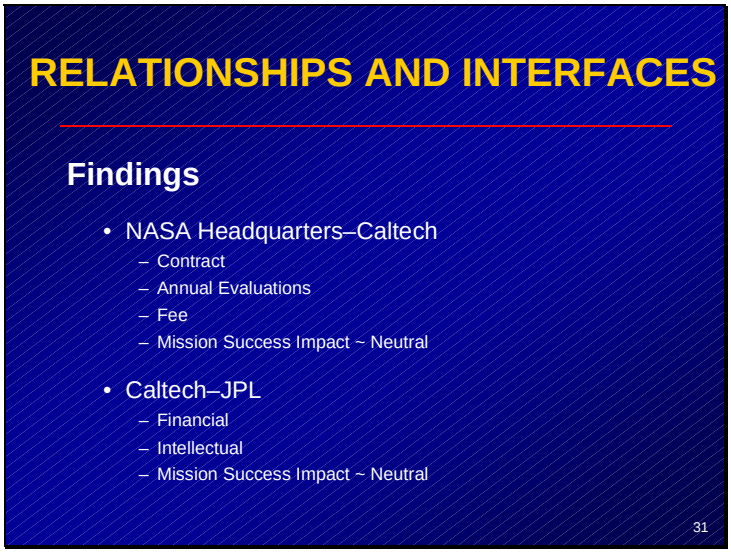
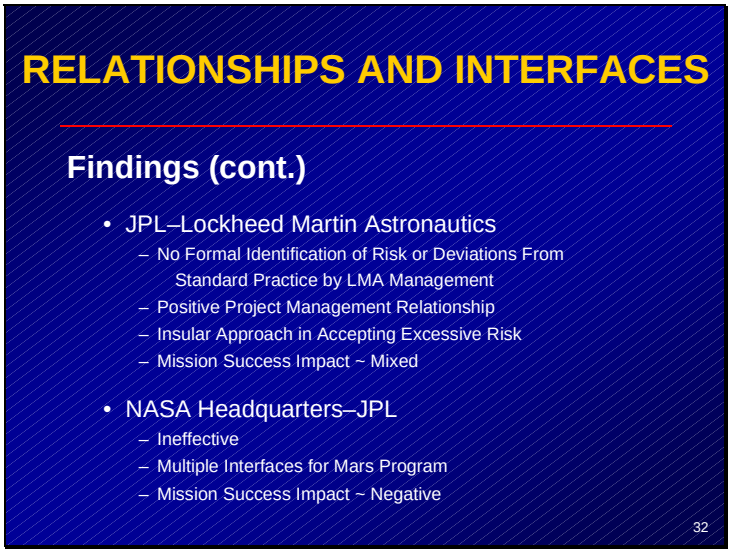


The following six charts discuss the nature of the interfaces among the key organizations involved in the Mars Program.

The Jet Propulsion Laboratory is a Federally Funded Research and Development Center managed by the California Institute of Technology under contract to NASA. Annual performance evaluations of JPL are performed by NASA Headquarters, and an annual fee is determined and awarded to Caltech. The team finds that this interface had no impact on mission success.

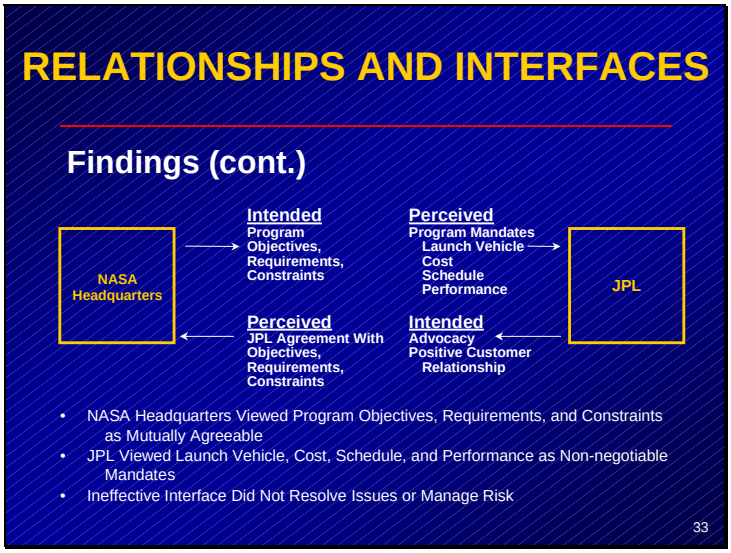
JPL is managed by Caltech as a division headed by the Laboratory Director, who is also a Vice President of Caltech. The Caltech–JPL interface is focused on financial management and an effective intellectual relationship. There is no appreciable involvement by Caltech in JPL technical activities; therefore, the impact of the interface on mission success is neutral.



The JPL–Lockheed Martin Astronautics interface for Mars ’98 was characterized by a positive, close working relationship between the JPL and LMA project managers and their offices. However, this relationship had a negative, insular effect when accepting excessive risk. The insular relationship was characterized as “circling the wagons” around some of the risk issues of the spacecraft development process. There was no formal identification of risk nor of deviations from standard practice by LMA management. The nature of this interface seemed to work well for most of the activity, but had a mixed result on mission success, with the risk management issues a clear negative.

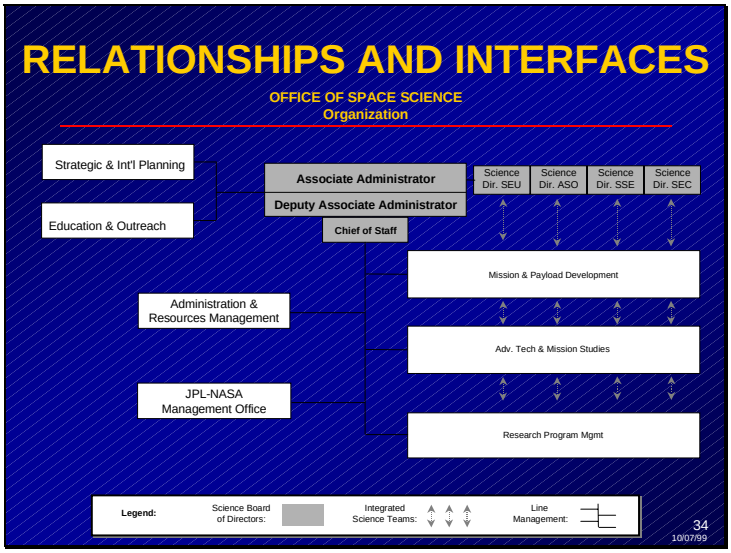
The NASA Headquarters–JPL interface was found to be ineffective as the result of a failure to clearly communicate. Examples of the communication failure will be found on the next page.

Multiple interfaces at NASA Headquarters for the JPL Mars Program Manager caused difficulty at both organizations. The nature of the multiple interfaces will be illustrated on the Office of Space Science organization chart. The ineffective nature of the interface is judged to have had a negative impact on mission success.



Ineffective communication between JPL management and NASA Headquarters contributed to an unhealthy interface and significant misunderstandings in conducting the Mars Surveyor Program. NASA Headquarters thought it was articulating program objectives, mission requirements, and constraints. JPL management was hearing these as non-negotiable program mandates (e.g., as dictated launch vehicle, specific costs and schedules, and performance requirements).

The team believes that JPL management was intending to convey general program advocacy and to promote a positive customer relationship, motivated by fear of losing business. The result was that JPL management did not convey an adequate risk assessment to NASA Headquarters. What NASA Headquarters heard was JPL agreeing with and accepting objectives, requirements, and constraints. This communication dynamic prevented open and effective discussion of problems and issues. JPL management did not effectively express their concerns to NASA Headquarters about programmatic constraints, and NASA Headquarters did not seem receptive to receiving bad news. Consequently, frank discussions identifying and managing program risks and problems did not occur.



This chart illustrates the complexity of the Mars Program interface at NASA Headquarters. For the formulation phase of the program, the JPL Program Manager deals with the Advanced Technology and Mission Studies Division. For the implementation phase of the program, the JPL Program Manager deals with the Mission and Payloads Development Division. For the operations phase of the program, the JPL Program Manager deals with the Research and Program Management Division. For all, there is critical involvement with the Science Board of Directors. Not shown is the involvement with other organizations, such as the Human Exploration and Development of Space Enterprise.

The JPL–Caltech relationship has not historically included technical issues. Caltech could contribute to JPL's overall performance by providing limited top-level, independent oversight through a "visiting committee"-type activity.

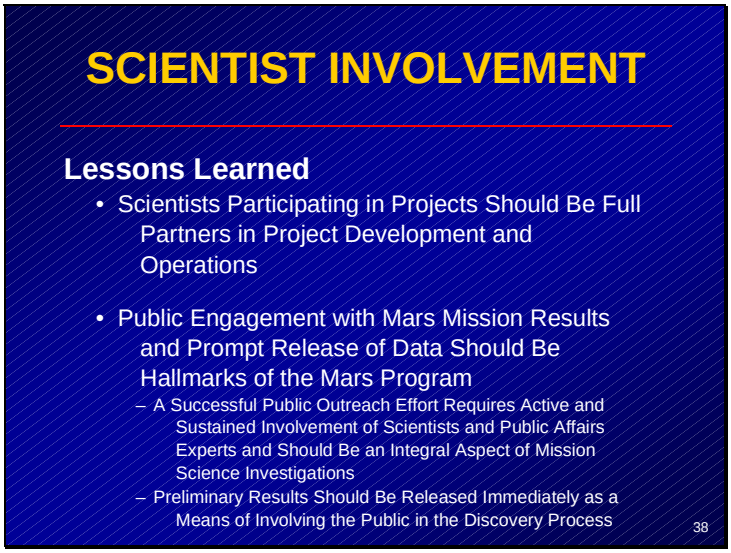
The team found multiple examples of ineffective risk identification and communication by both JPL and LMA. Compounding this, JPL and LMA each deviated from accepted and well-established engineering and management practices. Risk identification and any significant deviations from acceptable practices must be communicated to the customer in an open, timely, and formal fashion.

Successful program/project management requires frank and candid communication at all levels. Ineffective communication is a major contributing factor to mission failure. In this case, JPL and NASA Headquarters communications were inadequate, in part because JPL was concerned that Headquarters would perceive JPL concerns about programmatic constraints negatively; JPL did not want to antagonize the customer. NASA Headquarters was rigid in adhering to unrealistic constraints.

Communication between JPL and NASA Headquarters was impeded by a cumbersome and poorly defined organizational structure within the Office of Space Science (OSS). Multiple interfaces and points of contact within OSS contributed to confusion and dilution of effective communication. A single dedicated point of contact within OSS reporting to the Associate Administrator for Space Science is essential to ensure effective and timely communication.

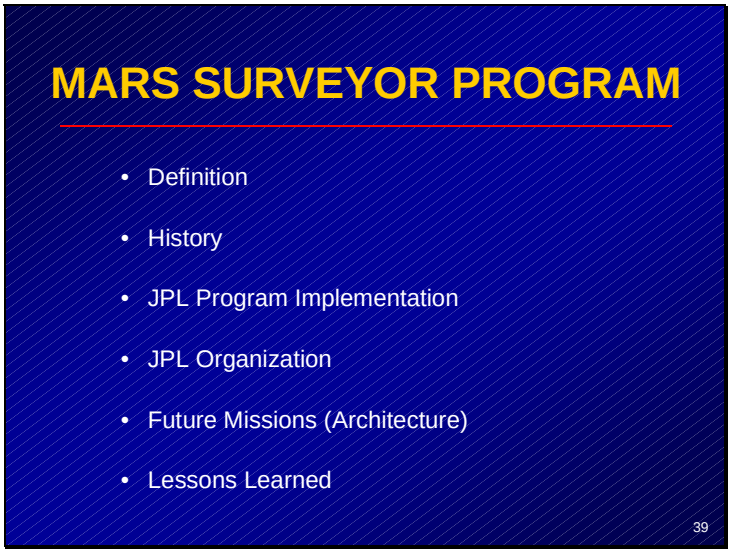
All mission characteristics, such as power, telemetry rates, payload mass, and orbital parameters, affect the achievement of science goals. Thus scientists must participate in all stages of project implementation to ensure that science goals are understood and taken fully into account. The actual extent of scientist involvement varied considerably from project to project. In a few instances, major decisions were made without formally consulting the scientists affected. The inevitable result was that some of the science eroded. Despite experiences like this, for the most part, participation of the scientists in the missions has been very good.

The missions examined differed considerably in the extent to which they succeeded in engaging the public. The Pathfinder mission was very successful, whereas some aspects of Mars Global Surveyor, although enormously scientifically successful, have been ineffective in this area. The Pathfinder success was achieved by promptly releasing the acquired data to the news media and making it available to the public at large on the Web. Scientists and engineers gave frequent press briefings. In contrast, release of parts of the Mars Global Surveyor data were delayed, and communication with the media was hindered by the wide dispersal of the scientists involved.



Mars mission success is largely a measure of how well the project has achieved the science goals. Scientists are in general the people best able to assess the science impact of pending decisions and make the accompanying scientific tradeoffs. They should, therefore, not only be consulted about the science impact of pending decisions, but they must also be active partners in making the decisions relating to science during all phases of a mission. This helps protect the science goals and maintain an appropriate balance among all of the different goals.

The Mars Program has a high public profile. One crucial part of satisfying public interest is the prompt release of science data. However, the release of data is not sufficient; an effective process for the delivery of mission results to the public is critical. In some situations, science data have been released only after a protracted period during which the scientists on the project have exclusive access to the data. Public affairs needs should be carefully balanced in any such restrictions. Scientists and engineers must also be available to explain the scientific significance of the results and to provide engineering background. They can energize the public and make them “see” the results of missions.

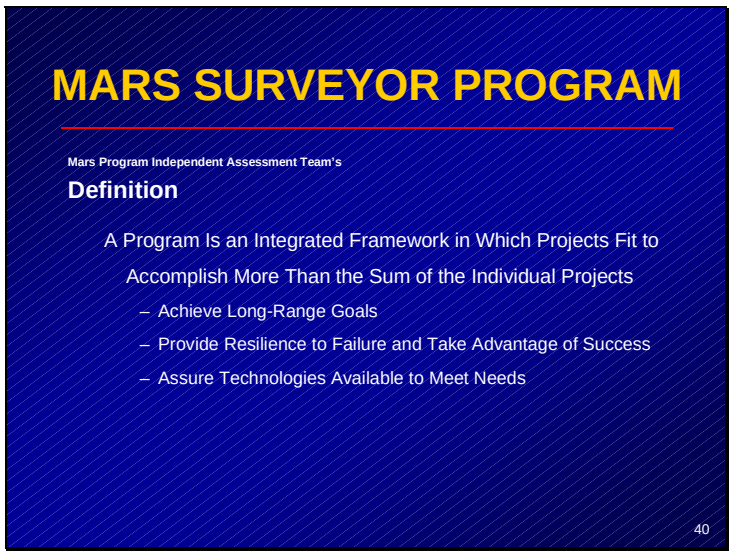


Earlier sections of this report have largely focused on individual projects. This section reviews the Mars Program. To aid the MPIAT evaluation, a program definition has been constructed.

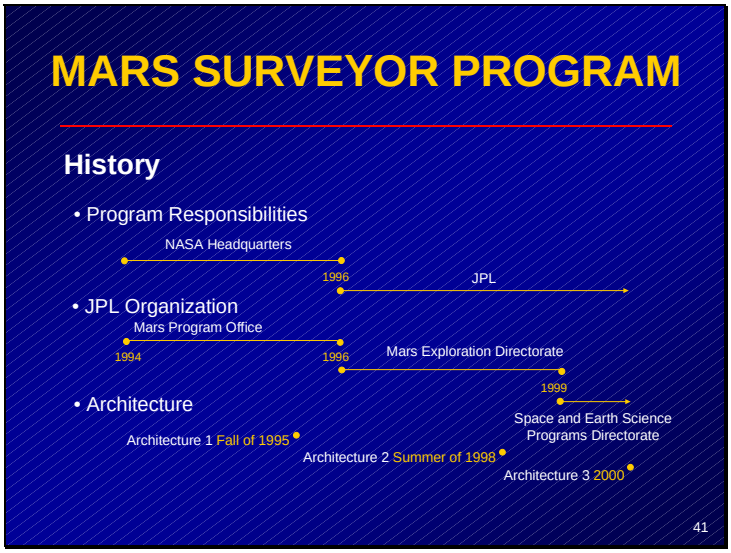
A review of the history of the Mars Program since 1994, including program implementation approach and organizational structure at JPL, is presented.

Findings are then presented, related first to the implementation of the program at JPL and then to the organizational structure at JPL.

Lessons learned are presented, which the team believes will lead to a healthy and resilient Mars Exploration Program.



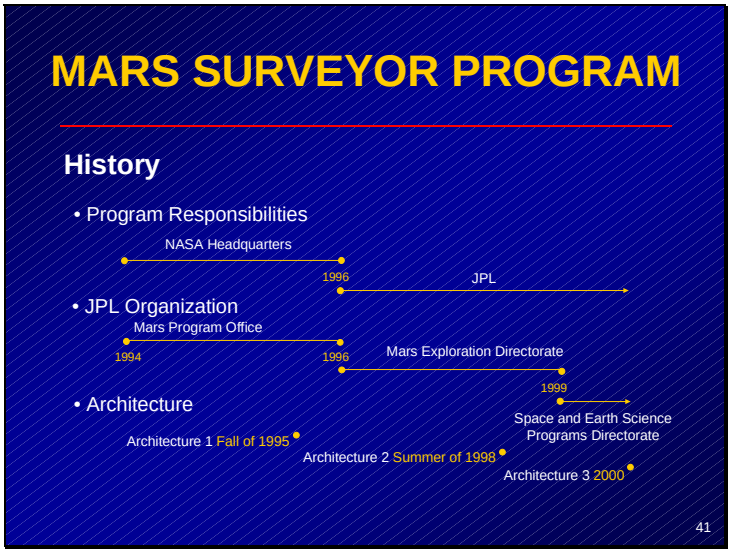
A program is more than the sum of the individual projects. There are long range program goals that require the contributions of multiple projects. For example, an orbiter mission may be required to gather data on potential landing sites for future lander missions. A program is the synergistic result of cooperative, interacting projects.



Historically, NASA Headquarters had management responsibility for all of the Agency's programs. This was generally true through 1996. At that time, the NASA Administrator directed that program management responsibilities be moved from Headquarters to the appropriate Field Center. Accordingly, program management for the Mars Program was transferred to JPL.

In recognition of the importance of the Mars Program, JPL created a new organizational element, the Mars Program Office, in 1994. This office was responsible for the individual Mars projects and provided study and architecture support to the NASA Program Management Office at Headquarters. The manager of the Mars Program Office reported directly to the Director of JPL.

The first Mars Program architecture was defined in the fall of 1995. It consisted of a series of modest scale landers and orbiters on small launch vehicles. Sample return from Mars was included as a potential out-year program possibility, but was not within the planning horizon of Architecture 1.



Program responsibility was moved from NASA Headquarters to JPL in 1996. The Laboratory responded by creating a new organization, the Mars Exploration Directorate, which replaced the Mars Program Office. In addition to the functions and responsibilities of the earlier office, the new organization took on additional program responsibilities, including allocation of funds and developing collaborative relations with other NASA participants and international partners.

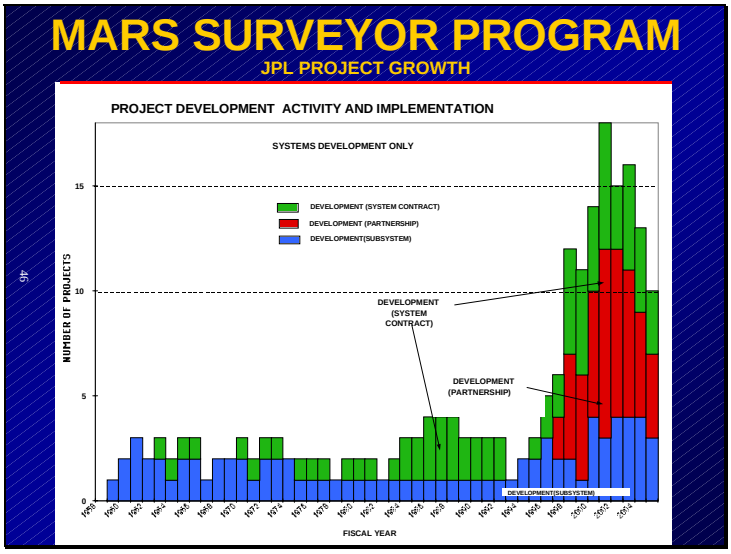
With the announcement of the “Mars Rock” (Alan Hills 84001) in August 1996, interest in an accelerated sample return mission required a change in the Mars Program architecture. Architecture 2, undertaken in the summer of 1998, was the response. The new architecture provided a sample return from Mars to Earth by 2008. This was to have been facilitated in large part by participation of the French.

Following the launch of the MCO and MPL, the Mars Exploration Directorate was merged with the Space and Earth Sciences Programs Directorate, a move intended to promote more effective use of resources and processes common to both organizations. It was also designed to leverage on the past successes of the Space and Earth Science Programs Directorate.

The MCO and MPL failures, as well as the recognized deficiencies in Architecture 2, require a new architecture. Architecture 3 is being developed as this report is being completed. This has allowed the MPIAT to comment on the process but not review the completed product.

The nature of the program implementation task changed significantly at JPL in response to the FBC initiative. The number of flight projects to be managed by the Laboratory greatly increased over a few short years. Furthermore, the nature of the projects changed from very large projects with budgets of a billion dollars or more to small projects with tightly constrained budgets. The Mars Program was only a part of this increased activity.

These changes, combined with the retirement of a significant portion of the experienced project leadership population, resulted in a demand for many new project managers. The demand was filled by the appointment of very capable, but inexperienced, people to project management positions. There was little mentoring for these managers in their new positions, especially in the use of project management principles and engineering practices such as reviews and testing. Simultaneously, the new leaders were required to meet the challenge of change to Faster, Better, Cheaper while not being well-grounded in prudent risk management. At the program level, these projects were not integrated and managed as a group. As a result, it was very difficult for the newer project managers to obtain outside help, to learn from each other, or to define interdependencies among their projects.

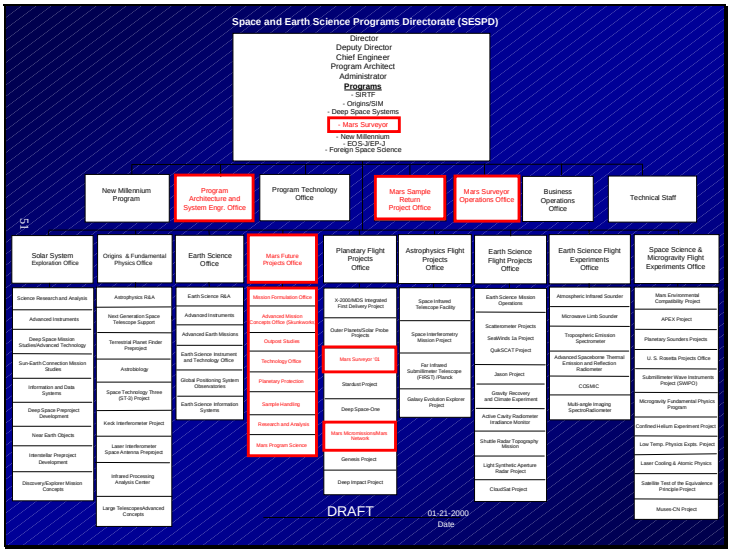


The tremendous and rapid growth in the number of projects at JPL is clearly shown in this chart. Over a period of approximately 3 years, JPL went from its long history of normally managing two large projects simultaneously to managing more than a dozen significantly smaller projects.

The Mars Program organization at JPL between 1994 and 1996 is described on this chart. The Mars Program Office was responsible for the mission planning, program advocacy, and flight project development. It was under this organization that the Mars ’98 project was initiated. Several difficulties were encountered. The roles and responsibilities of the program office relative to program direction and control were interpreted differently in the JPL Mars Program Office and the NASA Headquarters sponsoring office. This led to conflicts and protracted resolution activities, which diluted the attention needed to accomplish the missions. The result was that oversight of individual projects was inadequate and integration of ongoing and proposed projects into a unified program vision was not effective. The individual projects were not developed or managed within a clearly defined overall framework that identified interdependencies and risk management strategies. During this period, the integrated Mars Program architecture was developed, which included the early planning for the Mars ’01 project.

In 1996, NASA Headquarters delegated full program management authority to the NASA Centers. To implement this direction, JPL reorganized its Mars Program management as described on this chart. A Mars Exploration Directorate (MED), which reported to the Laboratory Director, was created. The MED was responsible for all program management functions, including those previously executed at Headquarters. With the change came the loss of a single point of contact at Headquarters for the Mars Surveyor Program. This situation was further complicated by the "Mars Rock" announcement in August 1996, resulting in a heightened public interest in Mars. Major redirection was given to JPL to include planning for robotic exploration related to the long-term needs of Human Exploration (managed by a different part of Headquarters) in its Mars Program plans. This led to a revision of the Mars architecture in 1998. The increased complexity and the deluge of new requirements was such that the ongoing projects were still not integrated at the program level. They operated as independent entities. Oversight of the projects was ineffective.

In 1999, JPL reorganized its entire space and Earth science effort into one directorate. This was done to better manage the significantly increased number of programs and projects in both science areas. Within this new organization, the Mars Program Manager no longer reports to the Laboratory Director as a separate entity. Projects report at a lower level, and many related program functions are distributed to other parts of the organization. The result is a serious loss of visibility and management focus on the Mars Surveyor Program as an entity. Complex lines of authority and communication abound, rendering a successful management of the Mars Program unlikely.



The JPL Space and Earth Sciences Programs Directorate (SESPD), illustrated in the accompanying figure, is intended to combine all management and planning functions for space and Earth sciences. It is an extremely broad organization that includes responsibilities for project management, program management, advanced studies, program planning and architecture, science experiments, and instrument and technology development.

The Mars Surveyor ’01 Project Office is embedded in this structure at the third level. Thus it is far removed from senior JPL management. Further, it is on par with a large number (68) of other equivalent level units, most with substantially smaller scope. This organizational position makes it difficult for the project to have visibility and ready access to management. In the team’s opinion, it invites project isolation, as happened in the Mars ’98 project.

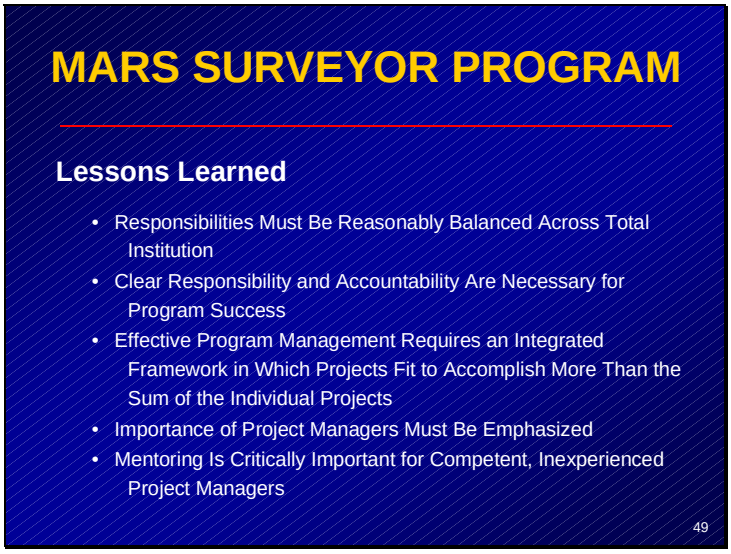
The SESPD structure raises even more questions relative to the management concept for the Mars Program. Various parts of the program responsibilities are scattered throughout SESPD, as highlighted in the organization chart. Program organization elements report at various levels and appear to have overlapping, and even conflicting, responsibilities. An example is the Program Architecture and Systems Engineering Office. Its systems engineering overlaps with the Mars Future Project Office, the Mars Sample Return Office, and the current flight projects.

The Mars Program Office must have the visibility and stature to oversee the planning and implementation of the entire Mars Program throughout the NASA Centers, industry, and the science community.

The MPIAT extensively reviewed the planned Mars '01 Project and concurs with the NASA decision not to fly the Mars '01 Lander in 2001 and to consider its use at a later opportunity. The MPIAT also concurs with the NASA decision to proceed toward flight of the Mars '01 Orbiter in 2001.

The new architecture is in an early stage of development; therefore, a detailed evaluation is not currently feasible. MPIAT has reviewed and provided comments on the preliminary architecture and its development process. The MPIAT believes that the new architecture is critically important to a successful Mars Surveyor Program.

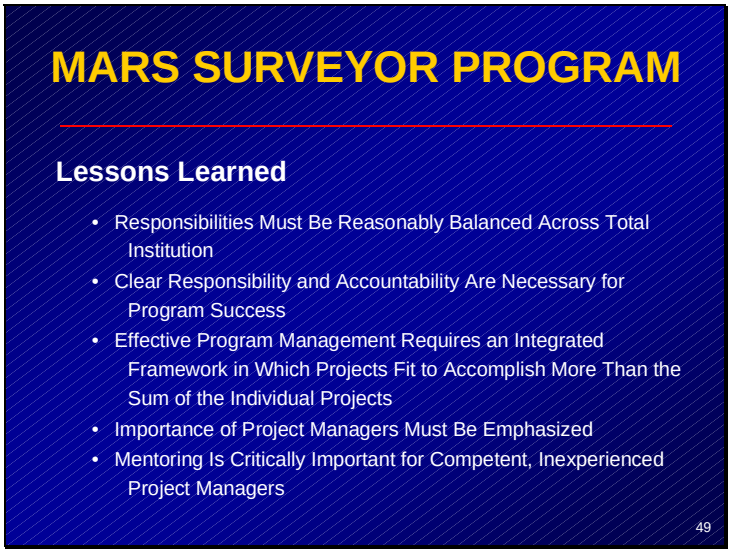
A substantive review will be conducted at a later time.



The Mars Surveyor Program was a difficult assignment for JPL. It came at a time of major internal changes involving simultaneous downsizing in personnel and growth in the number of projects. Though the formal Program Office title was transferred to JPL, the lines of responsibility among programs, projects, and the science community were not clearly delineated. Critical program requirements were set without adequate resources. The Program Office did not perceive that it had the flexibility to balance program elements or to deal with risk, except within individual projects. As a result, the JPL Program Office was unable to establish and play an effective role in implementing the Mars Program.

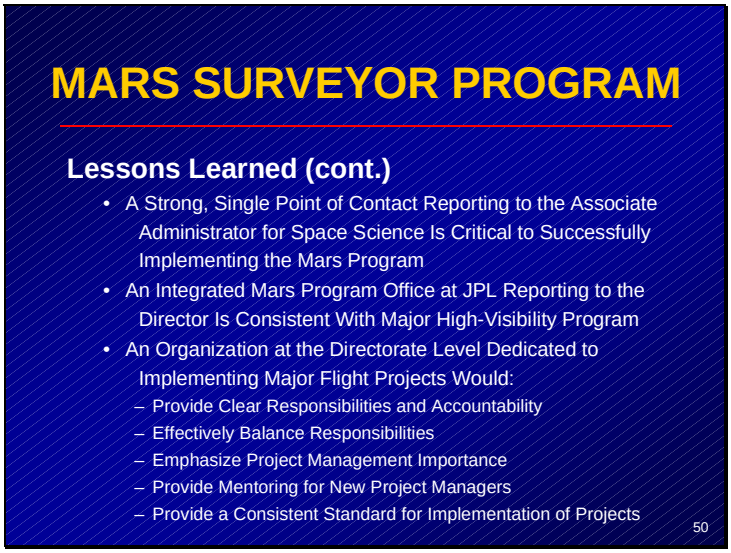
The lessons learned summarized herein are fundamental. They are basic to good program and project management and need to be part of the foundation of all future Mars Program activities.

Responsibilities must be accepted and balanced across all parts of the institutions involved. Clear lines of responsibility and attendant accountability are necessary.



Effective program management must provide a framework in which all program elements are balanced and optimized in light of NASA's overall objectives. The Program Office must have the flexibility to realign and to adjust various science, technology, and flight project elements.

Equally important is the capability and experience of project managers. Project management is one of the most demanding professional skills. It can only be acquired through years of experience. NASA, its Centers, and its contractors are challenged to provide managers capable of executing the series of complex projects required in the Mars Program. The success of the Mars Program is critically dependent on first-class project managers, and it is the responsibility of the respective institutions to assure their full training and mentoring.

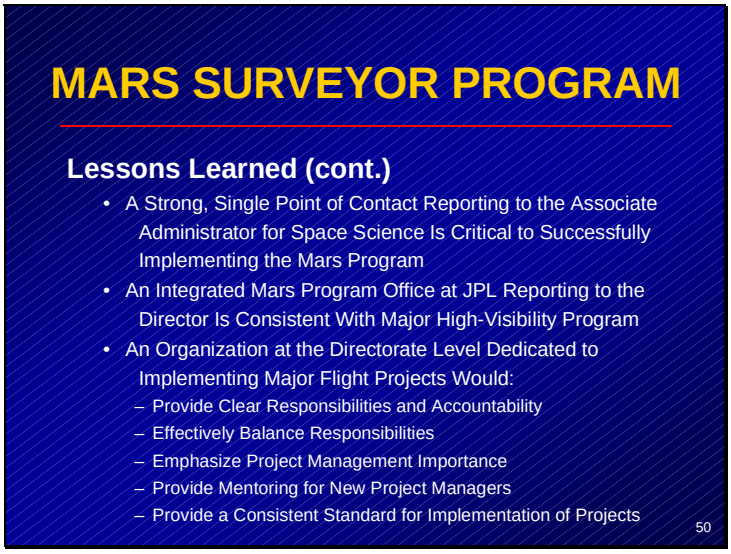


Relative to the overall structure of the Mars Program, the Mars Program Independent Assessment Team offers three points for consideration:

First, NASA Headquarters needs to clearly define the overall framework and direction of the Program. What does NASA want to accomplish in the long run? What should the products be for science, for human exploration, for technology, and for the public imagination? What are the near-term and long-term budget targets? All of these must be based on inputs from a wide range of constituencies, but must be compatible with what is technically feasible, and of scientific value. The program must be firmly based on well-thought-out studies performed under the auspices of the Program Office. Further, it is critical that there be a single point of contact at NASA Headquarters setting the overall framework. This person must also be responsible for the resolution of major issues and for authorization of program redirection, should that become necessary. It also should assure that national resources are being fully utilized.

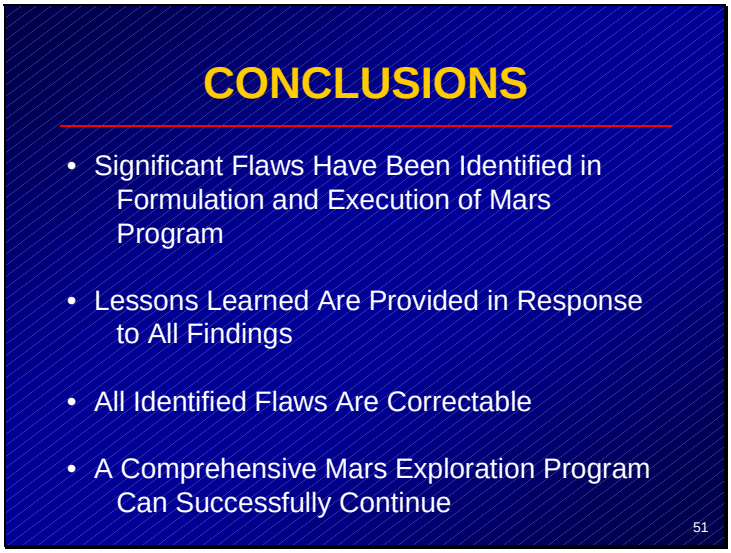
Second, at JPL, the Program Office needs the stature and visibility of reporting directly to the Laboratory Director. The Program Office will deal with multiple entities, both inside and outside of JPL. The Program Office needs the access to, and the authority of, the Laboratory Director.

Given the importance of Mars exploration, both as an established national goal and as an engaging program of enormous public interest, the Mars Program Office requires very high visibility.



Third, the Mars flight projects along with other major flight projects need a highly visible profile. They also need the opportunity to share in the rich heritage resident at JPL and ongoing experience among all flight projects. A way to accomplish both objectives is to create a Flight Projects Directorate. Such a directorate would provide direct and clear lines of responsibility and accountability. It would have the overall resources of the Laboratory at its disposal to balance the needs of various projects. It would also provide a home for the training and growth of project managers and would assure that consistent standards of implementation, review, and corrective action are taken across all projects.

The MPIAT believes that merging the Mars Exploration Directorate with the Space and Earth Sciences Programs Directorate is ill-suited to the successful implementation of the Mars Program.



The MPIAT believes the flaws identified in this report can be corrected in a timely manner to allow a comprehensive Mars Exploration Program to continue successfully.

Appendix

MPIAT Membership Biographies

Biographies of the Mars Program Independent Assessment Team

Thomas Young – Chairman

Tom Young retired as Executive Vice President of Lockheed Martin in 1995. He had previously served as President and COO of Martin Marietta and President of the Martin Marietta Electronics and Missiles Group. Prior to joining Martin Marietta, he had held positions at NASA including, Director, Goddard Space Flight Center; Deputy Director, Ames Research Center; Director, Planetary Program at NASA Headquarters; and Mission Director for the Viking Project at Langley Research Center. He is the recipient of NASA's highest award, the Distinguished Service Medal, for his work on the Viking Project. He received BSME and BSAE degrees from the University of Virginia, and a Masters in Management from MIT, which he attended as a Sloane Fellow. Mr. Young is a Senior Fellow of the American Institute of Aeronautics and Astronautics (AIAA), a Fellow of the American Astronautical Society (AAS), and a member of the National Academy of Engineering. He is a member of the NASA Advisory Council, and Chairman of the National Academy of Engineering Committee on Technology Literacy.

James O. Arnold

Jim Arnold's career with NASA spans nearly four decades. Currently, he serves at NASA Ames Research Center as Chief of the Space Technology Division. His service has included research engineering, branch management, a tour of duty at NASA Headquarters (aerothermodynamics program manager), and division and directorate management. Dr. Arnold received the NASA Medal for Outstanding Leadership and the NASA Medal for Outstanding Scientific Achievement. He was a recipient of the Senior Executive Service (SES) Meritorious Executive Award and of the SES Distinguished Executive Award. He received his B.S. at the University of Kansas, his M.S. from Stanford University, and his Ph.D. from York University, Toronto, Canada. He is a Fellow of the AIAA.

Thomas A. Brackey

Thomas Brackey serves as Executive Director, Technical Operations, and as a Chief Technologist for Hughes Space and Communications Company. In more than three decades of service to Hughes, he has gained extensive experience in line, project, and program management and business development encompassing all aspects of the space and communications business. He also has in-depth technical expertise in the areas of advanced technology, design, analysis, test, systems engineering, and operations for large, complex systems. He is a Distinguished Graduate of The Ohio State University, where he received a B.E.E., M.S., and Ph.D. in Electrical Engineering. He currently serves as a member of the NASA Advisory Council, Chairman of the NASA Technology and Commercializing Advisory Committee, and a member of the Air Force Scientific Advisory Board. He is a senior member and Distinguished Lecturer of the AIAA and is a member of many other organizations.

Michael H. Carr

Michael Carr is a geologist with the U.S. Geological Survey, Menlo Park, California. He is an Interdisciplinary Scientist on the Mars Global Surveyor mission and a member of the Galileo Imaging Team. Since joining the Geological Survey in 1962, he has been involved almost exclusively in lunar and planetary studies. After participating in the selection of the Apollo landing sites and analysis of returned lunar samples, he focused mainly on Mars. He was a member of the Mariner-9 imaging team and leader of the Viking Orbiter Imaging team. He received a Distinguished Service Award from the Department of Interior, the G. K. Gilbert Award from the Geological Society of America, and the National Air and Space Museum Medal for Lifetime Achievement in Air and Space Science and Technology. Dr. Carr received a B.Sc. from the University of London and a Ph.D. from Yale University, both in Geology. He has written over 150 papers about Mars and two widely used books, the *Surface of Mars* and *Water on Mars*. He has chaired many planning groups, most recently one looking into how NASA should prepare for return of samples from Mars. Dr. Carr is a Fellow of the Geological Society of America and the American Geophysical Union.

Douglas L. Dwoyer

Doug Dwoyer is the Associate Director for Research and Technology Competencies at the NASA Langley Research Center. At Langley he has previously served as Director, Research and Technology Group; Chief, Fluid Mechanics Division; Aerospace Technologist; and head of the Hypersonic Technology Office and of the Computational Methods Branch. Prior to joining NASA, he held positions at the Virginia Polytechnic Institute and State University, United Aircraft Research Laboratories, and the U.S. Air Force Aerospace Research Laboratories. He is the recipient of the U.S. Air Force Commendation Medal, the NASA Exceptional Engineering Achievement Medal, the NASA Outstanding Leadership Medal, and the SES Meritorious Executive Award. He received his B.S., M.S., and Ph.D. in Aerospace Engineering from Virginia Tech. During his research career in Computational Fluid Dynamics, he has had over 40 publications and edited four books. Dr. Dwoyer is a Fellow of the AIAA and a member of the Committee of 100 of the Virginia Tech College of Engineering. He serves on the Advisory Boards of the Department of Aerospace and Ocean Engineering of Virginia Tech and the Aerospace Engineering Department of the University of Maryland.

Gen. (Ret.) Ronald Fogleman

Ron Fogleman retired from the U.S. Air Force on September 1, 1997, after serving as the Chief of Staff. He is now President and CEO of a holding company that includes an aerospace consulting firm and several small businesses. As a member of the Joint Chiefs of Staff, General Fogleman served as a military advisor to the Secretary of Defense, the National Security Council, and the President. He has extensive operational experience having served as Commander-in-Chief, U.S. Transportation Command; Commander, Air Mobility Command; Commander, 7th Air Force; and Commander, Air Component Command, U.S./R.O.K. Combined Forces Command. He received his B.S. from the U.S.A.F. Academy and an M.A. in Military History/Political Science from Duke University.

General Fogleman serves on the editorial board of the *Strategic Review*. He has published numerous articles in the defense arena and frequently lectures at leading academic institutions. He donates considerable time to national security affairs and serves as the director of several aerospace companies.

Maj. Gen. (Ret.) Ralph Jacobson

Ralph Jacobson retired as President and Chief Executive Officer of the Charles Stark Draper Laboratory, Inc., in July 1997. He had held this position since his retirement from the U.S. Air Force as a Major General ten years earlier. Throughout his career, he had a variety of assignments involving the space program. His final Air Force post was as Director of Special Projects, Office of the Secretary of the Air Force. Among his awards are the Distinguished Flying Cross and the Defense, National Intelligence Community, and Air Force Distinguished Service Medals. General Jacobson graduated from the U.S. Naval Academy with a B.S. in Engineering and a commission as a Second Lieutenant in the U.S. Air Force. He earned an M.S. in Astronautics from the Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio, and a second M.S. in Business Administration from The George Washington University. General Jacobson is a Fellow of the AIAA and a trustee of the U.S. Naval Academy Foundation. He is a member of the Strategic Advisory Group for the U.S. Strategic Command, the NASA Advisory Council, the U.S. Naval War College Board of Advisors, and several others.

Herbert Kottler

Herbert Kottler is Associate Director of Lincoln Laboratory. He is responsible for the ballistic missile defense activities at the Laboratory; space activities for the Air Force, NASA, and NOAA; and interactions with Congress and the Office of the Secretary of Defense. Dr. Kottler has been with Lincoln Laboratory since 1969. Previous positions include Associate Head and Head of the Aerospace Division, Manager of the Re-entry Systems Program, Leader of the Advanced Systems Group, and Leader of the Countermeasures Technology Group. He is the recipient of a NASA Public Service Group Achievement Award. Dr. Kottler received a B.S. in Electrical Engineering from Drexel Institute and an M.S., and Ph.D. in High Energy Physics at Case Institute. Dr. Kottler has written extensively in the areas of sensor system design, testing and development. He is a member of the AIAA, Sigma Xi, Tau Beta Pi, Eta Kappa Nu, and Phi Kappa Phi.

Peter T. Lyman

Peter Lyman retired as the Deputy Director of the Jet Propulsion Laboratory, a NASA facility operated by the California Institute of Technology. In his 29 years at JPL, Dr. Lyman served as a spacecraft development specialist, as Director of spacecraft operations for several NASA deep space missions, and as Deputy Project Manager of the Voyager project. Additionally, he has managed the JPL Applied Mechanics Division and the Information Systems Division. As Assistant Laboratory Director for Telecommunications and Data Acquisition, he was responsible for the overall management of the NASA worldwide Deep Space Network, including long-range planning, advanced development, implementation, and operation of the network. Dr. Lyman was awarded the NASA

Outstanding Leadership Medal twice, the NASA Equal Employment Opportunity Medal, the NASA Exceptional Achievement Medal, and the NASA Distinguished Service Medal. Dr. Lyman holds degrees in Mechanical Engineering and Naval Architecture from the University of California at Berkeley. He co-chaired several task forces for NASA. In addition, he is a consultant to the Lawrence Livermore National Laboratory. He is a Fellow of the AIAA, a Fellow of the AAS, and a member of the International Academy of Astronautics.

Joanne M. Maguire

Joanne Maguire is Vice President and Deputy General Manager for core business development in the TRW Space & Electronics Group (S&EG). In this role, she leads the group's pursuit of strategic business opportunities encompassing responsibility for marketing, planning, and discretionary investments. Her past positions at TRW include Vice President and General Manager of both the Space and Laser Programs Division, where she led the S&EG NASA programs, including the Chandra X-ray Observatory, and previously the Space & Technology Division, the S&EG spacecraft engineering and technology organization. Since joining TRW in 1975, Ms. Maguire has held a succession of increasingly responsible technical and management positions. She received the 1999 Outstanding Leadership Award from Women in Aerospace. She has a B.S. from Michigan State University and an M.S. in Engineering from UCLA.

Robert A. Pattishall

Bob Pattishall is the Director of the National Reconnaissance Office (NRO) Advanced Systems and Technology Directorate. He is responsible for conducting an aggressive, customer-focused R&D program to provide enabling technologies that will revolutionize global reconnaissance. During his 24-year career in the NRO, Mr. Pattishall served in a variety of engineering management positions involving development and operations of state-of-the-art reconnaissance satellite systems. Previous to his appointment as Director of Advanced Systems and Technology, Mr. Pattishall was the Director, S Program Group. As such, he was responsible for the design, manufacture, and operation of a multiple satellite integrated architecture that provided critical intelligence to national decisionmakers and military commanders. Mr. Pattishall successfully managed the development and deployment of a new generation collection system and consolidation of two existing National Space Reconnaissance programs into a combined program. Prior to the NRO, he worked as an aerospace engineer for McDonnell-Douglas and Fairchild Space and Electronics Company. Mr. Pattishall has received numerous awards and recognition including the National Intelligence Certificate of Distinction, the Intelligence Medal of Merit, and the Joseph Charyk Award for Contributions to the National Intelligence Space Program. He received a B.S. in Aerospace Engineering from the University of Maryland.

Laurence A. Soderblom

Larry Soderblom is a geophysicist with the U.S. Geological Survey. He has been involved in numerous scientific investigations on NASA planetary exploration missions, including the Mariners 6, 7, and 9; Viking; Voyager; Magellan; Galileo; Mars Pathfinder;

Mars Global Surveyor; Cassini; and New Millennium missions. He twice served as Branch Chief of Geological Survey's Astrogeology Program. Dr. Soderblom has received the NASA Public Service Award and twice received the NASA Exceptional Scientific Achievement Award. He was awarded the Department of Interior Meritorious Service Award and Distinguished Service Award. Dr. Soderblom attended New Mexico Institute of Mining and Technology, receiving dual B.S. degrees in Geology and Physics, and later Caltech, from which he received a Ph.D. in Planetary Science and Geophysics. He served as President of the Planetology Section, American Geophysical Union, and has led a number of NASA advisory committees, including the NASA Space Science Advisory Committee, NASA Space and Earth Science Advisory Council, and the NASA Solar System Exploration Subcommittee. He was a Sherman Fairchild Distinguished Scholar in residence at the California Institute of Technology.

Peter Staudhammer

Peter Staudhammer is Vice President and Chief Engineer of TRW Inc. Prior to this position, he worked in rocket engine combustion at the Jet Propulsion Laboratory for two years before joining TRW. He was one of the principal architects and chief engineer for the development of the Lunar Module Descent Engine. He later managed space instrument development, including the Viking Mars biology and meteorology instruments, the Voyager Jupiter/Saturn Ultraviolet spectrometer, the Pioneer Venus atmospheric analysis, and several Earth radiation and climatology instruments. Dr. Staudhammer subsequently directed the TRW Central Research Staff. He was named Vice President for classified space systems before being named to his present position as the TRW Chief Technical Officer. He received B.S., M.S., and Ph.D. degrees in Engineering from UCLA. He is a member of the National Academy of Engineering.

Kathryn Thornton

Kathryn Thornton, a former astronaut, is currently Assistant Dean for Graduate Programs at the University of Virginia School of Engineering and Applied Science; a professor in the Division of Technology, Culture, and Communication; and the director of the University of Virginia Center for Science, Mathematics, and Engineering Education. Selected by NASA in May 1984, Dr. Thornton is a veteran of four space flights, including the first Hubble Space Telescope Service Mission. She has logged over 975 hours in space, including more than 21 hours of extravehicular activity. Prior to becoming an astronaut, Dr. Thornton was employed as a physicist at the U.S. Army Foreign Science and Technology Center in Charlottesville, Virginia. She has received numerous awards, including NASA Space Flight Medals, the NASA Distinguished Service Medal, and the National Intelligence Medal of Achievement. Dr. Thornton received her B.S. in Physics from Auburn University and her M.S. and Ph.D. in Physics from the University of Virginia. She is a member of the National Research Council Aeronautics and Space Engineering Board, the U.S. Air Force Air University Board of Visitors, and the National Academy of Sciences Committee on Technological Literacy.

Peter Wilhelm

Peter Wilhelm is the Director, Naval Center for Space Technology, at the Naval Research Laboratory. The Center's mission is to "preserve and enhance a strong space technology base and provide expert assistance in the development and acquisition of space systems." The Center is unique within the Department of Defense and has provided its expertise to a wide variety of customers, including the Naval Service, Army, Air Force, NRO, NASA, BMDO, and NPOESS. Several satellites, currently under development, will raise the Center's total to over 90 satellites in the past 40 years. Mr. Wilhelm's role in this field has been recognized by many awards and honors over the years, including the Robert H. Goddard Astronautics Award. He was elected into the National Academy of Engineering.

Brian C. Williams

Brian Williams is the Boeing Associate Professor of Aeronautics and Astronautics at the Massachusetts Institute of Technology (MIT) and is a member of the Space Systems and Artificial Intelligence Laboratories. His research concentrates on model-based autonomy—the creation of long-lived autonomous systems that are able to diagnose and repair themselves through common-sense reasoning. Prior to joining MIT, he formed the Autonomy and Robotics area at the NASA Ames Research Center, noted for the development of the remote agent autonomous control system for the Deep Space 1 probe. At Xerox Palo Alto Research Center, he co-invented the GDE and Sherlock model-based diagnosis systems. Dr. Williams holds an S.B., S.M., and Ph.D. in Computer Science from MIT. He is on the editorial boards of *AAAI Press* and the *Journal of Artificial Intelligent Research*, and he has been a guest editor for the *Artificial Intelligence Journal*. He has won several best paper prizes for his research in model-based and qualitative reasoning.

Maria T. Zuber

Maria Zuber is the E.A. Griswold Professor of Geophysics and Planetary Sciences at the Massachusetts Institute of Technology. She is Deputy Principal Investigator of the Mars Orbiter Laser Altimeter on the Mars Global Surveyor spacecraft; Team Leader of the laser ranging investigation on the Near Earth Asteroid Rendezvous mission; a member of the geophysics team of the Clementine mission to the Moon; and lead of the geophysics investigation of the MESSENGER mission to Mercury. Previously, Dr. Zuber held a faculty position at Johns Hopkins University and a staff position at the Goddard Space Flight Center. She is a recipient of the NASA Exceptional Scientific Achievement Medal. Dr. Zuber received a B.S. from the University of Pennsylvania and M.S. and Ph.D. degrees in Geophysics from Brown University. She currently serves on the editorial board of *Science*. She serves as President of the Planetary Sciences Section of the American Geophysical Union and is a member of the NASA Space Science Advisory Committee, the American Astronomical Society, and the American Association for the Advancement of Science.

Kurt Lindstrom

Kurt Lindstrom, Executive Secretary for the MPIAT, has been at NASA since 1983. Mr. Lindstrom is currently a program executive in the NASA Advanced Technology and Mission Studies Division. He is responsible for the process of technology integration across the Office of Space Science activities. Mr. Lindstrom is the former Director of the NASA Management Office at JPL. In this position, he was responsible for the institutional management of the NASA Jet Propulsion Laboratory. Prior to that, Mr. Lindstrom directed the Program Analysis Branch in the NASA Office of Space Science and Applications and was the Development and Operations Contract Manager for the Numerical Aerodynamic Simulation Program at Ames Research Center. He began his career at NASA as a Presidential Management Intern.

Consultants

John Casani

John Casani retired in 1999 after 43 years with the Jet Propulsion Laboratory. He spent the majority of his career in systems engineering and project management. He was Project Manager for three major space missions at JPL: Voyager, Galileo, and Cassini. He held senior project positions in several early space programs, including Explorer, Pioneer, Ranger, and Mariner. He is a recipient of several NASA awards, including the Distinguished Service Medal, the Exceptional Achievement Medal, and the Medal for Outstanding Leadership. He received the AIAA Space System Award and the von Karman Lectureship, the National Space Club Astronauts Engineer Award, and the AAS Space Flight Award. He received a BSEE and an Honorary Doctor of Science degree from the University of Pennsylvania. He a Fellow of the AIAA and is a member of the National Academy of Engineering and the International Astronautics Academy.

Brantley Hanks

Brantley Hanks is the Special Assistant for Framework and Metrics, Intelligent Synthesis Environment Programs Office, NASA Langley Research Center. He has 37 years of experience in leading and conducting spacecraft technology development at Langley, including serving as the Leader, Spacecraft Technology Thrust Office and Head, Spacecraft Dynamics Branch. He has had temporary assignments to NASA Headquarters as Deputy Chief Engineer, Technical, responsible for integrated engineering and technology planning, and in the Space Technology Directorate, assisting in the planning of the Small Spacecraft Technology Initiative. His experience in spacecraft/space systems technology development focused on Apollo, Viking, Voyager, the Space Shuttle, the New Millennium Program, and the International Space Station. Mr. Hanks received the NASA Exceptional Service Medal. He received B.S. and M.S. degrees in Engineering Mechanics at Virginia Tech; his post-M.S. study was in Aerospace Engineering at Purdue University. He is an Associate Fellow of the AIAA and past Chairman of the AIAA Structural Dynamics Technical Committee.

Bruce Murray

Bruce Murray is Professor of Planetary Science and Geology at the California Institute of Technology (Caltech) in Pasadena, California. He has been at Caltech since 1960 and currently teaches courses in Global Environmental Science and Planetary Surfaces, and he supervises graduate student research. Dr. Murray was Director of the Jet Propulsion Laboratory for 6 years, which included the Viking landings on Mars and the Voyager mission through the Jupiter and Saturn encounters. Dr. Murray was a member of the science teams of the early Mariner Mars flights. More recently, he was a science team member of the Russian Phobos 1 mission, the Russian Mars 96 and the U.S. Mars Observer missions, the Mars Global Surveyor mission, the New Millennium Mars Microprobe (DS-2), Mars Climate Orbiter, and Mars Polar Lander. In 1979, he and the late Carl Sagan founded The Planetary Society, a 100,000-member international organization dedicated to exploring the solar system and the search for extraterrestrial intelligence.

Peter Norvig

Peter Norvig is Chief of the Computational Sciences Division at NASA Ames Research Center and the Thinking Space Systems Thrust Area manager in the Cross-Enterprise Technology Development Program. Prior to these positions, he was Chief Scientist for Junglee Corp., where he helped develop an industry-leading database-backed comparison shopping service. He was a Senior Scientist at Sun Microsystems Laboratories, where he did research and development in information retrieval and helped set Sun's strategic Internet policy. He was a faculty member at Berkeley and the University of Southern California. Dr. Norvig has over 40 publications in artificial intelligence, natural language processing, and software engineering, including the leading textbooks *Artificial Intelligence: A Modern Approach* and *Paradigms of AI Programming*.

Robert L. Sackheim

Bob Sackheim is the Assistant Director and Chief Engineer for Propulsion at the NASA Marshall Space Flight Center. He is responsible for providing technical leadership for all of the Center's flight propulsion systems and for research and development of new propulsion technology for advanced space transportation systems. He has been an instructor in Space Propulsion at UCLA for 9 years. He recently retired from TRW Space and Electronics Group after 35 years in various management positions, the most recent being Manager of the Propulsion and Combustion Center. Mr. Sackheim is the recipient of numerous awards for contributions to space propulsion, including the AIAA Wylde Propulsion Award, the AIAA Sustained Service Award, three NASA Public Service Awards, and three TRW Chairman's Awards for Innovation. He received a B.S. in Chemical Engineering from the University of Virginia, received an M.S. in Chemical Engineering from Columbia University, and completed all coursework towards a Ph.D. at UCLA.

Mr. Sackheim holds seven patents and has published over 120 technical papers on propulsion for launch, missile, and space vehicles. He is a Fellow of the AIAA, a recently elected member of the National Academy of Engineering, a member of the International Academy of Astronautics, and a member of many other organizations. He has participated on numerous NASA, Department of Defense, National Research Council, AIAA, and university advisory boards and committees.

Steven F. Zornetzer

Steve Zornetzer is Director of Information Sciences and Technology at NASA Ames Research Center. Previously, he served as Director of Life Sciences at the Office of Naval Research. A principal focus of recent interest and effort, for both NASA and the Navy, has been the improvement of technology infusion into operational settings. Prior to joining the Senior Executive Service, Dr. Zornetzer was a Professor of Neuroscience at the University of California at Irvine College of Medicine and the University of Florida College of Medicine. He was a recipient of a Presidential Rank Award for Senior Executives. Dr. Zornetzer received his B.A. from the State University of New York, Stony Brook; an M.S. from the University of Wisconsin, Madison; and a Ph.D. in Biological Sciences from the University of California at Irvine. He has published over 70 research papers and co-authored two books. Dr. Zornetzer served as Vice-Chair of the White House Planning Committee for the Decade of the Brain and numerous other national committees and review teams.