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The PI-Mode of Project Management

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List of Abbreviations and Acronyms

ACE	Advanced Composition Explorer
AIP	Assurance Implementation Plan
AO	Announcement of Opportunity
CASS	Center for Astrophysics & Space Research
CDR	Critical Design Review
CIRS	Composite Infrared Spectrometer
CMB	Cosmic Microwave Background
COBE	Cosmic Background Explorer
DMR	Differential Microwave Radiometer
ESSP	Earth System Science Pathfinder
FAR	Federal Acquisition Regulation
FFRDC	Federally Funded Research & Development Center
FUSE	Far Ultraviolet Spectroscopic Explorer
FY	Fiscal Year
GSFC	Goddard Space Flight Center
HEXTE	High Energy X-ray Timing Experiment
HQ	Headquarters
I&T	Integration & Testing
IDIQ	Indefinite Delivery/Indefinite Quantity
IMDC	Integrated Mission Design Center
IPM	Instrument Project Manager
JHU	John Hopkins University
JPL	Jet Propulsion Laboratory
L1	Libration point 1
L2	Libration point 2
LPARL	Lockheed Palo Alto Research Laboratory
MAP	Microwave Anisotropy Probe
MIDEX	Mid-sized Explorer

MIT	Massachusetts Institute of Technology
MO&DA	Mission Operations & Data Analysis
MSFC	Marshall Space Flight Center
MTPE	Mission To Planet Earth
NASA	National Aeronautics and Space Administration
NEAR	Near Earth Asteroid Rendezvous
NEMS	NASA Equipment Management System
NFS	NASA FAR Supplement
OSS	Office of Space Science
OSC	Orbital Sciences Corporation
PAR	Performance Assurance Requirement
PDR	Preliminary Design Review
PDT	Product Design Team
PI	Principal Investigator
PM	Project Manager
PMS	Performance Measurement System
PQAP	President's Quality Award Program
RFO	Request For Order
RFP	Request For Proposal
SMEX	Small Explorer
SR&QA	Safety, Reliability & Quality Assurance
STEDI	Student Explorer Demonstration Initiative
SwRI	Southwest Research Institute
TBD	To Be Determined
TBR	To Be Reviewed
UCLA	University of California, Los Angeles
UCSD	University of California, San Diego
UNEX	University Explorer
XTE	X-ray Timing Explorer

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The PI-Mode of Project Management

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Abstract

The PI-Mode is NASA's new approach to project management. It responds to the Agency's new policy to develop scientific missions that deliver the highest quality science for a fixed cost. It also attempts to provide more research opportunities by reducing project development times and increasing the number of launches per year. In order to accomplish this, the Principal Investigator is placed at the helm of the project, with full responsibility over all aspects of the mission, including instrument and spacecraft development, as well as mission operations and data analysis.

This paper intends to study the PI-Mode to determine the strengths and weaknesses of such a new project management technique. It also presents an analysis of its possible impact on the scientific community and its relations with industry, NASA, and other institutions.

1. Introduction

The Principal Investigator-Mode (PI-Mode) of project management transfers responsibility over space science missions from NASA to the scientific community. It places the Principal Investigator as the maximum authority over a project, with responsibility over all aspects of the mission, from mission definition to instrument and spacecraft development to final in orbit operations and data analysis.

The PI-Mode is a result of NASA's new policy to deliver "better, faster, cheaper" products to its customers and stakeholders: the Administration and Congress, the science and education communities, the aerospace and nonaerospace industries, federal agencies and, ultimately, the American taxpayer. In its Strategic Plan, NASA established its overall guidelines to implement the Agency's new directives. A series of enterprises has been created to act as independent strategic business units, with a set of goals, objectives, and strategies that address the requirements of its primary customers. One of these enterprises is the Space Science Enterprise. Its mission is to seek answers to fundamental questions about the galaxy and the universe, the Sun-Earth interaction, and the origin and evolution of planetary systems. It also aims to develop and transfer state-of-the-art technologies that benefit the scientific competitiveness of the United States. Finally, the Space Science Enterprise strives to improve the scientific and technology literacy of Americans by promoting education and public outreach programs. The Goddard Space Flight Center (GSFC) is at the forefront of the NASA's space science effort with programs such as Explorers.

Over the last 15 years this program has been very successful in developing highly capable scientific missions. However, these missions also have been highly

expensive and riddled with inefficiencies that have led to long project development times and few research opportunities. All along, the scientific community has expressed its dissent and frustration at this situation. NASA's Strategic Plan established the policy framework to resolve these issues; nevertheless, a good plan was needed to fully implement the overall directives. The Discovery program, started at NASA Headquarters, was the first program to pioneer new management techniques designed to drastically reduce project costs and schedule times. It also introduced the concept of placing responsibility (and control) over the mission on the Principal Investigator. The Explorers Project Office, at GSFC, has followed this approach with programs such as Small Explorers (SMEX) and University Explorers (UNEX). These programs foster low-cost projects that rely on heavy involvement from the scientific community. However, it was the Far Ultraviolet Spectroscopic Explorer (FUSE) project which served as a "pathfinder" into the PI-Mode after it underwent a restructuring process that significantly reduced its budget and placed the PI in control of the mission. Following FUSE, the Mid-sized Explorers (MIDEX) program introduced the term PI-Mode in its first Announcement of Opportunity (AO) dated March 27, 1995.

The MIDEX AO provides an understanding of the rules that govern the solicitation process for new missions under the MIDEX program with regard to funding and schedule constraints. It presents the necessary criteria that proposals have to meet in order to proceed into advanced stages of selection. The complexity and scope of such a solicitation process molds the shape of the proposals and, thus, the future development of selected missions. This is evident in the way that the PI chooses and arranges his team of cooperating organizations (research institutions, contractors, etc.) to produce a viable management proposal. The MIDEX AO is carefully analyzed to determine its effectiveness in promoting the PI-Mode. Furthermore, FUSE and the two missions that were selected under this solicitation process have been studied to show the response of the scientific community to the new opportunities offered by MIDEX.

This report concludes with a series of commentaries on the strengths and weaknesses of the PI-Mode based on interviews with top investigators and project managers involved in the PI and traditional modes of project management. The report presents the most fundamental concerns regarding the PI-Mode: Does the PI have the necessary managerial skills to head a mission of this scope? What are the risks involved, and is NASA willing to assume them? What are the consequences of failure? How will the PI-Mode affect the way space science missions are designed and developed in the future? What are the consequences of the PI-Mode for NASA's engineering and scientific communities? How will the PI-Mode shape relationships between NASA, Industry, and the scientific community?

Many of the conclusions presented in this report are derived from interviews with managers and scientists, inside and outside of NASA. However, I would like

to thank Mr John R. Thurber, my mentor at Goddard, for his kind support and advice. He has helped me ask the right questions. I would also like to mention Mr. Don Margolies, ACE Mission Manager, for his valuable advice and constructive criticism, and Mr. Orlando Figueroa for his far-reaching views. Special acknowledgment goes to all the people who volunteered their time to express their views on such a fascinating research topic. I hope I have reflected their opinions in an honest manner.

2. NASA's Traditional Approach to Project Management

NASA's traditional management approach to space science missions is based on a strong, in-house management team that oversees all aspects of the mission, from development to launch and in-orbit operations. External research institutions and private industry work for NASA under contract to supply flight hardware and software as well as other elements of the mission.

Missions start as proposals from the National Academy of Sciences' Astronomy and Astrophysical Survey Committee or as research concepts at scientific forums such as the Woods Hole conference. NASA then creates a group of prominent scientists to study the different proposals and select the ones that offer the best research opportunities. This group would choose an investigator to lead the detailed definition of the mission, and this investigator would eventually become the PI of the project. However, upon authorization to proceed into the Preliminary Design phase, NASA selects an in-house Project Manager (PM) to take over the project and lead it through its next development phases.

The PM is responsible for selecting the management team, setting up a budget and schedule profile that best suits the requirements of the program, and establishing a control system that ensures efficient and productive integration of all the partners in the project. The management team is also responsible for allocating and keeping track of human, financial, and material resources, evaluating performance, safety, and quality assurance. The PI is in charge of overviewing the scientific aspects of the mission: instrument development and scientific performance and objectives. However, the PI's decisions are ultimately subordinated to the authority of the PM even though they tend to work together toward a common goal.

An example of a standard in-house project is Goddard's X-ray Timing Explorer.

2.1 XTE

The X-ray Timing Explorer is a Goddard mission which was launched into low Earth orbit (580 km altitude, 23 degrees inclination) on December 30th, 1995. It is designed to facilitate the study of time variability in emission of X-ray sources with moderate spectral resolution. Time scales of microseconds to months are covered in a spectral range of 2 to 250 keV.

The spacecraft was designed and built by the Engineering Directorate at Goddard. Its primary instrument, the High Energy X-ray Timing Experiment (HEXTE) was designed, fabricated, and tested at the University of California at San Diego's (UCSD) Center for Astrophysics & Space Sciences (CASS). Together with HEXTE, two other instruments were developed by the Massachusetts Institute of Technology's (MIT) Center for Space Research and NASA's Laboratory for High Energy Astrophysics. On-orbit operations are currently being managed by the Mission Operations Center at Goddard. The scientific planning and data processing take place at the Science Operations Center. This center runs the satellite observatory; processes, distributes, and archives the data; and provides scientific services to astronomers who use XTE.

Essentially, mission management was conducted by Goddard through a team of experienced managers. Goddard provided the spacecraft as well as managerial, testing, launch and in-orbit operations services. UCSD, MIT, and private contractors provided instrument hardware and software under contract to Goddard.

3. The PI-Mode

3.1 Definition

Under the PI-Mode of project management, the principal investigator of a space science project takes responsibility for all aspects of the mission, including instrument and spacecraft definition, development, integration, and test; ground system; science operations; mission operations; and final data analysis. This allows PIs the maximum flexibility to conduct their investigations. The PI has the responsibility and accountability to accomplish the mission within the program's cost and schedule constraints.

The PI is free to elect and organize the team of cooperating institutions of his or her choice. This team will have to develop its own processes, procedures, and methods to manage the project. It will have to devise ways to perform tasks at the lowest possible cost with the best scientific results. NASA will provide minimum oversight to verify that the mission is on schedule and meets the budget and that all scientific objectives are being met. Periodic status reporting will center on cost, schedule and technical issues using the team's own internal management system to comply with U.S. Government reporting requirements.

3.2 Framework of the PI-Mode

The PI-Mode is a direct result of NASA's new policy to attend the needs of its direct customers in a "faster, cheaper, better" way. To better understand why and how the PI-Mode is being introduced we will take a close look at NASA's Strategic Plan and how it is being implemented through the Agency's research centers and the programs within these centers.

3.2.1 NASA's Strategic Plan

In recent years, NASA has been undergoing a continuing process of redefinition in order to respond to the needs of the scientific and academic communities, industry, government agencies, and, ultimately, the citizens of the United States.

The social, political, and economic environment around the world has shifted dramatically, from the Space Race Era of the Cold War to a new forum of international cooperation in space exploration, research, and development. Budgets are also changing, and it is the sign of the times to observe a steady decrease in funding for both manned and unmanned space missions. Thus, it has been NASA's aim to respond to these changes by streamlining its operations in order to accomplish its present and future goals.

One of NASA's primary directives, stated in NASA's Strategic Plan, instructs the Agency to satisfy its customers' needs. NASA's customers have been defined to be the Administration and Congress, the science and education communities, aerospace and nonaerospace industries, federal agencies, and the public. To deliver its products, NASA's Strategic Plan establishes a management system that effectively separates the Agency's programs into five strategic enterprises:

- Mission to Planet Earth
- Aeronautics
- Human Exploration and Development of Space
- Space Science
- Space Technology

"Each enterprise behaves as an independent strategic business unit, employed by private sector companies to focus and respond to their customers' needs" (NASA Strategic Plan, 1996). Thus, they operate independently, with a unique set of goals, objectives, products, and customers. However, all enterprises must work together to fulfill NASA's common goals.

These strategic enterprises will have to deliver high-quality products and services at a *faster* rate, for a *cheaper* price, and with *better* results.

However, this reorganization will be of little value without an adequate plan to implement the new strategies. The activities of each strategic enterprise must be executed through adequate processes which develop and deliver NASA's products and services to the customer. These processes and their subprocesses are being analyzed and redesigned to determine how they can be made more efficient to the public. The PI-Mode is one such process to implement the overall Strategic Plan in the field of Space Science. It is a response to this need for redesigning the processes that allow NASA to accomplish its goals. Figure 1 presents a NASA's strategic framework.

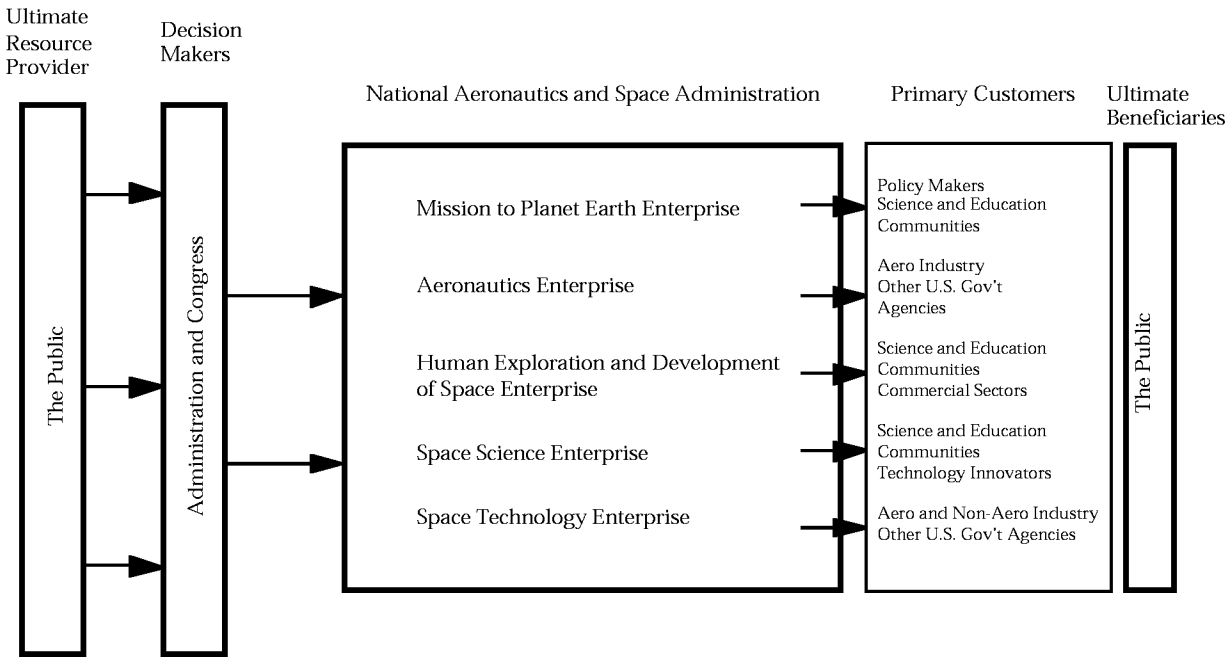

Figure 1. Strategic framework for a single NASA.

3.2.2 The Space Science Enterprise

NASA's Space Science Enterprise has a threefold mission: science, technology and education, and public outreach. Fundamental questions about the universe, our galaxy, and the solar system are asked, and the proper technologies are developed to try to seek some answers. The knowledge and discoveries made are shared with the rest of the scientific and educational community.

A program of constant scientific exploration has been developed with the goal to establish a "virtual presence" in the solar system and scan the universe across the entire electromagnetic spectrum. It also endeavors to understand the Sun-Earth interaction and search for locations in the solar system where life could have existed.

This constant presence will be achieved through the development of low-cost missions that achieve the best science for the dollar. This implies frequent launch windows that offer more scientific research opportunities at a manageable risk. New approaches to project management will have to be developed in order to achieve these objectives and the PI-Mode is one of these new approaches.

3.2.3 First Steps of the PI-Mode: The Discovery Program

One of the first programs to implement NASA's Strategic Plan in the field of Space Science is the Discovery program for planetary exploration. It was started at NASA Headquarters in response to NASA Administrator Daniel Goldin's push to restructure flight programs toward smaller, more frequent missions. It presents a series of new innovations that divert from the traditional manner in which planetary missions were carried out: mission costs are now capped at a level much lower than before; projects will be cancelled in response to overruns; and, the most significant change is that the Principal Investigator will be in complete control of the project.

The manner in which Discovery proposals are solicited is through an AO. This document is prepared in conjunction with all members of the planetary community in order to design a well-balanced proposal that meets its needs while establishing the ground rules for an impartial competition. The response to this initial AO resulted in a total of 73 mission concepts identified during a Discovery workshop in 1992, followed by 28 full proposals that turned out two successful final selections. The first spacecraft to come out of this solicitation process were the Mars Pathfinder (to land on Mars on July 4, 1997) and Near Earth Asteroid Rendezvous (NEAR).

3.2.4 The Explorers Program

The Goddard Space Flight Center is now at the forefront of NASA's space science effort with programs such as Explorers and Pathfinder. These programs are being reshaped to meet the need for a new family of small to medium spacecraft that materialize the new philosophies introduced by NASA Headquarters. More specifically, one of the Center's goals is to "enable more science by increased cost effectiveness" (Application for the President's Quality Award Program, 1997). This will be accomplished by decreasing the mission cost and increasing the number of flight opportunities. Customer service will focus on the quality of the science delivered. Specific actions will concentrate on improving project planning,

streamlining program management and strengthening ties with industry. An example of how these improvements have been implemented is the Explorers program.

The Explorers Project Office has been an integral part of Goddard's scientific program since the 1960's. Its main scientific objective is to conduct world class scientific research in astrophysics and space physics through the development of space flight missions.

During the early history of the Explorers program, relatively small missions were launched into Earth and Moon orbits to develop necessary technologies, instruments, and scientific expertise that would pave the way for a future, larger-scale scientific program. In the 1980's, the program deviated from these small and frequent missions to a few focused, but highly capable projects such as the X-ray Timing Explorer (XTE), the Far Ultraviolet Spectroscopic Explorer (FUSE) or the Advanced Composition Explorer (ACE). Nevertheless, the initial spirit of the program has been preserved with classic small-mission capability programs such as the Small Explorer (SMEX) and a later Student Explorer Demonstration Initiative (STEDI), started in the 1990s to develop missions at a university graduate level for less than $5 million dollars.

The Explorers Project Office is currently focusing its efforts on three unique programs:

University Explorers - UNEX - Very low-cost projects (up to $5 million dollars) directed primarily to minority universities.
Small Explorers - SMEX - Highly focused and inexpensive science missions (up to $35 million dollars) with frequent flight opportunities.
Mid-sized Explorers - MIDEX - Small-to-medium sized missions characterized by their relatively moderate costs (up to $70 million dollars) and short development periods (3 to 4 years).

Larger Delta-Class programs such as the above-mentioned ACE or FUSE are also managed by this office. However, they are being phased out in favor of the smaller, more focused missions.

All of these programs involve heavy participation from the scientific community. The PI-Mode of project management epitomizes this participation, since it places full responsibility over the mission on the PI.

3.2.5 MIDEX

The MIDEX program has been one the first pioneers in the development of this new approach to project management. Its primary operating premise is to

develop a series of low-cost flight projects that maximize the science value of a mission for a fixed cost ($70M excluding launch and Mission Operations & Data Analysis, MO&DA, after 30 days in orbit). These missions will be flown at an initial rate of once a year with development times of less than 4 years to increase the current number of space science research opportunities. The first two MIDEX missions (to be launched in 1999 and 2000, respectively) are the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) project and the Microwave Anisotropy Probe (MAP). These missions have been assigned under a solicitation process similar to the Discovery program. This process started with an AO dated March 27, 1995, that first introduced the term "PI-Mode" as a management option for carrying out the development of a mission.

MIDEX offers scientists the opportunity to implement their scientific research in an environment that promotes the use of new architectures, operations concepts, and technologies to increase mission value. It also supports the development of new products and techniques that are high risk for Industry.

To achieve its objectives, MIDEX emphasizes the need for integrated cooperation between industry and the science community in an effort to create an infrastructure of partnerships that will enable the development of a continuous space science program. This is accomplished by a managerial approach that facilities day-to-day synergy between NASA, its contractors, and researchers. Some of its guiding principles include trust, individual and team responsibility, common sense in all processes and activities, seeking ways to maximize team efficiency and to reuse available resources, and applying systems engineering approaches to all management levels. However, the most important feature of the MIDEX program is that it gives the scientist the option to select and lead his or her own team in the development of all aspects of the proposed mission. This independence is designed to foster projects in which the scientific community is ultimately responsible for the final outcome of the mission.

4. Reasons for the PI-Mode

The PI-Mode is NASA's response to growing concerns from the scientific community regarding their lack of participation in the design and development of scientific missions. The traditional mode in which NASA has carried out most of its space science missions has been to overview and control all aspects of the project through a structure of experienced PMs. NASA would effectively behave as a customer to its major contractors, and would establish the rules that govern how all processes are implemented, controlled, reviewed, and reported. The PI and his or her team would work under this structure and take on the responsibility to design and develop the scientific payload, and preserve the scientific goals established early in the mission design phase. However, the PM would be ultimately responsible for all decisions concerning not only the schedule and budget, but also the science. Most

importantly, he or she would be directly responsible for descoping the scientific objectives of the project in order to avoid jeopardizing the overall success of the mission. This, and other situations, would lead to frustrating moments in which the PI's views would clash with those of the Project Manager. In many cases, the PI's opinion on matters concerning overall aspects of the project were not duly regarded. For these reasons, NASA Headquarters has decided, under the Discovery and Explorers programs, to transfer project responsibility to the scientific community as a way to provide researchers with the opportunity to implement their work in a more independent environment.

Moreover, NASA believes that producing small space science missions under cost-capped budgets and short development times, while maintaining the same science quality will be accomplished only by placing the scientists at the helm of the project. The cost, schedule, and technical constraints imposed by the Discovery and Explorers/MIDEX programs will be implemented in an arena that is quite different from the historical NASA mode in which the Agency has supported overriding these "constraints" in order to assure mission success. NASA can no longer support missions at all costs and accept delays for a grasp at the science objective. The PI must work within the constraints and must accept termination if the project cannot be achieved within them. Accordingly, NASA has turned over full responsibility for achieving the mission to the PI. The PI is expected to assemble a team of scientists, engineers, and managers from research institutions, government agencies, and contractors, that will use their own management approach to develop new ways of "doing business" where cost, schedule and technical improvements can be achieved. Under the current MIDEX AO, the different proposals are evaluated on the basis of scientific merit and viability of the management approach to carry out the project under MIDEX's budgetary and schedule constraints. Thus, the PI will have to present a viable project based on a strong research concept and the support of a capable team.

5. Expectations and Anticipated Benefits

The PI-Mode is expected to introduce a new way of "doing business" that will allow NASA to implement its dual goal to produce high-quality scientific spacecraft under a fixed cost and schedule, and to satisfy the needs of the scientific community. The PI will have to implement new management strategies that streamline project development, oversight, and control. New methods of cost and schedule control, team work, performance evaluation, risk management, and quality assurance will have to be devised to create efficient project management techniques that function under the very tight constraints of NASA's new flight programs.

The PI-Mode is also expected to forge strong partnerships between industry, research institutions, NASA centers and the scientific community to produce viable mission proposals that satisfy mission selection criteria. These partnerships are

expected to create platforms that combine a strong knowledge base with adequate human resources and project experience. The competitive environment of the PI-Mode selection process will force investigators to coordinate their efforts with institutions that have the technical capacity to produce the best mission designs for the dollar.

New technologies should result from the PI-Mode as PIs push the boundaries of the state of the art to develop new instruments for a lesser cost. NASA's new policies (as implemented by its different Space Science programs) provide the adequate environment for this to happen. NASA is also willing to accept a higher degree of risk because of the low relative cost of each mission. This will enable the proliferation of new technologies combined with proven heritage hardware and software.

The PI-Mode will transfer responsibility to the people who are going to gain the most from the scientific outcome of the mission: the scientists. This entails a lot of risk on the part of NASA, and raises many questions and concerns that will be addressed later in this report. Nevertheless, successful PI-Mode programs will generate missions that focus on the science, by the scientists, and for the scientists. This, in itself, will be beneficial not only to the scientific community, but also to NASA and all the partners that cooperate in this effort.

6. Implementing the PI-Mode

6.1 Types of Missions Suitable for the PI-Mode

The PI-Mode is adequately suited for small-scale missions of the SMEX, MIDEX, or Pathfinder class. These missions are cost-capped at values ranging from $30M to $100M U.S. dollars (excluding launcher costs and MO&DA). They are also constrained to 3 to 4 years in their development times in order to achieve an overall expected launch rate of one mission per year. These missions require small management teams and highly integrated partnerships between cooperating institutions. The PI-Mode is intended to develop management schemes in which a selected group of scientists and engineers headed by the PI will direct and control the activities of small product development groups. Their highly focused scientific objectives also make these types of programs ideal for implementation under a PI-Mode management structure.

Large-scale projects such as Hubble or COBE have resulted in highly capable scientific missions that have advanced our knowledge of the Universe in ways never imagined. However, the cost and resources involved in such programs have been proven to be unmanageable without the presence of large organizations to overview them. The PI-Mode definitely will not migrate into programs of the scale of Hubble (declared a national resource), since NASA will not take the risk to place a

PI and his team in control of such projects. It is also questionable whether a PI would be willing to accept such a responsibility.

6.2 The Announcement of Opportunity (AO)

The AO is the first step toward implementation of the PI-Mode of project management. It is the framework through which NASA presents the chance to conduct scientific research in several fields of Space Science. Furthermore, it sets up the rules and regulations that shape the proposals submitted by investigators in response to this announcement. A case study of the MIDEX AO-95-OSS-02, presented on March 27, 1995, is performed in order to provide further insight into the PI-Mode of project management.

6.2.1 The MIDEX AO

During the last few years, the Office of Space Science (OSS) has been initiating a series of medium-class scientific missions to be launched at an approximate rate of one per year. Through the AO, the OSS intends to solicit missions and investigations that are mature enough, both scientifically and technically, to design and manufacture the necessary flight hardware in no more than 3 years, following a 10-month (or less) mission-definition phase. These missions are enclosed within Goddard's MIDEX program.

The MIDEX AO establishes research opportunities in the fields of astrophysics (radio, submillimeter, infrared, visible, ultraviolet, x-ray, and gamma-ray astronomy; gravitational astrophysics; and relativity) and space physics (ionospheric, thermospheric, and mesospheric physics; magnetospheric physics; cosmic and heliospheric physics; and solar physics). It invites proposals for two medium-class-type missions, the first one to be launched in 1999 and the second, in 2000. All categories of organizations are invited to submit their proposals: educational institutions, industry, nonprofit institutions, NASA field centers, and other governmental agencies, as well as non-U.S. research institutions.

The total cost for each mission, as established in the MIDEX program, is "capped" at $70M in 1994 Fiscal Year (FY) dollars. This includes the cost for definition and development through launch plus 30 days. It excludes the launch vehicle and MO&DA following the first 30 days in orbit. Missions will be selected based on their ability to produce the highest possible science value per unit cost. A balance is sought between lower and higher cost missions that will allow for launches every 12 months.

Proposers have two basic options for the flight portion of their mission: a NASA-provided spacecraft or the PI-Mode. In the first case, the investigator provides a scientific investigation and an instrument, while NASA provides the

spacecraft. Based on a preliminary analysis of the mission, NASA will study the feasibility of using a GSFC-developed spacecraft or a spacecraft procured from industry. Goddard will cooperate with the investigator in the selection and contract of the procured spacecraft, from the initial definition and design phases to its final development process. In this "NASA-provided spacecraft mode" Goddard maintains overall control of the project in the traditional mode of past Explorer missions.

The second option is the PI-Mode. This management technique places the Principal Investigator in charge of all aspects of the mission. The PI may elect to cooperate with any institution of his or her choice, and it is NASA's intention to provide the minimum necessary oversight needed to comply with its legal obligations to the taxpayer. This mode implies that the submitted proposals will be very carefully scrutinized, prior to selection, in order to determine the capabilities of proposing teams to carry out a flight project of this scale. Scientific merits will be studied in parallel with detailed management plans, program schedule, etc.

Missions using a NASA-provided spacecraft should not exceed $40M in FY 1994 dollars, which should cover the costs already mentioned plus a minimum of 15 percent realistic budget reserve. This compares to the $70M (FY 1994 dollars) allocated to those missions in which the spacecraft is manufactured by a non-NASA partner under the PI-Mode.

All proposals undergo a two-step selection process. In response to several concerns from the scientific community NASA was made aware of the work needed to put together a proposal of this kind and, thus, effectively divided the selection procedure into a two-step negotiated procurement process.

All applicants must first submit a Step-One Proposal, providing a detailed description of the planned science investigation and the instrument(s) required. The proposal should focus on the scientific research to be performed, including plans for the analysis of the data. Also, it should describe the technical approach to the project, as well as the new technologies to be developed. An outline of the cost and management plan should be presented.

Step-One proposals will be evaluated primarily on the scientific and technical merit of the proposed mission and its likely contribution to space science. Careful examination will also be made of the proposed cost and schedule, as well as the approach taken to fulfill the main objectives of the mission.

The proposing teams that satisfy the requirements established in the Step-One selection process will be asked to submit further details of their projects. This is the second phase of the selection process, the Step-Two proposal. This proposal should include additional information on the scientific value of the mission, and the

minimum science to be covered. Realistic analysis of the total cost of the project should be presented, and the adequacy of the approach, as evaluated by the government, should show that the mission will be flown at the budgeted cost cap of $70M (excluding launch and operations after 30 days in orbit).

During the entire selection process, close attention will be placed on the PI and his team. Review boards are generally constituted by a panel of NASA-appointed scientists and experienced project managers. Effectively, the PI will be evaluated by his or her peers, who will consider his or her experience, level of commitment and prior performance in space science-related projects. The team of cooperating organizations (universities, federal agencies, contractors, etc.) will be reviewed, and key personnel will be evaluated based on their capabilities and prior experience in NASA programs.

On the basis of the recommendations presented by the review boards and further considerations from the Explorer Program office, the Associate Administrator for Space Science will select the Two-Step proposals to be supported for further project definition, as well as the alternates.

One of the primary missions will be chosen to proceed into its mission definition phase, while the other will enter an extended definition phase with anticipated funding not to exceed $500,000 for the first year. After this first year, the second mission will proceed into full mission definition. The alternate missions will undergo preparatory definition studies and will be provided with limited funding to maintain a small investigation team. If either of the primary missions were to prove technically or programmatically infeasible, then NASA will choose an appropriate alternate to proceed into mission definition.

International participation in the MIDEX program is welcomed by NASA, since it offers potential scientific, technical, and financial benefits to all partners. Thus, opportunities for bilateral cooperation are encouraged in the AO. International partners may contribute in any and all aspects of the mission (instruments, spacecraft, mission operations, etc.) maintaining the scope of the mission consistent with the size, cost and schedule of other MIDEX class programs. These contributions will be considered as an addition to the project budget without influence on the initial project cost cap. Partnerships also may be created between NASA and other domestic agencies, in which they may contribute, from their own resources, to any component of the mission.

Evaluation of this Announcement of Opportunity shows that it will influence future space science missions under the Explorer Program in three important aspects: management structure, mission size, and project partnerships. In the first case, the AO proposes the PI-Mode as a management system in which the PI is fully responsible for the success of the mission. Therefore he or she has full control over

the mission, with the prerogative to decide on the management plan and allocation of resources. This is an important step away from NASA's traditional conception of project management in which a strong Project Manager would head the project and the PI would be in charge of maintaining the science portion of the mission. The new approach places the PI at the top of the management scale, and this will clearly influence the way projects are carried out.

The AO also places a limit on the scale of the mission. The MIDEX program establishes a series of budgetary and schedule constraints that must be adhered to in order to be accepted for future flight missions. The main advantage of these requirements is that it imposes well-defined limits on the management team in order to ensure that missions will be completed on time and on schedule. This is fundamental if a planned periodicy of one launch per year is to be attained.

The third important aspect of the AO is that it opens the scope of possible partnerships between the scientific community and other institutions. Proposers can range from federal agencies to small teams of scientists with industry support and international cooperation. Proposals will be evaluated solely on the basis of scientific merit and technical viability within the defined constraints.

6.2.2 Perceived Problems With the MIDEX AO

A recent assessment of the Space Studies Board of the National Research Council has determined that the MIDEX AO places the Explorers program on the right path and, if properly administered, should prove successful in the near future (Assessment of Recent Changes in the Explorers Program, 1996). However, there are a series of perceived problems that must be addressed in order to produce a more effective solicitation.

Most of these problems deal with the "dual mode option," in which the scientist can choose to use a Goddard-provided spacecraft or a spacecraft of his or her own. This implies that the project could be run under a "NASA-provided spacecraft mode," in which NASA retains control over the project, or a PI-Mode, in which the investigator is the maximum authority. The main concern of this issue is that the selection process could be biased toward proposals that accept the first approach. Until recently, NASA programs have been influenced by conservative instincts related to a history of past successes under traditional management models. However, it is believed that the "dual-mode option" will be eliminated in favor of the PI-Mode.

Another concern focuses on the requirement placed on industry to produce detailed cost analysis early in the selection process. This investment could be significantly reduced by providing "cost-not-to-exceed" estimates that meet AO requirements.

Problems in estimating costs might also arise from the lack of full-cost accounting for government contributions. In addition, the review board determined that the MIDEX AO should follow the Discovery AO in placing the cost cap at the full-cost-to-NASA level instead of project development plus 30 days in orbit.

It was generally perceived that these and other errors could have been avoided if the scientific community had been consulted actively during the development of the AO. In spite of this, the panel concluded that the "PI-Mode" established in the MIDEX AO is a step in the right direction toward "bringing new vigor to the program at a time when diminishing opportunities could lead to disillusionment amongst the scientific community" (Assessment of Recent Changes in the Explorer Program, 1996).

6.2.3 The ESSP AO

Parallel to the MIDEX AO, the Earth System Science Pathfinder (ESSP) Project Office produced an AO (AO-96-MTPE-01) dated March 20, 1996.

The ESSP AO is similar to the MIDEX announcement, since it promotes low-budget scientific exploration missions that support the PI-Mode system of project management. It also follows NASA's policy to provide frequent (once per year) scientific missions that offer the best science for a fixed cost. The program itself focuses solely on Earth system science investigations that fall within the objectives of NASA's Mission To Planet Earth (MTPE) program, as opposed to the research policy of the Explorers Project Office. Costs will be based on total cost to NASA, including launch, MO&DA, and civil service staff.

Two missions will be selected for launch in the years 2000 and 2001. Maximum costs for the first and second missions will be $60M and $90M, approximately, although proposals below these caps are encouraged because of budgetary difficulties. The proposing teams must be led by a PI, who will have full authority over the project and freedom to select the team of cooperating institutions of his or her choice.

6.3 Modifications to NASA's Contracting and Procurement Policies

In order to implement the most fundamental aspects of the PI-Mode for the Explorers project, several new modifications had to be introduced to NASA's procurement procedures. These changes are designed to facilitate the "transfer of mission responsibility" from Goddard to the PI. They involve a waiver to the NASA procurement regulations that deal with the level of review, approval, and reporting to meet Goddard overview requirements.

The Federal Acquisition Regulations (FAR) establish the procedures, rules and regulations that dictate the manner in which all federal agencies solicit, award, and administer their procurements. These regulations are in place to protect the interests of the taxpayer. All U.S. government organizations must abide by them regardless of the project or program they are involved in. NASA has a FAR supplement document (NFS) that complements FAR. It expands the procedures and provides agency procurement requirements beyond the FAR.

The waiver was first designed and implemented by the Explorers Project Procurement Office during the change to medium-class spacecraft and instruments (MIDEX) and the restructuring of the FUSE mission. Introducing the PI-Mode into the FUSE project forced the Explorers Procurement Office to undergo an early learning process. This process led to recommendations to waive the nonstatutory requirements of the NFS regulations that adjust the office's procurement (solicitation and award), review, approval, and reporting policy in the contract itself to implement the new management technique.

The government issued a contract (prime) to the PI (from John Hopkins University) and the mission control and management was taken from the government except for very minimal requirements that assure that the government's interests and money are being protected.

The waiver to deviate from the NFS is presented in a planning document entitled "Potential Waivers of Contractual Requirements". Some of the most significant departures are as follows:

- Group waiver for procurement demonstration for both the award stage and the postaward stage of the PI-Mode. Other PI-Mode contracts apply the waiver more at the preaward AO to promote more efficiency and latitude in the award process. FUSE is different from other PI-Mode contracts because it was a noncompetitive procurement, and the waiver was applied more to the terms of the award document rather than to the AO. The waiver met the desire to turn over responsibility to the PI and to reduce government overview.

- Safety, reliability, and quality assurance (SR&QA) functions are turned over to the PI. This eliminates the Government Performance Assurance Requirements (PAR) and the contractor's Assurance Implementation Plan (AIP).

- Foreign travel requests to the government will not be required. The PI is in the position to determine what travel is necessary within the constraints of the budget. Subcontractors must request travel and report their results to the PI.

- Purchases of equipment: the FAR requires that, when possible, agencies and cost-reinbursement contractors should use surplus property as their first source of

supply before initiating procurement actions. In order to facilitate the process, the PI is provided with current screening materials from the NASA Equipment Management System (NEMS). The screening procedure is normally a lengthy review and approval process through the government. A simpler system was developed for screening, and this information is maintained by the PI's staff in a log for adequate reference and documentation.

- The NFS requires the Performance Measurement System (PMS) to report the percentage of completion in relation to costs expended in a massive reporting format of this dollar value. However, the Explorers Project management concluded that a significant amount of reporting could be waived if the PI establishes an effective performance-tracking mechanism to satisfy NFS and GSFC requirements.

As a result of the waiver, these reduced requirements will have to be monitored and revised as necessary in order to achieve an efficient and adequate equilibrium between GSFC project overview and the PI's independence. This equilibrium is key to promoting streamlined management techniques that support scientific missions with very short development times and maximum scientific benefits. All of this is done in an effort to reduce mission costs.

Goddard is also studying new procurement techniques designed to reduce the time between mission definition and spacecraft procurement. One such program is called the Indefinite Delivery/Indefinite Quantity (IDIQ) Procurement initiative. It responds to NASA's Strategic Plan to develop the most adequate processes to provide the most competitive services to its customers. It is being implemented by the GSFC Flight Projects Directorate. The program proposes to compile a comprehensive database of complete satellite systems (minus mission-specific payload) based on existing flight or flight-imminent hardware to aid the PI in the selection of an appropriate spacecraft that meets mission needs. For this purpose, a Request For Proposal (RFP) for existing satellite buses will be issued to industry and proposals will be prequalified based on past performance, core system, description, and price comparison to similar missions. Acceptable offerings will be placed in the IDIQ catalog, and IDIQ contracts will be awarded to the offering companies. The principal user of this database would be a government sponsored PI who has been selected through the AO process.

To assist the IDIQ initiative, an Integrated Mission Design Center (IMDC) has been set up to provide the PI with the engineering support needed to transform a mission profile into a viable mission design. Based on this design, the PI would select a "short list" of spacecraft that best fit the necessary requirements. The IDIQ office would then create a "miniprocurement" team to send Requests For Offers (RFO) to the top-ranking best fits. The RFOs would include overall mission requirements, program schedule, interface requirements or expectations, and observatory level Integration & Testing (I&T) program requirements. The

companies would then be approached to submit a "miniproposal" within 30 to 120 days of solicitation (depending on mission uniques). Upon selection, project management authority would be transferred to the user, that is, the PI. Figure 2 presents a diagram of the IDIQ process.

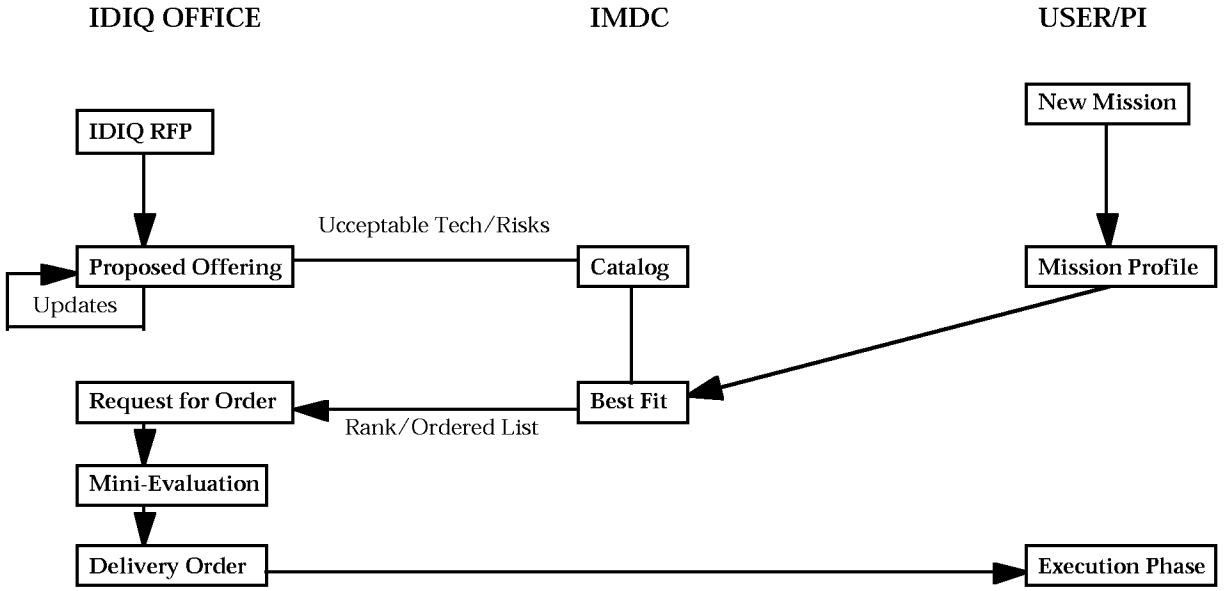

Figure 2. IDIQ process flow.

The IDIQ program would be most appropriate to MIDEX and other small-to-medium space science missions. It is intended to speed up the procurement process of a spacecraft in an effort to reduce the mission development time frame. The first RFP is scheduled to be announced in May 1997, and the first IDIQ contract is expected to be awarded in December 1997. This would preclude a first delivery order for May 1998.

All of these initiatives show an encouraging effort to transfer project responsibilities from NASA to the PI. They also streamline the procurement process by reducing the amount of reporting needed to assure the adequate level of overview on the part of NASA. Furthermore, the waiver to the NFS, along with new procurement architectures, attempts to promote a policy of rapid response to customer needs; however, there are concerns that these efforts will not be sufficient to support a growing number of independent missions while maintaining adequate NASA oversight.

7.0 Examples of the PI-Mode

7.1 FUSE

The Far Ultraviolet Spectroscopy Explorer (FUSE) is one of the last Delta-class astronomy spacecraft to be developed by Goddard. It will extend the high-resolution spectroscopic analysis of astronomical radiation from the short wavelength cutoff of Hubble down to the Lyman limit at 912 Å. "FUSE will complement the investigations carried out by Hubble, measuring both emission sources and absorption lines in intervening gas clouds throughout our galaxy and beyond." (Moos, 1996). The instrument itself consists of four instruments with coaligned telescopes and spectrographs. Multiple telescopes, rather than a single one, are used to reduce the size of the instrument. The instrument will be mounted on a three-axis stabilized spacecraft provided by the Orbital Sciences Corporation (OSC).

The project was originated in 1982, when the Astrophysical Committee of the National Academy of Sciences declared it as its maximum priority for the upcoming Explorer-class missions. A group of prominent scientists was created to study the FUSE concept, and, in 1985, this group selected Dr. Warren Moos of the John Hopkins University (JHU) to further define the mission concept. Dr. Moos was selected as the project's PI, and FUSE was chosen to continue into Phase A feasibility study. Subsequent to this phase, NASA authorized Dr. Moos and his team of scientists and engineers to continue into Phase B. Initial designs called for a shuttle-installed instrument on the Explorer Platform. However, the Challenger disaster forced an early Phase B redesign that transformed the instrument into a free-flying spacecraft to be launched on a Delta vehicle. This redesign produced shifts in the development schedule that would have led to a launch in late 2000. Parallel to this, NASA Headquarters started to introduce its "faster, better, cheaper" policy with FUSE representing a stumbling block in the path to implemention in the Explorers program. In 1994, in the midst of Phase B study, NASA HQ directed that all work on the Delta-class FUSE mission cease because of programmatic funding constraints on both the Agency and the GSFC Explorers program.

However, efforts on the part of FUSE's PI convinced NASA HQ to proceed with a "restructured" FUSE project. JHU would have to prepare a plan for the new FUSE based on three basic guidelines: 1) mission development costs would have to be capped at $108M, 60% less than the initial budget; 2) science prioritized and optimized to maintain 60% of the mission's original scientific goals and capabilities; 3) the PI would be placed in charge of development and management of all aspects of the mission except the launch vehicle (FUSE: a different approach to lowering cost). In March 1995, NASA accepted the plan and granted approval to JHU to proceed with Phase B studies. Under this plan, Dr. Moos is now fully responsible for all aspects of the mission. Effectively, FUSE has been transformed from a standard in-house project to a PI-led mission. The restructuring process of FUSE can be

considered a "pathfinder" experience for the Explorers Project Office since mission has been downsized to a MIDEX-class program, and the management structure has been converted to a PI-led effort.

FUSE is a joint venture between NASA, the Canadian Space Agency, and the Centre National d'Etudes Spatiales of France. The PI's team is led by the John Hopkins University. Team support is provided by the University of Colorado, the University of California at Berkeley, Swales and Associates, and the JHU Applied Physics Laboratory. GSFC is also a cooperating partner in the mission.

Restructuring of the management system focused on a critical reduction of the mission's cost and schedule. A 60% reduction in the budget was achieved by descoping the mission's scientific objectives. Requirements were prioritized, negotiated, and refocused to produce a more efficient instrument that preserves the mission's core scientific goals. Further reductions were achieved through an intelligent redesign process that concentrated on modifying the existing design rather than creating an entirely new solution to the problem. Furthermore, commercial suppliers were found to attend a variety of subsystems ranging from structure to software. A commercial spacecraft bus was sought and OSC was awarded a contract to build a spacecraft that minimizes interface complexity with the instrument and maintains stability over mission lifetime.

The development schedule was reduced from 5 to 3 years, moving the launch date back to the fall of 1998. Scientists, engineers, and managers were brought together in an integrated effort to achieve this significant reduction. NASA has provided an adequate funding profile to adapt to this new schedule. The waiver to the NFS has also allowed more flexibility in the procurement procedures between nongovernment institutions, which has allowed the PI's team to place more contracts on time.

Scientists have played a crucial role in the redefinition of FUSE. In other projects, it is often the case that the scientists issue a set of scientific requirements and sit back to let the engineers perform their task. However, in FUSE, the scientists work with the engineers as part of integrated teams. This requires discipline, communication and understanding of each other's issues. This integration has permitted a broad system view of the project and rapid turnaround in discussion and requirement trades. The FUSE team brings together the knowledge and experience of people from different technical backgrounds and cultures, and the success of the team is based on how this wide range of expertise is brought to bear on actual problems. Authority and responsibility are delegated to the subsystem level, and lead engineers are expected to find solutions to cost and schedule problems, even if it means renegotiating the requirements.

The John Hopkins University, through Dr. Warren Moos, is leading this team effort in a strong systems engineering approach to project management. NASA-GSFC is providing general oversight, environmental testing, engineering support and launch services. However, responsibility for the project lies with its PI.

7.2 IMAGE

In response to the MIDEX AO of May 1995 (AO-95-OSS-02), the Southwest Research Institute submitted a proposal for space science research defined as the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE).

The IMAGE mission has been designed around the following questions: What are the dominant mechanisms for injecting plasma into Earth's magnetosphere on substorm and magnetic storm time scales? What is the directly driven response of the magnetosphere to solar wind changes? And, how and where are magnetospheric plasmas energized, transported, and subsequently lost during storms and substorms? (Burch, 1995). To answer these questions, IMAGE will be placed on a 500 km x 7 Earth Radii altitude orbit with an inclination of 90 degrees. It will make use of neutral atom, far ultraviolet, extreme ultraviolet, and radio plasma imaging techniques, with a scientific payload composed of 6 interrelated instruments. These instruments will enable IMAGE to acquire, for the first time, a variety of three-dimensional images of magnetospheric boundaries and plasma distributions extending from the magnetopause to the inner plasmasphere (IMAGE mission proposal, 1995).

The IMAGE team is headed by its PI, Dr. James L. Burch, from the Southwest Research Institute (SwRI) of San Antonio, Texas. A number of institutions are also involved in this project, such as GSFC, MSFC, the Universities of Maryland, Arizona and Mass-Lowell, and the Lockheed Palo Alto Research Laboratory (LPARL). Furthermore, a longer list of Co-Investigators from research institutions across the U.S. as well as Canada, Switzerland, the UK, Belgium and Japan are also heavily involved in the project.

SwRI, through its PI, will be directly in charge of managing the project, and it will be responsible for the technical and financial performance of all IMAGE team members. Design, development, and fabrication of the instruments will be performed at the SwRI and the primary institutions mentioned above. These instruments will be integrated at the SwRI, and will then be integrated into the spacecraft as a single subsystem. The spacecraft will be based on Goddard's SMEX Fast Auroral Snapshot Explorer design because of its similarity with IMAGE mission requirements.

The PI is the ultimate authority and is fully responsible for the success of the mission. Figure 3 presents a diagram of the IMAGE organizational chart.

The PI is assisted in the day-to-day management of the program by the Project Manager and a small group of experienced engineers and scientists consisting of one representative from each instrument team, the spacecraft, the ground segment, the theory and modelling team, and the education and public outreach team. Instrument development activities will be coordinated by a single Instrument Manager. Furthermore, he will have a single point contact within each institution building flight hardware. A single individual will coordinate all the activities of the Co-Investigators.

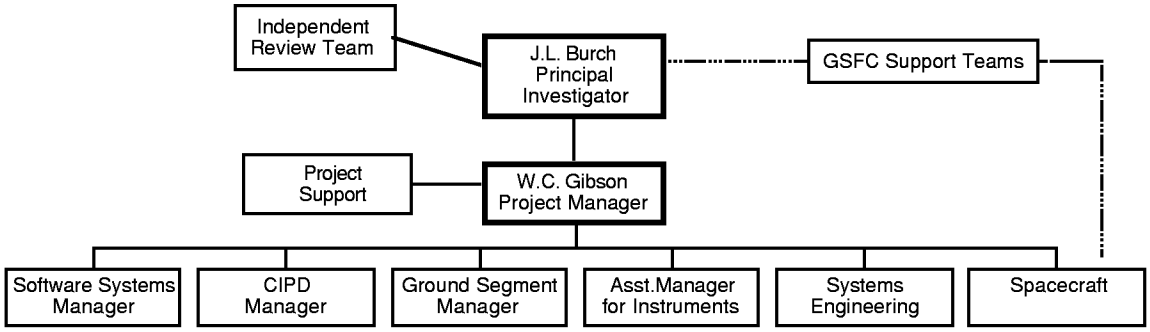

Figure 3. IMAGE management structure.

Core funding to all U.S. IMAGE subcontractors (except those directly dependant on Goddard and Marshall) will be channeled by the SwRI.

The program will be managed with the goal to obtain the best science within the contract limitations established by the MIDEX program. A strong systems engineering activity will be applied to the technical aspects of the mission in order to obtain an efficient scientific payload that meets all mission requirements. All development teams will be coordinated by SwRI following an integrated philosophy that streamlines communication between each research institution and the management team. Risk management will be focused on early identification, avoidance, and control. Furthermore, the use of heritage components and proven technologies will provide for rapid risk mitigation. Risk analysis also will be applied to areas of costing, scheduling and instrument performance.

From the management point of view, the project will rely heavily on the expertise of a single institution, the SwRI. This institution has to coordinate the acquisition, development, and integration of an array of instruments with different thermal, power, and control requirements. It also has to channel funds and provide adequate cost tracking and control. All of these functions will be overseen by a small management team composed of the PI, the PM, and the principal team managers.

This team has to be sufficiently small to handle a fast-paced program. On the other hand, it has to be sufficiently experienced to make technical decisions very early in the development phase of the project and, most importantly, to be able to adequately descope the mission in order to meet budgetary and schedule constraints. This will require people with enough background and stature to make quick decisions at critical times in the project. NASA has stated clearly, that the response to budget and/or schedule overruns will be project cancelation. Therefore, a critical issue will be to identify problematic areas very early in the development phase of the project. Descoping could become a critical issue for the PI and the SwRI, and this would be one of the first PI-Mode missions in which a PI would have to be faced with giving up science in order to successfully complete the mission.

Solid coordination will also be required to manage such an important group of participating research institutions and investigators. There is a significant number of U.S. and international co-investigators directly involved in the project and a number of participating scientists who contribute to many scientific aspects of the mission. This is positive, in the sense that a good portion of the scientific community is actively participating in the project. However, the tasks of each participant will have to be specified clearly in order to maintain the focus of the mission and freeze scientific objectives early in the definition phase of the project.

IMAGE can be considered to be the closest approach to a PI-Mode mission that Goddard would accept at such an early stage in the development of the PI-Mode. Goddard retains responsibility over mission management, launch vehicle procurement, ground station development and operation, and flight operations team selection and training. However, the PI is in direct control of the project. NASA simply behaves as a supplier of products and services.

A preliminary analysis of the mission, reviewed by Goddard, has verified that the proposed mission costs (with reserves) will meet the requirements imposed by the MIDEX AO. Several concerns were voiced during the IMAGE Preliminary Design Review (PDR) held at Goddard on February 25, 26, and 27, 1997, concerning the number of To Be Determined (TBD) and To Be Resolved (TBR) issues. This is probably caused by a short mission definition phase, which has left several issues unresolved. This problem probably will resurface in future projects until sufficient experience is gained in developing well-rounded mission concepts in such short time periods. Another significant suggestion from the review panel recommended raising the systems engineering function to a level above other engineering functions.

7.3 MAP

The second mission to be selected under the MIDEX AO is the Microwave Anisotropy Probe (MAP). MAP is the result of a cooperative effort between

Princeton University and the Goddard Space Flight Center. It must be noted that MAP is not a PI-Mode mission *per se*, however, it could be considered an "in-house PI-Mode" mission, since the PI has full authority over all aspects of the project.

MAP will attempt to answer three of the most important and fundamental cosmological questions: Which cosmological structure formation model best describes our universe? What are the values of the fundamental parameters of cosmology? What was the ionization history of the universe? (Bennett, 1995). To answer these questions, MAP will make a full sky examination of cosmic microwave background (CMB) fluctuations. By mapping the CMB radiation at ~0.3 degrees resolution, we can make an important number of observations on the physics of the early universe.

The probe's design is centered around a single instrument modelled after COBE's Differential Microwave Radiometer (DMR). This minimizes risk and takes advantage of a proven design. Its design is driven by the overriding importance of the requirement to minimize systematic errors. The probe itself will be placed on an orbit around Earth-Sun libration point L2. This is a disturbance-free orbit that will permit several observations of the full sky under thermally stable conditions.

The MAP team consists of a close partnership between Goddard and Princeton University. This integrated team will produce the main flight hardware and software. Both institutions have proven experience in these tasks, with Goddard launching more successful scientific missions than any other institution and Princeton producing very successful instruments flown on the Space Shuttle. Other collaborating institutions are the University of Chicago, UCLA, and Hughes STX.

The project will be carried out using concurrent engineering with small Product Development Teams (PDT) in charge of designing, manufacturing, integrating, and testing the instrument. This management style is intended to reduce costs while producing high quality, robust designs that deliver an optimized product within the proposed schedule.

The PI, Dr. Charles L. Bennet from Goddard, is the ultimate authority and is fully responsible for the success of the mission. He has direct control over all scientific decisions with advice from his Instrument Scientist and a Science Working Group. He is also directly responsible for descoping the mission, if needed to contain the budget or meet necessary deadlines.

The PI delegates day-to-day decisions on project costs and schedule to its Project Manager, Mr. Rich Day. Both the PI and the PM supervise the activities of the PDTs who have independent decision making authority over their respective areas subject to approval from the PM and the PI. Figure 4 displays MAP's management structure.

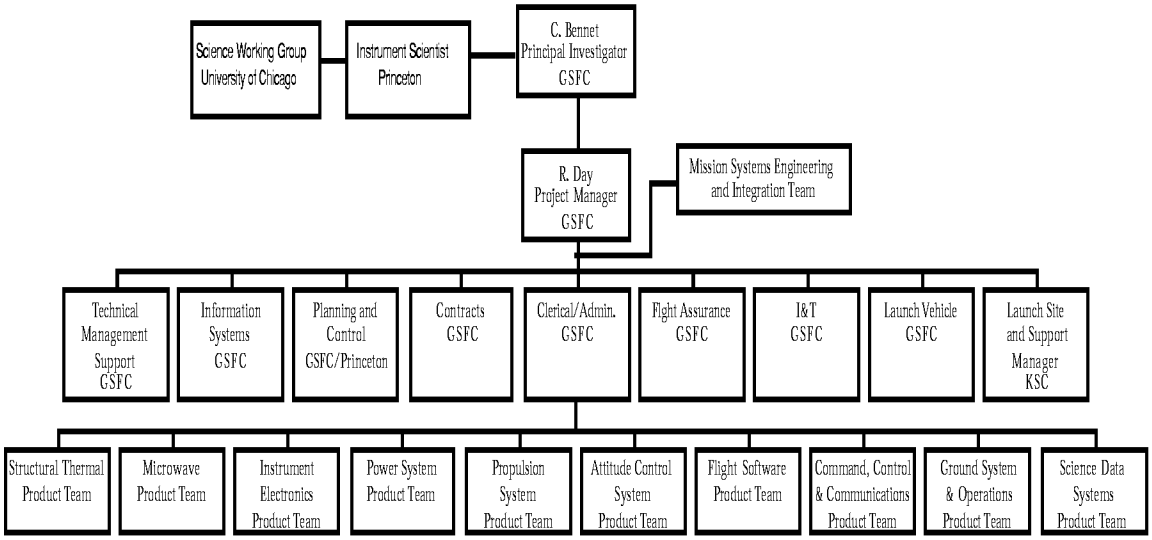

Figure 4. MAP management structure.

Overall management remains at Goddard with Princeton supporting a business manager to negotiate and control procurements with contractors and subcontractors. Flight hardware will be developed and delivered by Princeton under full contract to Goddard. On the other hand, Goddard commits to provide labor and facilities, as well as space flight expertise, and assistance with handling and qualification of flight subsystems. The remaining partners will provide data analysis and mission science oversight and operations. The PM will report to the MIDEX Project Office once a month on the progress of the project.

MAP management will capitalize on a simplified project structure to reduce costs and deliver on schedule:

- There are only two highly qualified institutions involved in the development of the flight hardware.

- Goddard and Princeton have been working together on projects for several years. They are physically close (3-hour car trip) and have the required facilities and technical expertise.

- The instrument itself operates in a single survey-scanning mode with little ground intervention.

- Data analysis uses modified software inherited from the COBE mission. On-line electronic systems such as the Internet will be used to provide rapid internal communications.

MAP also uses Goddard's management expertise from projects such as SMEX, XTE, CIRS and ACE to develop active management techniques that provide accurate program control and risk management. Technical, schedule and cost data is made available to all team members via electronic interfaces. In order to reduce the amount of paperwork involved, MAP uses an on-line information and configuration management system to process and disseminate controlled documents.

MAP is considered the last of Goddard's in-house projects. The PI leads the investigation and is ultimately responsible for all decisions, however, the PI is an in-house scientist and, thus, overall responsibility for the project remains at Goddard. This is not the only difference with the IMAGE project. MAP's management structure is based on heavy participation from Goddard personnel. Goddard retains control and exercises its scientific and managerial expertise over all aspects of the mission. The PI uses the resources available from Goddard to its fullest extent. This is positive for the project as it provides the mission with a considerable pool of knowledge that has been used in many space missions over the years. It is also positive for NASA since it keeps this pool of knowledge under good use.

MAP could very well serve as an example of how the PI-Mode can be applied within the framework of NASA.

8. Concerns and Questions Over the PI-Mode

"The policies that led to the establishment of the Discovery program and to the reformulation of the Explorer program have profound implications for NASA management, for NASA centers, for industry, and for the science community." (Assessment of Recent Changes to the Explorer Program, 1996)

The PI-Mode is a new way of thinking. It implies important changes to NASA's way of "doing business." Yet, is it the right approach? What are the consequences of placing the Principal Investigator at the helm of a project? What does this entail to the rest of the parties involved in the design and development of space science missions? These are the questions must be asked in order to assess the effect of the PI-Mode.

Does the PI have the knowledge and experience needed to become a successful project manager? This question has no clear answer. As project managers, PIs will have to manage teams of engineers and scientists in a coordinated effort to develop managerial techniques that control costs and streamline schedules. This involves

skills that are only acquired after many years of project management experience. The question is whether there are scientists who have these skills. FUSE's PI is a good example of a highly qualified scientist/manager. He has been able to bring new breath to a project destined for cancelation through new managerial approaches that have redefined the way projects will be carried out in the future. However, it is not clear whether there are enough scientists with the same stature to handle projects of similar characteristics. It is very likely that there are not enough. NASA has an important pool of in-house scientists with relevant experience in flight projects, but this defeats the purpose of opening opportunities to the entire research community by relinquishing in-house control. Furthermore, experience is not the only prerequisite to leading a project of the MIDEX or Discovery class. The researcher will be required to have a strong consortium of institutions supporting his proposal in order to be selected. This raises the issue of lack of research opportunities for upcoming scientists who do not have the required level of experience and support, but who have viable research proposals. Selecting an investigator with a good scientific background but little managerial experience involves a great deal of risk on the part of NASA. The tight constraints of the Agency's new programs require a great deal of important decision making early in the initial stages of the project. These decisions are crucial in order to maintain all mission parameters within the prescribed limits. Will an upcoming PI be able to make the right decisions on subjects that do not involve science? It is possible, but only a process of trial and error will corroborate this. The pitfall is that error results in cancellation of the mission and cancellation implies loss of financial, material, and human resources that, today, have tremendous opportunity costs associated with them.

Is the PI-Mode the right approach to managing NASA's new programs? NASA believes so. In projects of the magnitude of COBE, Hubble, or XTE, the Agency's managers have always adopted severe measures to identify, control, and mitigate risk. This is understandable because of the magnitude of the financial resources invested in such projects. However, the amount of overview and reporting required to assure mission success carried significant penalties to the efficiency of day-to-day management, which resulted in longer development times and increased costs.

To break this cycle, NASA adopted a new mentality that significantly shifts the focus of mission management: mission costs are drastically reduced, development times are shortened, and the number of missions is increased. This is designed to spread the risk over more missions, which means that higher risks can be taken for each mission. These risks can be in the form of "single-string" designs or in using selective redundancy. This does not imply a careless approach. On the contrary, improved techniques will have to be used to develop products that address the issue of risk aversion, reduction, and control in the first stages of the design process. These new design techniques will be essential to further reduce project costs and increase the amount of resources that can be allocated to science. But, is the PI-

Mode the adequate management environment required to introduce these changes? There are many experienced voices that say yes. Traditionally, scientists in their research centers, following their own management techniques, have been developing instruments for astrophysics for a long time under moderate budgets. These instruments have pushed the state of the art in technology and science under environments of independence, and there is no doubt that the PI-Mode will also bring significant improvements to many aspects of mission management. FUSE, MIDEX, and the Discovery program have already paved the way in many aspects of procurement simplification and have proven that small, well-prepared management teams can deal with problems in an efficient manner without NASA's oversight. However, the PI-Mode is such a new management approach that no mission has completed its life cycle yet. IMAGE and MAP are the new missions under the Explorers MIDEX program, and it is yet to be seen whether they will introduce the necessary techniques needed to implement the Agency's goals.

How will mission designs be influenced by the PI-Mode? PIs have a natural tendency to place science at the forefront of the mission. Instruments will constitute the bulk of the spacecraft's mass and cost, and these will be designed and manufactured using the latest technologies. The rest of the subsystems will be purchased under "fast-paced" contracts (of the IDIQ type) as off-the-shelf, prequalified modules. The first three phases of the project (Phase A, Preliminary Analysis; Phase B, Definition; Phase C, Design) will be significantly compressed. Phase A, and most of B will have to be performed before flight opportunities are even awarded. This is necessary to achieve full mission development schedules of less than 4 years. A top-level systems engineering approach will be implemented to coordinate development team activities and assure accurate subsystem interfaces early on in the design process.

What is NASA's role under the PI-Mode? By serving as a supplier rather than a customer, the Agency wants to provide the scientist with the necessary tools and expertise to carry out the research as he best sees fit. Over the years, NASA's research centers have accumulated a wealth of human and material resources that places them at the forefront of the world's space research community. Goddard itself has fostered programs that have pushed the boundaries of our knowledge of the universe and our solar system farther than any other organization. This is a valuable asset that PIs should take advantage of by bringing NASA on as a partner.

To implement this policy of partnership with the scientific community, NASA will have to forego a significant amount of control over mission management. It is obvious that overview is needed to protect the overall integrity of the project and to preserve the interests of the Agency and the U.S. taxpayer. However, the PI-Mode implies that full responsibility lies with the investigator. Therefore, it is necessary to clearly set the limits that define NASA's involvement in project development: where, when, and how much. NASA, as an overall

organization, is intrinsically set up to undertake large-scale projects such as Apollo, the Space Shuttle, Hubble, and the International Space Station that need direct and constant supervision. However, the PI-Mode requires a "microenvironment" of independence. This environment can be fostered only by smaller organizations within NASA designed to carry out these small, independent initiatives. Programs such as Discovery, Explorers, or Pathfinder are examples. What is needed from these organizations? Fundamentally, vision. Vision to have the correct frame of mind to facilitate the development of PI-led missions. Vision, to be able to select the missions that offer the most adequate management structure to achieve the best possible science. And vision, on the part of its leaders, to channel NASA's resources to the benefit of its customers.

Nevertheless, there is true concern with regard to the loss of scientific expertise on the part of NASA's research centers. There is a general perception that NASA scientists will lose ground to outside researchers and, therefor, will not be able to present competitive proposals to future research opportunities. Many in-house scientists and engineers fear that by giving away responsibility to external Pis, they will choose to work with other external organizations. Some even go as far as to say that outside investigators will be reticent to work with NASA managers and scientists for fear of losing control to them. This is a possibility, and NASA scientists should expect to lose research opportunities to out-of-house institutions over the next few years. MAP is an example of an "in-house PI-Mode," but as this technique gains momentum, fewer missions will be assigned to in-house groups. What can NASA centers do to avoid a possible degradation of its scientific expertise? Continue with projects led under the traditional management style? This is not the solution. NASA's research centers will have to reorganize themselves to become as competitive as any other organization. In fact, Goddard is currently undergoing such a restructuring process to enable its scientists and engineers to develop technologies and expertise that will result in competitive mission proposals. In essence, Goddard is trying to compete with the rest.

Other opinions voiced by in-house managers focus on the role of NASA personnel working for external PIs. Some are concerned that these individuals will not play a significant role in the project unless they are selected for top managerial positions. Assignments to PI-led missions could have no promotional potential for NASA engineers and scientists other than doing the same job again on a larger scale PI-Mode project. Would junior or intermediate-level engineers be willing to accept this risk? Mr. George Daelemans, retired Systems Manager for the Explorers Project Office stated in a memorandum on PI projects that "acceptance by GSFC of responsibility for Headquarters' initiated/mandated PI-Mode projects is probably not a good utilization of GSFC's manpower, either technical or managerial. These programs will at best be no-winners for the centers and its personnel, and can easily be losers if they fail in any respect, managerially, financially or technically." This is a biased opinion, but it is one shared by many Goddard managers. They have

commented that one of Goddard's strengths is based on sharing knowledge and experiences from one project to another. Recurring problems are solved by contacting the person who worked on a similar project under similar circumstances. This accessibility to knowledge is something that would not exist under the PI-Mode.

What will the PI have to do in order to successfully implement his research? The PI will need to forge strong partnerships with industry and other institutions in order to achieve the necessary integrity and credibility required to satisfy NASA's selection process. Ultimately, the strongest competitors are selected, and close examination of the IMAGE and MAP proposals show that the PI is backed by strong institutions that offer the necessary expertise and resources to direct the project to a successful completion. Some believe that researchers work well with researchers. Under the PI-Mode, researchers must also work well with industry and government. The PI will have to form integrated partnerships with all the players in the space business. Very few universities or Federally Funded Research and Development Centers (FFRDC's) can develop a project on their own. They do have an important knowledge base but cooperation is needed to accomplish missions under very strict budgetary and schedule constraints. The PI will have to establish a support network of organizations that promotes close interaction between partners, and efficient interdisciplinary communications.

A good balance is required to develop a project: NASA has extensive human and material resources, and excellent MO&DA facilities. It also provides the allocated funds. Industry has the necessary technical expertise and management know-how. Some nonprofit institutions offer adequate work environments for scientists. The research community provides the necessary scientific perspective as well as new instruments. Thus, the PI must create the most adequate team to fulfill the set objectives. How is this team created? The PI must have the necessary stature and standing in the scientific community to attract his or her partners, both national and international.

From a technical point of view, NASA's new policy for space science projects imposes a significant challenge to the PI or any Project Manager for that matter: low, cost-capped budgets and short development times require a very efficient team of designers and implementers. In fact, it is the short mission definition phase which is presenting the most amount of difficulties to development teams. Therefore, a project-wide systems engineering approach should be proactively pursued to produce efficient system architectures and interfaces that ensure a successful balance between cost, schedule, and risk early in the project.

Risk management is another area that deserves special consideration. The MIDEX AO allows for single-string systems (although some redundancy is recommended in order to avoid an excessive number of single-point failures). An adequate risk management plan provides early risk identification, tracking, and

mitigation. Ensuring long life and reliability in a single-string system requires robust designs and a well-defined testing program. Adding selective redundancy to subsystems where satisfactory robustness cannot be achieved or demonstrated is an interesting option to be pursued, and the use of heritage components and techniques can result in significant cost and schedule savings. Although risk is generally associated with the use of unproven technologies, it also encompasses areas of schedule, cost control, and instrument performance. An adequate descoping plan should be studied and built into the design to allow for possible budget and schedule overruns. Descoping should be done in a way that reduces costs while sacrificing the least amount of science. However, the issue of descoping posses significant challenges to the PI-Mode. It is not clear whether the PI will be able to descope the scientific objectives of the mission in a manner that will reduce costs while sacrificing the least amount of science. Taking the decision to reduce the capacities of an instrument, or eliminating it from the mission altogether, is a mature step toward understanding the nature of the new way of doing business.

What is the overall response of the scientific community to the PI-Mode? The scientific community welcomes the PI-Mode as a positive step in the right direction. With the PI-Mode, responsibility for the project is in the hands of the people who are going to gain most from it, and, thus, support from the science community will be essential for PI-Mode programs to succeed. Both the Explorers and Discovery programs are received with enthusiasm. However, some investigators believe that too much emphasis is placed on cost. Others believe that the program is not directed at universities because of the amount of resources required to run such projects. This would place institutions such as JPL or other agencies at an unfair advantage over universities with good ideas but few resources. Would this be a true concern? Adequate partnerships with meaningful sharing of responsibilities could prove this wrong.

The Discovery Lessons Learned report suggests that the science community must learn how to correctly cost modern spacecraft built in highly competitive environments. "Too much experience is based on situations where funding was not capped and there was no competition" (Workshop on Discovery Lessons-Learned, 1995). Science must also be assessed and given a dollar value so that it can be properly evaluated.

Industry believes that the PI-Mode introduces an innovative and progressive approach that will lead to favorable partnerships. Working directly for the government has its returns, but it also has its pitfalls. Government is sometimes not the most desirable customer (slow pay, hundreds of regulations). Dealing directly with the investigator can lead to the avoidance of intermediary functions and reporting demands. New procurement initiatives studied by the Explorers Program will lead to more efficient interactions between industry, government, and

the PI. In addition, multiple research opportunities are viewed by industry as a way of keeping scientists on the field, and a chance to foster interest and investment.

Problems arise when it comes to evaluating the science return per dollar. Cost evaluations may overshadow science at an early stage of the development phase. Cost estimates are easy to forecast. However, science vs. science is more difficult to evaluate numerically. The PI must therefore, establish a way to gauge the value of the science early on.

The government's perspective is that the PI-Mode will help bring the science to the forefront of the mission. Until recently, the scientific portion of a mission would account for 25% of the total cost. Today it represents 60% of the total budget. NASA centers must be supportive of this effort. There is an important pool of knowledge within NASA that must be maintained in order to preserve the Agency's integrity as a scientifically oriented organization. Thus, NASA needs to support the PI-Mode offering its services at a competitive price. But, how much support can be offered without the natural tendency to control?

9. Conclusions

The PI-Mode of project management offers no checks and balances. It is an uncomfortable situation that involves taking high level risks and leaps of faith. Many ask themselves, why is the PI-Mode the solution to NASA's "faster, cheaper, better approach to space science project management? Why would a scientist be a good project manager? Why should NASA modify its traditional way of carrying out a project? These are the questions that create a cloud of doubts around the PI-Mode. However, very few people question the fact that the PI-Mode is the wave of the future for NASA's small-to-medium-class missions. The Agency will continue to foster projects of the scale of Hubble, but these will be fewer and farther apart. The new science frontiers will be crossed by small probes with highly focused, state-of-the-art instruments interfaced with commercial, off-the-shelf spacecraft. These programs will create the "virtual presence" in the universe that NASA's Strategic Plan has envisioned, and it is a sure bet that the scientific community will have to bear the responsibility for driving these programs to a successful completion.

However, the day-to-day management of a space science project imposes an incredible amount of reality checks that experienced in-house managers have had to deal with for many years: overruns, delays, communication problems, redesigns, testing, personnel, accounting, contractors, subcontractors, descoping, schedule, budget, etc. The PI will have to deal with these issues on a daily basis no matter how much he or she delegates to experienced engineers and scientists. The PI will be responsible and accountable for all aspects of the mission, and the success or failure of the mission will ultimately be linked to his or her reputation. How many investigators are there capable of assuming this responsibility? Many have

submitted their proposals to the Discovery, MIDEX, and ESSP AOs, but only a few were chosen. We will never know how many of them were truly worthy of further support and how many would have led the project to failure or success.

The key to the success of the PI-Mode will depend on the PI's ability to assemble a truly capable team of people with mustidisciplinary backgrounds. This team will need to combine experience, knowledge, vision, and managerial expertise. One could say that these characteristics should be a reflection of the PI's own personal background. The effectiveness of the team will be crucial to creating the designs and processes that will allow the project to evolve, unobstructed, from start to finish. Difficulties and stumbling blocks will have to be dealt with rapidly, since schedule requirements are too constrained to afford significant delays. The PI will have to judge his or her own managerial skills, and determine the degree of delegation required to carry out the project with adequate supervision. In fact, PIs should take advantage of the number of accomplished managers within NASA's ranks, and in Industry. The personal stature of the PI will be of great significance to the mission, since it influences the way the PI interrelates with his or her team. The PI will need to make use of his or her background and intuition to keep the mission in focus, make the right tradeoffs, and determine what is important, what is nonnegotiable, and what is simply good enough. The PI-Mode will only fail if the team fails. If the PI is not able to obtain the proper level of commitment and support from all of his or her partners, then the mission will be headed for rough times that could become insurmountable.

As an engineer, this author believes that there are scientists capable of undertaking projects of the magnitude of IMAGE or FUSE. However, there are doubts whether there are enough of them capable of responding to the opportunities being fostered by NASA's new programs. As of today, Goddard alone will be expected to produce 3 to 4 missions per year, and space science opportunities are expected to increase significantly in the next 10 to 20 years. NASA is already preparing for this by creating the programs that will allow the PIs to work under their own terms. Nevertheless, this author believes that there might be a shortfall in the number of PIs required to keep up with the intended launch rate. The fast-paced nature of the new programs will force investigators to work full time on their projects, making critical decisions on a daily basis. Are there enough scientists that can do this? If not, what is NASA doing to encourage the growth of capable PIs?

What are NASA's future perspectives, in relation to the PI-Mode? Will it retain its stature as one of the world's leading research organizations? Or, will it lose its capacities to external institutions? The PI-Mode will not help NASA control a slow degradation of its in-house scientific capabilities unless the Agency becomes as competitive a player as the rest. Missions will go to other research institutions, and the knowledge and lessons learned from them will most likely remain there or

disappear. The Agency will have to find new vigor within itself to support its exceptional workforce.

The PI-Mode is a risk, much like any new undertaking in life. Will it succeed? Probably. What is the price of failure? Significant, monetarily, but crucial in terms of lost opportunities. How many projects will NASA accept to lose before considering the PI-Mode a failure? It is not known. Let us hope that the spacecraft already in space and the new missions under development here on Earth, prove to be a success not only for the scientists, but for everyone in the space science community.

10. References

1. *Application for the President's Quality Award Program*, pp. 17, NASA, 1997.

2. *Assessment of Recent Changes to the Explorer Program,* pp. 1-17, Space Studies Board, National Research Council, 1996.

3. Badawy, M.K.: *Developing Managerial Skills in Engineers and Scientists*, pp. 233-251, Van Nostrand Reinhold, New York, 1982.

4. Bennett, C.H. (PI): *MAP, A MIDEX Mission Proposal, Step Two,* Management Volume, pp. 1-19, NASA-Goddard Space Flight Center document, 1995.

5. Burch J.L. (PI): *Imager for Magnetopause-to-Aurora Global Exploration Proposal*, pp. 1-29, SouthWest Research Institute, 1995.

6. *Medium-class Explorer Missions Announcement of Opportunity,* AO-95-OSS-02, pp. 1-30, NASA, 1995

7. Moos, W.H.: "FUSE: A Different Approach to Lowering Cost," pp. 3-6, John Hopkins University.

8. *NASA Strategic Plan*, pp. 4-7 and 16-17, NASA internal document, 1996.

9. *NASA: Strategic Management Handbook*, pp. 1-30, NASA, 1996.

10. Ritz, G.J.: *Total Engineering Project Management,* pp. 173-211, McGraw-Hill Publishing Co., 1990

11. Ruskin, A.M. and W.E. Estes: *Project Management*, 2nd Ed., pp. 109-117, Marcel Dekker Inc., 1994.

12. *Workshop on Discovery Lessons Learned*, LPI Technical Report #95-03, pp.3-47, Lunar and Planetary Institute, 1995.

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The PI-Mode is NASA's new approach to project management. It responds to the Agency's new policy to develop scientific missions that deliver the highest quality science for a fixed cost. It also attempts to provide more research opportunities by reducing project development times and increasing the number of launches per year. In order to accomplish this, the Principal Investigator is placed at the helm of the project with full responsibility over all aspects of the mission, including instrument and spacecraft development, as well as mission operations and data analysis. This paper intends to study the PI-Mode to determine the strengths and weaknesses of such a new project management technique. It also presents an analysis of its possible impact on the scientific community and its relations with industry, NASA, and other institutions.

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