		babs.soller@umassmed.edu
Ulrich H. Straube, MD	ESA, Crew Medical Support Office		ulrich.straube@esa.int
Jeffrey P. Sutton, MD, PhD	NSBRI President and Director		jps@bcm.edu
William A. Thomson, PhD	Baylor College of Medicine NSBRI Team Leader		wthomson@bcm.edu
Aleksandra "Sasha" Titova	Yuri Gagarin Cosmonaut Training Center		mtitova_00@yahoo.com
Vladimir G. Titov	Boeing Russia, Vice President	Cosmonaut	vladimir.g.titov@boeing.com
James M. Tour, PhD	Rice University Professor Chemistry & Computer Science		tour@rice.edu
James M. Vanderploeg, MD, MPH	UTMB Preventive Medicine & Community Health		jmvander@utmb.edu
Marcelo E. Vazquez, MD, PhD	NSBRI Senior Scientist Space Radiation and Exploration		vazquez@bnl.gov
Col James S. Voss	USAF Retired NSBRI Board of Directors, User Panel	Astronaut	jim.voss@sncorp.com
Fei Wang, PhD	NIH, Director Musculoskeletal Develop. Tissue Eng & Reg Med		wangf@mail.nih.gov
Lin-jie Wang, PhD	China Astronaut Research and Training Center Researcher		wlj823@sina.com
Pauline Ward, PhD	Baylor College of Medicine Irish Scholars Program		paulinew@bcm.edu
David E. Warden, PhD	Rice University Professor - recommended by Leroy Chiao		david.warden@mac.com
David A. Watson, PhD	NSBRI Senior Scientist for Integration		dawatson@bcm.edu
Sheila Whelan	Project Director, Space Medicine Program, McMaster Univ.		spacemed@mcmaster.ca
Dave Williams, MD, PhD	McMaster University NSBRI Liaison	Astronaut	wildd@mcmaster.ca
Richard S. Williams, MD	NASA Chief Health and Medical Officer		richard.s.williams@nasa.gov
Laurence R. Young, ScD	MIT Apollo Program Professor of Astronautics & Health Scien		lry@mit.edu
Fathi Karovia	Self-invitation U of H graduate student		
Steve Lewis	Baker Invitation Baker Institute: Ancient Studies		
Wei Wang	Guest of Benkowski		
Ci Yinghui	Added by Baker staff		

Total 147

Appendix C: International Space Medicine Summit III Group Assignments

Invitee	Institution	Other
Group A: Cooperative Research Opportunities During Space Station and Lunar Missions		
Jeffrey P. Sutton, MD, PhD- Group Leader		
Ellen S. Baker, MD	NASA, NSBRI User Panel	Astronaut
Valery B. Bogomolov, MD, PhD	IBMP RAS Deputy Director for Science of the SSC of RF	
Eugenia "Genie" Bopp	Wyle Laboratories Vice President	
Filippo Castrucci, MD	ESA Flight Surgeon Crew Medical Support Office	
Franklin Chang-Diaz, PhD	AdAstraRocket	Astronaut
Shanguang Chen, PhD	China Astronaut Research and Training Center Director	
Leroy Chiao, PhD	NSBRI User Panel	Astronaut
Brig. General Jean-Loup Chretien	Tietronix/Safetronix President, Founder	Astronaut
Jonathan B. Clark, MD	NSBRI Space Medicine Advisor NSBRI User Panel	
Walter Cunningham	NSBRI User Panel	Astronaut
Volker R. Damann, MD	ESA Head, Crew Medical Support Office	
Scott A. Dulchavsky, MD, PhD	Henry Ford Hospital	
Marybeth A. Edeen	NASA National Lab Manager - ISS Program	
Dennis J. Grounds	NASA Manager Human Research Program	
Judith Hayes	NASA Deputy Chief Human Adaptation	
Smith L. Johnston, MD	NASA Flight Surgeon	
Jeffrey A. Jones, MD	NASA Constellation Lead Surgeon	
Thomas D. Jones, PhD	NSBRI User Panel	Astronaut
Joseph P. Kerwin, MD	NASA (retired) NSBRI User Panel	Astronaut
Inessa Kozlovskaya, MD, DSc	IBMP Professor, Head of the Department	
Paul Christopher Levetzow, PhD	Hamburg University	
James P. Locke, MD	NASA	
Valery Morgun, MD	Russian Federal Space Agency [FAX: 1.256.961.6418]	
Charles M. Oman, PhD	NSBRI Team Leader	
Neal R. Pellis, PhD	NASA Chief Scientist Space Life Sciences	
James D. "JD" Polk, MD	NASA Space Medicine Chief NSBRI User Panel	
Merri J. Sanchez, PhD	NASA Liaison to US AFSPC and NORTHCOM	
Charles "Chuck" Sawin, PhD	NASA (retired) Wyle Laboratories	
Richard "Rick" Scheuring, DO	NASA Constellation Med Ops Flight Surgeon/NSBRI User Panel	
Olga Shimbireva, MD	Russian Academy of Science	
Ulrich H. Straube, MD	ESA, Crew Medical Support Office	
James M. Vanderploeg, MD, MPh	UTMB Preventive Medicine & Community Health	
Col James S. Voss	USAF Retired NSBRI Board of Directors, User Panel	Astronaut
Fei Wang, PhD	NIH, Director Musculoskeletal Develop. Tissue Eng & Reg Med	
Lin-jie Wang, PhD	China Astronaut Research and Training Center Researcher	

International Space Medicine Summit III

Group B: Suggestions for Analog/Ground Based Collaborative Research

Lauren B. Leveton, PhD- Group Leader

Colonel John R. Allen	NASA Program Executive, Crew Health and Safety	
Oliver Angerer, PhD	ESA Human Exploration Science Coordinator	
Jeff Ayton, MD	Chief Medical Officer Polar Medicine Australian Antarctic Div	
Robert J. Benkowski	COO MicroMed Cardiovascular Technologies	
Joseph V. Brady, PhD	NSBRI Associate Team Leader	
George "Bud" Brainard, PhD	NSBRI Team Leader	
Timothy J. Broderick, MD	NSBRI External Advisory Council	
Francis A. Cucinotta, PhD	NASA Radiation Program, Chief Scientist	
Richard W. Danielson, PhD	BCM/NASA	
David F. Dinges, PhD	NSBRI Team Leader	
Dorit Donoviel, PhD	NSBRI Senior Researcher	
JM "Mike" Duncan, MD	NASA Deputy Chief Medical Officer, Space Life Sciences	
Earl W. Ferguson, MD, PhD	NSBRI External Advisory Council	
Edna Fiedler, PhD	NSBRI Senior Scientist	
Rupert Gerzer, MD	DLR, Director Institute of Aerospace Medicine	
Antony S. Jeevarajan, PhD	NASA, Deputy Chief, Habitability and Environmental Factors	
Ann R. Kennedy, DSc	NSBRI Team Leader	
Elizabeth Klerman, PhD, MD	NSBRI Associate Team Leader	
Amy Kronenberg, ScD	NSBRI External Advisory Council	
Thomas F. Lang, PhD	NSBRI Team Leader, UCSF Professor Radiology/Biomed Imagin	
Pascal Lee, PhD	NASA Ames Research Center, Mars Institute Chairman	
Yinghui Li, PhD	Astronaut Center of China	
Saralyn Mark, MD	NASA Senior Medical Advisor Office of Women's Health	
Helen Matushevskaya, PhD	Russian Academy of Science	
Boris V. Morukov, MD, PhD	IBMP Deputy Director	Cosmonaut
George P. Noon, MD	BCM Professor of Surgery	
Christian A. Otto, MD	CSA Consultant, ER Physician	
Adrian A. Perachio, PhD	NSBRI Board of Scientific Counselors	
Yi-Xian Qin, PhD	NSBRI Associate Team Leader	
Marc L. Reagan	NASA STL Office Lead, ISS Capcom	
Capt Kenneth S. Reightler, Jr.	(USN retired) Lockheed Martin Space Systems	Astronaut
Judith L. Robinson, PhD	NASA Associate Director Space Life Sciences JSP	
Igor A. Savelev, PhD	Wyle/NASA/NSBRI International Liaison	
Walter Sipes, PhD	NASA Chief Operational Psychology, Beha Health & Perform	
Babs R. Soller, PhD	NSBRI Team Leader	
Marcelo E. Vazquez, MD, PhD	NSBRI Senior Scientist Space Radiation and Exploration	
Dave Williams, MD, PhD	McMaster University NSBRI Liaison	Astronaut

Group C: Education Needs and Career Opportunities

Ludmila B. Buravkoa, DSc- Group Leader

James V. Abbey	Texas/UK Collaborative Swansea University	
Jeanne L. Becker	NSBRI Vice President and Associate Director	
Antonio Belli	University of Southampton, Neurosurgeon	
Jacob Berlin	Rice University Postdoctoral Associate Tour Laboratory	
Susan A. Bloomfield	NSBRI Associate Team Leader	
Maj. Gen. Charles F. Bolden, Jr.	NSBRI Board of Directors	Astronaut
Jay C. Buckey, MD	NASA Dartmouth University	Astronaut

International Space Medicine Summit III

Gilbert A. Castro, PhD	NSBRI External Advisory Council	
John B. Charles, PhD	NASA Program Scientist, Human Research Program	
Clifford C. Dacso, MD	The Methodist Hospital's Abrahamson Center	
Julie Do, MBA	NSBRI Director of Finance	
Bonnie J. Dunbar, PhD	Washington State Aerospace Scholars President and CEO	Astronaut
Kevin Fong, BSC, MBBS	University College London	
David A. Green, PhD	Kings College London, Reader Human Geography	
Dennis R. Headon, PhD	Director, Texas/United Kingdom Collaborative Rice University	
David C. Hilmers, MD	NSBRI User Panel	Astronaut
Jeffrey A. Hoffman, PhD	MIT Aeronautics and Astronautics	Astronaut
Craig E. Kundrot, PhD	NASA Marshall Space Flight Center	
Helen W. Lane, PhD	NASA Chief Nutritionist	
Ashley Leonard	Rice University student	
Matthias Loebe, MD, PhD	BCM Associate Professor of Pediatrics and Critical Care	
Charles W. Lloyd, PhD	NASA Physiological Countermeasures Manager	
Yaofeng "Jason" Lu	ACC Foreign Affairs Rep	
Marlene Y. MacLeish, EdD	NSBRI Team Leader	
Kathryn S. Major	NSBRI Chief Communications Officer	
Dr. Robert Marchbanks	University of Southampton	
Padraig Moloney	Rice University student	
Barbara Morgan	NASA retired/now at Boise State University	Astronaut
Ronke M. Olabisi, PhD	Rice Engineering, NSBRI Postdoctorate Fellow	
Patricia Reiff, PhD	Rice University's Space Institute	
Michael Simpson, PhD	International Space University President	
William A. Thomson, PhD	Baylor College of Medicine NSBRI Team Leader	
Aleksandra "Sasha" Titova		
James M. Tour, PhD	Rice University Professor Chemistry & Computer Science	
Pauline Ward, PhD	Baylor College of Medicine Irish Scholars Program	
David E. Warden, PhD	Rice University Professor - recommended by Leroy Chiao	
David A. Watson, PhD	NSBRI Senior Scientist for Integration	
Sheila Whelan	Project Director, Space Medicine Program, McMaster Univ.	
Richard S. Williams, MD	NASA Chief Health and Medical Officer	
Laurence R. Young, ScD	MIT Apollo Program Professor of Astronautics & Health Scien	

Appendix D: Summary of ISMS III Findings, Suggestions, Recommendations

Unsolved problems

(18)¹ Young: scientific community does survey, but not enough attention paid to it—operations constraints take over

(23) Bogomolov: no common sciences programs, only national programs. Need to bring resources together: medical staff, scientists and engineers

(25) Pettit: “shroud” of medical privacy complicates access to data

(27) Segmentalizing of crews

(27) Bogomolov: crews sometimes find themselves in unequal circumstances with regard to resources, leading to psychological conflict.

(29) Obtaining more budgetary funding

(36) Bone loss, radiation exposure, loss of aerobic capacity

(37) Damann: Challenge of conducting countermeasure research using small number of subjects and preserving privacy

(46) Getting the analogs operational messages across

(71) Obstacles to technology transfer at NASA

(85) Tour: need for good, free exchange of knowledge is complicated by export laws

(89) Benkowksi: Difficulties in figuring out what NASA has and negotiating the license agreement, especially exclusive license

(132)

- International collaboration problems caused by legalities (ex. Iran Nonproliferation Act of 2000 and the 520-day Mars simulation study)
- Costs
- Perception, relative to their image and credibility
- No forum to discuss use of analogs

(140) Hoffman: time frame of average student’s course of study

(141) Fong: outreach statements at conferences have not led to actual concerted efforts

¹ Numbers in parentheses refer to the page on which the item is referenced.

Recommendations

(10) Gerstenmaier: As we learn from the lessons of the past, we should project the future and figure out how to use that experience as effectively as possible, because the ISS offers tremendous opportunities in the areas of medicine, engineering and operations

(13) Morukov: Need to integrate our resources: material, intellectual and technological

(16) Williams: All agencies representing the space-faring nations of the world to come together and articulate their long-term vision for future space exploration

(17) Williams: Shared agreement, where space-faring nations would define the objectives that would be accomplished within the next 50 years

(17) Bolden: Human space flight community came up with an international decadal survey – perhaps encompassing a longer period of time. Would formalize an international agreement and state goals to be achieved within time frame, possibly minimum goals people can agree on

(18) Cunningham: Individual countries should not be limited by the international agreement – within larger framework they can pursue own national subset of goals

(20) Use space station as it is to push science in a new direction

(23) Damann: Need true international collaboration

(24) Williams: Nations should share information from data being collected by astronauts

(25) Williams: Ways to integrate our science and challenge ourselves to get access to data needed to make appropriate risk-management decisions

(25) Grounds: Need to balance privacy of individuals with need for data.

(26) Davis: Human System Risk Board to share data

(28) Chen: Create a platform for more nations and people to participate in ISS

(29) Williams: Sharing story of successes, spin-offs

(31) Heflin: Take what exists across entire international community and continue to find ways to come to common ground

(36) Morgun:

- Continue efforts and develop new medical standards
- Develop psychological training activities
- Support and monitor health of crew members and countermeasures and medical treatments for trauma or illness
- Rehab after completion of space flight

(37) Damann: Astronauts may voluntarily share, but not a requirement

(37) Kozlovskaya: Advocates integration of countermeasures systems on board. Compare and integrate systems. Joint system of evaluation. Create international board of specialists to select priorities and approaches.

(38) Morukov: Doctors and lead investigators work together to create standardized battery of tests

(40) Sutton: In going forward with new health countermeasure protocols for long duration missions:

- An interface between users and the scientific community set priorities
- Should be international effort with formal mechanism
- Needs to be done now, with urgency

(47) Gernhardt: Specificity in presenting hypotheses to be tested

(47) Williams: Increase amount of international collaboration in analogs and obtain appropriate funding for analogs to support research studies

(71) Benkowski: Do a better job of making NASA-developed technology available commercially

(102) Hoffman: do everything possible in political and economic sphere to stimulate supply of another generation of scientists and engineers to carry space exploration

(104) Simpson: Need for intergenerational partnership. Need to invest time and enthusiasm, not just money

(104) Thomson:

- Use ISS as an opportunity for collaboration in education
- Use NASA's technology to exploit social and web-based media
- Develop pathway programs that work with minority-serving institutions and best colleges and universities to increase access of underrepresented citizens to science and medicine

(107) Hoffman & Dunbar: Re-institute program that gives college students a chance to participate in ISS experiments

(108) Bolden: Open up collaboration and involvement beyond just NASA to Department of Education, other federal agencies and start-up space companies (seconded by Williams on p. 78)

(110) Williams: Use analog sites as educational outreach

(113) Doetsch: Proposed a service to collect these ideas in a structured way and coordinate with education department, industry, or an agency like NASA in preparing a document enumerating all the suggestions for improvement

(123) Recurring theme of cutting across national interests and focusing on science and the development of medical countermeasures and the need to take action

(123) Sutton:

- Need to expand the current medical evaluation platform that exists, to incorporate a standard protocol for research measures. Need to be internationally agreed upon and to be enacted and implemented soon. (standard platform of tests of physiological measures)
- Review ISS expeditions from a medical and research standpoint
- Desirable to have international crew involvement in the research enterprise and that consent be shared internationally
- As number of crew members of ISS increases, there will be an increased need for use of common resources and equipment (medical resources)
- Need for universal protocols for consistent reporting on use of countermeasures
- With increasing crew size, need to organize and structure crew activities, the complexity of tasks that are going on, to best utilize not only time but also resources, and also to be aware of off-nominal events and contingencies that take place.
- Need an inclusive international joint working group pertaining to research, which needs to be established in a timely way. Needs to be an inclusive enterprise, to address the multinational stakeholders, the partners, the operational people, the crew, the physicians, the basic and translational researchers and the commercial participants.
- Critically important to address some of the international questions concerning the transitions in gravity, and with respect to lunar ops, the fundamental question concerns the differences in physiological systems at one-sixth versus zero g.

(125) Alford:

- Four Cs: communication, cooperation, coordination and collaboration. Commit to trying to make this truly and international model for how nations can cooperate.
- Consensus: “As a group of leading biomedical scientists, physicians, engineers, and other participants at the third International Space Medicine Summit, we feel that it is very important for our governments and our countries to get behind the International Space Station: to promote collaboration and cooperation at all levels; and, to the greatest extent possible, magnify and enhance the work that we all have envisioned and are trying to accomplish in order to be able to ensure safe long-duration human space flight, and to do other things that will be of great benefit to all the people on Earth.”

(129) Bogomolov:

- Findings of the Summit be brought to the management of the agencies of the partners, and also be presented in the program office of the ISS.

(132)

- Space analogs fill a critical gap in keeping humans safe, healthy and productive for human space flight. They are a necessary component of our space exploration strategy. Analogs are going to provide a venue for translational research so that we can transition science for operationally relevant products and deliverables that we need in order to have long-duration, safe and productive space flight. We know there is no one end-all and be-all that fulfills all our needs. We need to be much more systematic and much more integrative in how we utilize the various analogs for reducing human space exploration risks. We believe that international collaboration is the opportunity to provide us both the systematic assessments that we need and the integrative quality of the work.

(134)

- Characterize the pros and cons of all the different space analogs
- Catalog all the analogs in an international inventory
- Define a systematic process of the optimal use of analogs
- Review and vet how we select the work we do on analogs; how we select an analog; how we prioritize what will be done on the analogs (both science and operational feasibility)
- Establish international oversight for prioritizing and selecting all the studies that go on in the different analogs
- Leverage current international collaborations
- Make educational outreach a priority

(135)

- Convene an annual international Analog Workshop
- Establish an International Space Analog Network
- Create a road map for international participation in the different analogs
- Involve all stakeholders, including the NSBRI, all the international partners and commercial partners. Develop guidance in a system for doing this
- Learn from our current experience with analogs as an international community, to ensure that the knowledge and experience of our analog research is presented on a regular basis

(138) K-12: There is an urgent need for more information and active training opportunities for teachers, museums and science centers to effectively address space and its benefits: national security, exploration, and competitiveness.

- Increase visibility of the information and training jobs and their importance to senior management for national space and education authorities as a systemic program regarding science and technology teaching.
- Expand outreach opportunities. Use space center resources and personnel for outreach in schools, museums and newsletters.
- Establish national competition with top prizes which, where appropriate, would involve projects and flight opportunities.
- Establish living international best-practices education documents for teaching this community.

University Level: The number of aerospace programs at universities is sufficient at this time, but could need expansion in the future. By and large, the program content is matched to the needs of

the employment sector, but needs more hands-on opportunities outside the university. There is an insufficient number of students for the broader needs of SS&T for future demands and for the aerospace sector in three to four years. There is a potential short-term challenge for job opportunities in aerospace, but mostly in the longer term.

- Universities should work closely with employers to match needs.
- More cooperative activities and exchanges between universities should be encouraged.
- More short-term internship need for students in the work force; more hands-on experience.
- More close disciplinary training.
- International project opportunities at the university level on the ISS for all partners.

Opportunities

(137) Unsolved problems:

- K-12 education
- college student training
- postgraduate education

Comments

(41) Grounds: Echoes value of standardized testing, especially pre- and post-flight

(138) The International Space Station is available as an international, accessible, and inspiring tool for all levels of education in many countries to foster international cooperation.