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SPACE TIMES

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SPACE TIMES
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ENTERING SPACE

SPACE NEWS

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FEATURES

IN ORBIT

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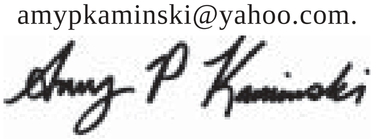
Editor's Message

It is my honor and privilege to serve AAS as the new editor of *Space Times*. I wish to thank Jim Kirkpatrick and the 2003 board of directors for their confidence in my ability to pick up the reins from Roger Launius, who more than ably oversaw the production of fifty-four issues during the past nine years. Indeed, Roger's talents and dedication transformed the magazine into the esteemed professional publication the aerospace community recognizes it as today.

I cannot imagine a better time to be assuming the editorship of *Space Times*. Having just celebrated the 100th anniversary of powered flight, the United States and the world stand at the brink of what promises to be a very exciting year—and future—in space. Within the first two weeks of January, the nation claimed three successes in space exploration: *Stardust*'s rendezvous with a comet, *Spirit*'s landing on Mars, and a presidential announcement committing the country to a sustained human and robotic program to explore the solar system and beyond. Political will and funding provided, the global public will witness a human return to the Moon in the next decade and, ultimately, visits to Mars and yonder worlds. Until then, 2004 should continue to be a banner year in space for still other reasons, including *Cassini*'s arrival at Saturn in July, SpaceX's anticipated first flight of its Falcon small launcher, and the potential for a claim to the $10-million X Prize for the first private, crewed sub-orbital space flight demonstration.

Space Times is published to benefit AAS members. Please let me know what you what you like—or don't—about the magazine and how you think it could be improved. I also welcome your article ideas and contributions. Contact me at amypkaminski@yahoo.com.



Amy Paige Kaminski

President's Message

I want to sincerely thank my fellow members for electing me your president for 2004, the year the Society will celebrate its 50th anniversary as the premier professional society representing the dedicated men and women in academia, government, and industry engaged in the profession of astronautics.

We welcome a new slate of officers and some new, as well as continuing, directors to serve for the next year. Together with our professional executive director and administrative staff, your officers are committed to facing some real challenges in 2004 and leading the AAS into the next half century. This is the time for the AAS to be strong and to lead. I believe that the best years of the AAS lie ahead of us.

In his final president's message and statement of the state of the Society, my friend Bob Lindberg challenged you, the members of the AAS, to take an active role in the society, and on this, Bob was right on. We need to—and we intend to—revitalize our committee structure, speak out on public policy issues critical to our field, and expand our membership, while continuing to hold relevant conferences and publish one of the world's premier technical journals. These things take dedicated member volunteers.

The Society is a proud organization with a bright future. I invite you to enjoy our heritage—and to meet our commitment to astronautics—together. Stay tuned to our web site, www.astronautics.org, and to future issues of this great publication, and you'll find out how we're meeting our challenges and how you can play a role. It's YOUR Society!

Jon Malay

ON THE COVER

This digital still camera image of Cape Hatteras and Cape Lookout, North Carolina, with a Soyuz vehicle docked to the orbital outpost in the foreground was taken in 2003 by Expedition 6 crewmember Don Pettit during his five-and-a-half-month stay on the International Space Station. The largest inland body of water is Pamlico Sound. Kitty Hawk, on North Carolina's Outer Banks is also visible. On December 17, 2003, the world celebrated a century of human flight with the anniversary of the Wright Brothers' first flight at Kitty Hawk. The brothers used the Outer Banks' prevailing winds and a 27-meter hill (Kill Devil Hill) to successfully demonstrate powered flight. (Source: NASA; ISS006-E-50419)

Florida Space Authority Establishes New Facilities at Cape

November was a busy month for the Florida Space Authority, which celebrated the opening of an educational launch facility and a space research laboratory on the Florida space coast. The economic development organization was integral in making both facilities possible.

A November 7 ceremony marked the Air Force's transfer of Launch Complex 47 at Cape Canaveral Air Station to the Authority for use as an educational launch facility. The transfer, through a licensing agreement under the *Commercial Space Transportation Act*, marks a new capability for students to experience a wide range of hands-on operations ranging from launch vehicle test and checkout to payload design and construction.

The Authority will have operational control of the launch pad through a real property agreement with the Air Force. Brevard Community College will be responsible for ground operations, and the University of Central Florida/ Florida Space Institute will be responsible for flight operations.

The Space Life Sciences Lab. (Source: Florida Space Authority)

November 19 marked the dedication of the Space Life Sciences Lab (formerly known as the Space Experiment Research and Processing Laboratory), a partnership between NASA and the state of Florida. "The Space Life Sciences Lab is an outstanding example of a federal-state partnership that is providing a resource for government, commercial, academic and international space research programs," said Lieutenant Governor Toni Jennings. Jennings serves as Chair of the Authority's Board of Supervisors.

The Space Lab, located at NASA/Kennedy Space Center, was completed in August 2003 for $30 million. The state of Florida, through the Authority, built the 9,300-square-meter research lab, which will serve as the primary gateway to the International Space Station for science experiments and house ground-based research in fundamental and applied biological science. NASA's Life Science Services contractor, Dynamac Corporation, is leasing the facility.

The Space Life Sciences Lab serves as the magnet facility for the International Space Research Park being developed by the Authority and NASA at Kennedy Space Center.

The Florida Space Authority provides economic development for Florida through space. Established in 1989 by Florida's governor and legislature to support the retention, expansion, and diversification of the state's space-related industry, the Authority has generated more than $1 billion for Florida's space-related businesses through technology, research, education, finance, tourism and launch. ■

National Air and Space Museum Opens New Annex

The Steven F. Udvar-Hazy Center, a companion facility to the National Air and Space Museum's building on the National Mall in Washington, D.C., opened on December 15. Located at the Washington Dulles International Airport in Chantilly, Virginia, the new facility provides a second location for display of the Smithsonian's flight collection.

Until now, many rare and historic artifacts have been in storage because the Mall building is capable of housing only 10 percent of the museum's aircraft and space objects.

The new center is named for its most generous individual donor, Steven F. Udvar-Hazy, who pledged $65 million for the project. He is president and chief executive of-

Observatory and Communications Company Team to Build Telescope

Lowell Observatory and Discovery Communications, Incorporated, have announced a collaboration to jointly fund and build a powerful new $30-million telescope at the Flagstaff, Arizona, observatory.

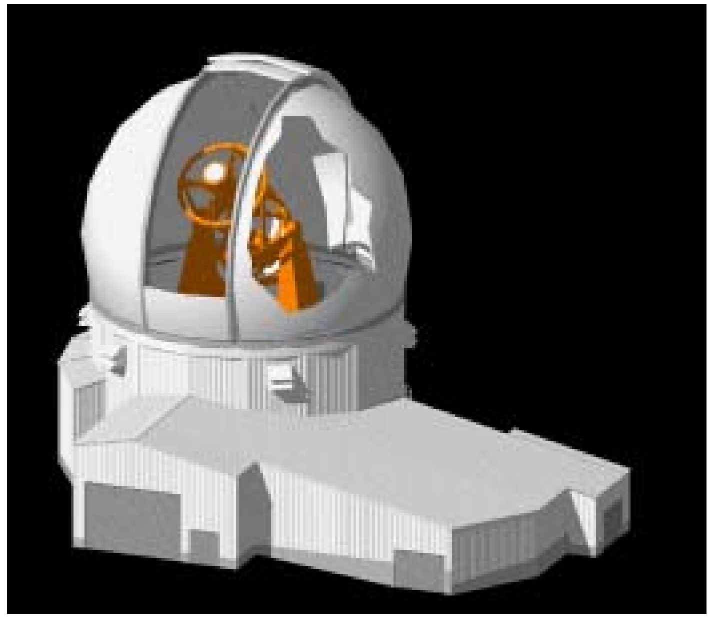
Having a two-degree field of view, the four-meter Discovery Channel Telescope (DCT) will see more sky at once than any existing ground-based telescope of its size, giving it the unprecedented ability to survey the sky at nearly eight times the largest existing survey telescope's capacity. In addition to performing deep imaging surveys in wide-field mode, an alternative optical configuration will allow the DCT to remain effective during bright phases of the Moon. The DCT also will have real-time capability, allowing its images to be simultaneously broadcast around the world.

"Since its founding more than a century ago, Lowell Observatory has been dedicated to astronomical research, particularly the study of our solar system and its evolution, and to sharing that knowledge with the public," said Robert L. Millis, Lowell's director. "The Discovery Channel Telescope will have a considerable impact on the exploration of our solar system and the deep reaches of space."

The DCT will substantially advance the search for near-Earth asteroids, Kuiper Belt Objects, and planets orbiting other stars.

Approximately 2,300 near-Earth asteroids have been discovered in the last decade. The DCT will make it possible to identify not only the same number of potentially life-threatening near-Earth asteroids in just thirty days but also smaller near-Earth asteroids capable of causing regional devastation. Currently, the federally mandated search for near-Earth asteroids focuses on objects larger than a kilometer in diameter that are capable of creating global devastation.

Similar results are expected in the search for Kuiper Belt Objects, of which only 863 have been identified. They



A computer-generated conceptual rendering of the enclosure that will house the Discovery Channel Telescope. (Source: Lowell Observatory)

can range in size from that of large asteroids to objects of Pluto's size.

Construction on the DCT is expected to begin in fall 2004, with completion in 2008.

Percival Lowell, who was determined to prove the existence of life on Mars, founded Lowell Observatory in 1894. Significant achievements made at Lowell include the discoveries of Pluto and the first evidence of the universe's expansion. Discovery Communications, a leading global media and entertainment company, owns the Discovery Channel along with 32 other programming networks in more than 155 countries and territories. ■

ficer of International Lease Finance Corporation, a worldwide commercial aircraft-leasing company.

The total project cost—for design, site infrastructure, construction, move-in and start-up—is approximately $311 million. Congress mandated that only non-federal funds be used for the center's construction. The museum still needs to raise $90 million.

Unlike traditional museum galleries, the Udvar-Hazy Center displays artifacts in an open, hangar-like setting. When the entire facility is completed, more than 200 aircraft and 135 large space artifacts will be exhibited on 70,600 square meters of space.

Continued on page 23

The American Astronautical Society is proud to present our recently elected officers and board members

INTRODUCING THE AAS OFFICERS:

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FRANCESKA O. SCHROEDER (Legal Counsel) – Partner, Washington, DC, office of Pillsbury Winthrop LLP

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MICHAEL M. WATKINS – Manager, Navigation and Mission Design Section, Jet Propulsion Laboratory *Appointed by the President to fill a vacancy on the Board.*

20

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Shuttle Accidents: Patterns and Parables

The Challenger *and* Columbia *tragedies bear striking similarities. NASA should apply the common lessons learned to all future shuttle missions.*

by Stephen P. Waring

The parallels between the *Challenger* and *Columbia* accidents are haunting. Before the tragedies, some engineers worried about hardware safety. Before *Challenger*, their concern was damage to O-ring seals in the joints of the solid rocket motors; if the seals failed and hot exhaust gases penetrated the motor case, the vehicle would be destroyed. Before *Columbia*, they worried about insulating foam from the external tank shedding and hitting the tiles of the orbiter's thermal protection system; if hot gases infiltrated the protection system during re-entry, the orbiter would breakup. In both cases, engineers had been aware of these possibilities for years, having observed charred O-rings and shedding insulation on earlier shuttle flights. But for the most part, these incidents were dismissed as "acceptable risks" because they had never resulted in safety problems for the missions.

In eleventh hour meetings, some engineers expressed concerns about these problems. Before *Challenger's* launch, they worried about the freezing launch weather and whether the rubber O-rings would retain enough resilience to seal the joints. Before *Columbia's* re-entry, they worried about whether a fallen, suitcase-sized piece of foam had pierced the thermal protection system of the orbiter's left wing. In both cases, engineers were pessimistic in face of new circumstances, and managers were optimistic because of past success. In both cases, the senders and receivers of the warnings did not communicate effectively: managers who heard the warnings were not convinced of their significance and took no action to stave off disaster.

After the accidents, events also proceeded similarly. NASA and contractor teams tried to isolate the technical causes of the disasters. Independent commissions explored the organizational context underlying the tragedy. Journalists and pundits offered explanations and panaceas in an outpouring of writing about the accidents.

Years later, *Challenger* remains a well-researched topic. Investigators from diverse fields (including yours truly) have written about *Challenger*, drawn by the complex events that preceded the disaster and the possibility of applying a variety of discourses from ethical to social to technical. Journalists have recounted individual action and have focused on whistle-blowers, victims, scapegoats, guilt, suffering, scandals, and misspending; academics have narrated complex social interactions based on bureaucratic hierarchy, social structures, professional cultures, and unanticipated consequences.

The foam that struck Columbia*'s wing came from the bi-pod ramp, the twin attachment struts under the nose of the orbiter. (Source: NASA)*

Columbia is already inspiring research and comparison and contrast studies. Assuming that a scholar could offer a long-range perspective, the *Columbia* Accident Investigation Board chose as one of its members John Logsdon, an eminent social scientist who specializes in space history and policy. Also, the commission called as expert witnesses some accident academics, most notably sociologist Diane Vaughan, author of the acclaimed book: *The Challenger Launch Decision.*

The accidents produced similar patterns of interpretation. One view was that NASA had insufficiently funded shuttle safety. In years before both accidents, for example, the agency had cut numbers of safety officials, thus reducing independent monitors of the shuttle. If more safety officials had been onboard to identify the risks and raise concerns, perhaps the accidents could have been prevented. Moreover, NASA had not always funded upgrades in hardware: examples include the protracted study without development of a redesigned field joint (similar to the one in use now) before *Challenger* and the cancellation of a redesigned auxiliary power unit for the orbiter before *Columbia*. NASA had made its budget choices believing that leaner safety programs were still safe and that new hardware was expensive and might introduce new, unknown risks. By not buying all the safety it could, however, after the accidents NASA appeared not only penny-wise and pound-foolish but also negligent.

Another accident explanation held that NASA had recklessly ignored safety warnings. A long history of problems preceded each disaster, and at various times some engineers and managers expressed safety concerns. The facts seemed obvious: engineers observed, studied, and reported technical anomalies, but managers did not ensure that problems got fixed. To some, individual managers seemed culpable. But other critics reached the conclusion that NASA was a "bureaupathological" organization, having management and engineering cultures that too often experienced breakdowns in communications and risk assessment. After the second accident in less than twenty years, theories about organizational sickness convinced many.

Key evidence that a field joint on the right solid rocket motor had leaked before the Challenger *incident was this image of a puff of gray smoke, seen in the lower right. (Source: NASA)*

What Happened?

My own research on *Challenger* makes me doubt that NASA as an organization was, or is, sick. NASA and the shuttle program are very complex organizations. The shuttle is very complex hardware. Shuttle engineers have worked for years studying and reporting technical problems, and so a vast documentary record stretches back to the program's origins. Experts have often disagreed in their assessment of risks, and therefore the record has both assurances and warnings about risk. After an incident, investigators can easily find documents that seemingly "prove" that officials ignored warnings.

But isolating cases of what now seem like prophetic warnings can lead to the false assumption that managers deliberately ignored clear and correct signals of danger. How realistic is it that professional managers on the highly visible stage of the space program would recklessly dismiss valid engineering concerns? A more complete inspection of the evidence shows engineers verifying the safety of the solid rocket motor joints and the external tank foam. The record also reveals NASA managers usually deliberating carefully, weighing contradictory perspectives raised by engineers, and making decisions based on established, well-considered—but occasionally mistaken—technical rationales.

If NASA's organization seems reasonably healthy, how can we explain the accidents? How could managers keep flying hardware knowing about leaky joints and flying foam? Shuttle engineers and managers do not make decisions based on opinions of a single expert. They rely on technical rationales based on a campaign of models, tests, statistics, and flight experience and developed through formal reports and meetings of overlapping and cross-checking teams. Tests are overwhelmingly important in assessing the value of a design. Before the shuttle's first flight, engineers conducted rigorous tests. The solid rocket motors underwent pressure tests, dynamic tests, and full-scale static firings. The external tank foam underwent a battery of tests, including analyses of its impact on the orbiter's tiles. To the experts, these tests verified the safety of the designs.

The shuttle flights were also tests. Engineers had observed charred O-ring seals and foam chunks hitting the orbiter and conducted more tests. They devised sub-scale rigs to check the joints and O-rings and conducted more full-scale static firings. Engineers also devised experiments, including tests using sports cars, super-sonic wind tunnels, vacuum chambers, jet fighters, and cannons that fired small foam chunks at tiles. The test programs yielded similar results: although deemed imperfect, the designs were considered safe. The motor teams concluded that properly assembled joints had sufficient margin and that in a worst case scenario the O-rings would seal; the current design was safe to fly while they worked on a redesigned joint. Likewise, the foam and tile engineers determined that the foam pieces that flew off would be small, only hitting the tiles in glancing blows that would not damage the orbiter's structure; they intended to improve the foam but, too, did not believe they were dealing with an unsafe design.

Unfortunately, even on designs with a long history, engineering knowl-

ABOVE: *After the* Columbia *accident, investigators recovered debris and laid them out on a grid to show their location on the vehicle. They then studied the pieces to learn about the failure. (Source: NASA)*
BELOW: *One reason the design weaknesses in the field joints of the solid rocket motors went undetected before the* Challenger *accident was the packing of extra putty in the joints before test firing. (Source: NASA)*

edge is often incomplete. Veteran aerospace engineers often say they know more after a failure than they did before. A failure reveals design deficiencies. In retrospect, the shuttle teams did not know the limitations of their designs because their tests had not been realistic and so yielded misleading information. Understanding of the motor joint and seal weaknesses was crippled by the static test articles' configuration. The motors were fired horizontally, leaving the heavy propellant to slump down, distort the cases, and create gaps in the joints. The motor engineers crawled up the hollow core of the motor and packed in extra putty to protect the joints, reasoning that the slumping would not occur in vertical launch configuration. Unfortunately, the putty masked the weaknesses in the joint design.

Similarly, the foam and tile tests also showed limitations. Engineers had tested for small, light pieces of foam debris hitting the tiles. They had not anticipated that a heavy, ice-laden chunk could fall off, hit the leading edge of the orbiter wing, and severely damage the reinforced carbon-carbon panels. After each accident, the engineers devised more realistic tests, which further revealed gaps in their knowledge.

Moreover, in both cases, the shuttle teams' analyses of anomalies were flawed. Before each accident, shuttle engineers had developed computer programs based on test and flight performance to enhance their confidence in their designs. In retrospect, however, these programs had no predictive value: they used historical records from the small number of shuttle flights and from hardware anomalies that had caused no catastrophic failures. With such a restricted database, the programs could not predict future events outside the realm of past experience and so gave overly optimistic risk assessments.

Richard Feynman, the Nobel-prize-winning physicist who served in the *Challenger* investigation, colorfully diagnosed this analytic flaw. He argued that shuttle engineers and managers had perceived successful flights with anomalies as signs that their designs were safe rather than as warnings of potential catastrophe. After the shuttle flew and nothing disastrous happened, the shuttle team assumed the risk was not so high for the next flight. "When playing Russian roulette," Feynman wrote, "the fact that the first shot got off safely is little comfort for the next."

In her book on *Challenger*, Diane Vaughan put a sociological spin on this phenomenon, calling it the "normalization of deviance." The flight anomalies—charred O-rings and scarred tiles—violated technical requirements, but because the problems did not appear dangerous, engineering teams accepted deviant performance as normal. Rather than limiting her point to engineering technique, Vaughan used it to question the social system in which NASA operates. Congresses and Presidents had imposed limited budgets, tight schedules, and efficiency procedures on NASA. Consequently, shuttle teams had regularly accepted flawed designs in order to keep the shuttle up and costs down. After *Columbia*, Vaughan testified before the investigating board, receiving much favorable publicity.

Preventing Future Accidents

Academic views about *Challenger* and how to avoid "normal accidents" had considerable influence on the *Columbia* report. Vaughan found it difficult to imagine an alternative social system for NASA. Imagining that Congress and the President might reinvent NASA with open budgets and schedules and no efficiency procedures is indeed hard. NASA has taken steps to reorganize its flight safety functions, establishing an independent safety center at Langley Research Center. The stated intention was to give safety officials more independence so they could better see patterns of problems and misanalysis and prevent the "normalization of deviance." Indeed, a goal was to put responsibility for technical decisions with engineers outside the normal flight management chain.

The plume of flame from Challenger*'s right solid rocket booster indicated the failure of the field joint. (Source: NASA)*

After *Challenger* NASA tried to form an independent safety organization with mixed success. Shuttle engineers received safety seminars, and managers attended charm schools intended to make them better listeners. The increased oversight created a more complex and expensive safety organization with more reviews and reports. Highly skilled engineers, more interested in designing and building than monitoring, were not attracted to safety functions, and so the safety staffs gained a reputation as a repository for the less technically skilled. Moreover, the safety organization typically conducted no independent hardware tests and worked with the same data as the flight engineers, raising the question of whether safety officials, however independent, have better insight than flight officials or hardware engineers. Can they better separate sound technical recommendations from the unsound, safe hardware from the dangerous? Undoubtedly, the reorganization of flight safety after the first shuttle accident helped NASA regain credibility with Congress and the White House. We can only hope the current reorganization will help NASA make a third accident impossible without becoming too much of a financial and managerial burden.

The *Columbia* report made another recommendation that seems more likely to prevent space flight accidents than reshape NASA's organization. In advice buried in the report, the commission recommended that NASA replace the shuttle with another launch vehicle. While extra margins of safety may be gained through redundant reporting channels and independent safety managers, such changes cannot make up for a deficient design. Looking back on both accidents, one cannot help but conclude that the shuttle's design put the crew in danger, particularly by piggybacking the orbiter on the external tank. In several new vehicle designs, the crew cabin sits on top of the propulsion stack. If the orbiter had ridden on top of its stack, *Challenger* might have escaped a leak, and *Columbia* would have been above the flying foam.

I have learned many lessons from reading shuttle documents and talking to space engineers and managers. The lessons are less sociological and managerial and more technical, even methodological. The morals may seem too simple for so complex a machine, too trite for a public tragedy. But in space engineering, things simple to conceive are difficult to realize, and arcane advice is little solace in death's aftermath. The lessons include: always design with margin, test under realistic conditions, study even innocuous problems, and never assume that success with anomalous performance indicates low risk. ■

***Stephen P. Waring* is associate professor of history at University of Alabama-Huntsville and co-author of *Power to Explore: A History of the Marshall Space Flight Center* (NASA SP-4313, 1999).**

All of the Planets, All of the Time: Planetary Protection at NASA

Keeping the solar system clean is a top priority for NASA in planetary exploration.

by Linda Billings and John Rummel

Planetary protection made the news in the fall of 2003 as NASA's Galileo mission to Jupiter neared the end of its life. Earlier, mission managers had altered plans for the mission's end to ensure that the Galileo spacecraft would burn up in the planet's atmosphere and not accidentally crash on one of the Jovian moons believed to potentially harbor life. The Jovian system was not known to be a promising site for evidence of extraterrestrial life when Galileo was launched in 1989. But in the course of its mission, Galileo collected data indicating that liquid oceans might exist beneath the frozen surface of Jupiter's moons Callisto, Europa, and Ganymede. In order to preserve the pristine conditions at these sites for future astrobiological exploration, NASA triggered planetary protection measures at the end of Galileo's mission.

While the end of Galileo may have marked the first time many space observers had heard about it, the policy and practice of planetary protection go back to the beginning of the Space Age. Planetary protection is NASA's term for protecting solar system bodies from Earth life, while protecting Earth from life that could be brought back on sample-return missions from other solar system bodies. Over the past decade, scientists have made great progress in learning about locations on or beneath the surface of other planets and moons where indigenous life might thrive.

The U.S. *Apollo* and Soviet *Luna* missions of the 1960s and 1970s established a precedent of returning extraterrestrial materials to Earth, a practice continued in current comet and asteroid sample-return missions. And in the not too distant future, spacefaring nations may begin retrieving samples from the Martian surface and subsurface. Planetary protection measures for these missions will be stringent: requirements have already been established to prevent the backward contamination of Earth by possible extraterrestrial life and the forward contamination of Mars and other bodies by terrestrial microbes carried aboard visiting spacecraft. A major goal of planetary protection against forward contamination is to preserve the planetary record of natural processes by preventing human-caused microbial introductions. Such introductions would be most likely to cause harm on those planetary bodies that show evidence of materials and environments that support life as we know it and thus might also support any Earth life transported to those bodies—Mars and Europa, for example.

While a primary focus of NASA's solar system exploration program is the search for evidence of life on Mars, the agency's current approach to planetary protection is "all of the planets, all of the time." NASA's planetary protection policy goals are to ensure that: (1) all of its solar system exploration missions take precautions against forward and backward contamination; (2) the agency's planetary protection procedures and requirements are in tune with the latest relevant scientific findings; (3) advanced technologies continue to be developed and applied to meet evolving planetary protection requirements; and (4) the agency continues to coordinate with other national and interna-

Technicians swab small surfaces on one of the Mars Exploration Rovers in order to document any microorganisms that the spacecraft may carry with it to Mars. (Source: NASA/JPL) tional agencies on planetary protection issues and implementation.

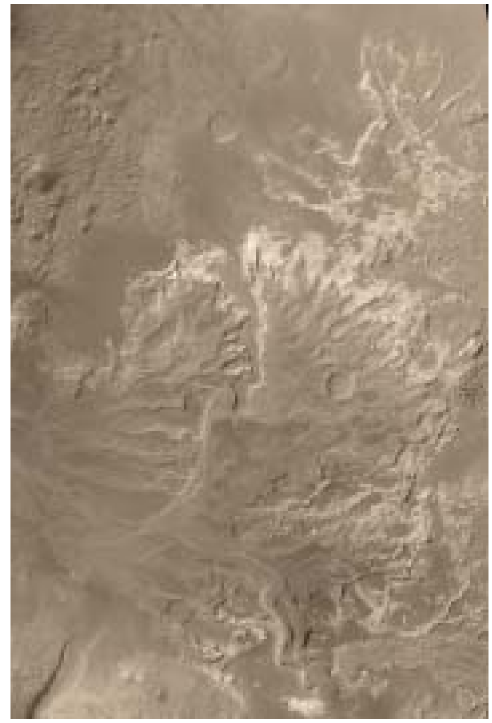
After the launch of Sputnik, the International Council of Scientific Unions (ICSU) introduced planetary quarantine standards for solar system missions, and the U.S. National Academy of Sciences (NAS) recommended that NASA institute non-contaminating space exploration practices. Article IX of the 1967 United Nations Outer Space Treaty also specified that solar system exploration missions should avoid forward and backward contamination. Today the ICSU Committee on Space Research (COSPAR) is the focal point for international standards for planetary protection, and the Space Studies Board (SSB) of the National Research Council (the operating arm of the NAS) is NASA's primary external advisor on planetary protection policy and practices.

NASA's Associate Administrator for Space Science is in charge of planetary protection at the agency, and the Planetary Protection Officer in the Office of Space Science (one of this article's co-authors) oversees policy and procedures and assigns requirements to each mission. Solar system missions are categorized according to the type of encounter they will have—flyby, orbiter, lander—and the nature of their destination. The Planetary Protection Officer may seek recommendations on requirements from the SSB and elsewhere, including the NASA Advisory Council's Planetary Protection Advisory Committee. The SSB has provided advice to NASA on planetary protection requirements for Mars and Europa exploration missions and also sample returns from a variety of small solar system bodies such as moons, comets, and asteroids.

From Viking to the Present

The golden rule of planetary protection is "keep it clean." NASA cleaned its Mars landers for the Viking missions of the 1970s until their total surface bioburden was less than 300,000 bacterial spores, with fewer than 300 bacterial spores per square meter. After cleaning, each lander was packaged in a fully enclosing "bioshield" (resembling a large casserole dish) and baked in an oven to obtain a temperature of 111.7 degrees Celsius for 30 hours in a dry-heat sterilization procedure. Since Viking and subsequent Mars observations revealed that Mars is harsher than previously thought, NASA revised its planetary protection standards for Mars lander missions in the 1990s. The agency established the Viking presterilization bioburden standard as the requirement for Mars landers not attempting life detection experiments and the full Viking standard as the requirement for life detection missions.

Scientists now know that terrestrial microorganisms are tough: some are able to survive in the space environment as well as in extreme Earth environments such as deep-sea hydrothermal vents, Antarctic rocks, and regions more than three kilometers beneath the continental surface. These Earth environments may have analogs on other solar system bodies—Mars, for example. The surface of Mars is cold and dry today, but conditions on the planet may have been much like those on Earth early in solar system history. And Martian subsurface conditions are and may have been quite different than those on the surface. If life ever evolved on Mars, it could have originated independent of life on Earth—or not. Researchers have examined the potential for a natural interplanetary transfer of microorganisms by the high-velocity ejection of soil and rock resulting from planetary impacts by comets and other small bodies. They have concluded that if microbes have ever existed on Mars, their viable transfer to Earth would be not only possible but also highly probable. Viable transfer of Earth life to Mars is also believed to be possible.



Recent images suggest that liquid water once flowed on Mars, possibly providing a haven for life. (Source: NASA)

For planetary protection purposes today, a spacecraft going to a target body that has the potential to provide clues about life or prebiotic chemical evolution must undergo stringent cleaning and sterilization processes. Planetary protection techniques applied to spacecraft bound for Mars, for example, currently include clean manufacturing processes for spacecraft components and cleanroom techniques during spacecraft assembly, test, and launch operations. NASA also employs bioload reduction methods such as alcohol wiping, dry heat treatment, and hydrogen peroxide sterilization. Radiation treatment is an option in some cases. Though cultivation-based microbial assays are still NASA's standard method of measuring spacecraft bioburden, characterization of biological contamination keeps improving, especially since the advent of molecular-level methods of analysis. Molecular detection methods such as Limulus amoebocyte lysate assay, polymerase chain reaction, and adenosine triphosphate measurement may also be employed to characterize bioload.

Surface cleanliness is the greatest planetary protection challenge for Mars-

Technicians conduct preflight processing on one of the Mars Exploration Rovers under clean room conditions. (Source: NASA/JPL)

bound spacecraft. While the dryness and intensity of ultraviolet radiation make the growth and spread of Earth microbes unlikely in Martian equatorial regions, missions to Martian polar regions may warrant more stringent requirements. Europa, while having virtually no atmosphere and a radiation environment that could kill any exposed Earth organisms on a spacecraft, presents a different challenge. Europan radiation may not necessarily reach organisms buried deep within the shielding of a spacecraft and does not penetrate deeply into the moon's ice cover. Thus, spacecraft bound for Europa will have to be cleaned from the inside out. But the real concern about Europa is the introduction of microbes into the ocean that lies beneath the icy surface: a single such introduction could cause global contamination.

Planetary protection requirements for Europa may be met in part through mission design. At the end of a mission, for example, a spacecraft orbiting Europa could be placed into a long-term orbit so that radiation in the local space environment would eliminate any Earth organisms onboard. For landers—especially those with onboard nuclear power sources capable of melting frozen water upon contact with the ground—a higher level of cleanliness will be required.

Mission Categories

NASA and COSPAR have established five categories of planetary protection, defined by the nature of the mission to be launched and the target body to be studied. Category I missions, which include any missions to the Sun, Mercury and Pluto, require no planetary protection procedures. Category II missions are those for which the target body is of interest for studies of organic chemical evolution and the origin of life but where contamination by Earth organisms is not a concern because conditions do not appear conducive to supporting Earth life. These missions must document spacecraft trajectories, inventory onboard organic materials, and possibly provide for the archival storage of certain spacecraft materials. Category III missions include those to fly by or orbit planets that might now support, or in an earlier era might have supported, indigenous life and where Earth life might be able to survive. These missions apply Category II requirements plus other restrictions such as spacecraft operating constraints (for instance, trajectories or orbital lifetimes planned to avoid impact with the planet or limitations on a spacecraft's viable bioburden). Category IV missions, those intended to make direct contact with Mars, may be required to meet all Category II and III requirements plus more severe restrictions on biological contamination, possibly including comprehensive decontamination and sterilization of the spacecraft.

Category V missions include both unrestricted Earth return missions, with no additional planetary protection requirements imposed on the missions' return portions, and restricted Earth return missions. For unrestricted Earth return missions, science and mission safety requirements address concerns about sample return, landing site targeting and retrieval, and sample condition. For restricted Earth return missions, the primary challenge is to devise a return sample containment system that provides a containment reliability perhaps as high as 0.999999 while meeting mass and cost constraints. The cost of meeting stringent Category V requirements on a Mars sample return mission is estimated at about 5 to 10 percent of the project's budget.

Future Challenges

NASA has more than a dozen solar system exploration missions in development or underway for which planetary protection is a consideration. Other spacefaring nations are launching their own solar system missions, and the number of nations engaging in solar system exploration is rising.

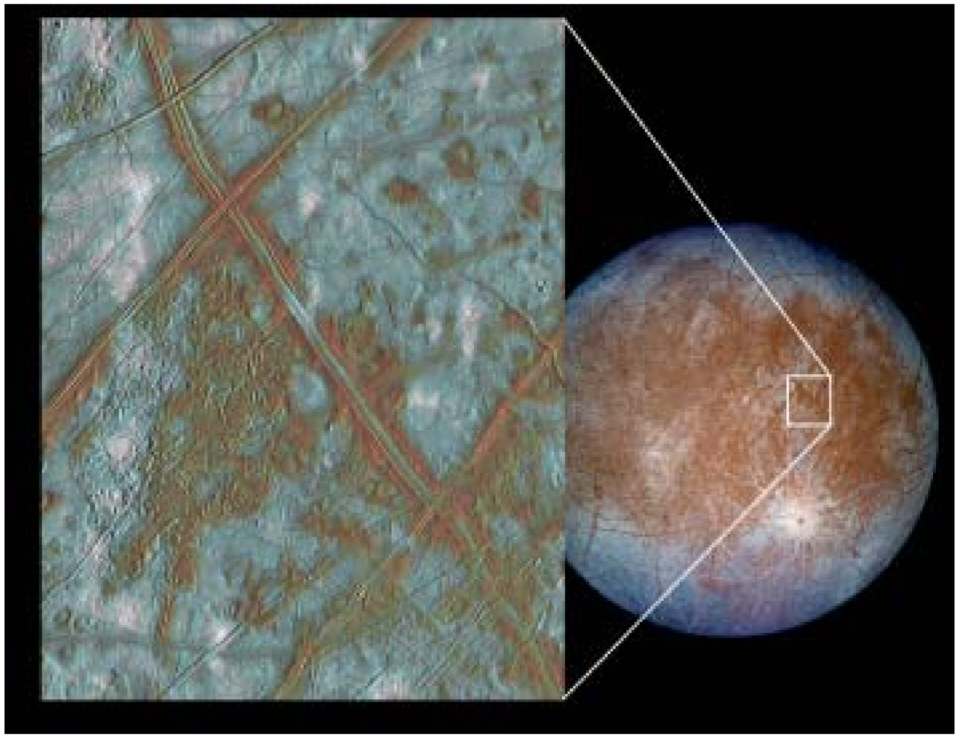
Planetary protection requirements for Mars sample return are drawing considerable attention. The SSB has recently urged NASA to launch its first Mars sample return mission as early as 2011 and to proceed immediately with planning and developing a Mars sample handling facility. NASA is considering the option of launching a Mars sample return mission by 2013. Accordingly, planetary protection specialists at the

Jet Propulsion Laboratory are in the beginning stages of planning a sample handling facility that would receive, analyze, and distribute Martian materials. The facility would be designated Biosafety Level (BSL)-4, the U.S. government's strictest safety requirement for facilities dealing with biological agents. The development of government-funded BSL-4 laboratories for biodefense research may yield useful information for this planning process.

Other factors will have to be considered to ensure pristine Martian samples. Research should be initiated now, according to the SSB, on questions that will affect Mars sample handling facility design, such as how to combine biological isolation with clean-room conditions. The SSB also called for the development of more sensitive life detection techniques and new techniques for collecting, packaging, and returning samples. NASA's Office of Space Science currently sponsors research on new life detection techniques and sample processing methods.

With Mars mission planning tentatively calling for sample return missions starting in the second decade of this century, NASA, with participation and support from the Centre National d'Etudes Spatiales (CNES, the French space agency) has developed criteria for Mars sample handling. These criteria are described in "A Draft Test Protocol for Detecting Possible Biohazards in Martian Samples Returned to Earth," specifying tests and procedures needed to safeguard samples against contamination. This sample return protocol will remain in draft form and be subject to updating until shortly before the first Martian samples are returned to Earth.

Questions about life and the need for planetary protection will continue to define the acceptable range of NASA solar system missions. As knowledge of the solar system grows and exploration moves forward, implementation of planetary protection policies and practices will grow more precise, guided by knowledge of our potential to contaminate other planetary bodies and the ability to measure and control it—and by the continuing quest to find extraterrestrial life.



This Galileo image of Europa shows evidence of subsurface liquid water—a possible abode for life. (Source: NASA)

Linda Billings **is a research associate with the SETI Institute and is currently conducting science communication studies for NASA's Planetary Protection Office.**

John D. Rummel **is NASA's Planetary Protection Officer and is based NASA Headquarters in Washington, D.C.**

AAS News & Conference Information

The AAS wishes to acknowledge a generous holiday donation from Dr. Horace Ngan in memory of his beloved mother, Lady Mamie Y.M. Ngan.

The Goddard Memorial Symposium returns to the Greenbelt Marriott on March 16-17, 2004. Program details will be posted on the AAS web site.

A complete report on the AAS 2003 National Conference and 50th Annual Meeting will be published in the next issue of *Space Times*. All of the presentations and an uplifting video ("Thank God Dreams Survive") have been posted on the AAS web site.

Microsat Launchers: The New Generation

A revolution in small satellite launch vehicles is beginning to take place in the United States.

by Matt Billie and Robyn Kane

On August 12, 2003, the crowd of 500 people at the annual Conference on Small Satellites gave their full attention to a man who had no formal background in space and had not yet been born when Neil Armstrong stepped onto the Moon. The speaker, Elon Musk, launched into a briefing peppered with lucid explanations of rocket technology and references to lessons learned going back to the days of Redstone and the original Atlas. He was proposing to solve the problem that has bedeviled small satellite owners and operators since the Space Age's dawn: the absence of a low-cost American small launch vehicle.

Musk's start-up corporation, Space Exploration Technologies (SpaceX), is one of several companies and government agencies currently attacking what has been an intractable problem. The lack of an affordable, responsive, and reliable small launcher–what, for convenience, we call the microsatellite launch system (MLS)–has plagued the American small-satellite community. Rides on dedicated vehicles may cost $20 million or more, while shared space is hard to find and schedule. Add the difficulties of exporting satellites from the United States, plus legal restrictions on using foreign launchers for government-sponsored payloads, and it is easy to see why American microsatellite ("microsat") owners and operators–government, private, scientific, and academic–feel incredibly frustrated. An American MLS is long overdue. Fortunately, it just might become reality.

A Long-Standing Problem

Several private efforts to build an MLS, generally focusing on cheap expendable launch vehicles, have failed, as did the government's much-touted Bantam launch vehicle effort in the 1990s. It is important to define a microsat launcher. The definition NASA used for its Bantam Low-Cost Boost Technology program was a vehicle capable of lifting 150 kilograms into polar low Earth orbit (LEO). This capability would accommodate most research microsats, clusters of smaller "nanosatellites," and many military and commercial satellites. Accordingly, the Bantam definition is a good starting point.

The first American launch vehicles, Vanguard and Jupiter C, were microsat launchers. When measured by the common standard of cost-per-kilogram placed in orbit, they were very inefficient. They could lift less than 30 kilograms to LEO and had success records of only 50 percent. Aerospace companies designed ballistic missiles and the space launchers derived from them to emphasize low weight and maximum payload–a formula not conducive to low cost for an expendable machine built in relatively small quantities.

The microsat market became less important to American launch vehicle makers as satellites grew larger, and by the 1980s, the only small American launch vehicle, NASA's Scout, was nearing the end of its career. The Defense Advanced Research Projects Agency (DARPA) contracted with Orbital Sciences Corporation to use its small launcher, Pegasus. The air-launched Pegasus boasts a reliable design, but predictions of flights costing as little as $6 million have proven overly optimistic. The current Pegasus XL is able to launch over 280 kilograms into polar LEO but has a price tag of over $20 million, putting it beyond the reach of most academic institutions and many government programs. In 2003, Futron Corporation performed a space markets study for

Sprite small launch vehicle. (Source: Microcosm)

NASA and found that the size of the small payload market has been much more strongly affected by launch costs than have larger payload markets.

Indeed, the unavailability of a low-cost MLS has had substantial impacts on those who operate or desire to operate microsats. The DoD's Space Test Program can afford to launch only 20 percent of the payloads approved by its Space Experiments Review Board. Two Air Force microsats, PICOSat and XSS-10, were delayed for years by lack of launch opportunities. The ten-satellite DoD-University Nanosatellite Initiative, originally planned for launch in 2001, has decomposed into three missions with no firm launch dates. Many proposals for other microsats, including commercial ventures such as KitComm, have evaporated or have stalled short of the hardware stage, due in part to the difficulty of securing a launch platform.

Universities, too, have been affected. The University of New Hampshire's CATSAT and the student-built Starshine 4 and 5 are sitting in storage with an uncertain future. NASA's University-class Explorers program was suspended in large part due to launch costs. As Daniel Baker, director of the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder, maintains, the lack of affordable small launchers is choking the development of the next generation of engineers and space scientists. Futron found that university-sponsored small science payloads would likely increase in number if launch prices fell modestly. The study also concluded that a 75-percent decline in the cost of launching small payloads would trigger more than a 200-percent increase in flights through 2021.

Small Launcher Development Efforts

Over the past 20 years, there have been several efforts to build smaller, cheaper American launchers. During the 1980s and 1990s, these efforts met only with adversity. In 1981 Space Services, Incorporated, began work on the liquid-fueled Percheron. Investment faded after the first vehicle exploded during a static test. A similar fate befell EER Systems a decade later, when the first Conestoga rocket failed. Pacific American Launch Systems, founded in 1982, developed the Liberty to place a 220-kilogram payload into polar LEO for $2.5 million but failed to secure financial backing. In 1988 MicroSat Launch Systems partnered with Canada's Bristol Aerospace in a venture called Orbital Express. Again, firm deals proved elusive, and the venture died in 1993. AeroAstro explored the launch services market with its PA-X launcher, but the vehicle never demonstrated economic feasibility, and the project ended in 1995. In 1997 NASA tried to break the logjam with Bantam but canceled the initiative when none of the companies receiving study funds could meet the goal of limiting recurring marginal cost per flight to $1.5 million.

Past failures, however, have not prevented entrepreneurs and government agencies from rallying in recent years to the challenge of MLS development. The following projects exemplify the renewed recognition of small launchers' value:

- **Microcosm Sprite.** This launcher has been partly funded through the Air Force Research Laboratory (AFRL). The program's goal is a modular design (the orbital launcher has seven identical propulsion "pods"), lofting 220 kilograms into polar LEO for an estimated $2.5 million ($11,000 per kilogram) price. Microcosm chose a pressure-fed liquid-fuel rocket, using liquid oxygen and kerosene in high-pressure composite tanks. Assuming continued funding, the first orbital flight could occur by 2006.

ABOVE: *The EER Conestoga vehicle on the launch pad. (Source: EER Space [company no longer exists])*
BELOW: *SpaceX Falcon small launch vehicle. (Source: SpaceX)*

- **SpaceDev Streaker.** Space Dev, a small satellite builder, has Air Force funding for early development of this launcher, which can lift 315 kilograms to polar LEO. The total price of launch is expected to be under $10 million ($32,000 per kilogram). SpaceDev en-

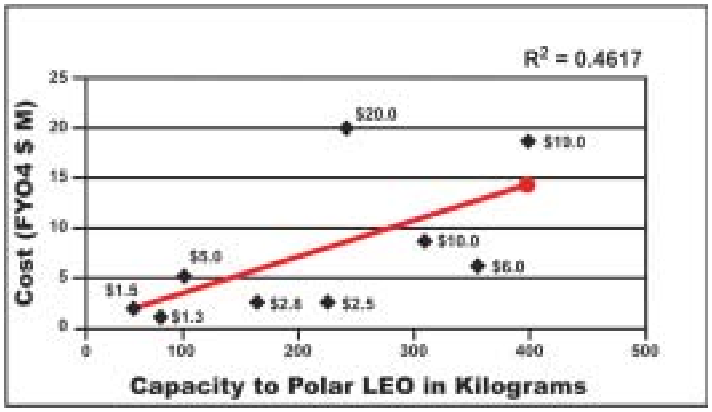


Figure 1: Weight versus cost (including flight-proven systems)

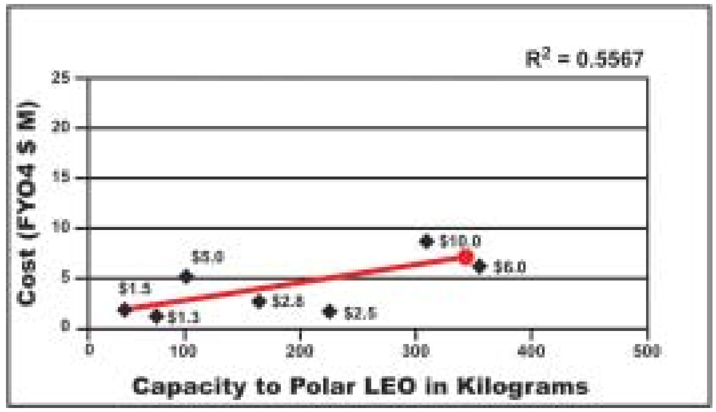


Figure 2: Weight versus cost (excluding flight-proven systems)

gineers claim to have redesigned the hybrid rocket motor (historically viewed as inefficient) to produce an efficient, low-cost propulsion system for this vehicle.

- **SpaceX Falcon.** Musk's SpaceX is relying on its own liquid-fuel design with a recoverable first stage for its Falcon small launcher, whose capacity is about 350 kilograms to polar LEO. The company has benefited from a steady financing source: the private investment of founder Musk. SpaceX is offering a firm price of $6 million per launch ($17,000 per kilogram) and has three customers signed. Musk predicts four or five launches a year can be sold at that price to DoD and NASA. The first launch from Vandenberg AFB is slated for this March.
- **AFRL vehicle.** AFRL has proposed a very small vehicle that could be launched from an F-15E fighter. The three-stage, solid-fuel launcher would be able to orbit up to 100 kilograms. The laboratory is currently focusing on a version that uses off-the-shelf motors and would cost about $5 million per flight ($50,000/kilogram).
- **DARPA RASCAL.** DARPA is funding the Responsive Access Small Cargo Affordable Launch (RASCAL) project. RASCAL will use a custom-designed Mach 3 aircraft with thrust-augmented jet engines as a reusable first stage. An expendable upper stage will be released above the atmosphere. The idea is to orbit up to 110 kilograms at $11,000 per kilogram. The development contract went to Space Launch Corporation, which will develop technology both for RASCAL and a private version, the SLC-1. DARPA expects the first RASCAL flight to occur in 2006.
- **Air Force/DARPA FALCON.** The Air Force is joining DARPA in acquiring a responsive, low-cost small launch vehicle (SLV) under the project name FALCON (Force Applications and Launch from the Continental United States), of no relation to SpaceX's vehicle. The SLV will launch sub-orbital test vehicles for DARPA's hypersonic technology effort and global conventional strike as well as place microsats in orbit. The project goal is a small launcher costing under $5 million per flight. Study contracts were let to nine firms in November 2003.

How Inexpensive is Affordable?

What is technically and financially practical in small launcher costs? What price level is necessary to allow launch of the current backlog and also encourage expansion of the American microsatellite industry and market?

In an effort to answer these questions, we conducted a study in the summer of 2003. We obtained cost estimates for nine small vehicles. The two flight-proven systems, Pegasus and Minotaur, cost approximately $20 million and $19 million per flight, respectively. These figures, along with the estimates from seven developers of new vehicles, are shown in Figure 1. Range costs, launch licensing, and use of a flight termination system acceptable to range safety authorities add approximately $1 million to the launch price of any American-launched MLS, regardless of size. This base is included in all price estimates in Figure 1.

It is important to remember that cost is not the same as efficiency, and the difference is stark with small launchers. The most efficient way to launch a satellite is to use a launcher appropriately sized for the payload. Measured in dollars per kilogram, a large launch vehicle appears cost effective but often is not so in reality, at least from the payload developer's perspective. Microsat builders need low per-launch costs, which may involve a launcher that is, by the per-kilogram measure, very inefficient.

In Figure 1, the correlation coefficient, R, measures the strength and direction of the relationship between vehicle cost and capacity. The coefficient of determination, R^2, represents the proportion of variance in cost that is attributable to weight. For the nine pairs of data, there is a medium positive, linear correlation between weight and cost within the bounds of these data, with 46 percent of the variation in cost being explained by weight. Interestingly, if the two flight-proven vehicles are removed, the graph takes a

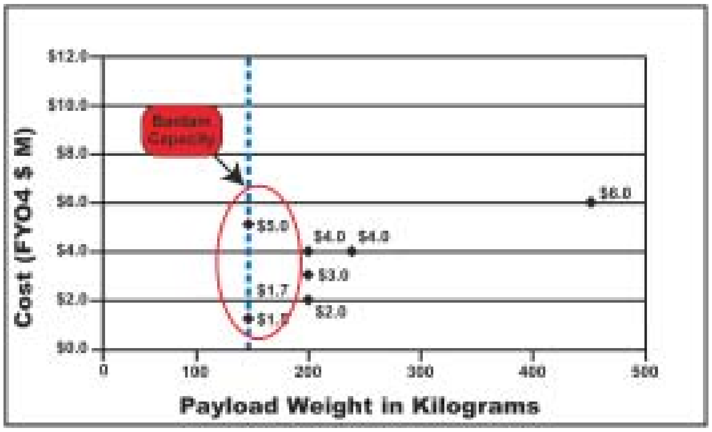


Figure 3: Payload developer inputs–desired performance/cost

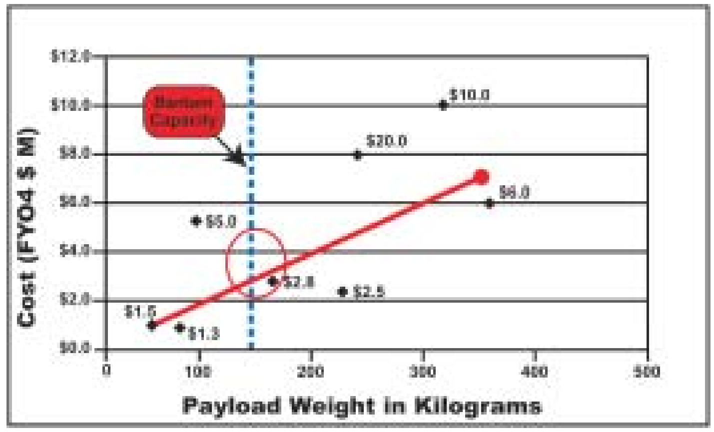


Figure 4: MLS developer estimates compared to payload developer preferences

slightly different turn, as Figure 2 shows. The coefficient of determination rises from 0.46 in Figure 1 to 0.56, indicating that the trend line is more reliable when the vehicles using the past approach to design and operation are separated from the proposed vehicles, which use new approaches. The fact that the weight-versus-cost predictions of the MLS developers are closely related shows the analysis is consistent even when performed by different companies, indicating that the correlation is valid and is likely to be close to reality when new MLS systems are built.

There is a market for a low-cost MLS, although it is very difficult to quantify. Payload developers' estimates of the price per flight required to expand the market are $1 million to $6 million per flight. Given the varying capacities of the vehicles involved, this translates to a range from $10,000 to $33,000 per kilogram. MLS developers' estimates of the price to customers of a suitable launch vehicle range from $1.5 million to $10 million, translating to a range from $6,000 to $50,000 per kilogram. The per-flight and per-kilogram costs do not change in lockstep because each vehicle, in addition to having a different price, has a different payload capacity.

Figure 3 displays the inputs from the payload developers. Focusing on the Bantam-like weight of 150 kilograms, we received a variety of inputs: a range from $1.5 million to $5 million was suggested. (The outlier on this chart, $6 million for 450 kilograms, came from SpaceX's own market studies.)

Figure 4 compares MLS developers' estimates (shown in Figures 1 and 2) to payload developers' desired launch prices (shown in Figure 3). The data are not very firm, given that none of the vehicles involved have been flight-tested, but a picture emerges of a trade space in which technology and economics can meet.

Pegasus small launch vehicle after release from launch aircraft. (Source: Orbital Sciences Corporation)

How to Build an Inexpensive Launcher

For a successful MLS, the requirements must not be stretched beyond the basics. As Henry Vanderbilt of the Space Access Society said, "Consider the pervasive tendency for any potential low-cost launch project to get latched onto by all the major government launch customers and end up stretched to gargantuan size and performance to meet all their requirements. Add in the tendency for multiple government research and development (R&D) centers to lobby to have their pet technologies incorporated, and you have a recipe for repeated failure."

There are classically three ways of building something at lower cost: build more, build using new cost-saving designs or technology, or build more efficiently. While all three strategies will probably need to be employed for a successful MLS, building in quantity must wait until the market develops in response to a proven vehicle. Most MLS concepts now under development include some new ideas or emerging technology, from SpaceX's recoverable first stage to SpaceDev's large hybrid motor. Building and operating with as small a team as possible is a nearly universal theme among current MLS developers.

Continued on page 23

Disney's "Mission: SPACE" is Mission Accomplished

(Copyright 2003: The Walt Disney Company)

Epcot Center's newest attraction offers an out-of-this-world experience for those eager to visit the space frontier.

by Amy Paige Kaminski

Two years before the launch of the first satellite into Earth orbit, entertainment magnate Walt Disney recognized two catalysts that could fundamentally alter American culture: the proliferation of television ownership and the coming of the Space Age. In 1955 he teamed with rocket scientist and space visionary Wernher von Braun to produce a series of three television shows to teach viewers about the nation's plans for human space exploration. Harnessing popular interest in science fiction and conveying technical concepts in lay terms, the series has been credited with helping to sell the American public on the idea of funding the new civil space flight program.

Those television shows were just the start of Disney's infatuation with all things extraterrestrial. For nearly fifty years, the entertainment company has married technology and imagination to imbue the public with the notion that humanity has a real future in space. That concept has been carried through multiple Disney films and theme park attractions. But no Disney project has brought space to the public in a manner as palpable and dynamic as its newest attraction at Walt Disney World's Epcot Center in Lake Buena Vista, Florida.

Welcome Mission: SPACE. On the drawing boards at Disney and industry partner HP for more than five years, the new attraction—the most technologically advanced Disney has ever built—allows visitors to savor the energy and exhilaration of a voyage to Mars. Calling Mission: SPACE a virtual reality ride is understating the adventure it offers. From the rumbling and intense force of gravity felt upon the vertical launch into a blue-to-black sky to the disorientation—even nausea—associated with flight through the Red Planet's steep canyons, it is a multi-sensory experience that gives riders a chance to step into the role of astronaut without ever leaving the ground. Space tourism may not yet be an option for the masses, but Disney's new thriller brings cosmic travel to the global public for the price of park admission.

According to Walt Disney World sources, the company had long envisioned adding a "space park" to Epcot's collection of forward-looking attractions. The challenge, however, was to develop as its centerpiece a ride that provided visitors with a highly realistic space travel experience. Disney "Imagineers" used NASA astronaut input and flight simulators as their inspiration for Mission: SPACE, designing a centrifuge-based ride system that combines pitch and roll movement as well as special effects, visuals, and high-end audio. A virtual imaging system built to the highest optical standards used in industrial or military applications ensures that guests of all heights enjoy the stunning space views; scientists at the Jet Propulsion Laboratory helped create the Mars flight sequences using data from the Mars Global Surveyor and Mars Odyssey spacecraft. Meanwhile, stereo woofers bellow thunderously from behind each seat during launch, and computers synchronize the video, audio, and motion to maximize the drama.

Disney went to lengths so that even before boarding the ride, Mission: SPACE visitors readily sense that they are truly part of the space adventure. Colorful planetary orbs and inspirational words from some of

Epcot guests become a four-person team of astronauts working together to fulfill a mission when they step into a capsule and prepare for takeoff at Mission: SPACE. Everyone in the capsule participates in completing the mission—all while viewing outer space through a personal video screen. (Copyright 2003: The Walt Disney Company) history's most esteemed scientists, poets, artists, and astronauts adorn the entry point to the attraction. Once inside, visitors are within the perimeter of the International Space Training Center in the year 2036. As they wend their way through the switchback, cordoned line, they see mockups of futuristic space stations, timelines of space firsts, and the specs of their Mars vehicle, the X-2 Deep Space Shuttle, complete with aerospike engines, carbon structures, and other technologies currently under study for use in future space vehicles. Echoing voices, the digital beeping of computers in mission control, and the presence of flight suit-clad ride operators serve to beckon riders for their impending travels.

Since Mission: SPACE's August debut, hundreds of thousands of park visitors have experienced the new attraction. Disney sources report that they have received positive feedback from a wide audience. "The public says the realism is great," says Sue Bryan, Mission: SPACE senior show producer. "Older adults have expressed gratitude for the chance to experience what the astronauts they grew up admiring felt on their missions. Kids have come out of the ride saying they want to be astronauts."

Disney can rightfully claim success with Mission: SPACE. Sure, it may not be as intellectually appealing as older Epcot attractions, its impact also being more inspirational and less pedagogical than Disney's earliest space projects. And yes, the attraction perpetuates the astronaut-centric view of the space program most Americans hold rather than seizing the opportunity to expose its captive audiences to the thousands of other people and projects that make space exploration possible. But romantic tendencies aside, Mission: SPACE does wonders for those thirsty to travel into space personally and to glimpse at possible tomorrows on the next frontier. Reasonably optimistic and adroit in mingling scientific fact and visionary license, Mission: SPACE is likely to prove itself as Disney's most effective endeavor to date to inspire young and old alike to imagine the future—their future—in space and, perhaps in turn, generate public support to make the dream reality. ■

Space travel and exploration was always a fascination for Walt Disney, who stands with a model of the Moon in one of his space-themed television specials. (Copyright 2003: The Walt Disney Company)

AAS Co-sponsors GMU Space Policy Course

AAS co-sponsored a course entitled "The U.S. Government Space Sector," held October 22-24, 2003, at George Mason University's (GMU) Arlington, Virginia, campus. The course was the first event organized by GMU's new Center for Aerospace Policy Research of the School of Public Policy.

Senior representatives from the Bush Administration and U.S. government agencies, the Congress, the private sector, and non-U.S. space agencies delivered a series of presentations on their involvement in space affairs and participated in a number of discussion panels. The class consisted of about twenty-five individuals representing a cross-section of U.S. and non-U.S. government and industry organizations.

AAS Vice President/Public Policy Jim Vedda, Vice President/International Frederic Nordlund, and two past Vice Presidents/International, Lynn Cline and Graham Gibbs, served as panelists. Past Vice President/International Ian Pryke organized the course. The Space Foundation also co-sponsored the course.

The course provided participants with overviews of the history of the Space Age, the federal budget process, the U.S. departments and agencies involved in space matters, and Congressional decision-making processes. Participants also learned approaches for interfacing within and with the government and received updates on current and future space policy. Presentation materials from the course are available on the web at www.gmupolicy.net/space.

A relatively new initiative of GMU's School of Public Policy, the Center for Aerospace Policy Research is developing educational programs and conducting research across a wide range of aerospace issues and topics.

Is Our President a Space Cadet, or What?

by Laura S. Woodmansee

On the evening of Thursday, January 8, I was watching my local news. At the end of the broadcast, up came the words "Breaking News." I thought I was in for another famous Los Angeles car chase, but instead I got a very pleasant, very curious surprise. President Bush was going to announce plans to send astronauts to the Moon and Mars. Wow! I was floored. I thought of the rumors of a possible return to the Moon announcement that was to have taken place at last December's Centennial of Flight celebration at Kitty Hawk. When it didn't happen, I figured that the administration had dropped the idea.

> Having a clear goal means that NASA must now deliver.

I'm pretty sure the January 8 news was a trial balloon. The Bush administration leaked the plan because it wanted to see how the public would react to the idea of a Moon base and human mission to Mars. The general public reacted to this news the way it always does about new space initiatives. According to a recent Associated Press poll, half of Americans support the idea, half don't. Apparently, that was enough for the Bush administration to go ahead with the January 14 announcement.

Now that I've heard Bush's speech, I wonder: is our President a space cadet? As a space enthusiast, of course I support any far-reaching plan to explore space. But, I felt that something was missing from the big speech. I found myself wishing that the President had reminisced about how the Apollo program affected him personally.

As an extreme space supporter, I have to ask. Is this plan realistic? Is it practical? It does give NASA a long-term goal that it has been lacking since the last days of Apollo. But, having a clear goal means that NASA must now deliver. The problem is that there doesn't seem to be enough money to get the job done. If NASA doesn't deliver, this program could break the agency.

Money is critical, and Bush's plan shifts funding from other NASA programs towards the new grand plan. What does this mean for all those NASA projects that don't directly support Bush's new space plan? What will happen to the Terrestrial Planet Finder (TPF), the Webb space telescope, the MESSENGER Mercury orbiter, the Pluto/Kuiper New Horizons mission, the Prometheus/Jupiter Icy Moons Orbiter (JIMO)? And what about the Earth science, aeronautics, and astrophysics programs at NASA? All of these projects have legitimate and worthwhile scientific goals but don't directly support sending people to the Moon or Mars. Which of these projects do we abandon? Hopefully none. But what will happen when the cost of the new plan overruns, as it inevitably will?

I find myself wondering if we will really return to the Moon by Bush's plan. I hope it happens, but I'm skeptical. I really believe that NASA will need far more than $12 billion to get going on sending astronauts to the Moon and building a base there. Will NASA acknowledge this? And if it does, will Congress be wise enough to give the agency the money it needs? I sincerely hope so because exploration is part of what makes us human. We need to get over this hurdle and out into space where we belong. ■

> What does this mean for all those NASA projects that don't directly support Bush's new space plan?

***Laura S. Woodmansee* is a freelance science journalist. She is the author of *Women Astronauts* and the new book, *Women of Space: Cool Careers on the Final Frontier* (Apogee Books). Laura can be contacted by e-mail: astronaut@woodmansee.com.**

Microsat Launchers: The New Generation

Continued from page 19

What kind of MLS program could actually succeed? Pegasus designer Dr. Antonio Elias has noted that three factors dominate a small launcher's cost: propulsion, mission support labor, and payback of R&D investment each contribute over 20 percent of the price to a customer. For a low-cost system not likely to be built in mass-production quantities, funding R&D by signing up investors who need a quick payback is unworkable. This reality highlights the importance of a government customer covering at least part of the R&D investment. Additionally, a lean, dedicated organization with a steady funding source is essential, and designing to cost (including operability cost) is more important than maximizing performance. Finally, the developer must have sufficient resources to survive an early failure.

Our analysis indicates an affordable MLS is possible. Three factors separate current efforts from past failures. First, the launch situation for microsats today is, by all accounts, the worst it has ever been, and American microsatellite companies are not shy about pointing to advancements being made by foreign competitors in satellite operations. The leader, Britain's Surrey Satellite Technology, Limited, is doing a brisk business in small remote sensing and communications satellites and has embarked on cooperative ventures to create small satellite programs in China and several developing nations. Second, there is increasing DoD interest in and funding for microsatellites and new small launch vehicles. Third, while it is too early to pick winners in this competitive field, the star power and cash provided by the confident Musk has re-energized the search for a solution.

But the problem is not as good as solved. Vehicle size and cost have a tendency to rise no matter the expertise involved. And early accidents can consign a viable design or company to the dustbin while business goes to a company which may look like an underdog today. The future, though, looks promising. Professors worrying about flight opportunities for their students and scientists hoping to get their instruments into space have reason to believe that, in a couple of years, they will be able to launch their payloads at a price they can afford. ■

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In Memoriam

Dr. Fred Lutze
1937-2003

Dr. Lutze was a professor in the Aerospace and Ocean Engineering Department at Virginia Tech. Donations may be made to The Fred Lutze Memorial Scholarship Fund, Virginia Tech Foundation, c/o AOE Department, 215 Randolph Hall (0203), Blacksburg, VA 24061.

National Air and Space Museum Opens New Annex

Continued from page 5

Many engines, rockets, satellites, gliders, helicopters, airliners, ultra-lights and experimental flying machines will be displayed for the first time. Visitors will see a Concorde, the Lockheed Blackbird SR-71, the original prototype of the Boeing 707, an F-4 Phantom fighter, the B-29 Superfortress *Enola Gay*, and the de Havilland Chipmunk aerobatic airplane.

When complete, the facility will comprise a three-level aviation hangar as well as a separate space hangar. While the aviation hangar has opened to visitors, the James S. McDonnell Space Hangar will not be publicly accessible until at least March. Still undergoing refurbishment, the centerpiece of the space collection will be Space Shuttle *Enterprise*.

The center also has an IMAX theater as well as an observation tower, from which visitors can watch air traffic departing and arriving at Washington Dulles International Airport. ■

Charitable Giving and the AAS

A popular way to donate to an organization is to make a gift by means of a will, i.e., make a bequest. You may wish to consider either a general bequest to AAS, or a bequest targeted to an existing or new AAS scholarship or award fund. Such bequests are deductible against estate and inheritance taxes. Of course, there are also tax advantages to making charitable donations to AAS while you're living. Such gifts could give tribute to the memory of someone who has passed away or be in honor of a person still living. Special occasions offer other opportunities for gifts to be directed to the Society. As a final note, although AAS can provide suggestions for charitable giving, such actions should always be reviewed by your financial or legal advisor.

AAS Meeting Schedule

February 4–8, 2004
27th Rocky Mountain Guidance and Control Conference
Beaver Run Resort and Conference Center
Breckenridge, Colorado
www.aas-rocky-mountain-section.org

February 8–12, 2004
***AAS/AIAA Space Flight Mechanics Winter Meeting**
Wailea Marriott
Wailea, Hawaii
www.space-flight.org

March 16-17, 2004
42nd Goddard Memorial Symposium
Greenbelt Marriott Hotel
Greenbelt, Maryland
www.astronautical.org

June 29–30, 2004
International Space Law Workshop
Doubletree Paradise Valley Resort
Scottsdale, Arizona
www.astronautical.org

August 16–19, 2004
***AIAA/AAS Astrodynamics Specialist Conference and Exhibit**
Rhode Island Convention Center
Providence, Rhode Island
www.aiaa.org

November 16–17, 2004
AAS National Conference and 51st Annual Meeting
Pasadena Hilton
Pasadena, CA
www.astronautical.org

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