SEPTEMBER/OCTOBER 2005

SPACE TIMES

THE MAGAZINE OF THE AMERICAN ASTRONAUTICAL SOCIETY

ISSUE 5 | VOLUME 44

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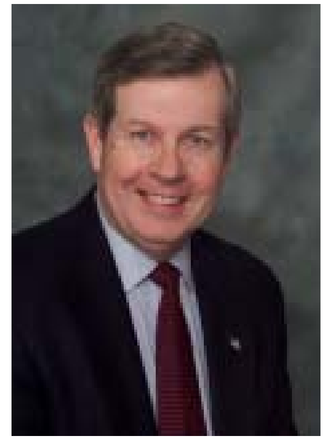


President's Message

The images are seared into our consciousness: first the tsunami and now Katrina. These events don't need to be identified by their time or location. They are just "the tsunami" and "Katrina." To the public at large, the horrific images of shattered homes, businesses, and lives provided by the press have put a human dimension on these recent disasters. To the trained eyes of geophysical scientists, however, there are other images that took our breath away. These are, of course, the images taken from space.

In the March/April issue of *Space Times*, I wrote about the critical roles played by space systems in monitoring our planet for the telltale signs of just such natural disasters as we have experienced. I urged you, our members and other professionals who read this AAS magazine, to be mindful of the responsibility we as space professionals share to use the tools of remote sensing to learn more about Earth and its complex, powerful, and sometimes deadly systems. I was trained many years ago as an oceanographer and a meteorologist. On the night before Katrina roared ashore to wreak her havoc, I stayed up late, sitting at my home computer, cycling between various National Oceanic and Atmospheric Administration web pages in order to study this storm from every possible angle. I realized that I was looking at exactly the same data as the National Weather Service forecasters – and every other meteorologist in the country – and I was stunned. One particular image, a color-enhanced infrared band picture that came in around midnight, is going to haunt me for a very long time. I don't care for the term "perfect storm" because it renders unto a killer hurricane an aura of beauty, although in a detached scientific sense I guess that's accurate. But that image of Katrina, covering nearly the entire Gulf of Mexico, was indeed the most fearful sight of the power of nature I have ever seen, or may ever see. It was perfectly scary because trained eyes knew what it was about to do to New Orleans and the Gulf Coast all the way to Mobile. And then, of course, nothing could stop it.

My point is to remind those of us who are conceiving, funding, defending, designing, building, testing, launching, operating, or using space systems which are designed to provide warnings to our citizens to do our jobs with pride. Developing these systems is far more than just a job. Observing a killer storm develop and move toward land and sending out the warnings is a noble calling, and the investment of taxpayer dollars for the satellites that enable the warnings is a bargain. Would having had the next generation of polar-orbiting and geostationary environmental satellites now in development up and flying that week have made the Katrina warnings earlier and better and the human toll less horrible? The simple answer is yes. The AAS supports these important programs, and this support is one of the top priorities, I believe, in our society's mission of "Advancing All Space."

And a final point which I have to make: members of our space family are, as you know, among the hundreds of thousands of homeless people of the Gulf region. NASA's Stennis Space Center in Mississippi and Michoud Assembly Facility in Louisiana both sustained damage but remain mostly intact. But, of course, a large majority of the government and contractor personnel who operate these important facilities have lost their homes and the means of showing up to do the important work needing to be done there. There will, of course, be an impact on NASA's completion of return to flight – the first step outward to the Moon, Mars, and beyond in the vision for space exploration. But first things first. If you have not yet done so, please do what you can to help these fellow space professionals and their neighbors by donating to one of the many great charities helping a shattered society get back on its feet. There's a lot of work to be done.

Jon Malay

ON THE COVER

As the sun rises over Edwards Air Force Base in California, Space Shuttle Discovery is shown just minutes after touching down on August 9, 2005, having completed NASA's first shuttle flight since the 2003 Columbia disaster. Discovery will fly again next year, carrying out STS-121, the second of two test missions, which is tentatively scheduled for no earlier than March 2006. (Source: NASA/Carla Thomas)

Keep the Space Shuttle Flying

Five arguments may add up to a compelling case for keeping the space shuttle in operation through 2010.

by John M. Logsdon

It is a melancholy reality that the two programs that have been the focus of the U.S. human space flight effort for the past third of a century – the space shuttle and the space station – are now seen as barriers to moving on with the next steps in space exploration, rather than as providing a firm foundation for those next steps.

In the wake of the foam-shedding problems with the recent shuttle mission, the National Aeronautics and Space Administration (NASA) has stood down the shuttle fleet until at least next March while it tries to understand what more is required to fix those problems. The devastation of Hurricane Katrina and its impacts on the Louisiana facility where the shuttle's external tanks are assembled and tested could cause additional delays; even nature is not being kind to NASA. There are widespread and intensifying calls for permanently grounding the space shuttle fleet now, rather than waiting until 2010 to retire it from service. That retirement date was fixed in the new space exploration policy approved by the president in January 2004. Ending shuttle flights now would also mean terminating the shuttle-based assembly of the International Space Station (ISS), leaving it less than half completed. Those advocating an immediate grounding argue that the additional costs and risks of operating the shuttle for five more years are not justified in terms of what the shuttle could accomplish in that time.

NASA Administrator Mike Griffin does not agree with an immediate shutdown of shuttle operations. He believes that "terminating the shuttle program abruptly . . . carries with it grave consequences for the United States' pre-eminence in space." It would be better, suggested Griffin, "to fly out the shuttle program in a disciplined fashion." I agree with Griffin, for the several reasons outlined below.

The decision whether or not to continue with future shuttle launches is an exceedingly complex one, requiring the balancing of unknown political, technical, and human risks and cost against uncertain benefits. It is a decision that should be made at the highest level of the U.S. government and only after judicious thought.

The space shuttle is an integral part of the present U.S. space program. The shuttle is the United States' only vehicle currently available for human space exploration and is the world's only vehicle capable at this time of delivering sections of the International Space Station into orbit. (Source: NASA)

The Case for Flying the Shuttle

What are the arguments in favor of flying the fifteen or so more shuttle missions that NASA is now hoping to carry out? Each of them taken singly probably does not make a compelling case for proceeding; however, I believe that cumulatively they add up to such a case.

First, the space shuttle with its post-Columbia fixes is probably safer to fly than it has ever been, if NASA manages its residual risks with care. This statement flies in the face of what was seen during the recent STS-114 (return-to-flight) mission, with foam-shedding incidents and the less threatening gap-filler protrusions. But some of this awareness of problems with the shuttle's thermal protection system is primarily an artifact of the vast increase in information available at all stages of a shuttle mission; what was seen on the last mission may have been happening out of sight all along. Clearly, the shuttle should not be returned to flight unless and until NASA does a better job of understanding and managing the risks of large pieces of foam coming off the external tank.

The recent minority report of the Return to Flight Task Group was very critical of NASA's efforts in this respect during the return-to-flight effort. But the individuals responsible for leading those efforts have left NASA or the shuttle program. It will be up to Mike Griffin and the new head of space operations, Bill Gerstenmaier, to restore a sense of confidence that NASA is indeed on top of the shuttle's remaining risks and is making prudent decisions as the shuttle resumes operations.

Presuming that NASA can meet this challenge, the many changes made in the space shuttle on the basis of the recommendations of the Columbia Accident Investigation Board and NASA's own initiatives have made the shuttle fleet less risky to operate. In its report, the board suggested that "the present Shuttle is not inherently unsafe" but said that implementing "the observations and recommendations in this report [is] needed to make the vehicle safe enough to operate in the coming years." That has largely been accomplished. The Return to Flight Task Force observed that "the return-to-flight efforts have eliminated or minimized many known risks" but added that "Space Shuttle missions will always be 'accepted risk' operations." Calling for immediate shuttle retirement on the basis that the vehicle is now too risky seems ill-conceived, given all that has been done since Columbia to make the vehicle safer.

Some believe the return-to-flight launch of Space Shuttle Discovery on July 26, 2005, shown here, should be the last launch in the space shuttle program. NASA Administrator Mike Griffin believes that the shuttles must continue to carry out their missions and service the International Space Station until their retirement by 2010. (Source: NASA/Kennedy Space Center)

Second, because of the many delays in completing assembly of the ISS, it is still not possible to judge with any assurance the value of the wide range of research that has been planned for years using the station's unique attributes. The current ISS is far from a completed laboratory, and there has not yet been an opportunity to utilize it in the ways originally justifying the research value of the facility. So it is impossible to say whether or not the ISS can be a truly valuable research facility.

It is indeed sad that more than twenty years after President Ronald Reagan approved NASA's development of a space station, many critical parts of the facility sit on the ground awaiting launch, including major laboratory elements and power arrays. Because of the program's many delays and then the need to limit the on-orbit crew to two people following the Columbia accident, there has never been an opportunity for more than three crew to stay aboard the ISS for a long-duration mission. The experimental equipment, power, and crew time to make substantial research use of the ISS have never been available.

Only the shuttle can launch most of the remaining station elements, leading to a final configuration that can approximate the originally planned ISS research capabilities. If the shuttle were grounded now, the ISS would always remain an incomplete facility. Certainly, it would be possible to continue ISS operations using Russian Soyuz spacecraft to take crew members up and down, and Russian, European, Japanese, and perhaps U.S. commercial systems for ISS logistics. But there are real questions of whether the ISS in its current state can be a useful research facility.

Ever since the original U.S. decision to build a space station, station advocates have claimed high value for the research that could be conducted aboard the orbiting laboratory. As *The New York Times* recently noted, "although it is fashionable in some circles to denigrate the research conducted so far as little more than make-work for the astronauts, the National Academy of Sciences rates some of it highly." Although such claims of the payoffs from ISS research have almost certainly been inflated, not completing the facility means that areas of potentially high research payoff may never get investigated. There is no way of telling *a priori* whether truncating research on ISS would result in a significant loss of valuable knowledge, but not using the station for its intended purposes will ensure that any such benefits will be forgone.

Third, abruptly shutting down shuttle operations now would mean at least a six-year hiatus in the U.S. capability to send people to space. It is difficult to see how this would be in the

This computer generated image represents the International Space Station's configuration as of summer 2005. Permanently grounding the space shuttle would likely end major assembly of the station, which is currently less than half complete. (Source: NASA)

country's interest, as Russia and China continue their space flight efforts, and the only way for U.S. astronauts to get to the ISS would be to fly on a Russian spacecraft. Moreover, the U.S. capability for human flight is based on an existing NASA and contractor workforce and on a ground infrastructure that will be needed when the United States begins to launch the shuttle replacement, called the Crew Exploration Vehicle, in 2011 or 2012. Keeping that workforce on a standby basis for a number of years would be expensive and probably infeasible; good people are not likely to wait out the gap in U.S. space flight when they have other alternatives for employing their talents. Certainly, it is desirable to downsize the "standing army" now required to process and launch the shuttle as the next stage of human space flight begins. But that transition is best done gradually, with shuttle operations phasing down as 2010 approaches.

Next, terminating shuttle flights would mean that a proposed fourth servicing mission to the Hubble Space Telescope would not be carried out, sentencing Hubble to an early end of its remarkably productive scientific career. Both the National Academy of Sciences and NASA have ruled out a robotic servicing mission to Hubble as technically too risky; that leaves only a shuttle servicing mission as a means of extending the telescope's life by several years and installing already-built new instruments. Administrator Griffin has said that NASA will undertake a shuttle servicing mission if it is at all feasible.

The National Academy last year called Hubble "arguably the most important telescope in history." According to the Academy, "with the replacement of aging components and the installation of new science instruments, Hubble is expected to generate as many new discoveries about stars, extra-solar planets, and the far reaches of the universe as it has already produced so far, with images 10 times more sensitive than ever before." The National Academy concluded that a shuttle servicing mission was "the best option for extending the life of the Hubble telescope and ultimately de-orbiting it safely."

Finally, terminating shuttle operations would mean abrogating the formal, treaty-like commitment of the U.S. government to launch ISS laboratories built by Europe and Japan and a complex robotic manipulator built by Canada, in addition to not honoring other U.S. commitments with respect to ISS operations. Both Europe and Japan have not only spent the equivalent of billions of dollars in building laboratories to become part of the ISS; they have also invested significantly in nurturing a research community to use those laboratories, which can only be launched by the shuttle. A U.S. decision to ground the shuttle would render those investments almost worthless.

Current U.S. policy calls for international participation in sending astronauts back to the Moon and eventually on to Mars. Unlike in the past, when the United States was the only viable space partner for Western Europe, Canada, and Japan, today those countries have sufficient capability to work together or with other partners, without the United States playing a key role. Europe, for example, has in the past few years pursued a strategic space partnership with Russia and is involving China in an increasing number of its space efforts. It strains credulity to think that current ISS partners would be soon eager to participate actively in a U.S.-led program of space exploration should this country walk away from its current commitments. Only if the ISS partners were to agree among themselves that a decision to end shuttle flights was the best course to pursue, since they as well as the United States would share in the risks and costs of continuing to assemble the ISS, would that decision not be a foreign policy disaster.

International leadership has been a consistent goal of U.S. space policy. Ending shuttle flights would mean that the United States has decided to give up its (admittedly shaky) leadership position for the time being, with the need to rebuild it as the initial missions beyond Earth orbit begin in the next decade. The policy costs of such a step in terms of this country's broader international relationships are essentially impossible to calculate; they could range from minor to significant.

Addressing the Counterarguments

The counterarguments to the points made above are somewhat more straightforward. Those advocating ending shuttle flights now argue that the shuttle remains an extremely risky vehicle, and the probability of a major accident on any particular flight is unacceptably high. Each time it launches a shuttle, NASA is risking much of its future credibility as an organization capable of carrying out the "sustained and affordable human and robotic partnership to explore the solar system and beyond" that is at the heart of President Bush's vision for space exploration. Some suggest that it is in NASA's own interest to end shuttle operations now, when the problems on the recent STS-144 mission and subsequent delays (perhaps accentuated by the aftermath of Katrina) give it a window of opportunity to do so. In addition, the Challenger and Columbia accidents were national tragedies, not just a blow to NASA's reputation. The impact of a third shuttle accident is difficult to gauge at a time when reports of U.S. casualties in Iraq and Afghanistan are the stuff of daily news but certainly would be disturbing. One way of avoiding such an impact is to keep the shuttles on the ground.

But space achievement in general – and since 1981, space shuttle missions specifically – are important elements of a positive U.S. self-image leading to the kind of national pride that is important to the country's morale. Walking away from future shuttle flights at this point would be seen by many in this country and overseas as a tacit admission that the United States no longer has either the political will to carry out challenging objectives or the technical and organizational capability to manage the risks of meeting those challenges.

Others argue that continuing to operate the space shuttle is too expensive within a constrained NASA budget and that other worthy undertakings, including space and Earth science, aeronautics research, and getting started on space exploration, are receiving inadequate resources. In its report, the Columbia Accident Investigation Board criticized NASA for spending many years "straining to do too much with too little." The costs of the shuttle and ISS programs, and particularly shuttle costs of over $4 billion a year, must be accommodated within a NASA budget that according to current plans will increase only slightly in the short-term. Seeking efficiencies within other programs and reducing the costs of NASA's human and facility infrastructure can only go a limited distance in relieving resource constraints within the organization. From this perspective, the best – perhaps the only – way to provide adequate resources for the rest of NASA is to remove the budget demands of the shuttle program.

This situation would be obviated if the Bush administration and the Congress were willing to grant NASA some budget relief over the next several years, but at a time of high budget deficits and the costs of the war on terrorism and the recovery from Hurricane Katrina, that is politically unlikely, however desirable. Thus if NASA is to continue shuttle flights and still move forward in its other efforts, it will continue "straining to do too much with too little." That is a situation which it is in the national interest to avoid, since it increases the likelihood not only of a future shuttle accident but also of failures and performance problems in other areas of space activity. It would be preferable to find a way to give NASA a bit more money over the remaining years of shuttle operations.

The United States finds itself today in an extremely difficult position with respect to its space program because of ill-conceived presidential decisions made beginning more than thirty-five years ago which have had long-term negative impacts. Those decisions include rejecting post-Apollo plans to build a space station using the large Saturn 5 launch vehicle developed for lunar missions but then accepting NASA's proposal to build its future efforts around a transportation system – the space shuttle – accompanied by promises about its performance that even

Some debate the benefit of the science conducted aboard the International Space Station. Much of the science includes biology, physiology, crystallography, and chemistry. In this photograph, Soyuz 5 Commander Sergei Zalyotin examines a plant that is part of an experiment to study growth in space. (Source: NASA)

The National Academy of Sciences has declared the Hubble Space Telescope "the most important telescope in history." Without future servicing missions with the shuttle, Hubble's ability to capture captivating images like the complex Cat's Eye Nebula, shown here, will soon diminish. (Source: NASA/European Space Agency, Hubble European Space Agency Information Center/The Hubble Heritage Team)

in 1971 many realized could never be achieved. A decade later, the White House decided to approve NASA's proposal to build a space station launched by the shuttle, to make it an international undertaking, and to focus on its research utilization rather than linking it to longer-term plans for space exploration.

Trying to undo the negative consequences of those decisions and thus relieve the constraints they place on today's space efforts by an immediate grounding of the shuttle is a superficially attractive proposition. But such a decision could have consequences for the future of the U.S. space effort almost as negative as those decisions made long ago that have led to the current situation. It is a course that should not be followed. ■

***John M. Logsdon* is director of the Space Policy Institute of The George Washington University's Elliott School of International Affairs in Washington, D.C. In 2003 he served as a member of the Columbia Accident Investigation Board.**

2006 CanSat Competition Announced

AAS, in cooperation with other organizations, is sponsoring the 2nd annual satellite design-build-launch competition for high school and college students (undergraduate and graduate) from the United States and Canada. CanSat teams are required to write a mission proposal, design and build a satellite which must fit into a 12-ounce soda can (hence the competition's name), travel to the launch site, and supervise preparations and launch to an altitude of one mile. Students will also collect telemetry data and retrieve the satellite. Judging is based on the excellence of the documentation, concept of operations, mission results, and final presentations. The first place team will receive a $2,500 prize, with lesser amounts for second and third place teams. Deadline for applications is October 30. The competition will take place in the Washington, D.C., area in early June 2006. See www.cansatcompetition.com for information and to view a video of the 2005 event.

Robots, Humans, and the Exploration of the Solar System

The age-old humans-versus-robots debate continues to hold the attention of the space exploration community. While valid arguments support using each for exploration, perhaps a third type of explorer will bring together the best features of each.

by Roger D. Launius

In the summer of 2004 esteemed space scientist James A. Van Allen asked the poignant question: "Is human space flight obsolete?" He added: "Does human space flight continue to serve a compelling cultural purpose and/or our national interest? ... Risk is high, cost is enormous, science is insignificant. Does anyone have a good rationale for sending humans into space?"

This was only the latest in a long line of similar statements from Van Allen. For more than forty years he has consistently spoken and written in opposition to human space flight. He opposed Project Apollo, the space shuttle, the space station, and the prospect of future human missions to the Moon and Mars. Van Allen, and a host of other scientists, have remained true to a belief that robotic explorers realize the greatest scientific return on investment.

Van Allen's comment points up a debate that has raged since near the beginning of the space age over priorities for space flight. As a scientist he wants to maximize scientific return on any program of government-sponsored space activities. He sees little value for humans in space from a scientific perspective, and he is probably right if science is the reason we choose to go into space. Clearly, the acquisition of scientific data may be expeditiously and relatively inexpensively obtained—at least in comparison to human space flight—using robotic spacecraft.

Advocates of human space flight counter with the assertion that the objectives of scientific discovery and astronaut-based activities are very different. They believe human flight is really about becoming a multi-planetary species and human colonization of other planets, moons, and asteroids represents the true goal of our space flight program. For these enthusiasts, human space flight is to a very real extent about making human civilization anew, revitalizing it in the mold of the best intentions of historic pioneers who have gone elsewhere to create a new society. While few publicly admit it, human space flight is, and in reality always has been, about creating a technological utopia at some new place in the solar system. It is about starting over and building a new life in a new and virgin land.

The debate between advocates of human space exploration (colonization) and space science missions has reached crescendo proportions at the start of the twenty-first century, in part because advocates of human space exploration failed to make meaningful predictions that took into consideration rapidly advancing capabilities in robotics and electronics and have strained to maintain the vision of exploration first developed in the 1950s. For example, when Arthur C. Clarke envisioned geosynchronous telecommunications satellites in 1945 he believed that they would require humans working on board. In such a situation, it is easy to conceive of the motivation that led people like Clarke and Wernher von Braun to imagine the necessity to station large human crews in space. Some of the most forward-thinking space flight advocates, in this instance, utterly failed to anticipate the electronics/digital revolution then just beginning. Humans, space

Once human explorers reach the surface of Mars, they will begin working side by side with robotic explorers. In this concept image, the human explorers repair a damaged wheel on a robot, suggesting that human and robotic space explorers will be mutually dependent. (Source: NASA/Pat Rawlings) flight visionaries argued, were the critical element in the exploration of the solar system and ultimately beyond. Human destiny required our movement beyond this planet, ultimately to the colonization of the solar system. With the rapid advance of electronics in the 1960s, however, some began to question the role of humans in space exploration. It is much less expensive and risky to send robot explorers than to go ourselves. This debate reached saliency early on and became an important part of the space policy debate by the latter twentieth century.

Humans at the Fore

The arguments used in support of human space exploration were first developed in the 1950s, honed to a fine edge in the 1970s, and carried to their logical conclusion by many in the more recent past. At core they express a broad belief in utopia, though rarely does anyone explicitly use that term. Promises in space of a bountiful future, in which all have enough resources to live a rewarding life, where there is unlimited economic potential, where peace and justice reign, and where the perfectibility of humankind is expected are all utopian sentiments. In addition, allusions to space flight as an attribute of human destiny and the hearkening back to a positive American frontier experience also stimulate visions of idyllic, perfect places.

Because of human space flight's critical role in creating a perfect society beyond Earth, it was logical that early enthusiasts would always envision space exploration with humans at the center.

The robotic explorers of Mars have helped pave the way for future human exploration. The concept image shown here depicts a human explorer visiting Sojourner, NASA's first Mars rover. (Source: NASA/Pat Rawlings)

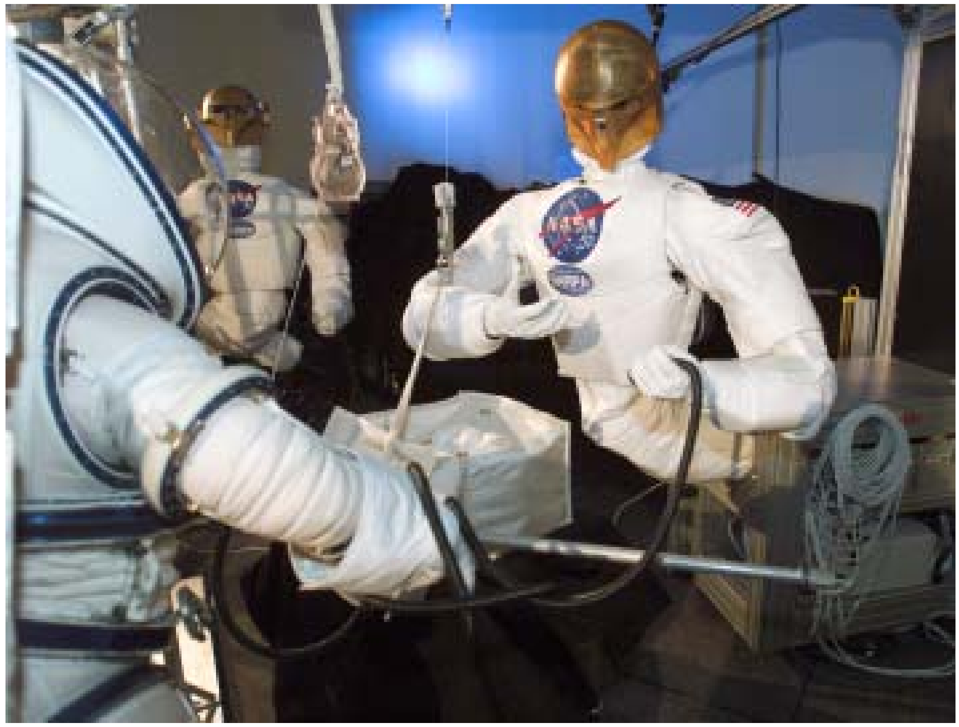
For them, it made no sense to send robots as surrogates. We had to go ourselves because our ultimate purpose was to move outward from this "cradle," to use Russian space flight pioneer Konstantin Tsiolkovskiy's term for Earth. And, of course, we did with resounding success, landing on the Moon only twelve years after the launch of the first Earth-orbital satellite. Early successes in human space flight, however, were followed by a retrenchment of the human space exploration imperative since Apollo. Humans continued to fly in space, but only in Earth orbit. As one exploration advocate recently pointed out: "If only we could get that money back and other wasted money back and put it on a manned lunar/Mars program."

Since the 1950s a human-focused, integrated, stepping-stone space exploration plan has centered on human movement beyond this planet. This integrated plan has cast a long shadow over American efforts in space for over fifty years. It conjured powerful images of people venturing into the unknown to make a perfect society free from the boundaries found on Earth. As such it represented a coherent and compelling definition of American ideals in space. The vision of human colonization was constrained, however, for without a coherent vision of the rise of electronics, advocates failed to perceive the role of robotic explorers. As John H. Gibbons, assistant to the president for science and technology during the Clinton administration, said in 1995:

> The von Braun paradigm—that humans were destined to physically explore the solar system—which he so eloquently described in *Collier's* Magazine in the early 1950s was bold, but his vision was highly constrained by the technology of his day. For von Braun, humans were the most powerful and flexible exploration tool that he could imagine. Today we have within our grasp technologies that will fundamentally redefine the exploration paradigm. We have the ability to put our minds where our feet can never go. We will soon be able to take ourselves—in a virtual way—anywhere from the interior of a molecule to the planets circling a nearby star—and

there exclaim, "Look honey, I shrunk the universe!"

Most importantly, the integrated approach to space exploration was ensconced in the National Aeronautics and Space Administration's (NASA) long-range plan of 1959, and with the exception of a jump from human orbital flights to a lunar (Apollo) mission driven by political concerns, the history of space flight has followed the paradigm consistently. Following the Apollo missions, NASA returned to the building of winged reusable spacecraft (the space shuttle) and a space station (Freedom/International Space Station) and has received a recent charter from the current U.S. presidential administration to pursue human lunar and Mars expeditions. This adherence to the paradigm is either a testament to its captivating nature or to a lack of imagination by current space advocates; the best guess suggests that the truth lies somewhere between the two.



NASA engineers at Johnson Space Center are developing Robonaut, a sophisticated humanoid robot, to assist astronauts in complex future extravehicular activities. In this photograph, one Robonaut (right) assembles an aluminum truss structure with astronaut Nancy J. Currie (left) in a demonstration scenario. A second Robonaut is visible in the background. (Source: NASA)

The Role of Robots

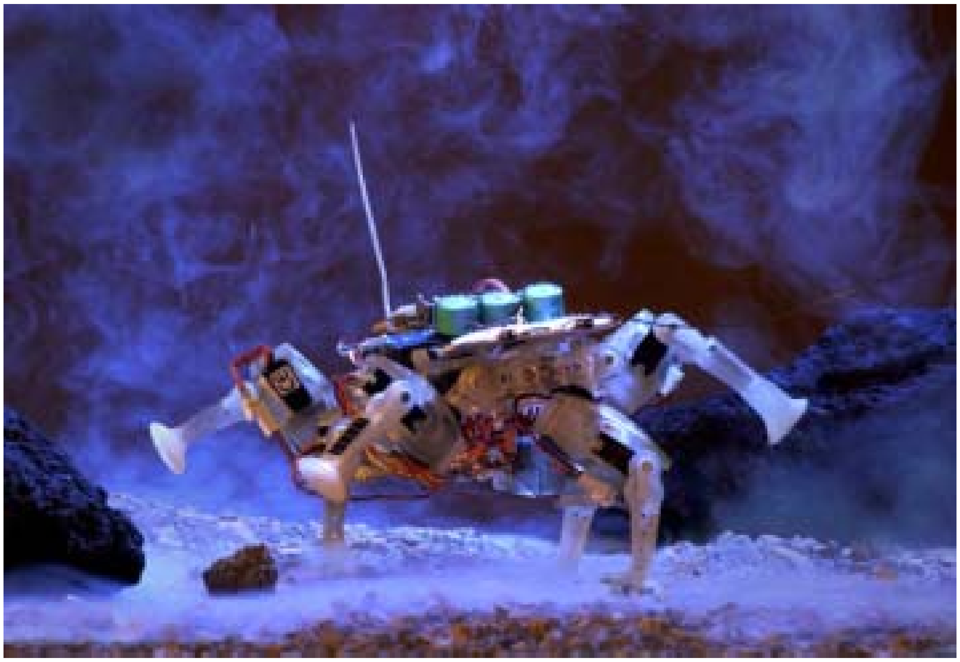
At the same time, beginning in the latter 1950s and accelerating with time, the United States has undertaken an exceptional set of robotic missions. Since the first flights, every planet of the solar system has been explored at least once save Pluto, and several of the moons of planetary bodies (including our own) and some comets and asteroids have been visited. We have placed spacecraft in orbit around our Moon and the planets Venus, Mars, Jupiter, and Saturn and have landed on Venus, Mars, and our Moon. NASA's stunning missions to explore the outer solar system—Pioneers 10 and 11, Voyagers 1 and 2, Galileo, and Cassini—have yielded a treasure trove of knowledge about our universe, how it originated, and how it works. Exploration of the planet Mars has shown powerfully the prospect of past life on the red planet. Missions to Venus and Mercury have harvested understanding of the inner planets. Lunar exploration has exponentially advanced human knowledge about the origins and evolution of the solar system. The great observatories, led by the stunningly successful Hubble Space Telescope, have transformed our understanding of the cosmos. Most importantly, we have learned that, as in Goldilocks and the three bears, Earth is a place in which everything necessary to sustain life is "just right" while all the other planets of our system seem "too hot," "too cold," or otherwise exceptionally hostile. The studies emanating from these new data have revolutionized humanity's understanding of Earth's immediate planetary neighbors and the universe beyond this solar system.

None of these robot space explorers, despite their very real accomplishments, have captured the imagination of the majority of Americans. In a 2004 study of attitudes and values registered by space policy leaders, policy analyst Jon D. Miller asked them: "What do you think should be NASA's number one priority?" He noted a "crystallization of policy attitudes." He explained:

> Thirty-five percent of space policy leaders indicated that they would like for NASA to place its top priority on science-based programs, such as the space telescopes and the monitoring and study of planet Earth.…Most of these responses focused on advancing space science, promoting astrophysics tools, and specific unmanned applications. These science-oriented responses included orbital systems for Earth as well as probes within and beyond the solar system.

At the same time, according to Miller, "twenty-seven percent of space policy leaders indicated a strong preference for activities designed to revive and expand the manned exploration program." He concluded: "It is clear that there is a strong division between leaders who value major unmanned programs such as the space telescopes and the Earth monitoring programs and leaders who see the primary mission of NASA to be manned space exploration."

This is a dichotomy that began with the launch of the first missions into space and has been a perennial debate ever since. If anything it has grown even more heated as robotic spacecraft have advanced in capability over time. Scientists have



Engineers at the Jet Propulsion Laboratory develop small robots capable of accomplishing a variety of tasks in environments that prove challenging for human exploration. The design of Spiderbot, seen here, mimics much of nature's design of the spiders we see here on Earth. Spiderbot can traverse very rugged terrain while carrying many data sensors. (Source: NASA/Jet Propulsion Laboratory)

viewed the amount spent on human space missions as excessive. The expansive costs of human space flight, they have argued, might be more effectively utilized for scientific purposes by sending only robots into space. They have perceived inefficiency, redundancy, and enormous costs to keep astronauts alive as waste; with only a small percentage of that funding, robotic explorers could accomplish so much.

The internecine warfare between advocates of human exploration and colonization of regions beyond Earth and the supporters of space flight for scientific purposes has grown more heated as time has passed. This is in no small measure because of the increasing capability of robotic spacecraft to accomplish ever more varied and complex missions.

Those advocating an emphasis on robotic space exploration never developed an integrated strategy for exploration as compelling as that Wernher von Braun envisioned for humans in space. Indeed, as space scientists have complained since the 1960s, the von Braun paradigm proved so powerful that it effectively transformed the nature of the debate over space policy into "us/them" camps—those who advocate human exploration of space and those who oppose it. It effectively stifled any alternative vision, and many within the space policy arena have intellectually accepted the paradigm as the model for all efforts in space. This plan, or "grand design," has been embraced by space enthusiasts, while those advocating robotic missions over human exploration have been tarred with connotations of negativity and a secular form of apostasy. In effect, those who have refrained from embracing the master design for space flight have been cast as naysayers who can do nothing but criticize rather than as individuals with legitimate alternative positions on the issue.

The official position of NASA on the debate over human versus robotic exploration at the beginning of the twenty-first century is that both are critical to space flight. As lunar scientist Paul A. Spudis wrote in 1999:

> If space exploration is about going to new worlds and understanding the universe in ever increasing detail, then both robots and humans will be needed. The strengths of each partner make up for the other's weaknesses. To use only one technique is to deprive ourselves of the best of both worlds: the intelligence and flexibility of human participation and the beneficial use of robotic assistance.

NASA officials would argue that while sending humans to Mars—or name the destination of your choice—is a long-term objective because of the desire to colonize the solar system, robotic explorers such as Spirit and Opportunity are leading the way.

This is the official position of the 2004 vision for space exploration. According to a recent NASA budget briefing, "NASA will send human and robotic explorers as partners….Robotic explorers will visit new worlds first….Human explorers will follow." The vision reemphasized the position expressed in 1960 by the President's Science Advisory Committee, whose members reported that "a great part of the unmanned program for the scientific exploration of space is a necessary prerequisite to manned flight."

A New Kind of Explorer

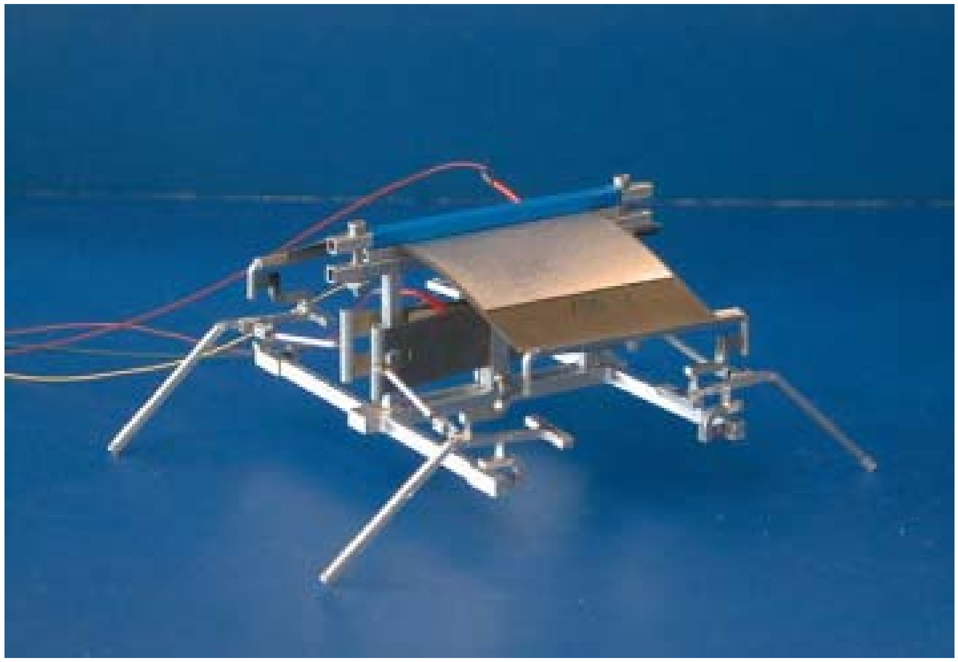
An intriguing possibility now in the offing is that independent human and robotic exploration, or even joint human and robotic exploration, may be soon outmoded by an even more radical concept—the merger of humans and robots into a single entity. The dichotomy between humans and robots is really a product of industrial-age thinking and the accompanying emphasis upon machines that serve humankind. In a post-industrial age we might re-conceptualize this issue and reach a new consensus.

A provocative possibility appears in futuristic literature portending an abrupt turn in robotic technologies. The study of artificial intelligence is leading some to question whether computers that drive technologically sophisticated robots might become so intelligent in the twenty-first century as to acquire sentient qualities. Such intellectuals as Ray Kurzweil note that we are on the verge of creating a new silicon-based life form. It might even include, as Kurzweil suggests, the downloading of a human's memory into a computer to create a new and virtual form of life.

Additionally, the rapid rise of biotechnology suggests that humans may be enhanced enormously through the application of machinery to the body. In work conducted under the auspices of the Defense Advanced Research Projects Agency, researchers have demonstrated the feasibility—mostly theoretical as yet—of attaching machine parts to biological entities. In one experiment, scientists used tissue from moth antennae to seek out explosives. If this tissue were attached to tiny flying robots in a battlefield setting, this merger of biological and robotic entities might prove enormously useful. At the opposite end of that spectrum, humans might be equipped with mechanical parts that permit them to operate in robotic fashion. One possibility involves combatants donning an exoskeleton that provides them with a combination of bodily armor, enhanced mobility, and sensory extension devices. While these ideas, as well as others that are even more extreme, may be a generation or more in the future they suggest tantalizing possibilities when thought about in the context of space flight.

How might we remake the human body to more effectively meet the rigors of space exploration through the adaptation of technology? It is important to recognize that the term "cyborg" was coined by Nathan Kline and Manfred Clynes in a study done for NASA in 1960. In particular, they thought that through the use of electronic implants they could modify humans to survive in space without a spacesuit. Is this a possibility?

Skeptics may scoff at these ideas as examples of science fiction, but space exploration was fiction in the truest sense of the word less than seventy-five years ago. Buck Rogers might have been entertaining in the Saturday matinee in the 1930s and 1940s, but few believed they would see space flight actually take place in their lifetimes. Advances in biotechnology, propelled by national security considerations to create more advanced robots, could permit the development of entities that are part biological and part machine. In science fiction, this is a familiar subject. Science fiction stories frequently feature cyborgs that merge biological and mechanical capabilities.



In research funded by the Defense Advanced Projects Research Agency that could be adapted for space exploration, this mobile robot consists of a lightly damped skeletal structure that moves when vibrationally excited at the appropriate resonance. This approach allows for extremely high movement efficiency, which results in minimal power consumption and long-range mission capability. (Source: Center for Intelligent Mechatronics).

The result, given sufficient time, may be the emergence of a new space exploration paradigm. For years advocates of robotic and human cooperation have envisioned the two exploring space together, but even in this vision, the two remain separate entities—master and servant, owner and slave, flesh and machine. Technological developments now beginning to take place in some settings might permit a true merger—humans equipped with robotic parts or machines possessing sentient qualities. In that sense, humans and robots would explore space together—really together.

The social metaphor for future space exploration might not be Luke Skywalker and his robotic companions R2D2 and C3P0, but the Terminator. Portrayed in the movies by now-California Governor Arnold Schwarzenegger, the Terminator is a super-intelligent cyborg dispatched through time to hunt down and kill a woman whose not-yet-conceived son is destined to lead a future rebellion against the machines. The possibility of this type of merger, which has negative consequences in *The Terminator* but need not do so in reality, is certainly worth considering in an analysis of the human-versus-robot debate.

The history of the human-versus-machine debate for space exploration is a fascinating one. It is made more interesting by the consideration of time, especially on scales entertained by people who believe that the ultimate destiny of human beings is to colonize the galaxy. Time may alter the debate in significant ways, providing a third paradigm quite different than those separating biological entities from their machines. What does this possibility do to the vision of humanity creating new settlements on new lands in the solar system? Perhaps it will make it more realizable. ■

Roger D. Launius is the chair of the space history department at the Smithsonian Institution's National Air and Space Museum. He is a former editor of _Space Times_. His forthcoming book, _Robots and Humans in Spaceflight: Technology, Evolution, and Interplanetary Travel_, is co-authored with Howard E. McCurdy and explores the concepts in this article in detail.

Picking the First Crew for Mars

HELP WANTED – Five to seven astronauts for the first human mission to Mars. Strong aptitude for math and science is a requirement. Good physical and mental condition must be maintained. Genetic testing will be required to eliminate candidates with potential degenerative or debilitating conditions. Must be willing to work hard and attend the world's great universities to obtain graduate degrees in science and engineering. Excelling in jobs that give diverse experience in the skills required is a plus. The ideal candidates will currently be less than sixteen years of age.

by Eric Hedman

NASA recently released roadmap documents outlining plans and timelines for both human and robotic exploration of the solar system. The plans run through the next thirty years and cover preparatory exploration for human exploration of Mars, with the first human expedition possibly happening around 2035. While many have speculated about when and how this could happen, little has been written lately about what the make-up of the first crew should be. The few articles I've read speculate that the first crew would be anywhere from four to seven people. They would be away from Earth for 450 days to well in excess of two years, depending upon the duration of time spent at Mars. From the perspective of crew capability, redundancy, and social structure, the largest crew possible would be the best choice. For purposes of minimizing the launch mass to Mars, the smaller the crew the better.

Who Should Go?

Selecting a crew and determining its size will be driven by a number of factors. One factor will be the primary mission of the first expedition. The primary mission could be either scientific exploration or preparations for a permanent settlement – or, as is likely, a balanced combination of the two. What the priorities of the mission are won't become clear until after we've returned to the Moon and serious planning for Mars gets started.

If the mission is balanced between exploration and settlement, skills will be needed for both purposes. Regardless of what we learn from robot probes between now and the first human landing, Mars will still be a treasure trove of undiscovered science. The fleet of robots now on or in orbit over Mars has exploded our understanding of the planet but has just scratched the surface. There have been hints that life might have existed or may still currently exist on the planet. Even if no life is discovered on Mars between now and the first expedition, that won't be proof that there isn't life there.

Understanding the geology of Mars is necessary for both exploration and building a permanent settlement. If we want to use the mission to maximize scientific return, understanding the geology of Mars is of utmost importance. Deciding where to build a settlement requires a good understanding of the geology of the site and the surrounding area. Any permanent settlement will require stable ground and useable resources within a reasonable distance.

The Apollo program waited for the last mission to send a geologist, but maximum scientific return and planning for a permanent settlement requires an experienced geologist on the first crew to Mars. The current Mars Exploration Rovers

The first person to walk on the surface is Mars is probably a middle-school student today. Students who stay physically fit, stay focused on their math and science studies, and remain devoted to the progress of space exploration are likely to be the best candidates for future human Mars exploration. The young students shown here cultivate their interest in space science by participating in a model rocket launch event with members of the 2004 NASA Academy summer internship program for college students at Goddard Space Flight Center. (Source: Miguel Roman)

Because one important goal for the early exploration of Mars will be to examine the planet's surface, the first Mars exploration crew is likely to include a geologist. A better understanding of martian geology could not only lead to biological findings but also aid in the planning of future exploration and, potentially, settlements on Mars. (Source: NASA/Pat Rawlings)

Spirit and Opportunity are great tools, but they have limitations a human would not. A geologist on site could in a few short moments decide what to examine and what to skip and therefore would cover ground much more quickly. A geologist on site can also, with a significant delay, converse intelligently with colleagues back on Earth about what he or she is seeing and what is important to observe. Nothing we have developed to date can replace a well-educated mind in making quick decisions about what is worth further exploration. Without significant breakthroughs in artificial intelligence and robotics, which are not totally out of the question, a geologist is a must for the first mission.

Whether or not there is proof of life on Mars prior to the first human expedition, there is a strong case for including a biologist on the mission. A biologist could have multiple tasks. The first task would be to search for indigenous life. If life is found, a biologist would be very useful in understanding its make-up and assessing whether it is benign or possibly threatening to life on Earth. Even if there is no native life on Mars, we can't discount the possibility that some life form brought to Mars and inadvertently released could survive and spread into subterranean aquifers. Tracking the spread of the alien species invasion would also be of great scientific interest, just as studying how life reaches a new volcanic island on Earth and takes root. A biologist with some additional training may also be the ideal back-up for a doctor on the mission.

The question of bringing a doctor on the expedition is an interesting one. Based on the experience of the crews on board the International Space Station, odds are probably against any crew member having a life threatening illness or injury over the course of a two-and-a-half-year mission. While unlikely, it is not, however, out of the question. The risks to the crew from surface activities, long-duration exposure to low gravity, and chemicals carried in from trips out on the surface are still an unknown. Another duty a doctor would have is to monitor and maintain the health of the crew. This is a task that could possibly fall into the hands of a biologist with some additional training and plenty of support from Earth. If a severe injury or illness does affect the crew, having a trained physician on hand would be absolutely necessary. Real-time telemedicine support from Earth is not possible the way it is in Earth orbit and on the Moon due to the time lag in communications. With the need to have some redundancy in skills in addition to technical systems, it would seem that having a doctor on board becomes a must. With no quick help available from Earth, the crew, like the ship, the base, and any other systems, needs to be repairable.

The remaining non-scientist members of the crew will have to be the ones with the skills and the responsibility to get the crew to Mars, enable them to operate on the surface, and get them safely back to Earth. I would suspect that the ship, the habitat on the surface, the lander, and most of the equipment will be automated to a significant degree more than is the case with the space shuttle and the International Space Station. While landings on Mars and the return to orbit and docking with the mother ship will undoubtedly be automated, having a manual override and crew members on board capable of taking over in the case of equip-

As a matter of safety, the first human habitats on Mars may be constructed in pairs. Each habitat could fully support the exploration crew, and the second structure would serve as a back-up in case something went wrong with the first habitat. This or any other method of habitat redundancy will be necessary because no kind of rescue mission could be mounted from Earth in the event of a habitat or environmental control emergency on Mars. (Source: NASA/John Frassanito and Associates)

ment failure will probably be a requirement even if it is just to make us humans feel we aren't totally obsolete. Maintenance and repair of the ship, landers, surface habitat, rovers, and a myriad of equipment will require significant engineering talent. Some of the skills the crew will require are piloting, electrical engineering, mechanical engineering, software engineering, propulsions systems engineering, hydroponics farming, and command. Obviously the crew cannot include specialists in every area, so great weight will be given to candidates with a great breadth of talents and experience. The bare minimum number of people to fill the non-scientist slots requiring these skills is two for the reason of having a back-up capability if one dies or becomes disabled to the point of being incapable of carrying out his or her duties.

By the Numbers

By my reasoning, the minimum crew to do any meaningful work on Mars with a good chance of success is five people. If the mission profile is a long cruise phase to Mars early in the launch window with a month stay on the surface, then it would probably make no sense to have a crew any larger than five. It may also then make sense to combine the duties of the expedition's doctor with the biologist, reducing the crew to four. If the mission profile is to send the crew at the optimal point in time for the quickest, most energy-efficient cruise to Mars, a stay of approximately two years, and the quickest possible cruise home, then the baseline crew size almost certainly has to start with the minimum of five.

For a long stay on Mars, whether the crew is to have one or two additional members will depend on a number of factors. These include what kind of heavy-lift launch capability is available to send a Mars ship to Earth orbit and how much equipment and habitat capacity is prepositioned on Mars. Most of all, the crew size may depend on how the economy is doing twenty to thirty years from now. The state of the U.S. and world economies will affect the goals of the mission. If solid, chances are there will be a series of expeditions leading to a permanent settlement, and a bigger ship with up to seven crew members would be more likely.

If the crew is expanded beyond five, it will be done after trade studies that balance the extra costs and resources required with what the larger crew could accomplish. If the crew has one or two pressurized rovers for exploration, the time spent doing science over a greater distance from the landing site would greatly increase the need for more people. Resource prospecting and scientific research would be especially enhanced if the rovers have deep core drilling capabilities. Additional crew members also would be needed if significant cargo for expanding the base for future crews is sent along and construction is required.

Politics, Personalities, and the Crew Profile

Considerable international participation in a mission to Mars is a high likelihood. International participation brings both strengths and complications to large projects, adding an extra layer of politics into the crew selection process.

Each country contributing resources to the mission will want representation because the first crew is the one that will be remembered. If more countries are contributing to the mission than there are crew slots, the politics of crew selection will get interesting to say the least. If the United States pays for half or more of the mission, it is unlikely that it would be acceptable for there to be only one American on the mission. Picking the mission commander and second in command will trigger similar issues.

If up to seven people are to share a confined space for more than two years, picking a compatible crew is going to be very important. Without crew compatibility the success of human exploration and eventual settlement is less likely. Long-term close confinement, even if voluntary, causes conflict because a normal human being still has needs for privacy, companionship, and variety of experience. Tension building over time could destroy teamwork, compromise safety standards, and possibly even lead to violence. One model to consider for the importance of crew compatibility is the experience of the Biosphere project in Arizona several years ago. Regardless of the quality and credibility of the biological science of the project, it did highlight the compatibility problems that can develop within a small group of people confined in a small space for an extended period of time.

Russia's newly adopted ten-year plan for its space program calls for putting six people in an isolated simulated Mars mission environment for five hundred days. The goal is to find out what it takes to get crew members to work together and get along with each other in what for humans is an unnatural environment. This would be a great opportunity for international cooperation. If three of the test subjects were from other countries, it would be an excellent planning exercise for picking a crew given inevitable cultural and primary language differences. These kinds of projects do not draw as much interest for international cooperation as human space flight or planetary probes but could be immensely important for the success of a human mission.

Aside from politics and human compatibility, there are a host of other factors that will come into play for crew selection. Considering the time the crew would be away from Earth and the limited medical facilities available, the age of the crew might need to be kept reasonably low to reduce the risk of untreatable medical conditions. This move, of course, will conflict with the advantage of experience. The crew will probably be genetically tested to determine their propensity for developing disabling conditions or even mental illnesses that would probably be impossible to treat. The right mix of technical skills will also be vital for survival because of the remoteness, which will induce a communications delay that makes real-time conversations with support from Earth impossible. Going into an environment with dangers both known and unknown with no outside help available means that the crew will have to be made up of people psychologically strong enough to accept the risks and not dwell upon them.

It is not uncommon for U.S. military families to undergo separations of a year or more with deployments in Iraq and Afghanistan. Even with soldiers able to make phone calls home, the year-long deployments are an incredible strain on marriages. A two- or three-year mission where the most intimate communication with a spouse back home may be a video e-mail may make choosing married astronauts out of the question. The stress on someone that could result from either a breakup or a death of a spouse back home also has to be a consideration.

The ultimate make-up of the crew will be an interesting choice for decision-makers because it is likely that a successful mission will depend on the group selected. If the crew consists of seven and the United States pays for more than half of the mission, it is probable that at least two of the crew will be American. If the other crew members come from countries like Germany, France, Russia, China, Japan, India, or any of a number of other possible nations, a cultural clash within the crew is also possible. Given that it may be hard to predict which countries

International cooperation in human exploration of Mars is quite likely given the high costs of the missions. Determining which nations' astronauts fly on which missions will be subject to political considerations and debate. (Source: Alessandro Gattuso)

The long-term separation that Mars explorers will experience apart from their loved ones may influence the selection of the first crew members. Military families know the hardships of having family members deployed across the world for long time periods, with only limited contact via satellite phone or email. Candidates with the ability to cope with isolation and loneliness will be desired. (Source: Department of Defense/Staff Sergeant James V. Downen, Jr.)

or regions may advance economically in the next thirty years, there may be some variation to this list. The crew will probably skew young with ages ranging from early thirties to late forties. The crew will also probably be mixed in gender. I don't think a single-sex crew would be acceptable to many groups for reasons both political and practical. I also suspect that factors as important as compatibility may be pushed aside for political and technical skill reasons.

Crew Dynamics in Practice

When a mission begins, the crew will have to get acclimated to life in a small habitat. Even though these people will have trained together, they will not have been isolated from the rest of the world the way they will be in space. The first true test will be the outbound trip. Depending on improvements in propulsion between now and then, the outbound trip could range from as long as nine months to potentially as short as six or eight weeks. During this time when the crew members will be spending twenty-four hours a day no farther apart than a few meters, they will get to know each other's bad habits, ticks, and foibles. Tolerance of inconsequential habits will probably be very important in making the mission tolerable.

During this time the basic social structure of the crew will form. Unlike training, where many other people will be present, the crew will be alone. It won't be long after leaving Earth orbit until the expanding distance will start causing a communications lag that will make real-time conversations with people back home impossible. The psychological effect of conversations with home becoming more difficult might reinforce the sense of isolation very quickly. A new generation used to communicating by e-mail and text messaging might not be affected as strongly. The crew selection committee will need to screen out people that won't be able to handle the isolation.

Free time during the mission will probably create some of the greatest options for tension among crew members. It will probably be the time during which the crew members will learn the most about each other. If the crew members come from very different countries, they may have very different core beliefs. Those differences are still possible if the entire crew is from the United States given the diversity of people even within small neighborhoods. While I don't believe it is necessary to screen out people for specific political or religious beliefs unless extremist, I do believe it is necessary to screen out people intolerant of different views. Imagine spending two years mostly in a space the size of a small house with people openly hostile to your views on politics, religion, and morality. On the flip side, shared adventure, adversity, interests, and challenges have the possibility of making a small group of people bond into very good friends and a team with capabilities greater than the sum of its parts.

If the first mission to Mars takes place in 2035, then most if not all of the crew is already alive today. The selection criteria will eliminate many people who would want to go. Some people will grow too tall or not tall enough. Some people are born and living in countries that won't be contributing to the mission financially or technically. Some people have genetic problems they don't currently know about but that will render them ineligible. Current high school students may already be too old to be considered, but somewhere in grade schools around the world may be the first crew. A combination of ability, ambition, hard work, and luck will lead a few individuals to a destiny that will immortalize them in history. It is an opportunity that many of us would love to have. For me it is enough to help push the dream and hope that I'm still around to see it happen. ■

Eric Hedman **is the chief technology officer and cofounder of Logic Design Corporation of Pewaukee, Wisconsin, a company that develops innovative software solutions that help manufacturing companies transform engineering and manufacturing. He can be reached at ehedman@ldcglobal.com.**

The Neurolab Spacelab Mission: Neuroscience Research in Space

Reviewed by Mark Williamson

The Neurolab Spacelab Mission: Neuroscience Research in Space, Results From the STS-90 Neurolab Spacelab Mission, Jay C. Buckey, Jr., and Jerry L. Homick (eds). Houston: National Aeronautics and Space Administration (NASA SP-2003-535), 2003. 333 pages. ISBN: 0-9725-3390-7. $67.00 (hardback).

Sometimes you come across books you know to be unique, and this is one of them: not only because very few books are dedicated to Spacelab missions, but also because only one Spacelab mission, aboard space shuttle mission STS-90, was dedicated to studying the brain. This volume presents the results from the twenty-six experiments carried out on that sixteen-day mission, which focused on how gravity affects the brain and nervous system. Prior to its publication, state the editors, the only other similar book was *Biomedical Results from Skylab* published by NASA in 1977.

It is important to note at the outset that this is no easy read: the book is aimed at a scientific audience familiar with the style and layout of academic papers. The publisher, however, has made significant efforts to improve the accessibility of the information by including numerous color photographs and diagrams to complement the equally numerous graphs and bar charts. The overall reading experience is further enhanced by printing on high-quality gloss paper.

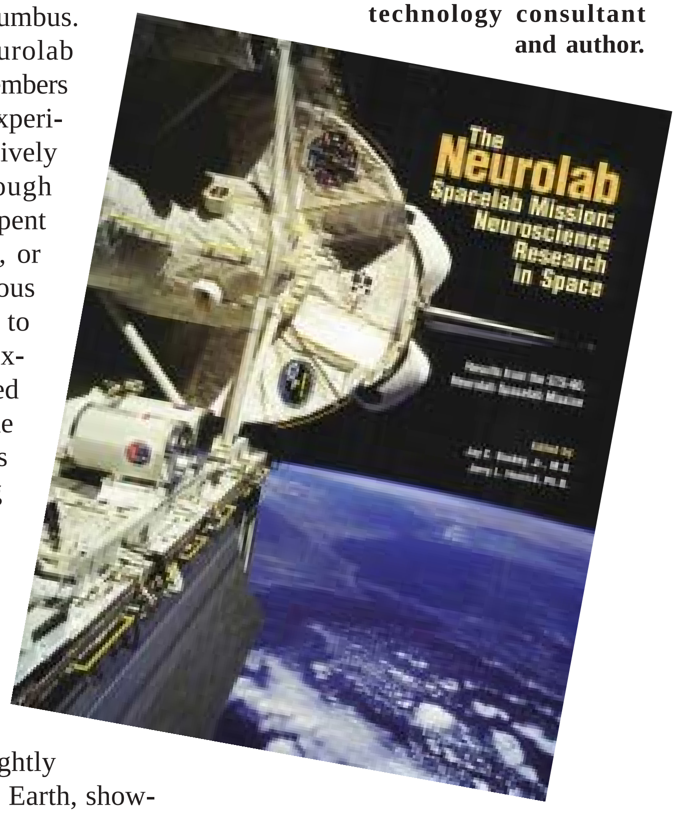
The papers are clearly organized into five sections, reflecting areas of research: the balance system, sensory integration and navigation, nervous system development in weightlessness, blood pressure control, and circadian rhythms. They are followed by ten reports on some of the most noteworthy techniques, procedures, and equipment that had to be developed for the flight. These include a portable sleep monitoring system, a virtual environment generator (similar to a virtual-reality visor system), and techniques for surgery and recovery in space.

This is fascinating stuff, not least because it addresses much of what we will need to know if we are ever to venture far beyond the confines of Earth orbit. Although Neurolab and the fifteen preceding Spacelab missions produced relatively little excitement in the space community at the time, they were fundamental to our understanding of how to approach human space flight. The Spacelab modules themselves were designed and built by European industry and flown on the space shuttle in the 1980s and 1990s, as a precursor to the collaborative relationship of the International Space Station, which one day will receive the European module, Columbus.

Of course, the Neurolab mission's astronaut crew members were a key part of all the experiments, as they were effectively the "guinea pigs." Although much of their time was spent strapped into chairs, beds, or other apparatus with various probes and sensors taped to their bodies, some of the experiments must have seemed like games. For example, the paper entitled "The Brain as a Predictor: On Catching Flying Balls in Zero-G" describes how astronauts were tasked to catch a ball projected towards them at three different speeds. Apparently, the astronauts "triggered anticipatory motor responses" slightly earlier than they would on Earth, showing that the central nervous system uses an "internal model of gravitational acceleration," in addition to sensory information, to help us catch balls. According to the research, the nervous system "applies this model by default." In other words, we expect a dropped ball to accelerate downwards and we react accordingly, even in microgravity when a ball does not behave this way.

Quite what this means for our future exploration of the solar system is anyone's guess, but perhaps the astronauts involved will be more "on the ball" when it comes to retrieving dropped wrenches and screwdrivers. Certainly, this book should be on the required reading list of anyone interested in the human ability to live and work in the space environment. ■

***Mark Williamson* is an independent space technology consultant and author.**



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AAS National Conference and 52nd Annual Meeting

Building Bridges to Exploration: The Role of the International Space Station

November 15-16, 2005, South Shore Harbour Resort, Houston, Texas

TUESDAY, NOVEMBER 15

7:30 Registration / Continental Breakfast

7:30 Sponsors Breakfast; Exhibits

8:45 WELCOME
Jonathan T. Malay, AAS President and Director, Civil Space Programs, Lockheed Martin Corporation
Jefferson Howell, Director, NASA JSC

9:00 KEYNOTE
Exploration and the NASA Architecture - Michael Griffin, NASA Administrator

9:45 Break; Displays

10:00 SESSION 1: Realizing the Promise of the International Space Station
Theme: Status of ISS program, discussion of its challenges and achievements to date, and challenges ahead after Shuttle is retired.

William Gerstenmaier, Associate Administrator, Space Operations Mission Directorate, NASA HQ
Michael Suffredini, NASA JSC
William Panter, NASA JSC

11:30 LUNCHEON
Speaker: Courtney Stadd, Former NASA Chief of Staff and White House Liaison

1:00 SESSION 2: Focus on International Space Station Research
Theme: International discussion on what partners are doing/planning with respect to ISS research.

NASA Utilization and the Exploration Vision - Donald A. Thomas, ISS Program Scientist, NASA HQ
Canadian Utilization of the ISS - Nicole Buckley, Director, Life & Physical Sciences, Canadian Space Agency
Life and Physical Sciences at ESA: Basic, Applied and Exploration Research - Eric Istasse, Head, Mission Science Office, European Space Agency
TBD - Japan Aerospace Exploration Agency (JAXA)
TBD - Russia

2:30 SESSION 3: International Space Station Challenges Enabling Exploration Risk Reduction
Theme: Discussion of ISS systems/operations/etc that have contributed directly to exploration risk reduction.

Augmented Reality for Space Flight Training and Mission Support - Anthony Majoros & Paul Jackson, The Boeing Company
Concepts for the Demonstration of Advanced Electric Power System Technologies on ISS - Ed Gholdston, Gyan Hajela, & Howard Oliver, P&W Rocketdyne
The Importance of Microbiological Prevention and Control in Space Exploration Water Systems - Mark E. Wilson, The Boeing Company
Utah, the Other Red Planet - Kurt Klaus, The Boeing Company
Natural and Induced Environment Design Issues for NASA Space Exploration Systems: Crew Exploration Vehicles, Cargo Delivery Missions, and Lunar and Martian Surface Landers - James Visentine, The Boeing Company
Nanotechnology Applications for Extended Duration Space Missions - Speaker TBD

4:00 SESSION 4: Roundtable on Integration Challenges of Large Scale Programs
Moderator: Stephen Johnson, Associate Professor, Department of Space Studies, University of North Dakota
Invited Panelists:

- William Gerstenmaier, NASA HQ
- Russia Representative TBD
- Alan Thirkettle, European Space Agency (ESA)
- K. Shiraki, Japan Aerospace Exploration Agency (JAXA)
- B. Marcotte, Canadian Space Agency (CSA)
- J. Elbon, The Boeing Company

5:30 Adjourn

6:30 Reception & Awards Banquet
Guest Speaker TBD

WEDNESDAY, NOVEMBER 16

7:30 Registration / Continental Breakfast

7:30 Space Alumni Breakfast; Exhibits

9:00 Carl Sagan Memorial Award Lecture and Presentation
Michael C. Malin, President and Chief Scientist, Malin Space Science Systems

9:45 Break; Displays

10:00 SESSION 5: Common Challenges: Human and Robotic Exploration
Theme: This session is dedicated to the "outbrief" of the JSC/JPL Personnel Bridges session. What challenges and risks exist within manned and robotic spacecraft missions? What can we learn from each other to reduce risks? How can we work together to reduce risks? Each JSC/JPL team will review their results/ideas/etc.

- Speakers TBD

11:30 LUNCHEON - Guest Speaker TBD

1:00 SESSION 6: Commercial Space: Lead, Follow or Get Out of the Way
Theme: This session will be a lively discussion on the possibilities and policies associated with commercial opportunities for human spaceflight, such as human transportation, cargo transportation to the ISS, and other possibilities for in orbit infra-structures operated on a commercial basis.

- Speakers TBD

2:30 SESSION 7: The Future of International Cooperation
Theme: This session will explore the impact of current events and policies on the future of international cooperation on human spaceflight projects.

ESA/Russia Cooperation on Soyuz in Kourou and the Clipper Development - Speaker TBD
The Global Impact of International Space University (ISU) - Michael Simpson, President, International Space University
International Coordination of Global Exploration Efforts - Peggy Finarelli, North American Representative, ISU and Ian Pryke, Senior Fellow, Center for Aerospace Policy, School of Public Policy, George Mason University

4:00 SESSION 8: ISS as a Mars Mission Testbed
Theme: Ideas for using the ISS in mission simulations or other operational risk reductions in support of the exploration spirals. Includes presentations on activities around the agency/outside the agency. Also includes presentations by student session leads.

- Outbrief #1 of Student Session
- Outbrief #2 of Student Session

5:30 Closing Reception

Boost-Testing the Crew Exploration Vehicle

A NASA Apollo test program offers lessons for the companies preparing to test-fly the Crew Exploration Vehicle.

by Anthony Young

As the vision for space exploration has gained momentum and organization, the National Aeronautics and Space Administration (NASA) has awarded contracts for space transportation architecture studies. In June NASA awarded competitive contracts to two teams – The Boeing Company and a Lockheed Martin/Northrop Grumman team – to present their operational designs to NASA for the Crew Exploration Vehicle (CEV). A "fly-off" of test versions, or "boilerplates," of the two CEV designs is currently scheduled to take place in 2008, whereupon NASA will award the contract for the CEV. In March of 2005, NASA's Exploration Systems Mission Directorate issued a requirements and guidelines document that states: "Demonstration of CEV and launch system performance are critical to enabling Spiral 1 objectives of safe transportation of the crew. Successive demonstrations of the CEV and launch system (including the ability to perform ascent and entry aborts) will begin with a series of risk reduction flight tests and lead up to crewed CEV operational capability to support human exploration missions beyond LEO. The CEV must have a high degree of automated control to accomplish the early uncrewed test flights."

The CEV must have the capability in an abort scenario to remove the crew safely from its launch vehicle during powered ascent and to parachute to a water landing, much like the system used on the Apollo capsules. The scope of the uncrewed CEV tests is yet to be defined. However, numerous such tests will need to be performed to validate the launch escape system that would pull the CEV free of a malfunctioning booster and to loft the CEV to a high enough altitude to test the parachute deployment system. Will the two competing contractor teams have to use expensive expendable rockets to perform these tests, or are there less expensive means of doing so? No doubt both teams have been studying NASA's own successful program to test the Apollo capsule during the 1960s.

The Little Joe II solid rocket booster, shown here, proved effective in testing boilerplate versions of the Apollo command module launch escape system before actual crewed flights. A similar launch vehicle using existing hardware could be built to test the Crew Exploration Vehicle launch escape system. (Source: NASA)

The Little Joe II Program

In March 1962, NASA approved a program for a new small booster for flight testing the boilerplate versions of the Apollo spacecraft which included the command module and service module in a sub-orbital capacity. The program was specifically conceived to validate the command module launch escape system and main parachute deployment system and to perform other tests related to the capsule. The program was given the name Little Joe II after the first program used for testing the Mercury capsules. In April NASA issued a request for proposals for five launch vehicles to achieve these goals, with three launches to take place in 1963 and two more in 1964. As with much of the Apollo program, decisions were made with amazing speed. Contractors had only several weeks to present their proposals. In May NASA awarded the contract to General Dynamics' Convair Division. The Manned Spacecraft Center in Houston, Texas, would handle the program within NASA.

Little Joe II would be a two-stage rocket powered by solid propellant rocket motors. In August NASA selected Aerojet-General's Algol motor as the primary sustainer motor. Lift-off thrust was augmented with up to six Recruit solid rocket motors in addition to the two Algol motors in the first stage. The second stage was powered by two Algol motors. Each Algol motor was rated at 465 kilonewtons, and each Recruit was rated at 167 kilonewtons. North American Aviation was the prime contractor for the command module, and the company awarded the solid rocket motor contract for the launch escape system to the Lockheed Propulsion Company. Design engineering, fabrication, and assembly of Little Joe II took place in Convair's main plant in San Diego, California. In September NASA approved General Dynam-

The Little Joe II booster. (Source: NASA)

ics' request to use the first flight of Little Joe II to qualify the booster. Various launch sites were considered, including Wallops Island in Virginia and Cape Canaveral and Eglin Air Force Base in Florida, but White Sands Missile Range in New Mexico was deemed best suited for these test launches.

The first test of the launch escape system for the Apollo capsule was actually a pad abort test with a boilerplate Apollo capsule from ground level at White Sands. Convair completed assembly of the qualification test vehicle in July 1963 and then disassembled the launch vehicle and delivered it to White Sands. It was re-assembled on its rail launcher and launched from launch complex 36 on August 28, 1963, reaching an apogee of eight kilometers. On May 13, 1964, the first Little Joe II with its boilerplate capsule, mission A-001, was launched. At forty-four seconds into ascent, a command was sent to the vehicle to rupture one of the solid rocket motors, which automatically triggered the launch escape system, pulling the capsule away from the launch vehicle. The capsule reached an altitude of just over nine kilometers, when the launch escape system itself was jettisoned. The capsule's drogue parachute and then main three parachutes deployed. One of the chutes failed, but the capsule landed intact with two chutes.

The remaining flights of Little Joe II were designed to test different aspects of the mission profile requirements. A-002 was launched on December 8, 1964, testing the launch escape system operation under maximum aerodynamic pressure. A-003 was launched on May 19, 1965. Two-and-a-half seconds after launch, the vehicle suffered a catastrophic failure. The launch escape system activated, but the vehicle was in an attitude far from nominal. The launch escape system canard system deployed, reorienting the launch escape system and capsule. The capsule only reached six kilometers before launch escape system jettison. This unintended low-altitude abort had a silver lining, as this was a possible manned launch scenario. A-004 was launched on January 20, 1966, and the Block 1 Apollo capsule achieved an apogee of twenty-three kilometers; all mission milestones were met, marking the completion of the Little Joe II program.

The CEV Boilerplate Launch Vehicle

The Crew Exploration Vehicle boilerplate capsule will also need a launch vehicle to perform the same duties that Little Joe II did for the Apollo program. NASA Administrator Mike Griffin has asserted that the CEV will be launched on its future missions with a shuttle-derived launch vehicle; however, the boilerplate versions of the CEV will need their own launch vehicles, and quickly. Boeing and Lockeed Martin/Northrop Grumman will each need a launch vehicle for the competitive "fly-off" of their respective CEV designs, targeted for 2008. Boeing would likely use one of its Delta 4 or Delta 4 Heavy launch vehicles for its demonstration flight. Lockheed Martin/Northrop Grumman might opt for using the Atlas 5. Regardless of which team wins the contract to build the CEV, the test flights of the uncrewed CEV boilerplate will need a launcher. If Boeing wins, it may choose to stay with its reliable Delta 4 to launch the CEV boilerplate and Block 1 CEV capsules until the shuttle-derived launch vehicle is ready for crewed flights.

The CEV launch escape system must be tested, and that would not require a launch vehicle with the sophistication and expense of the Delta 4 or Atlas 5. Some have proposed a solid rocket booster-derived launcher, but it would need a guidance system and its own unique launch pad. There are several launch venues available for such a vehicle, and White Sands would once again prove useful. Undoubtedly, both industry teams will reveal which launch vehicle they will use for these kinds of tests, but it will be some time before the world learns of their choices. The vision for space exploration is becoming a reality, and we will witness an all-new generation of launch vehicles to bring it to fruition. ■

Anthony Young **has published nine books covering transportation history.**

Shirley Thomas Perkins
1920 - 2005

Shirley Thomas, a prominent figure from the early days of the U.S. space program, died of lung cancer on July 21 at the age of eighty-five.

Born in Glendale, California, in 1920, Thomas earned a B.A. in 1960 and a Ph.D. in communications in 1967 from the University of Sussex in England. She was awarded a diploma by the Russian Federation of Cosmonautics in 1995.

Thomas worked in Hollywood for a number of decades. The company she owned with ex-husband Walter White, Jr., Commodore Productions, produced radio shows including *Hopalong Cassidy*. She later conducted radio broadcasts for Voice of America and red carpet interviews at motion picture premiers for NBC. Professionally, she used her maiden name of Thomas.

Thomas authored fifteen books including the eight-volume *Men of Space* series (published between 1960 and 1968), in which she told the tales of aerospace pioneers including Robert H. Goddard, Chuck Yeager, Wernher von Braun, and Theodore von Karman. She also authored thirty technical papers. She organized and chaired the Woman's Space Symposia from 1962-1973.

In 1992 Thomas succeeded in a multi-decade campaign to recognize the achievements of Theodore von Karman, father of the Jet Propulsion Laboratory and Operation Paperclip, by getting a U.S. stamp issued in his honor. She founded and chaired the Aerospace Historical Society at the California Museum of Science and Industry.

Thomas taught a writing course at the University of Southern California for thirty years until her passing. She served on the AAS history committee for many years and was a member of the International Academy of Astronautics, the American Institute of Aeronautics and Astronautics, the British Interplanetary Society (she was also a fellow), and the National Association of Science Writers. She was also a consultant for the Stanford Research Institute and the Jet Propulsion Laboratory.

Thomas is survived by her husband, Bill Perkins, and three stepsons.

UPCOMING SPACE EVENTS

The International Association for the Advancement of Space Safety (IAASS) will hold its first conference in Nice, France, October 25-27, 2005. The theme is "Space Safety, A New Beginning." For information see www.congrex.nl/05a15/.

Space Exploration: Who, What, When, Where and Why? 10th Annual International Symposium, November 30-December 2, 2005, in Strasbourg, France, hosted by the International Space University. See www.isunet.edu for registration information.

Space Technology & Applications International Forum – 2006 is scheduled for February 12-16, 2006, in Albuquerque, New Mexico. This semi-annual conference is hosted by the Institute for Space and Nuclear Power at the University of New Mexico. See www.unm.edu/~isnps/ for details.

Earth & Space 2006 is the theme for the 10th ASCE Aerospace Division International Conference on Engineering, Construction, and Operations in Challenging Environments. It will be held March 5-8, 2006, in League City, Texas; see www.asce.org/conferences/space06 for details.

IAF President Recognizes AAS at 50th Anniversary

AAS was recognized for its over 50 years of contributions to space activities by the International Astronautical Federation (IAF) in Paris, France, on March 23, 2005. Jim Zimmerman, IAF president, presented a plaque commemorating AAS's 50th Anniversary to Lyn Wigbels, AAS vice president, international, during the IAF International Program Committee plenary session. "It is a great pleasure to recognize the American Astronautical Society, a long-standing member of IAF, for its outstanding contributions to the promotion of space activities for over 50 years and for its longstanding partnership with the IAF," Zimmerman observed. Lyn Wigbels thanked the IAF for the recognition and said, "For over 50 years, the American Astronautical Society has been dedicated to advancing all space activities. During this time, we have been members of the IAF, and we look forward to continuing our successful collaboration with IAF in the future."

Lyn Wigbels and Jim Zimmerman. (Source: IAF)

UPCOMING EVENTS

AAS Events Schedule

November 15–16, 2005
AAS National Conference and
52nd Annual Meeting
"Building Bridges to Exploration: The Role of the International Space Station"
South Shore Harbour Resort
Houston, Texas
www.aashouston.org
See page 20 for details!

January 22-26, 2006
***AAS/AIAA Space Flight Mechanics Winter Meeting**
Westin Innsbruck Golf Resort
Tampa, Florida
www.space-flight.org

February 4-8, 2006
29th AAS Guidance and Control Conference
Beaver Run Resort
Breckenridge, Colorado
www.aas-rocky-mountain-section.org

March 14-15, 2006
44th Robert H. Goddard Memorial Symposium
"80 Years After Robert Goddard's First Rocket Flight: Engineers, Scientists and the Vision"
Greenbelt Mariott Hotel
Greenbelt, Maryland
www.astronautical.org

June 2006 See page 8
***Student CanSat Competition**
Washington, D.C. Area
www.cansatcompetition.com

August 21–24, 2006
***AIAA/AAS Astrodynamics Specialist Conference and Exhibit**
Keystone Resort & Conference Center
Keystone, Colorado
www.aiaa.org

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