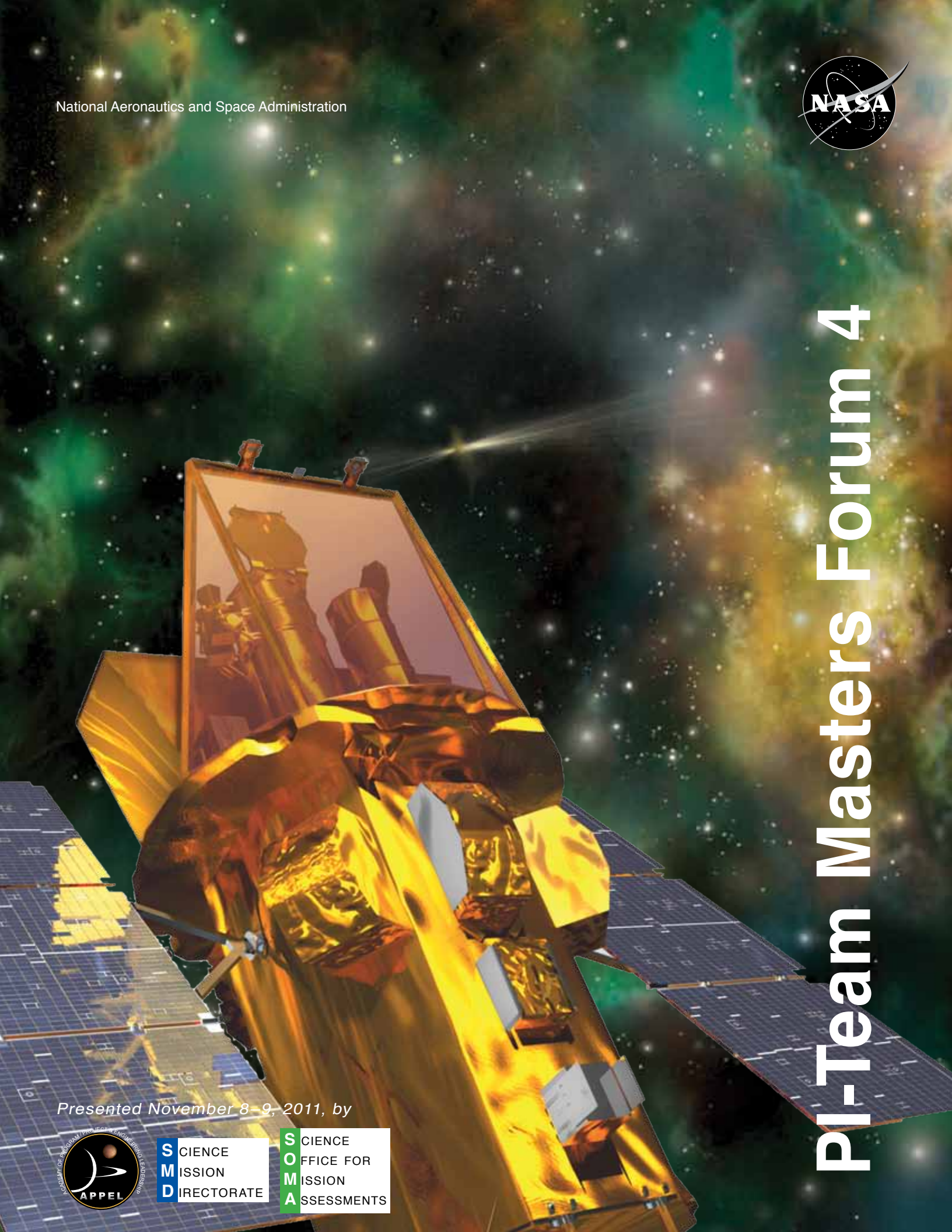
National Aeronautics and Space Administration



PI-Team Masters Forum 4

Presented November 8–9, 2011, by

APPEL ACADEMY OF PROGRAM/PROJECT & ENGINEERING LEADERSHIP

SMD SCIENCE MISSION DIRECTORATE

SOMA SCIENCE OFFICE FOR MISSION ASSESSMENTS

The NASA Academy of Program/Project and Engineering Leadership's Knowledge Sharing initiative, in partnership with NASA's Science Mission Directorate and NASA's Science Office for Mission Assessments, presents

PI-Team Masters Forum 4

November 8–9, 2011

Annapolis Marriott Waterfront | 80 Compromise St., Annapolis, MD 21401

http://www.annapolismarriott.com

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Cover Image: (Front) A composite illustration of the Swift spacecraft. (Back) Artist's concept of TRACE. Image Credit: NASA/Swift/Aurore Simonnet/ TRACE Project/Kerry Ellis

Table of Contents

Welcome to the Principal Investigator (PI)–Team Masters Forum 4, a collaboration between NASA's Science Mission Directorate (SMD), NASA's Academy of Program/Project and Engineering Leadership (APPEL), and NASA's Science Office for Mission Assessments (SOMA). This is the fourth of our PI-Team Masters Forum knowledge-sharing events, which are held following major science mission announcement of opportunity (AO) Phase A selections, as established by SMD's Policy Directive 13B (SPD 13B). The purpose of these Forums is to enable you to engage, share with, and learn from fellow practitioners from a broad range of science missions through their stories, shared experiences, and lessons learned as a means to share knowledge that will enhance the probability of executing a successful mission.

Your participation in this Forum is in recognition of your selection in the Explorer mission or mission of opportunity AO process, and we wish to congratulate your team on these outstanding accomplishments. The Forum reflects the importance that NASA places on providing a context for knowledge that can contribute to a successful mission. We are delighted to have you participate.

This Forum is patterned after the very successful NASA Academy Masters Forums, which have been hosted semiannually over the past twelve years and have involved master practitioners of program/project management and systems engineering in many NASA programs as well as other government agencies, industry, and university-led programs. The goal of these Forums is sharing knowledge and experience with future generations of master practitioners to develop a community of practice that enhances the disciplines critical to mission success.

Among the many benefits of your participation, this Forum is meant to help you gain an understanding of program/project management, systems engineering, and science mission design best practices and lessons learned; to cultivate a community of reflective practitioners within your team; and to help solidify cross-organizational relationships in support of your project.

In addition to thought-provoking presentations and dynamic group discussions, the Forum offers you the chance to build relationships with peers and meet face to face with key leaders in this community. Former Masters Forum participants have stated that the opportunity to network with colleagues from across NASA, other government agencies, universities, and private industry is one of the Forum's most valuable features.

While the Masters Forum process continues to evolve to meet NASA's new challenges—the PI-Team Forums being an excellent example of this evolution—one thing has remained constant: the belief in the power and purpose of storytelling. Good stories engage and motivate us; they illuminate subtle and contrasting points of view that otherwise would be lost to both novice and experienced practitioners. They provide a practical framework to deal with extraordinary change, better preparing us for the unanticipated challenges that lie ahead. We can also communicate our expectations and vision through storytelling, expanding the boundaries of the possible, while harnessing the capabilities within the team. Through stories, we can communicate knowledge that helps us innovate, find new solutions to problems, and add valuable tools for project management, engineering, and science mission management. We hope your participation will enrich your perspective and that you will continue to benefit from these experiences far into the future.

Sincerely,

Edward Hoffman, Academy Director;

Paul Hertz, Science Mission Directorate Chief Scientist;

Cindy Daniels, Science Office for Mission Assessments Director;

and the Academy Knowledge-Sharing Team

Message from the Acting Associate Administrator for Science Mission Directorate, NASA Headquarters

Welcome to the fourth Principal Investigator (PI)–Team Masters Forum. I hope that you, as a key member of your PI-led mission concept study or instrument team, find this Forum highly useful. Team is the key word here, as the PI does not operate in isolation but as the leader of a complex team. The associate administrator of NASA's Science Mission Directorate (SMD) relies on a highly integrated management team to execute NASA's science program, and you, too, will need a team approach to be successful.

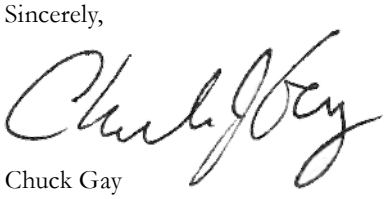
NASA is responsible to the Administration, Congress, and, ultimately, the American people for the missions that we fly; we make commitments to our stakeholders for the exciting science that our missions will yield as well as the funding that they require. It is crucial that you keep your mission within its available resource envelope so that we all succeed in meeting our commitments—your commitment to NASA and SMD's commitment to the American people.

In order to succeed, the PI must perform a job that is highly interactive with the mission management team and requires excellent communication skills. PIs who think, "I am in charge, and I will make all the decisions," will fail.

Even for those who have been a PI before, I believe that you will find this Forum extremely useful. We have invited some very experienced people who have different perspectives and different experiences than yours and who can provide you with fresh insight into what it takes to achieve mission success.

I hope that this Forum will provide you with an enhanced perspective in successfully conducting your concept studies, instrument investigations, and missions.

Sincerely,



Chuck Gay

Agenda

Monday, 7 November, 2011

- Travel day/hotel check-in (no formal events planned)

Tuesday, 8 November, 2011
7:30 a.m.–5:15 p.m.

- Breakfast—Ballroom Foyer (7:30 a.m.–8:00 a.m.)
  - *Note: "Day of" speakers breakfast to be held in private room—Nobs Room*
- Formal Welcome/Opening Remarks (8:00 a.m.–8:20 a.m.)
  - *Ed Hoffman, Academy Director, and Cindy Daniels, Science Office for Mission Assessments*
- NASA Science Missions: Opportunities and Challenges (8:20 a.m.–9:00 a.m.)
  - *Chuck Gay, Deputy Associate Administrator, Science Mission Directorate, NASA Headquarters*
- PI-Team Masters Forum Convener (9:00 a.m.–9:15 a.m.)
  - *Noel Hinners, Consultant*
  - *Introductory Remarks: Charge to Participants and Agenda Review*
  - *Brief Attendee Introductions (PIs introduce their team members at their respective tables)*
- Lessons from Previous Explorer Missions (I): MAP and WIRE (9:15 a.m.–10:15 a.m.)
  - *Panel Host: James L. Burch, OHMIC PI, Southwest Research Institute*
  - *MAP PM: Liz Citrin, Goddard Space Flight Center*
  - *WIRE PM: Bryan Fafaul, Goddard Space Flight Center*
  - *Q&A*
- Break (10:15 a.m.–10:30 a.m.)
- The Successful Project Team—Roles and Responsibilities (10:30 a.m.–12:30 p.m.)
  - *Panel Host:: Richard Eastes, GOLD PI, University of Central Florida*
  - *Principal Investigator: M. Patrick McCormick, Hampton University*
  - *Project Scientist: Steve Saunders, Lunar and Planetary Institute*
  - *Project Manager: G. Scott Hubbard, Stanford University*
  - *Systems Engineer: Orlando Figueroa, NASA, Retired*
  - *Contractor Team: Steve Jolly, Lockheed Martin*
  - *Q&A*
- Lunch—Patio (12:30 p.m.–1:30 p.m.)
- Lessons from Previous Explorer Missions (II): AIM and GALEX (1:30 p.m.–2:30 p.m.)
  - *Panel Host: Keith Gendreau, NICER PI, Goddard Space Flight Center*
  - *AIM PI: James M. Russell III, Hampton University*
  - *GALEX PM: James Fanson, Jet Propulsion Laboratory*
  - *Q&A*
- The SMD/ExPO Management Team: Overview, Guidance, and Expectations (2:30 p.m.–3:40 p.m.)
  - *Panel Host: Thomas J. Immel, ICON PI, University of California–Berkeley*
  - *Panel Chair: Paul Hertz, SMD Chief Scientist, NASA Headquarters - Introductory Remarks*
  - *The SMD Headquarters & Explorer Program Office (ExPO) Goddard Space Flight Center Management Team:*
    - Program Scientist: Barbara Giles, NASA Headquarters
    - Program Executive: Willis S. Jenkins, Jr., NASA Headquarters
    - Explorers Deputy Program Manager and Heliophysics Projects Division Associate Director: Joseph A. Dezio, Goddard Space Flight Center
  - *Q&A*
- Break (3:40 p.m.–3:55 p.m.)
- Managing Mission Development Risk (3:55 p.m.–4:45 p.m.)
  - *Panel Host: Lynn M. Kistler, SCOPE PI, University of New Hampshire*
  - *Managing Software Development—The Hidden Risk: Steve Jolly, Lockheed Martin*
  - *Q&A*

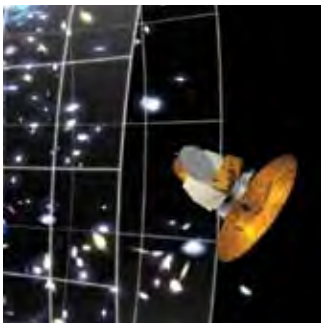
- Capturing Knowledge Exercise (4:45 p.m.–5:15 p.m.)
  - *Table Discussions, Reflections, and Knowledge Capture Exercise: Forum Participants*
- Group Photo (5:15 p.m.–5:30 p.m.)
- Dinner—Central and South Ballroom - Open Networking (5:30 p.m.–6:30 p.m.)

Wednesday, 9 November 2011
7:30 a.m.–4:45 p.m.

- Breakfast—Ballroom Foyer (7:30 a.m.–8:00 a.m.)
  - *Note: "Day of" speakers breakfast to be held in private room—Nobs Room*
- Reconvene (8:00 a.m.–8:15 a.m.)
  - *Noel Hinners, Consultant*
- Lessons from Previous Explorer Missions (III): COBE (8:15 a.m.–9:25 a.m.)
  - *Panel Host: John Kohl, CPI PI, University of New Hampshire*
  - *The Environment: Noel Hinners, Consultant*
  - *The Mission: John C. Mather, Goddard Space Flight Center*
  - *The Project: Dennis McCarthy, Consultant*
  - *Q&A*
- Managing Science Missions Cost Performance (9:25 a.m.–10:45 a.m.)
  - *Panel Host: Robert Pfaff, ASTRE PI, Goddard Space Flight Center*
  - *The Impetus for Better Cost Management: Noel Hinners, Consultant*
  - *Project Resource Controls and Earned Value Management: Roy Maizel, NASA Headquarters*
  - *Meeting Cost and Schedule Performance: Jim Adams, NASA Headquarters*
  - *Q&A*
- Break (10:45 a.m.–11:00 a.m.)
- Staying Within the Box (11:00 a.m.–12:30 p.m.)
  - *Panel Host: George R. Ricker, TESS PI, Massachusetts Institute of Technology*
  - *Viking—Managing Critical Resource Allocations: A. Thomas Young, Lockheed Martin (retired)*
  - *AIM—Dealing with Resource Challenges on an Explorer Mission: James M. Russell III, Hampton University*
  - *Mars Missions—Managing Critical Resources: Richard W. Zurek, Jet Propulsion Laboratory*
  - *Q&A*
- Lunch—Patio (12:30 p.m.–1:30 p.m.)
- Lessons from Previous Explorer Missions (IV): Swift (1:30 p.m.–2:30 p.m.)
  - *Panel Host: Mark Swain, FINESSE PI, Jet Propulsion Laboratory*
  - *Swift PI: Neil Gehrels, Goddard Space Flight Center*
  - *Swift PM: Joseph A. Dezio, Goddard Space Flight Center*
  - *Q&A*
- Managing International Missions (2:30 p.m.–3:20 p.m.)
  - *Panel Host: Pietro N. Bernasconi, GUSSTO Mission Scientist, Johns Hopkins University Applied Physics Laboratory*
  - *NASA and SMD Policies: Paul Hertz, NASA Headquarters*
  - *Q&A*
- Break (3:20 p.m.–3:35 p.m.)
- SOMA Analysis of Previous PI Missions' Performance (3:35 p.m.–4:10 p.m.)
  - *Cindy Daniels, Science Office for Mission Assessments*
  - *Q&A*
- Capturing Knowledge Exercise (4:10 p.m.–4:30 p.m.)
  - *Table Discussions, Reflections, and Knowledge Capture Exercise/Shared Experiences: Forum Participants*
- PI-Team Forum Survey/Questionnaire (4:30 p.m.–4:45 p.m.)
- Forum Concludes/Return Travel Home (4:45 p.m.) (Limited lodging available for non-locals, if required)
  - *Ed Hoffman, Academy Director, and Cindy Daniels, Science Office for Mission Assessments*

Presentations

Lessons from Previous Explorer Missions (I): MAP and WIRE



Panel Host: James L. Burch, OHMIC PI, Southwest Research Institute

MAP PM: Liz Citrin, Goddard Space Flight Center

WIRE PM: Bryan Fafaul, Goddard Space Flight Center

MAP

The Wilkinson Microwave Anisotropy Probe (WMAP) mission reveals conditions as they existed in the early universe by measuring the properties of cosmic microwave background radiation over the full sky. This microwave radiation was released approximately 380,000 years after the birth of the universe. WMAP creates a picture of the microwave radiation using differences in temperature measured from opposite directions (anisotropy). The content of this image tells us much about the fundamental structure of the universe.

To address its key scientific questions, WMAP measures small variations in the temperature of the cosmic microwave background radiation. These variations are minute: one part of the sky has a temperature of 2.7251° kelvin (degrees above absolute zero), while another part of the sky has a temperature of 2.7249° kelvin. In 1992, the Cosmic Background Explorer (COBE) satellite detected these tiny temperature differences on large angular scales. WMAP measures anisotropy with much finer detail and greater sensitivity than COBE did. These measurements reveal the size, matter content, age, geometry, and fate of the universe. They also reveal the primordial structures that grew to form galaxies and will test ideas about the origins of these structures.

The WMAP mission was proposed to NASA in 1995, launched in 2001, and is still collecting data. The spacecraft was launched on a Med-Lite Delta II 7425-10 vehicle into a lunar-assisted trajectory to the sun–Earth L2 libration point for a nominal twenty-seven-month mission (three months transit to L2, twenty-four months observing). The mission has now been extended for several years to collect additional high-quality data. The total payload mass is about 830 kg. The WMAP instrument is continuously shaded from the sun, Earth, and moon by the spacecraft to allow lower thermal disturbances. WMAP ended the collection of science data on August 19, 2010.

WIRE

The Wide-field Infrared Explorer (WIRE) was a small satellite carrying a cryogenically cooled infrared telescope designed to study starburst galaxies—vast clouds of molecular gas cradling the sites of newborn stars. Developed under NASA's Small Explorer Program, WIRE was intended to have a four-month primary mission.

WIRE was launched on a three-stage Pegasus XL vehicle released from an L-1011 aircraft over the Pacific Ocean after takeoff from California's Vandenberg Air Force Base on March 4, 1999. The satellite was successfully placed in orbit around Earth at an altitude of 540 kilometers (about 335 miles).

The mission failed soon after launch when the cover on the telescope/cryostat ejected prematurely. Uncontrolled heating of the cryostat caused the solid hydrogen cryogen to be expelled and resulted in the satellite spinning out of control. Flight controllers ultimately regained control of the satellite, but the primary science objectives were lost, as the infrared detectors could not be cooled.

Since then, WIRE's onboard star tracker has been used for two entirely different purposes: astroseismology and planet finding. The astroseismology program is intended to measure oscillations in nearby stars to probe their structure. The planet-finding program searches for changes in brightness of stars caused by any large planets passing between the star and WIRE. On May 10, 2011, at approximately 2:50 p.m. EDT, WIRE re-entered the atmosphere, ending the mission.

About the Presenters

James L. Burch is vice president of the Space Science and Engineering Division at Southwest Research Institute. He received his BS in physics in 1964 from St. Mary's University of Texas and his PhD in space science from Rice University in 1968. He was principal investigator for the Dynamics Explorer 1 high-altitude plasma instrument, the ATLAS-1 Space Experiments with Particle Accelerators, and the Imager for Magnetopause-to-Aurora Global Exploration mission. Currently, he is principal investigator for the ion and electron sensor for the European Space Agency Rosetta comet orbiter and for the instrument suite science team for the Magnetospheric Multiscale mission to be launched in 2014. Dr. Burch was elected fellow of the AGU in 1995; was the American Geophysical Union (AGU) Van Allen Lecturer and the Rice University Marlar Lecturer, both in 2001; received the first COSPAR Jeoujang Jaw Award in 2008; and in 2010 received the AGU Fleming Medal.

Dr. Burch previously served as president of the Space Physics and Aeronomy Section of the AGU and is a member of the International Academy of Astronautics. He served as editor and editor-in-chief of Geophysical Research Letters and is currently an editor of Space Science Reviews. He also previously served as chair of the National Research Council Committee on Solar and Space Physics, the AGU Committee on Public Affairs, and the AGU Meetings Committee. He currently chairs the Panel on Instruments and Computing for the National Research Council review of the NASA Technology Roadmap. As a member of the governing board of the American Institute of Physics (AIP), he was chair of the audit committee and now serves on the AIP Investment Advisory Committee.

Liz Citrin joined Goddard Space Flight Center in 1987, working on Hubble Space Telescope through the deployment and first servicing mission. She then joined the Wilkinson Microwave Anisotropy Probe (WMAP) mission as the systems lead and later became the project manager. WMAP launched in June 2001, studying the cosmic background radiation with unprecedented precision and accuracy, and answering some of cosmology's most fundamental questions. Ms. Citrin became the project manager for the Solar Dynamics Observatory (SDO), the first space-weather research mission in the Living with a Star program. SDO launched in February 2010. Immediately after the SDO launch, Ms. Citrin joined the Joint Polar Satellite System program as the deputy program manager.

Bryan Fafaul has worked at the Goddard Space Flight Center since 1986 in a wide variety of technical and management positions. He started his career in the Parts Branch and then moved into project management. Mr. Fafaul has served as the mission manager for the Wide-Field Infrared Explorer; instrument systems manager for Hubble Space Telescope Servicing Missions 3A, 3B, and 4; deputy project manager for the National Polar-orbiting Operational Environmental Satellite System Preparatory Project; and project manager for Glory prior to his current position as the project manager for the Joint Polar Satellite System flight project.

WHAT ARE YOUR LESSONS LEARNED OR INSIGHTS GAINED FROM THIS STORY?

HOW COULD YOU FACILITATE THE TRANSFER OR REUSE OF THESE LESSONS FOR OTHER INDIVIDUALS, YOUR PROJECTS, YOUR ORGANIZATION, ETC.?

ADDITIONAL THOUGHTS AND REFLECTIONS:

NOTES

The Successful Project Team: Roles and Responsibilities

Tuesday • 8 November 2011

Panel Host: Richard Eastes, GOLD PI, University of Central Florida
Principal Investigator: M. Patrick McCormick, Hampton University
Project Scientist: Steve Saunders, Lunar and Planetary Institute
Project Manager: G. Scott Hubbard, Stanford University
Systems Engineer: Orlando Figueroa, NASA (retired)
Contractor Team: Steve Jolly, Lockheed Martin

Principal Investigator

An overview of the building of a principal investigator (PI)–led team for a NASA mission will be presented as well as the important relationships the PI has with the project manager and systems engineer. PI traits, qualities, and responsibilities will be addressed and will be followed by a discussion of how a PI chooses the science team and structures the mission team. Other topics to be addressed include developing a clear mission requirements document and the process and importance of descoping. Finally, the importance of the total involvement and perseverance of the PI in following the mission development will be discussed along with key indicators of mission development status (e.g., the use of "planned" versus "actual" monthly milestone accomplishments).

Project Scientist

The presentation will cover experience and lessons learned as project scientist during the Mars Odyssey mission and will describe the duties of the project scientist's role and their relationship with the project team.

Project Manager

The multitude of roles played by the project manager (PM)—ranging from daily technical management to project psychiatrist—will be discussed. The criticality and complexity of the relationships between the PI and PM, PM and the mission systems engineer, and PM to NASA will be discussed. The process of building the team's infrastructure in the new world of earned value management and joint confidence level will also be presented.

Systems Engineering

Systems engineering plays a critical role in space-mission development and is the right hand of the PI and the PM. He or she provides the technical expertise for the design, integration, and verification of the platform and supporting systems to meet the mission's objectives in an affordable manner, and within an acceptable level of risk. The role of the systems engineer in complex technical development is not to act as a clerk to manage a requirements database, or merely an analyst to calculate mass and power margins, but is the technical "visionary" that leads vertical and horizontal design and integration of the mission—especially across the major interfaces of science instruments, launch, and mission operations. The roles and responsibilities of the systems engineer within the PI-led team, and the leadership qualities, experience, and "system view" that past successful PI missions have practiced, will be discussed in the context of the challenges of today's environment.

Contractor Team

Industry is a valuable member of the PI-led mission team and provides a different perspective from project leadership and science members. The need to embed compelling science coupled with the cost capped execution model creates a set of constraints that drive "best-fit" solutions. The experienced industry partner often becomes the "voice of reason" that seeks to accommodate the project/NASA center and PI science needs, while keeping an eye on execution risk. Industry is motivated to push for the early flow-down of science requirements, the development of a mission concept that balances complexity and cost, and prudent application of new technology that enables win discriminators. When well executed, the competed PI-led mission team effectively bonds together during the CSR and site visit activities. Examples will include Phoenix and MAVEN, including experience gained from problems and the ways they were successfully solved.

About the Presenters

Richard Eastes is the principal investigator for the Global-Scale Observations of the Limb and Disk mission. He came to the Florida Space Institute at the University of Central Florida, where he now works, from the Air Force Research Laboratory.

His research emphasis is the response of Earth's thermosphere-ionosphere system to the sun and other influences. His work has concentrated on ultraviolet remote-sensing of Earth's upper atmosphere, using both experiments and modeling techniques, as well as the application of unconventional analysis techniques to lengthy sets of heliophysical data. Dr. Eastes received his PhD from Johns Hopkins University.

For the past forty-seven years, M. Patrick McCormick has been performing research on the development and application of sensors for measurement in Earth's atmosphere. His research areas include the development of aerosol, ozone, and water vapor trends and climatologies; the study of polar stratospheric clouds and their characterization; and the role of aerosols in climate, cloud properties, and atmospheric chemistry. He is a fellow of the American Geophysical Union, a fellow of the American Meteorological Society, and a member of NASA's Advisory Council Earth Science Subcommittee. Dr. McCormick is principal investigator for SAM II, SAGE I, SAGE II, SAGE III, and LITE, and co–principal investigator for SAM and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation satellite experiments. He is the recipient of the NASA Exceptional Scientific Achievement Medal (1981), the American Meteorological Society's Jule G. Charney Award (1991), the NASA Space Act Award (1994), the NASA Outstanding Leadership Medal (1996), the NASA and Department of the Interior William T. Pecora Award (1996), the NASA Distinguished Public Service Medal (2000), and the American Meteorological Society's Remote-Sensing Lecturer Award (2000). He is co-director of the Center for Atmospheric Sciences at Hampton University and previously spent thirty years at Langley Research Center.

Steve Saunders was a scientist at the Jet Propulsion Laboratory (JPL) in Pasadena for thirty-two years. At JPL he was project scientist for the Magellan Venus mission and the Mars Odyssey mission. After leaving JPL, he worked at NASA Headquarters for five years, where he was NASA program scientist for the Planetary Data System, Mars Reconnaissance Orbiter, and Mars Express. He also managed NASA's Planetary Geology and Geophysics Program, which supports about 170 U.S. scientists. Dr. Saunders was the recipient of two NASA Exceptional Service Medals and the NASA Exceptional Scientific Achievement medal. He graduated from the University of Wisconsin, and after serving in the Peace Corps as a geologist in Ghana, he went on to Brown University for his PhD in geology. Dr. Saunders currently is employed by the Lunar and Planetary Institute and spends much of his time analyzing some of the Mars and Venus data he has helped to collect. He spends his free time blacksmithing and doing other metal arts work in Edgerton, Wisconsin, where he has a home and shop.

G. Scott Hubbard has been an innovator and leader in science, technology, and management for more than thirty years, including twenty years with NASA. He currently is a professor in the department of aeronautics and astronautics at Stanford University. From 2002 to 2006, Mr. Hubbard was the director of Ames Research Center. In 2003 he served as the sole NASA representative on the *Columbia* Accident Investigation Board, where he directed impact testing that demonstrated the definitive physical cause of the loss of *Columbia*. In 2000 he served as NASA's first Mars program director and successfully restructured the entire Mars program in the wake of mission failures. He is the founder of NASA's Astrobiology Institute. He conceived the Mars Pathfinder mission with its airbag landing and was the manager for NASA's highly successful Lunar Prospector Mission. Earlier, Mr. Hubbard led a start-up high-technology company in the San Francisco Bay area and was a staff scientist at the Lawrence Berkeley National Lab. He has received many honors, including NASA's highest award, the Distinguished Service Medal. He was elected to the International Academy of Astronautics, is a fellow of the American Institute of Aeronautics and Astronautics (AIAA), and was also awarded the Von Karman medal by the AIAA.

Orlando Figueroa retired from NASA in 2010 to start the Orlando Leadership Enterprise, LLC, aerospace consulting company. His career with NASA spanned thirty-three years at the Goddard Space Flight Center and NASA Headquarters (HQ), and includes many roles at Goddard—deputy center director for Science and Technology and director for the Applied Engineering and Technology Directorate—and at HQ—deputy associate administrator for Programs in the NASA Science Mission Directorate, director for the Solar System Exploration Division, director for Mars Exploration. He was also the Goddard manager for the Small Explorers (SMEX) project and lead cryogenic engineer for the Cosmic Background Explorer. Mr. Figueroa has received numerous achievement and performance awards. Among the most notable are the 2008 Smithsonian Latino Center Legacy Award; the 2005 Federal Employee of the Year Medal; NASA Presidential Rank Awards; Hispanic Business Magazine ranking as one the most influential Hispanics in the Nation in 2004, 2005, and 2010; the 2002 Pioneer Award from the Hispanic Engineer National Achievement Awards Corporation; NASA Outstanding Leadership Medals in 2004 and 1993; and the 1994 Community Stars Award from the Maryland Science Week Commission.

Steve Jolly is the Lockheed Martin systems engineering director for the GOES-R program (next-generation weather satellites in geosynchronous orbit) in the sensors and exploration systems line of business. He is also the program manager for the Mars Reconnaissance Orbiter and was chief engineer during its development. Dr. Jolly has served project Orion off and on as an independent advisor and tiger-team lead for entry, descent, and landing (EDL), and previously served as a member of EDL systems engineering team and critical events risk process for Phoenix, Stardust, and Genesis. He was also program manager for the Mars Science Lab (MSL) aeroshell and is a member of the Independent Assessment Panel for the MSL landing-site selection. He was chief systems engineer for Mars Sample Return. For the ill-fated duo, Mars Climate Orbiter (MCO) and Mars Polar Lander (MPL), he was flight systems design lead (MCO) and flight operations lead (MCO and MPL). Dr. Jolly has twenty-nine years of experience in spacecraft and launch vehicles from concept through flight operations. He is a 2007 recipient of the NASA Public Service Medal for distinguished service and is the American Astronautical Society chair for the Rocky Mountain Guidance and Control Section.

WHAT ARE YOUR LESSONS LEARNED OR INSIGHTS GAINED FROM THIS STORY?

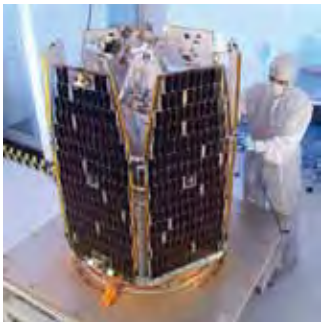
HOW COULD YOU FACILITATE THE TRANSFER OR REUSE OF THESE LESSONS FOR OTHER INDIVIDUALS, YOUR PROJECTS, YOUR ORGANIZATION, ETC.?

ADDITIONAL THOUGHTS AND REFLECTIONS:

NOTES

Lessons from Previous Explorer Missions (II): AIM and GALEX

Tuesday • 8 November 2011



Panel Host: Keith Gendreau, NICER PI, Goddard Space Flight Center

AIM PI: James M. Russell III, Hampton University

GALEX PM: James Fanson, Jet Propulsion Laboratory

AIM

The development and implementation of a satellite mission in today's world brings with it many problems, and it is often the case that many of these are unplanned and unforeseen. Consequently, the success of the mission depends heavily on the degree of preparation and anticipation of problems that has occurred going into the development. Despite such efforts, evolving technical and managerial requirements and unpredicted issues sometimes occur late in the development that could threaten mission success. A cohesive, excited, and unified team and the strength of the relationships between the principal investigator, NASA mission manager, project scientist, program executive, program scientist, and Executive Advisory Board are key factors for success. Some of the challenges faced in the AIM mission development, steps taken to address these issues, and some lessons learned will be discussed.

GALEX

The Galaxy Evolution Explorer (GALEX) mission was selected in 1997 and launched in 2003, performing the first extragalactic wide-area imaging and spectroscopic surveys in the ultraviolet. Designed to map the history of star formation over 80 percent of the history of the universe, GALEX has changed our understanding of where and when stars form in galaxies over cosmic time. Along the way several, surprising discoveries were made, including the first detection of a 13-light-year-long tail streaming behind the star Mira, and the first observation of the ultraviolet flash at the beginning of a supernova explosion.

Although a small mission, GALEX developed the largest microchannel plate detectors ever flown in space. Begun under the faster-better-cheaper era, implementation changed radically following a string of mission failures in the late nineties. Project implementation encountered an unusual array of technical and programmatic challenges, producing a useful collection of lessons learned. GALEX was ultimately flown and checked out in orbit for $72 million. Originally intended to operate for twenty-eight months, GALEX continues to produce unique data more than eight years later.

About the Presenters

Keith Gendreau received his PhD in astrophysics at the Massachusetts Institute of Technology in 1995, working on X-ray charge-coupled devices and the cosmic X-ray background with the Advanced Satellite for Cosmology and Astrophysics mission. He has been at Goddard Space Flight Center since 1995 and was the calibration lead on the X-ray spectrometer instrument on the ASTRO-E mission. Mr. Gendreau was the NASA scientist on the joint NASA–DARPA X-ray pulsar source–based navigation and timing study, and he is currently the principal investigator of the X-ray Advanced Concepts Test Bed sounding rocket and the Station Explorer for X-ray Timing and Navigation Technology study.

James M. Russell III's research has focused on atmospheric science, remote sensing, and satellite data analysis to study properties and processes in Earth's atmosphere. He began his career in electrical engineering at the Langley Research Center, developing instrumentation and performing ground and rocket reentry tests of heat-shield material used on the Gemini and Apollo capsules. He also worked on instrumentation for characterizing the Martian atmosphere during entry. Dr. Russell has served as co–principal investigator (PI) on the Nimbus 7 Limb Infrared Monitor of the Stratosphere experiment, and PI for the Halogen Occultation Experiment on the Upper Atmosphere Research Satellite (UARS). He currently serves as PI for the Sounding of the Atmosphere using Broadband Emission Radiometry experiment on the Thermosphere Ionosphere Mesosphere Energetics and Dynamics satellite, and PI on the Aeronomy of Ice in the Mesosphere mission. He also served as co-investigator on the Jet Propulsion Laboratory Atmospheric Trace Molecule Spectroscopy experiment launched on the Space Shuttle and the Oxford University Improved Stratospheric and Mesospheric Sounder experiment launched on UARS.

Dr. Russell served as head of the Chemistry and Dynamics Branch and the Theoretical Studies Branch in the Langley Atmospheric Sciences Division and currently is an endowed professor of atmospheric and planetary sciences and co-director of the Center for Atmospheric Sciences at Hampton University in Virginia. He received a BSEE degree from Virginia Tech, an MSEE degree from the University of Virginia, and a PhD in aeronomy from the University of Michigan. He is author or co-author of more than 400 papers in the scientific literature, including first authorship of the most cited paper in all geosciences during the period 1991–2001. He has received the NASA Exceptional Scientific Achievement Medal; the NASA Outstanding Leadership Medal; the Virginia 2008 Outstanding Scientist Award; and the University of Michigan, College of Engineering, Alumni Merit Award.

Born and raised in Wisconsin, James Fanson moved to California to attend graduate school at Caltech, where he earned his PhD in applied mechanics in 1987. His twenty-five-year career at the Jet Propulsion Laboratory has spanned technology development, instrument development, and flight project implementation. Dr. Fanson was part of the team that repaired the Hubble Space Telescope in 1993 with the Wide Field and Planetary Camera 2 (now in the Smithsonian Air and Space Museum). He led the team that produced the preliminary design of the Spitzer Space Telescope and, as project manager, led two telescope missions (Galaxy Evolution Explorer and Kepler) to launch and early science operations. He is the recipient of the Lew Allen Award for Excellence, the NASA Exceptional Engineering Achievement Medal, and two NASA Outstanding Leadership Medals. He enjoys photography and exploring the remote desert regions of the American Southwest.

WHAT ARE YOUR LESSONS LEARNED OR INSIGHTS GAINED FROM THIS STORY?

HOW COULD YOU FACILITATE THE TRANSFER OR REUSE OF THESE LESSONS FOR OTHER INDIVIDUALS, YOUR PROJECTS, YOUR ORGANIZATION, ETC.?

ADDITIONAL THOUGHTS AND REFLECTIONS:

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The SMD/ExPO Management Team: Overview, Guidance, and Expectations

Panel Host: Thomas J. Immel, ICON PI, University of California–Berkeley

Panel Chair: Paul Hertz, NASA Headquarters

The SMD Headquarters and Explorer Program Office Management Team:

- **Program Scientist: Barbara Giles,** NASA Headquarters
- **Program Executive: Willis S. Jenkins, Jr.,** NASA Headquarters
- **Explorers Deputy Program Manager and Heliophysics Projects Division Associate Director: Joseph A. Dezio,** Goddard Space Flight Center

Roles of the Program Executive and Program Scientist

The Science Mission Directorate (SMD) at NASA Headquarters has designated the program executive (PE) as the key technical and programmatic point of contact for SMD's projects. The PE provides a vital link between supporting the execution of the project and the top-level management and oversight responsibilities of the Directorate. In this position, the PE takes on the dual persona as both the Headquarters advocate for the project and "the enforcer" of NASA project management rules and requirements.

The SMD program scientist (PS) is the senior NASA scientist responsible for a flight program or project's science content to carry out an SMD science investigation. The PS is SMD's interface with the project scientist or the principal investigator (PI) for an Announcement of Opportunity selected mission. The PS monitors science management program execution and ensures the science of the mission remains viable and true to strategic objectives during development of the mission.

The PE and PS are partners on decisions relevant to mission formulation, design, development, and oversight. Recognizing these roles and understanding how they interrelate will aid the project team in getting comfortable when interacting with their PE and PS, which can add great value to the project.

Working with the Explorer Program Office

The primary responsibility of the Explorer Program Office is to ensure Explorer missions are successful in achieving their science objectives. We do this by working with the PI and the project team to manage the cost, schedule, and technical elements of the project and by guiding them through the various processes that make up the life cycle of these missions. This presentation will provide an overview of the Explorer Program Office organization, functions, and approach to working with the PI, the project team, and SMD to ensure the success of Explorer missions. The intent is to provide guidance on working relationships and processes as well as lessons learned by the program office from the management of Explorer missions. Expectations of the PI on a PI-led mission will also be addressed.

About the Presenters

Thomas J. Immel is an associate research physicist at the Space Sciences Laboratory at University of California–Berkeley (UCB). He is the principal investigator for the Ionospheric Connection Explorer mission. Currently, he is the project manager for UCB's National Science Foundation CubeSat for Ions, Neutrals, Electrons, and Magnetic fields mission, to be launched in June 2012. His expertise is in upper-atmospheric and ionospheric physics and magnetospheric–ionospheric coupling processes, and he has been a NASA guest investigator on both the Imager for Magnetopause-to-Aurora Global Exploration and Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics missions. Dr. Immel obtained his PhD in physics from the University of Alaska Fairbanks.

Paul Hertz is chief scientist for the Science Mission Directorate (SMD). He manages Directorate-level science activities, including the solicitation, evaluation, and selection process for SMD; the SMD Science Management Council; and SMD's research policies and procedures. He joined the NASA Office of Space Science as a senior scientist in 2000. He later served as theme scientist for the Structure and Evolution of the Universe Theme as well as senior scientist in the Astronomy and Physics Division. Other positions he has held include program executive for the Chandra X-ray Observatory, senior scientist for Space Science Research in the Research Program Management Division, program executive for Solar System Exploration missions, Stratospheric Observatory for Infrared Astronomy program scientist, Discovery program scientist, and Explorer program scientist. Prior to joining NASA, Dr. Hertz was an astrophysicist at the Naval Research Laboratory.

Dr. Hertz is a recipient of the Meritorious Presidential Rank Award, the Robert J. Trumpler Award of the Astronomical Society of the Pacific, the Alan Berman Research Publication Award of the Naval Research Laboratory (twice), three NASA Group Achievement Awards, third place in the Naval Research Laboratory's Science as Art contest, the Baltimore Orioles' Heavy Hitter Award, and most recently the Washington Nationals' Spirit Award.

Director of the Heliophysics Division at NASA Headquarters, Barbara Giles earned her PhD in physics from the University of Alabama in Huntsville in 1993 and joined Marshall Space Flight Center, where she was part of a team that built suborbital and spaceflight heliophysics instrumentation. In 1998, she transferred to the Goddard Space Flight Center to pursue new flight mission opportunities. She stepped into the role of deputy project scientist, and was promoted later to project scientist, for the Polar and Radiation Belt Storm Probes (RBSP) missions.

In 2004, Dr. Giles joined NASA Headquarters as the program scientist for RBSP and led the science procurement for that mission. Since that time she has served as the program scientist for the Solar Terrestrial Probes Program (STP) and managed the procurement for the Explorer 2011 missions. As the Heliophysics strategic planning lead, she charted the division's course for the future by planning new missions to study the sun, its effects on Earth's space environment, and its influences out to the far reaches of the heliosphere. Dr. Giles was promoted to the position of director of the Heliophysics Division in October 2011.

Willis S. Jenkins, Jr., is the senior program executive for NASA's Explorer Program in the Science Mission Directorate/Heliophysics Division at NASA Headquarters. He began his NASA career as an electrical engineer at the Goddard Space Flight Center in 1994 and came to NASA Headquarters as a program executive detailee for the Explorer Program in 2000, and later permanently in 2003.

Mr. Jenkins has been awarded two of NASA's highest honors: NASA Equal Employment Opportunity Medal (2008) and the Medal for Exceptional Service (1999). He has also garnered accolades for his work performance within and external to the agency, including several outstanding team efforts in Earth and space science. He was nominated Black Engineer of the Year in 2001. He also received the outstanding Professional Excellence in Federal Career Award, signed by Senator Barbara Mikulski of Maryland. At Headquarters, Mr. Jenkins also assists the Office of Diversity and Equal Opportunity in the Office of Education of the NASA Speaker's Bureau and the Science Mission Directorate by participating in outreach events, at which he addresses spaceflight, career development, and the value of science, technology, engineering, and mathematics. Prior to NASA, Mr. Jenkins enjoyed a successful career in the private sector.

Joseph A. Dezio came to the Explorers Program as the deputy program manager in November 2001 to support the numerous Explorer missions' activities and principal investigators. Since arriving at the Explorers Program Office, he has supported the successful launches of the Swift, Time History of Events and Macroscale Interactions during Substorms, Aeronomy of Ice in the Mesosphere, and Interstellar Boundary Explorer missions.

Mr. Dezio received a BS in engineering science from Oakland University, Mich., in 1967 and came to Goddard Spaceflight Center from the physics department of that institution in 1969 to begin work on the IMP-I project. That was followed by numerous other successful projects, including the Heat Capacity Mapping Mission; Landsat 4; Earth Radiation Budget Satellite; Space Station Platforms, now Aura and Aqua; Geostationary Operational Environmental Satellites recovery, 1989–1993; Global Geospace Science Wind and Polar missions; and the Ice, Cloud, and land Elevation Satellite. Over the course of his forty years at Goddard, he has received numerous performance and group awards as well as the NASA exceptional service medal in 1997.

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ADDITIONAL THOUGHTS AND REFLECTIONS:

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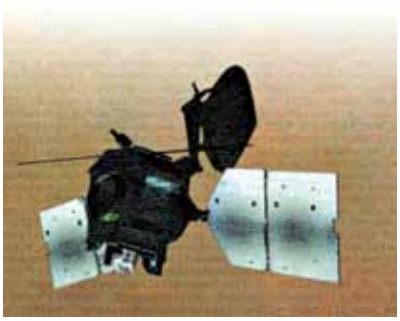

Panel Host: Lynn M. Kistler, SCOPE PI, University of New Hampshire

Managing Software Development—The Hidden Risk: Steve Jolly, Lockheed Martin

Managing Software Development—The Hidden Risk

There is not a major space system that has not experienced serious software development challenges, especially true of real-time, embedded software for spacecraft. But what is at the root cause? Are flight-software-development processes inadequate? Are spacecraft more functionally complex than in the past, resulting in these challenges? Why can't the software subsystem meet cost and schedule? Is systems engineering broken? This talk will address these questions head-on and explore the shocking truth of what modern space exploration, and more specifically spacecraft development, has become. A revolution has taken place and is accelerating. Ignore it and an enormous price will be paid. And the implications on safety and mission success are staggering indeed. A major transformation of how we develop these SOS must begin immediately.

Lynn M. Kistler is the principal investigator for the ion mass spectrum analyzer for the SCOPE mission. She is a professor in the department of physics and the Space Science Center at the University of New Hampshire. Her research focuses on using composition measurements as a tool for understanding the dynamics of the magnetosphere and solar wind. She has been involved in developing instrumentation to measure ion composition for missions including Solar Orbiter (HIS instrument), Solar Terrestrial Relations Observatory (PLASTIC instrument), Advanced Composition Explorer (SEPICA instrument), Cluster (CIS/CODIF instrument), Equator-S (lead for ion-composition experiment), and Fast Auroral Snapshot Explorer (TEAMS instrument).

Dr. Kistler received a PhD in physics in 1987 from the University of Maryland–College Park. Prior to coming to the University of New Hampshire, she was a research associate at the University of Maryland and spent two years as a visiting scientist at the Max Planck Institute for Extraterrestrial Physics in Garching, Germany.

Steve Jolly is the Lockheed Martin systems engineering director for the GOES-R program (next-generation weather satellites in geosynchronous orbit) in the sensors and exploration systems line of business. He is also the program manager for the Mars Reconnaissance Orbiter and was chief engineer during its development. Dr. Jolly has served project Orion off and on as an independent advisor and tiger-team lead for entry, descent, and landing (EDL), and previously served as a member of EDL systems engineering team and critical events risk process for Phoenix, Stardust, and Genesis. He was also program manager for the Mars Science Lab (MSL) aeroshell and is a member of the Independent Assessment Panel for the MSL landing-site selection. He was chief systems engineer for Mars Sample Return. For the ill-fated duo, Mars Climate Orbiter (MCO) and Mars Polar Lander (MPL), he was flight systems design lead (MCO) and flight operations lead (MCO and MPL). Dr. Jolly has twenty-nine years of experience in spacecraft and launch vehicles from concept through flight operations. He has a BS in aerospace engineering from Colorado University–Boulder, an MS from Florida Institute of Technology, and a PhD in aerospace engineering sciences from Colorado University–Boulder. He is a 2007 recipient of the NASA Public Service Medal for distinguished service and is the American Astronautical Society chair for the Rocky Mountain Guidance and Control Section.

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ADDITIONAL THOUGHTS AND REFLECTIONS:

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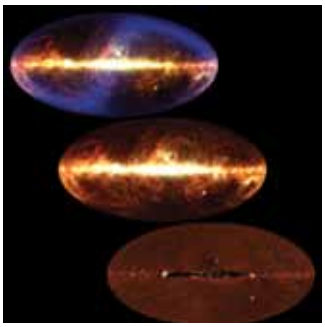
Lessons from Previous Explorer Missions (III): COBE

Wednesday • 9 November 2011



Panel Host: John Kohl, CPI PI, University of New Hampshire

The Environment: Noel Hinners, Consultant

The Mission: John C. Mather, Goddard Space Flight Center

The Project: Dennis McCarthy, Consultant

The Environment

Noel Hinners will rhapsodize on the major challenges he had as a center director in enabling the science and engineering implementation of the Cosmic Background Explorer (COBE). The internal Goddard Space Flight Center environment for COBE was unusual in that it was managed by the Engineering Directorate to provide essential hands-on training to the engineers. The science and engineering aspects of COBE were in and of themselves challenging. These were exasperated by episodic changes in launch vehicles. Combined, this led to much more staffing than originally envisioned, further stressing the center. Looking outward, there were the challenges in dealing with NASA Headquarters (13.7 miles distant) and the pressures to remain on the Space Shuttle rather than switching back to an expendable launch vehicle. Sanity won.

The Mission

John Mather will discuss the challenges of organizing and running two teams: the COBE science team and the James Webb Space Telescope (JWST) science team. COBE's three instruments presented unique challenges. Each instrument had its own principal investigator (PI), so there were different executive styles, which will be compared. Also, the Science Working Group was constituted as co-investigator on all three instruments, so there were team-level challenges and significant conflicts to be managed, as documented in the book The Very First Light: The True Inside Story of the Scientific Journey Back to the Dawn of the Universe.

Two of the PIs were in house at Goddard, leading to excellent communication with the engineering teams, while one PI was external at Berkeley, leading to significant difficulties that had to be managed by recruiting an in-house deputy PI. The special situation of a government team being led by an external investigator required serious negotiation, since NASA does not delegate management of its civil service staff to outside people. The whole science team played a major role in project decisions regarding improving the instrument sensitivity for the differential microwave radiometer (DMR) instrument (a good thing, otherwise the DMR would not have detected cosmic fluctuations).

The Project

Dennis McCarthy will discuss several aspects of program management for robotic missions. His topics will include using a systematic approach involving three phases: determining evaluation, validation and verification, and benchmarks; defining responsibilities of line and project management in the successful organization; and handling "the people problem" during the formulation and implementation phases.

He will also discuss what is involved in creating a work agreement, including predicting management success, achieving program excellence, and understanding root causes, systems engineering and its various phases, NASA governance, and requirements.

About the Presenters

John Kohl is a senior astrophysicist at the Smithsonian Astrophysical Observatory. He is the principal investigator for the Ultraviolet Coronagraph Spectrometer (UVCS) on the Solar and Heliospheric Observatory (SOHO), and he was the principal investigator for the Ultraviolet Coronal Spectrometer on Spartan 201, a shuttle-deployed and -retrieved satellite that carried out four successful two-day flights. The proof of concept for the SOHO and Spartan 201 instruments and the first high-resolution spectroscopy in the extended solar corona (i.e., above 1.5 solar radii from sun-center) was accomplished with a rocket-borne Lyman Alpha Coronagraph during three sounding rocket flights. All of his projects were fully successful and accomplished their proposed primary science goals. UVCS/SOHO has resulted in 518 published papers.

Noel Hinners consults for NASA, the aerospace industry, and 4-D Systems, which supports the NASA Academy of Program/Project and Engineering Leadership. He retired in 2002 from Lockheed Martin Astronautics, where, from 1994 through 2000, he was their vice president of Flight Systems responsible for planetary missions. Prior to that, Dr. Hinners was chief scientist of Business Development and Advanced Programs for Astronautics. He joined Martin Marietta Corporate as vice president of strategic planning in 1989. He served as NASA associate deputy administrator and chief scientist (1987 to 1989), director of the Goddard Space Flight Center (1982 to 1987), director of the Smithsonian's National Air and Space Museum (1979 to 1982), NASA's associate administrator for Space Science (1974 to 1979), and director/deputy director of Lunar Programs (1972 to 1974). Before entering government service, Dr. Hinners was department head of Lunar Exploration with Bellcomm, Inc., which he joined as a member of the technical staff in 1963 and where he was associated with science planning and site selection for Apollo. He has chaired and served on oodles of task groups and advisory boards and was the founding editor of Geophysical Research Letters. He currently serves on the University of Colorado Aerospace Engineering External Advisory Board and chairs the Management Operations Working Group for the NASA Chief Engineer.

John C. Mather is the senior project scientist for the James Webb Space Telescope at Goddard Space Flight Center. His research centers on infrared astronomy and cosmology. As an NRC postdoctoral fellow at the Goddard Institute for Space Studies (New York City), he led the proposal efforts from 1974 to 1976 for the Cosmic Background Explorer (COBE) and came to Goddard to be the study scientist (1976–1988), project scientist (1988–1998), and principal investigator for the far-infrared absolute spectrophotometer on COBE. He showed that cosmic microwave background radiation has a blackbody spectrum within 50 parts per million, confirming the big bang theory to extraordinary accuracy. He is the recipient of numerous awards, including the Nobel Prize in Physics (2006) with George Smoot for the COBE work and the NASA Distinguished Service Medal (2007). He is a member of many professional societies, including the National Academy of Sciences and the American Academy of Arts and Sciences.

He received his Bachelor of Arts degree from Swarthmore College with highest honors in physics in 1968 and his PhD in physics from the University of California at Berkeley in 1974. His doctoral advisor was Paul Richards, and his thesis on measurements of the cosmic microwave background radiation led directly to the COBE satellite.

Dennis K. McCarthy has had the fortunate experience to work in the federal government, academia, and industry. He is currently a consultant to NASA to review specific programs. He was in industry as the Swales Aerospace vice president, director of engineering. Prior to that, he was at Johns Hopkins University as the program director for the first principal investigator program at a university: the Far Ultraviolet Spectroscopic Explorer.

Before that, Mr. McCarthy was in the federal government at Goddard Space Flight Center. He served as the deputy associate director of flight projects for Hubble Space Telescope in 1994. Previously, he was the deputy project manager for the Hubble Space Telescope servicing mission. Other positions he held include associate director for the Space Sciences Directorate and deputy project manager for the Cosmic Background Explorer, which won the Nobel Prize in Physics in 2006.

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ADDITIONAL THOUGHTS AND REFLECTIONS:

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Panel Host: Robert Pfaff, ASTRE PI, Goddard Space Flight Center

The Impetus for Better Cost Management: Noel Hinners, Consultant

Project Resource Controls and Earned Value Management: Roy Maizel, NASA Headquarters

Meeting Cost and Schedule Performance: Jim Adams, NASA Headquarters

Performing to committed cost has forever been a space and Earth science goal, along with attaining technical and scientific goals. Emphasis on the cost element, however, has greatly increased over the past decade. This includes enhanced external oversight of NASA's cost performance by the Government Accountability Office, Office of Management and Budget, and several Congressional committees. It is clearly in our own best interest to understand the rationale for that emphasis and pay special attention to increasing our ability to perform to committed cost.

Successful project-resource control on NASA projects is grounded not just in the application of specific cost monitoring and control techniques, but also in a thorough understanding of both the external and internal environments in which NASA projects are approved, formulated, developed, and operated. NASA is a part of the discretionary component of the federal budget and operates in a very constrained budgetary environment. It is therefore imperative that projects be managed within their approved budgets.

In the continuing effort to improve our processes for selecting and managing our projects, the agency and SMD have instituted a number of new processes designed to improve communication, understanding, and trust between the project, the supporting institution, SMD, the agency, and our sponsors and stakeholders. These processes may be self-imposed or in response to external requirements (e.g., legislation). The basic pattern of processes is driven by the life-cycle review process and is augmented as required. The project life-cycle review process and most of these processes are presented in the current version of NASA Policy Directive 7120.5, NASA Space Flight Program and Project Management Requirements, although some are evolving and are yet to be fully documented and implemented.

The origin for all these processes is the desire of the Directorate and the agency to establish and improve its credibility with our sponsors and stakeholders by demonstrating our ability to clearly define the cost, schedule, technical requirements, and risk associated with our major programs and projects at the commitment milestone (KDP-C) and to execute those activities within the commitments we make to the sponsors and stakeholders.

Lessons from NASA's recently launched Juno and Gravity Recovery and Interior Laboratory missions will be discussed, as they have been delivered on cost and schedule. Were these successes a result of the newly implemented 70-percent-confidence-factor budgeting policy at NASA? Or were they due to careful planning, commitment, and constant communication between the principal investigators, the projects, the program offices, and NASA SMD management? By relating stories from the mission development phase, a variety of methods tools and techniques will be examined that could prove helpful for future science missions.

After completing his PhD at Cornell University in 1985, Robert Pfaff joined the Goddard Space Flight Center, where is presently a space scientist in the Space Weather Laboratory in the Heliophysics Division. With more than twenty-five years of experience working with experimental electric field research at Goddard, he leads a team involved in all aspects of electric field double probe techniques. Dr. Pfaff is the principal investigator of the Vector Electric Field Investigation on the C/NOFS air force satellite. He has participated as a co-investigator on the DC electric-field teams for the San Marco and Detection of Electromagnetic Emissions Transmitted from Earthquake Regions ionosphere satellites, as well as the Polar, Cluster, FAST, and Radiation Belt Storm Probes magnetosphere satellites.

He has served as project scientist for NASA's FAST satellite, for the NASA Sounding Rocket program since 1994, and for the air force C/NOFS satellite. As study scientist, Dr. Pfaff led the Ionospheric Mappers planning for NASA's Living with a Star (LWS) program and later served on the Geospace mission definition team for LWS. He has served on the NASA Geospace Electrodynamics Connections definition team, as well as on the panel on Atmosphere-Ionosphere-Magnetosphere Interactions for the National Research Council Decadal Strategy for Solar and Space Physics, 2010–2011.

Since coming to NASA, Dr. Pfaff has received the following awards and medals: Robert H. Goddard Award for Exceptional Achievement in Science in 2008, NASA Exceptional Service Medal in 2007, and NASA Exceptional Achievement Medal in 1996.

Noel Hinners consults for NASA, the aerospace industry, and 4-D Systems, which supports the NASA Academy of Program/Project and Engineering Leadership. He retired in 2002 from Lockheed Martin Astronautics, where, from 1994 through 2000, he was their vice president of Flight Systems responsible for planetary missions. Prior to that, Dr. Hinners was chief scientist of Business Development and Advanced Programs for Astronautics. He joined Martin Marietta Corporate as vice president of strategic planning in 1989. He served as NASA associate deputy administrator and chief scientist (1987 to 1989), director of the Goddard Space Flight Center (1982 to 1987), director of the Smithsonian's National Air and Space Museum (1979 to 1982), NASA's associate administrator for Space Science (1974 to 1979), and director/deputy director of Lunar Programs (1972 to 1974). Before entering government service, Dr. Hinners was department head of Lunar Exploration with Bellcomm, Inc., which he joined as a member of the technical staff in 1963 and where he was associated with science planning and site selection for Apollo. He has chaired and served on oodles of task groups and advisory boards and was the founding editor of Geophysical Research Letters. He currently serves on the University of Colorado Aerospace Engineering External Advisory Board and chairs the Management Operations Working Group for the NASA Chief Engineer.

Roy A. Maizel is the Science Mission Directorate's (SMD) deputy associate administrator for Management, a position he has held since June 2008. In this capacity he is responsible for the oversight of SMD's more than $5 billion annual budget, strategic planning, policy development, and the provision of administrative support to SMD's two-hundred-person NASA Headquarters workforce. He also serves as a management focal point for institutional issues at Goddard Space Flight Center and the Jet Propulsion Laboratory.

Mr. Maizel holds a BA in political science and an MS in public policy analysis, both from the University of Rochester. He joined NASA in 1981 as a presidential management intern and acquired extensive experience as a program analyst on several projects within the Space Shuttle program. Since 1988, he has held a series of progressively responsible management positions in the Space Shuttle, International Space Station, Earth Science, and Space Science programs. When the Earth Science and Space Science programs merged in 2004 to become SMD, Mr. Maizel became director of the Business Management Division. Following a reorganization and consolidation of functions, he became director of the Management and Policy Division in 2006. He is the recipient of numerous awards, including NASA's Exceptional Service Medal in 2005 and the Senior Executive Service Meritorious Executive Award in 2008.

Jim Adams has more than thirty years of aerospace engineering and management experience, both in the private sector and as a civil servant at NASA. He has a broad background in acquisition, planning, implementation, and execution of space missions and is currently serving as a senior executive in the Science Mission Directorate.

Since 2007, Mr. Adams has been serving as the deputy director of the Planetary Science Division, encompassing planetary activities in development and numerous supporting activities ranging from operations systems to technology investments to international partnerships. He is also the program director for the Discovery, New Frontiers, and Lunar Quest programs.

He has worked on more than twenty-five successful space missions and received three NASA medals recognizing exceptional service and leadership, including NASA's Outstanding Leadership Medal. Mr. Adams holds a BS in physics from Westminster College in New Wilmington, Penn., and an MS in electrical engineering from Villanova University in Villanova, Penn.

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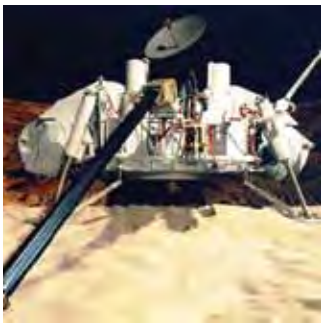

Panel Host: George R. Ricker, TESS PI, Massachusetts Institute of Technology

Viking—Managing Critical Resource Allocations: A. Thomas Young, Lockheed Martin (retired)

AIM—Dealing with Resource Challenges on an Explorer Mission: James M. Russell III, Hampton University

Mars Missions—Managing Critical Resources: Richard W. Zurek, Jet Propulsion Laboratory

These presentations will illustrate the techniques critical to managing resources of science projects. Those involved in Viking, AIM, and past Mars missions will share their experiences about managing critical resources and margins successfully. Critical resources traditionally include mass, power, schedule, cost, and, perhaps more provocatively, risk. (Risk is a resource in that decisions leading to increased or decreased risk will generally increase or decrease other resources.)

Critical resources also include operational timeline and relationships (teaming). Timeline here differs from development schedule although considerations of adequate timeline for post-launch activities have design and implementation trade-space implications. Team building includes many items, such as establishing effective communication paths and lines of authority, matching skills to tasks, delegating appropriately, and providing leadership. A common understanding and commitment to the goals of the mission, a shared understanding of priorities, and a basis of trust are invaluable "resources."

Proper attention to margins is a key aspect of establishing a strong foundation for program execution and goes beyond technical margins to include schedule, cost, and timeline margins. Proper application of heritage for missions is also key to avoiding surprises that may erode project margins.

The development of a satellite mission comes with many challenges even when everything develops as expected. Virtually always, however, the expected does not occur. Instrument sensitivities do not materialize as planned; pointing systems underperform; interactions among the payload, spacecraft, and the launch vehicle create vibration loads that threaten the integrity of the observatory; and looming cost overruns require compromises to be made in the hardware and science return. In order to develop and implement a robust mission, the unexpected should always be anticipated. Workaround approaches, design alternatives, team adjustments, and close attention to detail are essential in order to successfully implement a mission.

George R. Ricker is currently director of the CCD Laboratory in the Massachusetts Institute of Technology (MIT) Kavli Institute for Astrophysics and Space Research. He obtained a BS in physics from MIT in 1966, an MS in astronomy in 1967 from Yale University, and a PhD in physics in 1971 from MIT. Since 1971, he has been a member of the staff and research faculty at MIT, where he presently serves as senior research scientist.

Dr. Ricker was the principal investigator (PI) for the international High-Energy Transient Explorer (HETE) mission—a small satellite incorporating instruments from France, Japan, and the United States that flew successfully from 2000 to 2006. HETE was the first satellite mission entirely devoted to the study of gamma-ray bursts (GRBs). With the HETE team, Dr. Ricker is the co-discoverer of more than ninety accurately localized GRBs, including the event that definitively established the GRB–supernova connection, the first short-hard GRB with an optical afterglow, and more than two dozen X-ray flashes. He has published more than three hundred papers in astronomy, high-energy astrophysics, and experimental physics. Dr. Ricker's current astronomical interests are devoted to studies of extrasolar planets. His experimental interests are focused on the development of new solid-state photon detectors intended primarily for astronomical applications. He is the PI for the Transiting Exoplanet Sky Survey Explorer, a proposed mission that will survey all the nearest and brightest stars for rocky planets and water worlds.

A. Thomas Young is chairman of Science Applications International Corporation, the former director of Goddard Space Flight Center, and president and chief operating officer of Martin Marietta. He retired from Lockheed Martin in July 1995. Mr. Young is involved in various advisory and review activities associated with the U.S. space program. He is a member of the National Academy of Engineering.

James M. Russell III's research has focused on atmospheric science, remote sensing, and satellite data analysis to study properties and processes in Earth's atmosphere. He began his career in electrical engineering at the Langley Research Center, developing instrumentation and performing ground and rocket reentry tests of heat-shield material used on the Gemini and Apollo capsules. He also worked on instrumentation for characterizing the Martian atmosphere during entry. Dr. Russell has served as co–principal investigator (PI) on the Nimbus 7 Limb Infrared Monitor of the Stratosphere experiment, and PI for the Halogen Occultation Experiment on the Upper Atmosphere Research Satellite (UARS). He currently serves as PI for the Sounding of the Atmosphere using Broadband Emission Radiometry experiment on the Thermosphere Ionosphere Mesosphere Energetics and Dynamics satellite, and PI on the Aeronomy of Ice in the Mesosphere mission. He also served as co-investigator on the Jet Propulsion Laboratory Atmospheric Trace Molecule Spectroscopy experiment launched on the Space Shuttle and the Oxford University Improved Stratospheric and Mesospheric Sounder experiment launched on UARS.

Dr. Russell served as head of the Chemistry and Dynamics Branch and the Theoretical Studies Branch in the Langley Atmospheric Sciences Division and currently is an endowed professor of atmospheric and planetary sciences and co-director of the Center for Atmospheric Sciences at Hampton University in Virginia. He received a BSEE degree from Virginia Tech, an MSEE degree from the University of Virginia, and a PhD in aeronomy from the University of Michigan. He is author or co-author of more than 400 papers in the scientific literature, including first authorship of the most cited paper in all geosciences during the period 1991–2001. He has received the NASA Exceptional Scientific Achievement Medal; the NASA Outstanding Leadership Medal; the Virginia 2008 Outstanding Scientist Award; and the University of Michigan, College of Engineering, Alumni Merit Award.

Richard W. Zurek is currently the chief scientist for the Mars Program at the Jet Propulsion Laboratory (JPL), California Institute of Technology. He has been heavily involved in the development and implementation of recent missions to Mars, including lead of atmospheric advisory groups supporting the aerobraking phases of the Mars Global Surveyor, the 2001 Mars Odyssey, and Mars Reconnaissance Orbiter (MRO) spacecraft. He also continues to serve as the project scientist for MRO, now in its fifth year of observations of the atmosphere, surface, and subsurface of Mars. While at JPL, Dr. Zurek has studied the atmospheres of Earth and Mars, including the causes and effects of the great dust storms that occur episodically on Mars. Previously, he served as the project scientist for the Mars Surveyor '98 missions and was a theoretical investigator on the Upper-Atmosphere Research Satellite, helping to pioneer studies separating transport from photochemical effects on ozone change as observed from space. Dr. Zurek holds a PhD in atmospheric sciences from the University of Washington–Seattle and has been employed at JPL since 1976, where he is now a senior research scientist and JPL Fellow.

WHAT ARE YOUR LESSONS LEARNED OR INSIGHTS GAINED FROM THIS STORY?

HOW COULD YOU FACILITATE THE TRANSFER OR REUSE OF THESE LESSONS FOR OTHER INDIVIDUALS, YOUR PROJECTS, YOUR ORGANIZATION, ETC.?

ADDITIONAL THOUGHTS AND REFLECTIONS:

NOTES

Lessons from Previous Explorer Missions (IV): Swift

Wednesday • 9 November 2011

Panel Host: Mark Swain, FINESSE PI, Jet Propulsion Laboratory

Swift PI: Neil Gehrels, Goddard Space Flight Center

Swift PM: Joseph A. Dezio, Goddard Space Flight Center

The Swift mission was proposed to the 1998 medium Explorers announcement of opportunity; it was selected for Phase A study in January 1999 and for flight in October 1999. Launched in 2004, the Swift satellite is an astronomical robot that autonomously determines the position of a gamma-ray burst and slews to that position for afterglow observations. It continues to operate successfully to this day, relying on three instruments: a wide-field gamma-ray camera, a narrow-field optical telescope, and an X-ray telescope. The gamma-ray camera was developed at Goddard Space Flight Center while the telescopes were built largely in Europe with management at Penn State, with operations at Penn State and the data center at Goddard. Challenges with the hardware build and complex scientific management among a large international team will be discussed, with an emphasis on how a close partnership among the science, management, and engineering teams was a key aspect of the project's success. The mission has since returned major discoveries about gamma-ray bursts and other astronomical transients, and it has been highly ranked in the past three Senior Reviews.

About the Presenters

Mark Swain is one of the pioneers for methods for spectroscopic detection of molecules in exoplanet atmospheres, and he led the discovery team that made the first detection of methane and carbon dioxide in an exoplanet atmosphere. He has played a key role in developing calibration methods for exoplanet spectroscopy for Hubble, Spitzer, and ground-based instruments. He built and leads the multidisciplinary ExoSpec team, which includes domain knowledge in the areas of astronomical instrumentation, high-performance calibration, spectral retrieval, atmospheric chemistry, planetary atmospheres, and fundamental molecular properties; the ExoSpec team has published numerous papers and is one of the leading groups in the area of exoplanet characterization. Dr. Swain was among the first to recognize the discovery potential of a highly optimized, purpose-built, exoplanet spectroscopy mission; he originated the Terrestrial Habitable-zone Exoplanet Spectroscopy Infrared Spacecraft mission concept. He is a co-investigator and member of the board for the Exoplanet Characterization Observatory mission currently proposed as European Space Agency M3-class mission. Dr. Swain is also a co-investigator on the New Mexico Exoplanet Spectroscopy Survey Instrument, which is the first purpose-built instrument for ground-based transit spectroscopy. He has a strong background in infrared instrumentation, interferometry, technology development, and integration and test. Dr. Swain has extensive experience with debugging complex instruments (e.g., Keck Interferometer and the South Pole Imaging Fabry-Perot Interferometer), and he has served on tiger teams for both the European Southern Observatory Very Large Telescope Interferometer and the Orbiting Carbon Observatory spectrometer, as well as served as a consultant for instruments connected with Large Binocular Telescope Interferometer project.

Neil Gehrels is chief of the Astroparticle Physics Laboratory at Goddard Space Flight Center. He is also a College Park professor at the University of Maryland and an adjunct professor at Penn State. Heis principal investigator for the Swift mission performing observations of gamma-ray bursts starting in 2004. The mission has made major findings on the origin of the short class of gamma-ray bursts, the nature of the X-ray afterglows, and the use of gamma-ray bursts to probe the distant universe. He is also a deputy project scientist for the Fermi gamma-ray mission launched in 2008, mission scientist for the International Gamma-Ray Astrophysics Laboratory, and project scientist for Wide-Field Infrared Survey Telescope. Previously, he was the project scientist for the Compton Gamma-Ray Observatory, which flew from 1991 to 2000.

Dr. Gehrels received his PhD in physics at Caltech in 1981 and has been an astrophysicist at Goddard since that time. He has written more than 400 papers in professional scientific literature and over twenty popular articles, and has edited six books on gamma-ray astronomy. He received the NASA Outstanding Leadership Medal (1993), the American Astronomical Society Rossi prize (2007), and the National Academy of Sciences Henry Draper medal (2009). He is a member of the American Academy of Arts and Sciences and of the National Academy of Sciences. He was the chair of the Division of Astrophysics of the American Physical Society and High Energy Astrophysics Division of the American Astronomical Society, and is chair of the Commission on Research in Astrophysics from Space for the Committee on Space Research.

Joseph A. Dezio came to the Explorers Program as the deputy program manager in November 2001 to support the numerous Explorer missions' activities and principal investigators. Since arriving at the Explorers Program Office, he has supported the successful launches of the Swift, Time History of Events and Macroscale Interactions during Substorms, Aeronomy of Ice in the Mesosphere, and Interstellar Boundary Explorer missions.

Mr. Dezio received a BS in engineering science from Oakland University, Mich., in 1967 and came to Goddard Spaceflight Center from the physics department of that institution in 1969 to begin work on the IMP-I project. That was followed by numerous other successful projects, including the Heat Capacity Mapping Mission; Landsat 4; Earth Radiation Budget Satellite; Space Station Platforms, now Aura and Aqua; Geostationary Operational Environmental Satellites recovery, 1989–1993; Global Geospace Science Wind and Polar missions; and the Ice, Cloud, and land Elevation Satellite. Over the course of his forty years at Goddard, he has received numerous performance and group awards as well as the NASA exceptional service medal in 1997.

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ADDITIONAL THOUGHTS AND REFLECTIONS:

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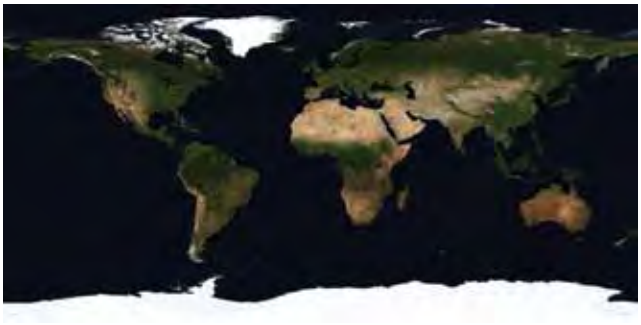

Panel Host: Pietro N. Bernasconi, GUSSTO Mission Scientist, Johns Hopkins University Applied Physics Laboratory

NASA and SMD Policies: Paul Hertz, NASA Headquarters

Throughout NASA's history, international collaboration has played an important role in both its science and human spaceflight programs. This collaboration has become the new norm in space, as more than sixty international space agencies increasingly work together in a broad range of space-related activities. Nearly two-thirds of NASA's space-science missions now involve international collaboration on many levels. Increased international collaboration in space is expected to continue in coming years and is well aligned with administration space policy. Tightening budget constraints are increasing the importance of collaboration even as they introduce new challenges. This session will consider these trends and how they affect project management.

Our international partners have diverse national goals in space as well as different general governance and space agency structures and processes. In addition, language barriers and variations in cultural norms and practices add to the interest but also to the challenges of implementing space projects with foreign partners. Awareness and adaption to these differences are an important key to success.

Ensuring NASA compliance with U.S. export control laws and regulations while accomplishing NASA missions internationally is also a challenge. Understanding the requirements under international cooperative agreements and the transfers required under those agreements is key for a successful export-compliance effort. We want to maximize the benefits of our international efforts while ensuring that we comply with U.S. export control laws and regulations.

Pietro N. Bernasconi is a senior scientist at the Johns Hopkins University Applied Physics Laboratory (APL) and is currently the observatory principal investigator (PI) and mission scientist of the Stratospheric TeraHertz Observatory balloon program (STO). He obtained a doctorate in natural sciences at the Swiss Federal Institute of Technology in 1997. He has worked at APL for fourteen years in a number of scientific, optical, and systems engineering, PI, and project management positions. These include project scientist of the Flare Genesis Experiment (FGE) balloon program and project scientist of the Solar Bolometric Imager (SBI) balloon program before becoming the PI and project manager, observatory PI, and mission scientist of the STO balloon program. Dr. Bernasconi has participated in a leadership role in two Antarctic balloon campaigns for the FGE and SBI programs, and three continental U.S. balloon campaigns for the SBI and STO programs.

Paul Hertz is chief scientist for the Science Mission Directorate (SMD). He manages Directorate-level science activities, including the solicitation, evaluation, and selection process for SMD; the SMD Science Management Council; and SMD's research policies and procedures. He is the Directorate lead for agencywide science activities, including grants activities, peer-review services, and postdoctoral and graduate student fellowship programs. He joined the NASA Office of Space Science as a senior scientist in 2000. He later served as theme scientist for the Structure and Evolution of the Universe Theme as well as senior scientist in the Astronomy and Physics Division. Other positions he has held include program executive for the Chandra X-ray Observatory, senior scientist for Space Science Research in the Research Program Management Division, program executive for Solar System Exploration missions, Stratospheric Observatory for Infrared Astronomy program scientist, Discovery program scientist, and Explorer program scientist. Prior to joining NASA, Dr. Hertz was an astrophysicist at the Naval Research Laboratory.

He holds bachelor's degrees in physics and mathematics from the Massachusetts Institute of Technology, and he received his master's and doctorate degrees in astronomy from Harvard University. Dr. Hertz is a recipient of the Meritorious Presidential Rank Award, the Robert J. Trumpler Award of the Astronomical Society of the Pacific, the Alan Berman Research Publication Award of the Naval Research Laboratory (twice), three NASA Group Achievement Awards, third place in the Naval Research Laboratory's Science as Art contest, the Baltimore Orioles' Heavy Hitter Award, and most recently the Washington Nationals' Spirit Award.

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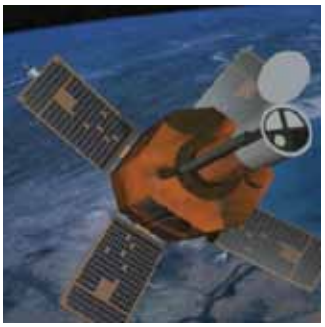
ADDITIONAL THOUGHTS AND REFLECTIONS:

NOTES

SOMA Analysis of Previous PI Missions' Performance



Cindy Daniels, Science Office for Mission Assessments

To encourage the submission of the highest-quality mission proposals and concept-study reports, the Science Office for Mission Assessments maintains an ongoing effort to identify and analyze common areas of major weakness resulting from the technical, management, and cost-review process. The results of this effort will be described, including appropriate lessons learned that can provide valuable guidance to future mission proposal and concept-study teams. Additionally, the cost and schedule performance of a set of Science Mission Directorate missions will be discussed to provide further insight into the challenges that can arise for missions in the detailed development and implementation phases.

About the Presenters

Cindy Daniels is the technical lead of the Science Office for Mission Assessments (SOMA) at Langley Research Center. Previously, she led the technical, management, and cost evaluation (TMC) for the Science Mission Directorate (SMD) Phase A studies for New Frontiers, Discovery, and Explorer. She also led the TMC evaluations for SMD instrument announcement of opportunities for Solar Probe Plus, the Focused Opportunity for Solar Orbiter, Solar Dynamics Observatory, Solar Terrestrial Relation Observatory, and Magnetospheric Multiscale.

Prior to moving to space science, she worked in human spaceflight at NASA Headquarters and Johnson Space Center. She started work at Johnson in 1984 and supported Space Shuttle mission operations in the shuttle Mission Control Center (MCC). Ms. Daniels held several management positions at Johnson, including MCC upgrade project manager, manager of the Engineering Directorate Program Control Office, and the manager of space station ground facilities in the Space Station Program Office. Ms. Daniels has a BS in mathematics, a master's in engineering management, and an MS in information systems.

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ADDITIONAL THOUGHTS AND REFLECTIONS:

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As a nonprofit, membership-based organization, INCOSE disseminates knowledge, facilitates international collaboration, promotes the establishment of competitive standards for systems engineering, and encourages governmental and industry support for research and educational programs that advance the field and practice of systems engineering.

The Project Management Institute http://www.pmi.org

The Project Management Institute (PMI) advocates the project management profession by setting professional standards, conducting research, and providing access to information and resources as well as opportunities for networking and community involvement. A leading membership organization for the project management professional, PMI has been working closely with NASA's Academy for Program/Project and Engineering Leadership to align the Agency's project management indicators with the industry standard and to encourage and facilitate project management certification for NASA civil servants.

NASA Engineering Network http://oce.nasa.gov (link to NEN is in the right column)

(Internal, NASA Only) Join collaborative communities, find engineering resources, find lessons learned, and search across engineering repositories. The NASA Engineering Network was created as a knowledge network to promote learning and sharing among NASA's engineers. Through engineering communities of practice, NASA Lessons Learned, agencywide search, expertise locator, and training, NASA's engineers are connected to engineering resources that help them effectively and efficiently solve problems and design solutions.

NASA Lessons Learned Information System

Knowledge is not found with only one person, one project team, or one organization. Sometimes, another project team, or person, knows something that can **help your project** or your task. How do you find "it" or the person who knows "it?" How does knowledge get from one place to another? A face-to-face meeting, e-mail, or telephone are methods traditionally used. The **NASA Lessons Learned Program** enables employees to **share and find knowledge** as easily and as broadly as possible. This system facilitates self-paced and **collaborative learning.** Knowledge sharing at NASA is critical to its success. The NASA Lessons Learned Program assists the agency's project teams in learning from one another's **on-the-job experiences** and recommendations for managing and mitigating project risk. Lessons are available by searching the NASA Engineering Network. **http://llis.nasa.gov/**





http://appel.nasa.gov

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