5-22-1990

Mars and Beyond: The Solar System Beckons

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by
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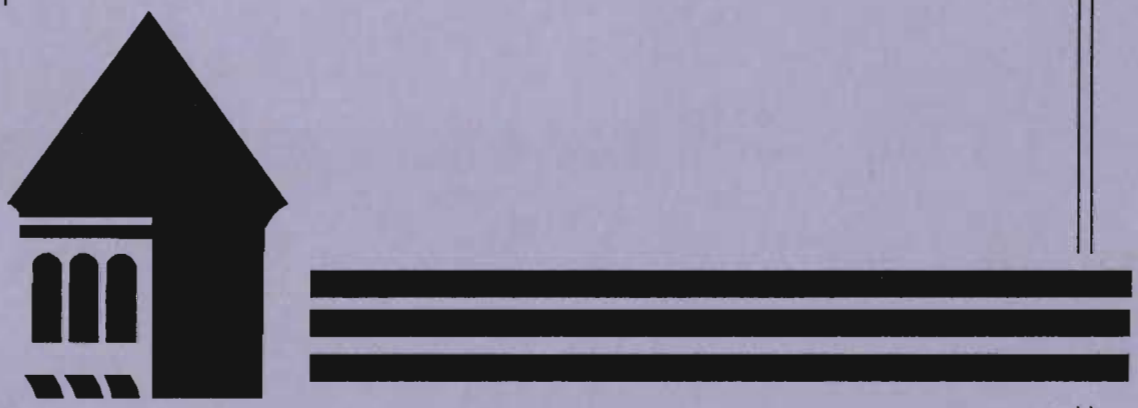

75th Faculty Honor Lecture

75th Faculty Honor Lecture
May 22, 1990
Utah State University
Logan, Utah

SEVENTY-FIFTH HONOR LECTURE
in the Natural Sciences
delivered at
UTAH STATE UNIVERSITY

A basic objective of the Faculty Association of Utah State University is to encourage intellectual growth and development of its members by sponsoring and arranging for the publication of two annual faculty lectures in the fields of (1) the biological and exact sciences, including engineering, called the Annual Faculty Honor Lecture in the Natural Sciences; and (2) the humanities and social sciences, including education and business, called the Annual Faculty Honor Lecture in Humanities.

Lectures are chosen by a committee of the Faculty Association. Amoung the factors considered by the committee in choosing the lecturers are (1) creative activity in the field of the proposed lecture; (2) publication of research through recognized channels in the field of the proposed lecture; (3) outstanding teaching over an extended period of years; (4) personal influence in developing the character students.

Dr. Frank J. Redd was selected by the committee to deliver the Annual Faculty Honor Lecture in the Natural Sciences. On behalf of the members of the Association we are happy to present Dr. Redd's paper.

J. Steven Soulier
President, USU Faculty Association

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INTRODUCTION

To space zealots, 1989 was the year the drought ended. The space shuttle was operational again; Voyager's grand reconnaissance of the Solar System climaxed with the glorious encounter with the planet Neptune and its startling moon, Triton; the launches of the Magellan spacecraft to Venus and the Gallileo to Jupiter broke a decade long hiatus in the launch of U.S. planetary missions; and, for the first time in over twenty years, a U.S. president announced a daring new initiative in human exploration with the goal of first returning humans to the Moon, then going on to Mars.

For awhile, it almost seemed like the sixties, again - a time when the U.S. Space program was the greatest. Perhaps the spirit of Apollo had returned to salve the painful wounds of the post Challenger agony. But, as the balm brought healing, it also brought soberness. We were entering the nineties, not the sixties. 1989's successes notwithstanding, the nation faced difficult challenges, the most aggravating of which was the national debt. The growing commitment to contain the debt and the profusion of competing budget interests would not allow the explosive growth of the Apollo era. Competition from the Soviet Union no longer opened the funding spigots and NASA itself, the custodian of the nation's space destiny, still found itself mired in the inertia of an entrenched bureaucracy. And, while the exploration of Mars and the outer solar system excited the imagination, we began to realize that the threat to the environment of our own planet Earth demanded that we focus some of our space exploration efforts homeward. Nevertheless, the catharsis of Challenger is yielding to a new, albeit bounded, optimism. Mars indeed beckons; Jupiter and Saturn and their moons await the arrival of inquiring spacecraft; and the Moon will again feel the footsteps of humans upon its surface.

This lecture will attempt to take a realistic look at the U.S. civil space program as it emerges from the pain of the post Challenger years into an era of new hope and challenge. Tough decisions must be made in a budget constrained environment. We may have to find new ways of doing things, or we may have to rediscover old ones. Perhaps a reexamination of "first principles" is in order. But, if we do it right, the possibilities and opportunities extend beyond our wildest imaginings.

HISTORICAL PERSPECTIVE

It is not the purpose of this lecture to conduct a detailed historical review of the U.S. space program. However, there are some key reference points that need to be identified and defined in order to understand the landscape that confronts us. The reference points essential to the thesis of this presentation divide the national "space past" into three eras: (1) The Apollo era, (2) the pre-Challenger era, and (3) the post-Challenger era. Each of these eras has been characterized by its own ambient spirit which strongly influenced the planning and conduct of the space programs during that era. That is not to say there has not been carry-over from one era to another. The same NASA people have been on stage through all three eras. The differences between the eras accompanied changes in national space policy; the people both influenced those changes and adjusted to conform to the new policy.

The Apollo Era

Radford Byerly, Jr., Director of the Center for Space and Geosciences policy at the University of Colorado and a former member of the staff of the House of Representatives Subcommittee on Space Science and Applications, characterizes the Apollo era as a "can do" era during which "America had set out to put a human on the Moon and NASA accomplished the task spectacularly well." His definition of the "Apollo Paradigm" extends the vision beyond the lunar landings to "..an even broader vision; a beginning that would lead to orbiting space stations, settlements on the Moon, and colonies on Mars. America was destined to lead the human race into space and it was NASA's job to do it." 1 An important footnote should emphasize that the Apollo program was formulated at a time of budget surplus, a phenomenon that most of us can hardly imagine today.

The Pre-Challenger Era

In its beginnings, the space shuttle era continued the vision and enthusiasm of the Apollo era, but it was conducted under a much more constricted budget climate. It competed with the Vietnam War for national resources and attention. (The NASA budget fell to about one-third of its Apollo peak.) The vision began to fade as cost overruns and further budget pressures began to force compromises in the development. Many feel that these pressures, and NASA's reaction to them, set the stage for the Challenger disaster a half a decade later.

Another factor clouding the vision was the lack of a fundamental objective associated with the space shuttle program, other than the program itself. There was no extraterrestrial destination — no Moon, no Mars. The official name of the program, the National Space Transportation System, described a logistics element, not an objective. The final product was to be an operational system to be flown repetitiously to and from earth orbit. NASA was not organized for that type of task. As an agency, it was programmed for singular missions which included a limited number of expendable spacecraft. Worse still, the price of continuing the space shuttle program included the cancellation of all other U.S. launch vehicle programs. The space shuttle was to be the one and only means of access to space. Perhaps, in this case, the vision exceeded reason.

For these and other reasons, the pre-Challenger space shuttle era became one of confused goals and drifting priorities. The hard questions which should have been asked during this era were not asked until after the Challenger accident.

The Post-Challenger Era

Almost no one can forget the circumstances surrounding the Challenger explosion on January 28, 1986. That event will no doubt be etched upon our memories for the rest of our lives. It has also become a landmark event in the history of the nation's space program, not just because of the tragic loss of the life, but also because it signalled the end of the infallible image of NASA and the nation's great adventure in space. Intense inquiry into the Challenger disaster expanded to a penetrating nvestigation of NASA and the U.S. civil space program. Amid accusations of mismanage-

ment and poor policymaking, the hard questions that should have been asked earlier were asked, and, in many cases, the answers were embarrassing. "Why did the U.S. rely solely on the Shuttle? Why are human crews used to launch communication satellites? Why are science missions and the human spaceflight program tied together? What is the rationale for the Station?"2

If there were some way to erase the human tragedy from the Challenger accident, it could be considered a beneficial event. The questions that flowed from the multitude of inquiries and investigations needed to be asked, and answers needed to be provided. Changes were made and still more will be made. That tragedy signalled the end of the space program's adolescence and an entry into what hopefully will become a more mature program with well defined, exhilarating goals, a program that will reestablish U.S. leadership in those areas of space exploration that best fit the national interest.

Planetary Exploration

Before leaving this brief journey through history, it would be well to discuss the impacts of these events on the planetary exploration program. There has been and will continue to be endless debate on the relative merits of expensive human exploration programs versus exploration with highly automated, unmanned spacecraft. There can be no argument that the funding allocated to planetary exploration is inversely proportional to that awarded to human exploration. Our euphoria at seeing the wonderful photographs of Jupiter, Saturn, Uranus, Neptune, and the satellite moons of these planets should be tempered with the realization that these pictures were taken by spacecraft that were launched nearly a decade before the Challenger disaster; and, until the Galileo and Magellan launches in 1989, none had been launched since. NASA's total commitment to the space shuttle program in an environment of severe budget constraints nearly killed the planetary exploration effort.

APPROACHING THE PRESENT

The National Commission on Space

Several significant events have occurred during the four years following the Challenger accident that have strongly influ-

enced the emergence of the still evolving posture of the current U.S. space program. One of these, of course, is the national debt and the limitations it places upon growth of new initiatives. The others are equally significant, however, because they have been forged with a clear knowledge of those debt constraints and have, to some degree, attempted to fit within them.

In 1985 President Reagan asked the Congress to appoint a National Commission on Space and charge them to "...formulate a bold agenda to carry America's civilian space enterprise into the 21st century."3 Headed by Thomas O. Paine, a former NASA Administrator, that commission traveled across the country for the next year obtaining testimony from experts and citizens. They concluded their report entitled, Pioneering the Space Frontier, and delivered it to Congress in May of 1986. Its delivery was almost totally obscured by the nearly concurrent delivery of the Rogers Commission report on the Challenger accident, but its comprehensive, imaginative, penetrating message could not stay buried long. The report proposed three aggressive thrusts: "Advancing our understanding of our planet, our Solar System, and the Universe; Exploring, prospecting, and settling the Solar System; and Stimulating space enterprises for the direct benefit of the people on earth." To accomplish these thrusts, the commission proposed two additional thrusts: "Advancing technology across a broad spectrum to assure timely availability of critical capabilities and Creating and operating systems and institutions to provide low-cost access to the space frontier."4 The report outlined a methodical expansion of the space infrastructure from low-earth orbit to Mars and beyond over a fifty year period, while postulating that commitment to such a long-term program could be carried out within known budget constraints.

The "Sally Ride" Report

Required by Congress to respond to the report of the National Commission on Space, NASA appointed Dr. Sally K. Ride, a former astronaut, to head a select NASA group to formulate a reply. Entitled, LEADERSHIP and America's Future in Space, that report quickly established itself as an extremely competent reference document for all future discussions of future U.S. space program initiatives. Noting that the reviews following the Challenger accident revealed the shortcomings of the national space pro-

gram and raised serious questions concerning U.S. leadership among spacefaring nations, the "Sally Ride Report" stated that, "The U.S. civilian space program is now at a crossroads, aspiring toward the visions of the National Commission on Space but faced with the realities set forth by the Rogers Commission. NASA must respond aggressively to the challenges of both while recognizing the necessity of maintaining a balanced space program within reasonable fiscal limits." It further noted that, "Two fundamental, potentially inconsistent views have emerged. Many people believe that NASA should adopt a major, visionary goal. They argue that this would galvanize support, focus NASA programs, and generate excitement. Many others believe that NASA is already overcommitted in the 1990s; they argue that the space agency will be struggling to operate the Space Shuttle and build the Space Station, and could not handle another major program."5

The Ride Report cuts to the heart of the dilemma facing the U.S. space program today, but it meets the dilemma head-on by reemphasizing the need for a long-range direction based upon clearly defined goals. It notes that, "...if there are no goals, or if the goals are too diffuse, then there is no focus to the program and no framework for decisions. The goals of the civilian space program must be carefully chosen to be consistent with the national interest and also to be consistent with NASA's capabilities...Without an eye to the future, we flounder in the present." In what may be its most quoted statement, the report then states that, "Leadership in space does not require that the U.S. be preeminent in all areas of space enterprise. The widening range of space activities and the increasing number of spacefaring nations make it virtually impossible for any country to dominate in this way. It is, therefore, essential for America to move promptly to determine its priorities and to pursue a strategy which would restore and sustain its leadership in the areas deemed important."6

The Ride Report then describes a process for the development of strategic options which can then be matched at various levels to national interests. The outcome of the process should be a national space strategy that is directed toward establishing U.S. leadership in those areas which best match the national interest. Although the process doesn't make the hard questions any easier, it does establish a systematic, logical way to arrive at answers which are weighed against a framework of established national

policy. To activate the process, the report proposes four bold initiatives for "definition, study and evaluation". The study doesn't propose that any one or combination of these initiatives be adopted in its entirety; rather, it proposes that national strategic options be developed that combine various aspects of each initiative. Intense evaluation of the strategic options should then lead to a national space policy which provides goals for the future that match national interests and policy. The referenced initiatives are "Mission to Planet Earth, Exploration of the Solar System, Outpost on the Moon, and Humans to Mars".7

Formation of the Office of Exploration

During the preparation of the Ride Report NASA decided to organize a separate office to begin to develop the strategic options to be presented to the NASA Administrator and, eventually, the President for their consideration formulating a national space policy. Dr. Sally Ride became the first Associate Administrator for Exploration. Soon after the completion of the report, she retired and is now associated with the Hoover Institute at Stanford University.

Since the publication of the Ride Report, the Office of Exploration has published several studies and reports on the progress of their development and evaluation of strategic options. While these reports have been widely read within NASA, other events seem to be overtaking these studies. Most recently, the Office of Exploration was combined with NASA's Office of Aeronautics and Space Technology to form a new Office of Aeronautics and Exploration Technology. The influence of this office on the formulation of the nation's future space program is yet to be determined.
The Reagan Space Policy

On two occasions President Ronald Reagan attempted to formally establish national space policy. In August of 1984, he approved a new National Space Strategy which "...implements a series of space initiatives including examination of new military and civil space vehicles beyond the space shuttle and efforts that could place the U.S. on course for a return to the Moon and possible manned flight to Mars."8 It directed NASA to make the Space Transportation System (space shuttle) "fully operational and cost-effective in providing routine access to space." It also directed NASA to develop a permanently manned Space Station within a

decade and identify major long-range national goals for the civil space program. There were few guidelines given for the development of those goals.9 Note that this strategy was issued before the Challenger explosion.

On January 8, 1986, President Reagan issued a new Presidential Directive on National Space Policy, following a comprehensive and lengthy review by the Interagency Group for Space (IG-Space). Membership in the IG-Space included representatives from the National Security Council, Department of State, Department of Defense, Department of Commerce, Department of Transportation, Treasury Department, CIA, Organization of the Joint Chiefs of Staff, NASA, OMB, and the Office of Science and Technology Policy. The review included a comprehensive focus on the report of the National Commission on Space, the Ride Report, and other applicable documents dealing with the commercial aspects of space. The new policy was significant in its specific attention to all aspects of the U.S. space program — military, civil and commercial. It was met with general enthusiasm, although it was criticized for its failure to provide quantifiable, prioritized goals and timetables. Wirin points out, for example, that, "The policy gives everybody everything and makes few, if any, hard choices....In fact, the biggest disappointment with the new policy is its failure to set a major goal before the American people and call for action."10 Possibly the most dramatic aspect of the new policy was its call to expand human presence and activity beyond Earth orbit into the Solar System. This goal is especially significant for three reasons. First, U.S. space policy has articulated a specific position on manned versus unmanned exploration of space. Second, it established a funded program, project Pathfinder, to develop the technology for human exploration, and third it brought focus to the to the potential for a human expedition to Mars.11

Formation of the National Space Council

Upon assuming the Presidency in January, 1989, President Bush made good on a campaign promise to form a National Space Council to be responsible for the formulation of a national space policy and the acquisition of the means to pursue it. Chaired by the Vice President, the membership of the council includes representatives from other cabinet offices as well as NASA. What makes this event significant is that NASA is no longer the agency soley

responsible for formulating and gaining approval for the nation's space program. NASA still has a substantial role to play in those activities, but it is only one of several players. Some have suggested that NASA may not even be the sole implementer of the program. Defense Department drawdowns will possibly relieve the National Laboratories (e.g. Los Alamos, Lawrence Livermore) of some of their workload, freeing up valuable national talent for work on the space program. It is interesting to note that the U.S. had a National Space Council during the Apollo era. It was disbanded by President Nixon along with the Apollo program.

The Bush Space Policy

On the twentieth anniversary of man's first footsteps on the Moon (July 20, 1989), President George Bush formally declared the national goal of returning humans to the Moon and mounting a human expedition to Mars. President Bush didn't claim that this policy was a ew one — rather, it was an implementation of the preceding Reagan policy. Although his policy was criticized for its lack of a timetable or budget, Bush assigned the responsibility for providing those items to his newly created National Space Council. That body has aggressively accepted that assignment and is very much in the midst of that planning. All of which brings us to the present.

OPPORTUNITIES, CHALLENGES AND ISSUES

Opportunities

An excellent summary of the opportunities confronting national space program strategists is presented in the Ride Report, LEADERSHIP and America's Future in Space. This document groups those opportunities under the four "Leadership" initiatives described earlier and discusses each in detail. This grouping facilitates the development of strategy options for evaluation and/or implementation.

The first initiative, "Mission to Planet Earth," can almost be

considered an imperative rather than an option. Growing concern over global change and its effects on the quality of life on the earth is increasingly demanding aggressive actions to measure, analyze, and understand that change. The Ride Report proposes: (1)"To establish and maintain a global observational system in space, which would include experiments and free-flying platforms, in polar, low-inclination, and geostationary orbits, and which would perform integrated, long-term measurements." and (2)"To use the data from these satellites along with in-situ information and numerical modeling to document, understand, and eventually predict global change."12

The second initiative, "Exploration of the Solar System," is based upon the strategy developed by the Solar System Exploration Committee of the NASA Advisory Council. The proposed programs include the Comet Rendezvous Asteroid Flyby (CRAF) mission to investigate the beginnings of the Solar System; the Cassini mission to explore Saturn and its largest moon, Titan; and the Mars Rover/ Sample Return mission to gather samples from the surface of Mars and return them to earth.13

The third initiataive, "Outpost on the Moon," proposes a three phase evolutionary effort to provide permanent human habitation on the Moon. "By 2010, up to 30 people would be productively living and working on the lunar surface for months at a time....This initiative represents a conceptual leap outward from Earth. The challenge is to tame and harness the space frontier - to go beyond Apollo, and explore the Moon for what it can tell us, and what it can offer us, as a research and development center and as a resource in itself. [It] would represent a significant extraterrestrial step toward learning to live and work in the hostile environments of other worlds."14

The final initiative, "Humans to Mars," seems to be the ultimate of initiatives. The President's policy statement included an admonishment that we are not to go for brief explore-and-return visits. The eventual goal is the establishment of a permanent presence on the surface. The scenario begins with comprehensive robotic exploration missions in the 1990s. Concurrently, an aggressive life sciences research program would be conducted on the Space Station to investigate and validate the feasibility of long-term space flight. Finally, sprint type, one-year piloted missions would be con-

ducted as precursors to the establishment of permanent outposts. As the Ride Report states, "This leadership initiative declares America's intention to continue exploring Mars, and to do so not only with spacecraft and rovers, but also with humans. It would clearly rekindle the national pride and prestige enjoyed by the U.S. during the Apollo era. Humans to Mars would be a great national adventure; as such, it would require a concentrated massive national commitment - a commitment to a goal and its supporting science, technology, and infrastructure for many decades."15

Challenges

Two severe challenges face the U.S. space program in the future; both deal with resources. The first, and most severe, is the budget. The pursuit of any combination of the Ride initiatives will require real increases in the NASA budget. This fact conflicts with the goals of the Balanced Budget and Emergency Deficit Control Reaffirmation Act of 1987 - the Gramm-Rudman-Hollings Act. That act "...will require some combination of reduced spending or increased taxes that lowers the annual federal deficit to zero by 1993." If each year's deficit target is not reached, across-the-board reductions are required. However, seventy-five percent of the budget is exempt and unavailable for cutting. The NASA budget is part of the remaining twenty-five percent. "Put another way, under current law, NASA's less than one percent of federal spending becomes four percent of the pie in the event that the sequester knife is applied."16

The other resource challenge is concerned with trained people. As we enter the decade of the 1990s, much of the experienced NASA and space industrial workforce is eligible and ready for retirement. From one viewpoint, this might be alright. The space agency and its industrial support system need new blood to begin the marvelous adventure. The real problem lies in the ability of the supply to meet the demand. The decline in the interest in mathematics and science among American youth during the past decade foreshadows a real shortage in scientific and engineering talent. Ironically, it was the Apollo era that generated a tremendous increased emphasis and interest in those areas during the decades of the 60s and 70s. The crucial questions are: Can the great challenge and adventure of an aggressive space program rekindle that interest and emphasis? and Is it too late for the supply to meet the currently emerging demand?

It's interesting that the principle challenges to the nation's future space program are resource related. Certainly there are tremendous technical challenges. We need large capacity propulsion systems that are capable of thrusting payloads into space that are enormous by today's standards. The damaging effects on humans of prolonged weightlessness must be understood and overcome. Closed-cycle life support habitats for long-term space flight and life on planetary surfaces must be developed. Automated/expert systems for the robotic exploration of the Moon, Mars and the outer planets are needed. The list goes on. But, one legacy of the tremendous technical explosion that began in the middle part of this century is the attitude that if resources are available, technical problems can be solved. If there is enough in the budget and if technical people are available, the technical challenges can be overcome.

Issues

The primary focus of this presentation to this point has been at the goal level of the national space program, but it is clear that controversies don't end when the goals have been established, even if a basic consensus regarding the goals exists. Issues over the implementation of the goals will persist. Some of these can be resolved within a reasonable period. Others will persist seemingly forever. It is important to understand some of these issues because a growing consensus on the future goals of the national space program is now causing the focus of attention to shift to these tough issues.

Manned versus unmanned systems/subsystems. Competition between of manned and unmanned space systems has existed since the beginnings of the space program. The focus of the conflict is, of course, resources; the dilemma is classic. "Utilitarian arguments in support of piloted space flight are difficult, if not impossible, to support in a limited cost-benefit analysis. Human presence is expensive and automated substitutes abound in most proven applications of space technology....Yet, in the public perception, the NASA program is equated with human space flight and it is a program attribute for which there is a willingness to pay."17 Historically, the development and deployment of human operated systems has inevitably drawn resources away from unmanned

programs. This was especially true during the development of the space shuttle. Consistent overruns in a climate of drastically reduced budgets required NASA to withdraw funds from other programs; and, the unmanned science programs suffered. The pathetic story of the Galileo mission presents a vivid example of this conflict. (See Murray, Journey into Space, The First Thirty Years of Space Exploration)18

It seems that the issue can only be resolved by clearly defining a strategy that specifically sets the roles and priorities for manned and unmanned exploration. One author has suggested that the unmanned planetary exploration program could be protected by somehow deciding "...how much we the people are prepared to invest each year in exploring the solar system. With a stable budget, scientists can lay out a plan for the systematic exploration of the planets. Such a plan has been put forward by the Space Science Board. Such a program would be pursued with a clear understanding that its overruns would simply delay the program, not tax others."19

The Space Station Freedom. In 1984 President Reagan committed the nation to the development, fabrication and deployment of an international space station to insure a permanent human presence in space. Since that day, the program has been batted back and forth in an intense controversy between its advocates and detractors. The U.S. Congress provided the arena for the nearly constant debate during endless budget hearings. An abundance of grist is provided by continuously upgraded cost estimates, program alterations to meet budget constraints, unhappiness of international partners, and a lack of consensus on functions and missions. The program sometimes seems like an anachronistic remnant of the pre-Challenger era. It, too, is a logistics element, an outpost without a clearly defined objective to support. It has alternatively been justified as a laboratory for the conduct of microgravity experiments, a staging base for expeditions to the Moon and Mars, a research facility for the study of long-term microgravity effects on humans, a platform for earth observing instruments, etc. Serious questions about the Space Station's ability to adequately serve any of these needs have continually been debated since its beginnings. These debates are conducted both out of the public eye in technical and scientific forums and very much in the public eye in the halls of Congress. The result has been a continuing reduction

in size and capability. Ensuing compromises in the Station's ability to support any of the postulated missions continue to fuel the debate.

There are alternatives to the Space Station Freedom. They include international cooperative arrangements with the Soviet Union for use of the Soviet Mir space station for shared research on the effects of long term weightlessness on humans and the construction of "man-tended" systems for the conduct of microgravity research.20 The utility of the current Space Station configuration for the on-orbit assembly of large interplanetary launch systems has yet to be proven. Perhaps such operations could be conducted with the space shuttle and its follow-on configurations.

It is unlikely that Space Station debate will be concluded in the near term. Although there is some sign of growing uneasiness among advocates, the momentum of the program and the reluctance to abandon international agreements will likely insure its continuance. Additional cost problems will be resolved by further reductions in capability. Only time will reveal the eventual configuration.

Scale. The history of the U.S. space program has seen continual growth in an institutional commitment to very large space systems. In its early days, the lack of a heavy-lift launch capability forced NASA to build small spacecraft with limited capabilities. These spacecraft were usually built in pairs to provide redundancy in case of failure. Illustrative are the Mariner, Viking, Pioneer, and Voyager series of spacecraft. More recently, however, this philosophy has given way to one featuring single, very large, very costly, multimission spacecraft. Arguments supporting this philosophy include economy of scale (It is cheaper to share common spacecraft utilities such as power, attitude control, communications, etc.) and pooling of requirements (The more requirements that can be met, the greater the constituency supporting the mission.).21

Although these arguments may have some validity, they must be weighed against serious counterarguments. There is a sort of "Maginot Line" effect that results in the loss of an entire combined scientific effort, not to mention a tremendous investment, with the loss of a single system. For example, NASA's currently proposed Earth Observation System is a $30 billion program which includes

two series of large polar platforms (EOS-A and EOS-B) supporting multiple complementary payloads.22 While the goal, comprehensive support of the Mission to Planet Earth initiative, is noble, the size and cost of this single program equals or exceeds that of the Space Station. Its size and complexity make it vulnerable to the budget cutting process, compromises in competing scientific requirements, and in-flight failures. Any system includes some similar vulnerabilities but the singular nature of large, complex systems makes their vulnerabilities potentially fatal.

Institutional space planners (NASA, DOD, the National Space Council) need to seriously consider a strategy which concentrates on the use of constellations of small, single-mission spacecraft to accomplish missions in support of national space objectives. Such a strategy incorporates a robustness growing from redundancy, which reduces vulnerability. Reductions in the budget would reduce numbers of satellites but would not threaten the entire system; competitive compromises would be eliminated in favor of spacecraft tailored to support each individual mission; and in-flight failures would result in the loss of a single sensor, not the entire mission.

International cooperation. A strong initiative for international cooperation among space faring nations, particularly the Unites States and the Soviet Union, has been vigorously promoted for the past several years by a group of notable space scientists, including Dr. Carl Sagan and Dr. Bruce Murray. The advantages of international cooperative efforts are argued on aesthetic, technical, and practical grounds. A Soviet/American cooperative mission to Mars, for example, would involve commitments by both nations to a transcendent goal that would eventually eliminate the tensions arising from conflicts over relatively petty political differences. Cost sharing in such an expensive mission makes its eventuality more certain. The sharing of technological strengths eliminates the need for duplicate technological developments. (It seems silly, for example, for the U.S. to mount a massive effort to develop heavy-lift launch vehicle for a Mars mission when the Soviet Energia is already sufficient.)

Arguments against international cooperation center primarily on the risks of technology transfer. Opposition ranges from absolute resistance to any cooperative efforts to an agreement with

the concept as long as proper safeguards are installed to insure against the transfer of "critical" technology. In a very significant move to resolve the issue, the Bush administration recently announced plans to open discussions with the Soviet Union, Japan, Canada, and the Europeans regarding international cooperative efforts leading to the establishment of a lunar base and a mission to Mars. The National Space Council has been asked to establish guidelines for such talks.23

Organizational responsibilities. The creation of the National Space Council has established a focal point for the development of national space policy and the setting of national space priorities. The National Space Council is not an implementing agency, but it can serve to coordinate the actions of implementing agencies in the execution of space policy. Although NASA should still serve as the principle implementing agency for U.S. space programs, other agencies, notably the National Laboratories, should also participate. Such participation cannot be expected to always produce harmony; some competitive conflict should be anticipated. However, if the Space Council is able to meet its charter, it should be able to productively manage such conflict. An important current example concerns the planning for the "Moon/Mars Initiative," officially entitled the Human Exploration Initiative (HEI). NASA's "90 Day Plan" for HEI has been subjected to serious scrutiny both within and without the National Space Council. The Council has solicited private and public inputs to the plan, even reaching out to individual Americans for suggestions on innovative approaches to the Moon/Mars missions. A competing proposal "...to explore the Moon and Mars quickly and inexpensively but with relatively high, Apollo-level risks..." has been promoted by Lawrence Livermore National Laboratories. The debate has been joined. If its managed properly, it could be a productive one.24

CONCLUSIONS

When one really stops to think about the possibility of landing humans on the surface of Mars and all the fascinating aspects of permanent Martian colonies, it truly seems beyond the imagination. Some of us still look at the Moon and wonder that man actually set foot on that planetary surface. And yet, we honestly do stand on the brink of an exploration adventure that transcends any ever attempted by man. There's no question about our technical

ability to do it. The real questions deal with our ability to devise the plans and programs to take us there in an affordable fashion. Such plans and programs will require a long-term commitment to a long-term program. Americans are not particularly good at that.

In order to reach the objectives of the tremendous adventure ahead, we must be able to devise a program that combines a number of elements into an infrastructure that secures ultimate success. We must, for example, insure that the Space Station becomes an integral part of that infrastructure, not an element that drives it. A balance between manned and unmanned systems and subsystems must be devised that reduces human risk by automating functions wherever possible. Tradeoffs between and scale and complexity need to be seriously conducted with cautious concerns for past institutional biases. International cooperation needs to be examined for the great potential opportunities it offers and national and international organizational responsibilities must be clearly defined.

In pursuing the Mars dream, we must also remember that the Solar System includes many more bodies that need to be explored. Exploration of the outer planets will not be done by humans. We must insure a balance in the nation's space program that includes a "fenced" budget for unmanned planetary exploration.

Despite its questionable ability to support all the needs it claims to support, the Space Station Freedom can be useful in the conduct of research on the effects of long-term weightlessness on humans in preparation for the lengthy missions to Mars. Serious attention to its role in the assembly of lunar and Mars bound launch vehicles must be paid early in order to insure the incorporation of design features necessary to facilitate that mission.

The U.S. institutional commitment to single, large, expensive space vehicles must be seriously reexamined. This presentation doesn't claim that small spacecraft offer a panacea; it simply suggests that the redundancy, resiliency, and flexibility of constellations of small spacecraft strongly support a serious reexamination of present directions.

Finally, the opportunity for international cooperation is too

good to reject. No doubt cooperative programs will open up a whole new set of challenges, but there is validity to the view that cooperation with each other on such a grand mission will inevitably transfer the conflicts from their current concentration on mutual annihilation. Furthermore, we can't afford to go it alone. The sharing of resources, the elimination of technology duplication, and the use of one another's assets and facilities are all good reasons to pursue such a course.

We have emerged from the Challenger disaster a wiser, more mature nation. Our goals are still intact. In fact, they are better defined now than ever before. Implementation strategies still need to be worked out and technology needs to be developed, but we'll make it. And, it will be a grand adventure.

REFERENCES

1. Radford Byerly, Jr., ed., *Space Policy Reconsidered*, (Boulder: Westview Press, 1989), p.3.

2. Byerly, p.5.

3. *Pioneering the Space Frontier*, The Report of the National Commission on Space, (Toronto: Bantam Books, 1986), p.1.

4. *Pioneering the Space Frontier*, p. 5.

5. Sally K. Ride, *LEADERSHIP and America's Future in Space*, (Washington: NASA, 1987), p.5.

6. Ride, p.6.

7. Ride, p.15-21.

8. Craig Covault, "U.S. Adopts New Space Strategy", *Aviation Week and Space Technology*, August 27, 1984, p.14.

9. Ibid.

10. William B. Wirin, "Reagan's Final Space Policy", IISL-88-084, 39th Congress of the International Astronautical Federation, Bangalore, India, 1988, p.1.

11. Wirin, p.5,6.

12. Ride, p.24.

13. Ride, p.27,28.

14. Ride, p.30.

15. Ride, p.32.

16. David H. Moore, "A Budget-Constrained NASA Program for the 1990s", Radford Byerly, Jr. ed., *Space Policy Reconsidered,* (Boulder: Westview Press, 1989), p.15.

17. Moore, p.23.

18. Bruce Murray, *Journey into Space, The First Thirty Years of Space Exploration,* (New York: W.W. Norton & Co., 1989), p.214-216.

19. Albert D. Wheelon, "Toward a New Space Policy", Radford Byerly, Jr. ed., *Space Policy Reconsidered,* (Boulder: Westview Press, 1989), p.64.

20. Bruce Murray, "Accelerating the American Future in Space", unpublished draft, 1990, p.6.

21. Wheelon, p.55.

22. *1990 Reference Hanbook, Earth Observing System (EOS),* (NASA/Goddard Space Flight Center, 1990), p.17.

23. "Bush Seeks Talks on Joint Space Venture", *Space News,* Vol.1, No.13, April 9-15, 1990, p.1.

24. Breck W. Henderson, "Livermore Plan for Exploring Moon, Mars Draws Space Council Attention", *Aviation Week and Space Technology,* January 22, 1990, p.84.