Enhancing Mission Success –
A Framework for the Future

A Report by the
NASA Chief Engineer
and the
NASA Integrated Action Team

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Executive Overview

Introduction

In March 2000, NASA released a series of reports that were the product of activities chartered by the Agency in response to failures in the Mars Program, Shuttle wiring problems, and a generic assessment of NASA's approach to executing "Faster, Better, Cheaper" projects. The subject reports are:

- Mars Climate Orbiter (MCO) Mishap Investigation chaired, by Mr. Arthur Stephenson, Director, Marshall Space Flight Center (MSFC),
- Mars Program Independent Assessment (MPIA), chaired by Mr. A. Thomas Young, Lockheed Martin (retired),
- NASA Faster, Better, Cheaper (FBC) Task, chaired by Mr. Anthony Spear, Jet Propulsion Laboratory Mars Pathfinder Project Manager (retired),
- Shuttle Independent Assessment (SIA), chaired by Dr. Henry McDonald, Director, Ames Research Center (ARC).

Recommendations contained in the reports not only addressed root and contributing causes of specific failures but also looked beyond those incidents to make broader recommendations to the Agency on ways it might improve its general approach to executing programs and projects.

The Office of Space Science (OSS) and the Office of Space Flight (OSF) are completing responses to program specific recommendations of the reports.

NASA Integrated Action Team (NIAT) Charter and Approach

In addition to the program-specific assessments, the NASA Administrator recognized a need to assess and respond to findings and recommendations that could be more broadly applied to the wide range of NASA programs and projects. The NASA Chief Engineer was given responsibility for defining an integrated plan to address those recommendations and to formulate proactive steps to address opportunities for improvement from an Agency perspective.

To accomplish this assessment, in March 2000, the Office of the Chief Engineer chartered a NASA-wide senior team, the NASA Integrated Action Team (NIAT), chaired by Carolyn Griner, Deputy Director of the MSFC.

The team was comprised of 42 senior-level staff from NASA Headquarters and all Centers with substantial awareness of Agency program and project management policy as well as insight to the way in which such programs and projects are being implemented across the Agency. The collective expertise of this team provided the ability to understand the recommendations of the reports and to evolve appropriate actions needed to respond to them.

The NIAT team was chartered to:

- Assess the selected recommendations from the reports,
- Define a specific set of actions focusing on which improvements were of value, with enough detail on the approach to guide the resultant implementation toward a desired outcome,
- Identify organizations responsible and accountable for implementation of each action,
- Identify areas requiring further study or management review, and
- Integrate the actions into a logical and meaningful format.

The NIAT evaluated 165 recommendations from the four reports.

Given the high degree of correlation of the recommendations in the various reports, the NIAT divided the recommendations into four key focus areas: People, Process, Process Execution, and Advanced Tools and Technology. Actions were defined for each area and then integrated into five implementation themes:

- Developing and Supporting Exceptional People and Teams
- Delivering Advanced Technology
- Understanding and Controlling Risk
- Ensuring Formulation Rigor and Implementation Discipline
- Improving Communication.

These themes are the tactical and strategic elements of response to the reports and are directly focused on critical implementation issues.

Approach to Readiness of Recent Missions

Before discussing the NIAT results, it is appropriate to describe how NASA has approached affirming readiness of missions launched subsequent to the Mars ’98 failures. Outside the scope of the NIAT activity, the Agency has expended significant effort on a case-by-case basis to ensure, through independent comprehensive assessment, that residual risks associated with such missions were fully understood prior to launch. Center Directors and the respective Enterprises have redoubled efforts to ensure that sound practices were applied, that risks were fully understood and to ensure that constraints associated with cost, schedule, and scope of the effort had not combined in a way that may have compromised the probability of mission success.

The process for ensuring such has been rigorous, well documented, and effectively executed. For missions launched on Expendable Launch Vehicles (ELV) following the Mars mission failures, the Directors of the managing Centers in consultation with the Enterprise Associate Administrators have, for each mission, chartered a group of respected experts, referred to as “Red Teams,” from outside of that Center. They are charged with evaluating the approaches used to identify, evaluate, and eliminate or control risks during the design, development, integration, and test activities, in order to understand the process used and, if necessary, to prescribe additional efforts needed to verify readiness for launch with high confidence of mission success. In some cases, the results of these "Red Team" evaluations have mandated additional analyses and tests to further mitigate risks. In all cases to date, these additional efforts have been fully completed prior to a successful launch. The Agency will continue this practice, as necessary, for future missions. In addition to this expert review, all ELV missions are subjected to an internal Certification of Flight Readiness (CoFR) review process to ensure the total vehicle readiness for flight.

For missions associated with human space flight endeavors, the Space Shuttle program has had, since its beginning, a rigorous CoFR process for each mission. In response to the findings of the Rodgers Commission following the *Challenger* accident, this process was significantly strengthened to provide assurance that risks are understood and accepted prior to each launch. Safety considerations have not and will not be compromised on human space missions. In addition to this rigorous approach for each mission, when problems of a general nature arise, independent assessments by experts from outside the program are conducted followed by implementation of comprehensive action plans in response to all recommendations. An example of this approach is the review chaired by Dr. Henry McDonald in response to problems associated with the Shuttle electrical wiring.

To meet the tremendous challenge of assembling the International Space Station (ISS), independent readiness reviews, similar to "Red Teams", are being held for each flight. The objective of the review is to ensure that assembly missions are safely executed and that the long-term operability requirements for the ISS are met for each flight. The review team assesses operability and capability issues by examining the interdependencies across upcoming flights and mitigation plans designed to address identified shortfalls. The expected outcome is the identification and understanding of residual risks that exists prior to launch and the expected effectiveness of risk mitigation activities. To strengthen this effort, the team also draws information from other reviews such as the CoFR, also used by the ISS, and the independent Aerospace Safety Advisory Panel (ASAP).

Prior to each launch, both the Space Shuttle and ISS programs conduct Flight Readiness Reviews (FRR) to determine the readiness of the vehicle, flight crew, mission operations, and payloads. Responsible organizations certify the completion of all tasks, open paper, and planned work required to prepare the flight and ground hardware and software, support facilities, and operations personnel to safely and successfully support a launch and mission. Readiness for launch is determined through the Senior Management review of necessary data to ensure satisfactory closeout of all FRR certification requirements, exceptions, and launch constraints in sufficient detail to provide management with the information needed to certify launch. The endorsement documentation required at the completion of the FRR becomes the CoFR for launch.

These proactive management, technical, and operational practices have been used to provide high confidence that risks have been appropriately mitigated for recently launched missions. They will continue, as appropriate, until the steps identified later in this report, are fully and effectively deployed. In the time since the failures of the Mars '98 missions until the issuance of this report, all NASA missions have fully met success objectives.

Results of NIAT Assessment

General Context

The result of the NIAT assessment presents a framework for strengthening the approach used by NASA to formulate and implement its programs and projects and to improve the supportive nature of the environment in which they are executed. It represents an adjustment for the future not a return to the past. Implementation of the NIAT actions provides the opportunity to ensure application of best practices across the entire spectrum of Agency programs and projects.

The stimulus for this assessment was principally provided by the failures of the multiple missions associated with the Mars ’98 program, and the various investigative reports that followed. The use of these incidents by NASA to trigger a reevaluation of its practices reflects a dedication to continual improvement through assessment of the lessons learned from the many recent successes achieved, as well as those from the disappointing failures encountered by the Mars ‘98 missions.

NASA has celebrated numerous successes over the past decade, many of which served as the vehicle for innovation in management and engineering practices, aggressive technology development, and acceptance of prudent risk taking when the potential for significant payoffs warranted it. Greater than 97 percent of the budgetary investment in flight missions has resulted in successful outcomes. This highlights the fact that NASA’s general approach to program and project management is fundamentally sound. However, the problems identified by the reports remind us that there is room for improvement and that, although the potential for failure will always be present, we must remain ever vigilant to minimize failures that are preventable.

As we move forward, acceptance of prudent mission risk that does not compromise safety considerations must remain the hallmark of our approach. This approach can enhance performance that achieves challenging mission objectives while vigorously pursuing cost and schedule improvements. Determination of acceptable risk must result from an objective assessment on a case-by-case basis by the team in concert with their customers, and with clear and consistent communication to and acceptance by management and stakeholders. The degree of acceptable risk will vary greatly as a function of mission-specific considerations such as complexity, cost, national need, etc. The mission risk profile and the balance of scope and resources must be continuously evaluated; budgetary reserves and design margins must be sufficient to support the risk posture. Additional funding is not the only alternative for maintaining balance. Changes in scope, provided that sufficiently viable mission objectives remain, must be considered. Sometimes, other alternatives, perhaps even cancellation, will be the proper solution. Obviously, a human space flight endeavor contrasts greatly in many of these considerations with a small, single-instrument science mission. Nonetheless, the underlying approach of defining and agreeing to acceptable risk remains the same for each mission, and departure from good planning and sound practice cannot be viewed as acceptable risk.

The NIAT actions represent a systems solution to continually improve NASA's ability to effectively execute its programs and projects. This involves a comprehensive set of practices that focus on the objectives of well prepared people, sound decisionmaking, and effective communications. As we move toward the future we must recognize that the practices by which we achieve those objectives are likely to be dramatically affected by emerging paradigms that will be enabled by technology developments. Currently we are only at the threshold of understanding how considerations associated with the bio-, nano- and info- technology triangle may revolutionize our ability to design, develop, validate, operate, and maintain systems in ways that are safer and more reliable while being able to autonomously adapt to unanticipated events. We must be open to and even actively pursue capabilities offered by innovative applications of such technology in order to more effectively guide programs and projects toward successful outcomes.

Assessment of Faster, Better, Cheaper

As first introduced in NASA in 1992, FBC reflected a management approach that intended to stimulate innovative development and application of technology, to streamline policies and practices, and to energize and challenge a workforce to continue to safely and successfully undertake bold new missions in an era of diminishing resources. It emphasized the following:

- Distribution of risk by moving from single high-cost, long-development time missions to multiple low-cost, shorter development time missions, when compatible with objectives,
- Accountability and responsibility for success that is clearly placed with the implementing teams at NASA's Centers, as well as within industry and academia,
- Efficiency in process and methodology, and exploitation of new yet mature technology to enable and enhance new and challenging science and technology programs and projects consistent with short development cycles.

The above principles were overarching, and were intended to stimulate NASA to strive to be "Faster, Better, Cheaper". In some instances, the principles were applied well and resulted in mission success. Programs such as Explorers, Discovery, Earth Science System Pathfinder, and New Millennium, were reinvented to capitalize on smaller, less costly, and technologically challenging approaches to achieve the scientific and technological objectives. In other instances, notably Mars '98, Lewis, and Clark, attempts to apply these principles resulted in mission failure.

FBC promoted prudent risk taking to push the technical and programmatic boundaries. Process constraints were minimally controlled to stimulate innovation. Resources were highly constrained and guidance on the boundaries of innovation and risk taking was lacking, thereby engendering a variety of approaches to adapting to this new paradigm.

At the same time, other changes occurred that exacerbated the potential difficulties associated with the adaptation.

The FBC emphasis itself resulted in a threefold increase in the number of programs and projects, particularly in small science payloads. This required more project managers and systems engineers. During this same period, NASA reduced its civil service workforce by 24 percent from Fiscal Year (FY) 1993 through FY 1999, causing both a loss in corporate knowledge and a substantially increased workload on the remaining employees. Losses also occurred within the vitally important aerospace industry workforce. Technical complexity, primarily in software utilization was increasing as well. These changes in practice, skills, and knowledge of the workforce, coupled with the demand for innovation in aerospace science and technology, particularly the revolution in information technologies, presented a tremendous challenge to NASA.

Despite these challenges, NASA’s overall mission success rate in the 1990’s remained impressively high as previously stated. However, the success rate for missions clearly associated with exploring the boundaries stimulated by the FBC approach was approximately two out of three. This result and the desire to evaluate the approach being used and to understand best practices and lessons learned had already engendered the effort by Anthony Spear. When the Mars ’98 failures occurred, other failure investigations and more formalized assessment of Agency practices resulted.

The reports reinforce the validity of properly applied principles of the FBC philosophy. They, of course, criticize the way in which those principles were applied to the Mars ’98 projects and point out that the dramatically disappointing results provide a case study that must be fully evaluated for lessons learned regarding current practices and approaches in order to modify them where necessary.

The Mars ’98 missions were over-constrained by the simultaneous existence of fixed resources, schedule, and science requirements that were not rebalanced. This forced the acceptance of significant risk that manifested itself as a lack of rigorous attention to sound process and practices. The combination of these factors was a significant contributor to the mission failures.

It is recognized that Agency guidance associated with the application of FBC principles to actual situations was not sufficiently articulated. As a result, the specific actions delineated in this report focus on how NASA must approach execution of all programs and projects because the underlying principles of FBC, when properly applied, have applicability to all that the Agency does. The governing process by which the Agency guides execution of its programs and projects does not currently differentiate projects that are FBC and those that are not. Instead, it relies upon a careful assessment on a case by case basis to establish the risk posture associated with a particular mission or endeavor. NASA’s work is and will continue to be inherently high risk. Therefore, the goal is to strive for the reduction of residual risk to that inherent in the challenge of the science or technology mission without compromising safety considerations. In this light, we do not see a need for differentiation of FBC projects. Rather, we must ensure that there is adequate guidance for decisionmaking and risk management for all projects.

Note that there is a high degree of correlation between the underlying principles of FBC and the independently developed five themes. Individual competency, team functionality, utilization of technology, prudent risk taking, rigor of practice, and management awareness and consent are all key considerations in getting the job done and are all elements of both FBC and the five themes. Through the actions of this report, the Agency will improve its approach to applying the principles of FBC with safety and prudent acceptance of mission risk as key criteria.

Key Themes

The NIAT themes reflect a framework to safely and successfully execute our missions. To that end, the actions delineated in this report represent a “required state” for formulation and implementation of NASA programs and projects. Key aspects of each theme are discussed below.

Theme I—Developing and Supporting Exceptional People and Teams

NASA has a vision of being a learning organization implemented by continual development of individuals and teams through experience and training in a supportive environment. The development and proactive support of our people is essential to the sustainability of our excellent capability. At the core of this is challenging work that provides opportunity to develop relevant skills, adequate training, and a safe and healthy work environment. The success of NASA depends on having a knowledgeable and skilled workforce, supported by clearly understood processes and methodologies, and armed with tools that leverage emerging technology to simplify and improve design, development, and verification related engineering approaches. Most importantly, however, the workload on individuals must be managed to enable their success.

The actions associated with this theme recognize that meaningful and relevant hands-on work is the primary way to develop skills and that a well-structured training program is essential support to those on-the-job-development experiences. They also recognize the importance of a revitalized engineering capability with emphasis on systems engineering, and finally, they recognize the importance of laying the groundwork to facilitate balance of the capabilities of the workforce with the demands of the workload.

Theme II—Delivering Advanced Technology

The imperative for new technology that both meets the needs of current missions and enables new, yet unforeseen, missions is required to accomplish NASA’s ambitious Strategic Plan and long term vision. This vision requires a successful and responsive technology pipeline, and aggressive pursuit of emerging paradigms in science and technology to solve the engineering challenges embodied in the vision. Delivering advanced technology has three codependent elements. First, a balanced technology investment strategy to maintain a pipeline of demonstrated technologies that meets the needs of near- to mid-term missions, as well as the revolutionary capabilities needed to enable new classes of missions for the 21st century. Second, that strategy must be developed and implemented through a well-defined planning process that identifies new technologies and emerging paradigms, defines opportunities, and ensures the efficient transition of new technologies into missions. Last, the technology life cycle, from basic research through application, must be done in a logical and thorough manner so that it meets the performance requirements and is easily infused into the programs and projects. Dramatically shorter mission cycles make it imperative that NASA finds ways to accelerate the introduction of new technologies into missions. Processes for managing the full life cycle of technology development, maturation, and infusion must enable new levels of performance and capability. Overlaying all these elements is the issue of stable and adequate funding that enables a healthy technology pipeline, and the pursuit of “out of the box” engineering approaches.

Theme III—Understanding and Controlling Risk

NASA is an organization charged with constantly pushing the envelope in science and technology. By its very nature, this work is unique to every mission and has inherent risks. The approach must not be risk averse. Prudent risk associated with the application of advanced technology to enhance performance that enables achievement of challenging science must be recognized and encouraged. NASA has always recognized risk management as a key factor in project management. However, the right risks must be identified, assessed, tracked, and continuously managed by the project team, and must be communicated and agreed to by management, customers, and stakeholders. Existing tools must be fully used to support this effort. In the future better tools, methodologies, and techniques, many of which utilize emerging paradigms enabled by intelligent systems that draw on soft adaptive computing will permit more comprehensive and objective containment and management of risk. The objective is to better ensure balance between the scope of the effort and the resources allocated for the job. Resource reserves and design margins must be adequate to support the risk posture. While balance must be maintained, this does not imply that adding money is the only way to maintain appropriate balance. A clear definition of “Acceptable Risk” and project “Success Criteria” is essential to effective life cycle risk management.

Primary responsibility for effective management of risk rests squarely with the program and project manager. All members of the team must fully understand their role in identifying and controlling risk. With the increased emphasis on analysis of risk, NASA’s Safety and Mission Assurance (SMA) community takes on an increasingly important role in supporting the program and project managers. SMA provides guidance during the formulation phase for the identification of risks and development of the risk management plan. During implementation, SMA provides independent assessment to ensure adequate attention to continued risk management. The SMA function at NASA must be enhanced through better preparation of people to support value added participation in appropriate activities of projects.

Theme IV—Ensuring Formulation Rigor and Implementation Discipline

NASA has developed new policies, processes, and practices for program/project management in keeping with the principles of FBC. NASA must ensure that these are understood at all levels of the organization and that they are applied with discipline throughout the life cycle of programs and projects.

To promote effective execution by the project team, the actions provide more detailed guidance in the use of the project management process. A comprehensive well-integrated review program, a risk-based supplier surveillance strategy, and a comprehensive verification and validation program are essential. The actions also provide for more direct engagement of the experience and skills of institutional management and independent experts who can help surface problems and determine solutions as early as possible.

To enable excellence in project management, excellence in engineering practice is a prerequisite. Improvement of software development processes and standards are a major new Agencywide thrust that will ensure that NASA operates at a level commensurate with the demand of increasingly complex software and its interaction with hardware.

The actions are intentionally not overly prescriptive, however. The ability to innovate and tailor approaches to unique needs must remain an essential part of the team's ability to meet its responsibilities and be accountable for its results. Successful performance of the project team remains the critical aspect of achieving mission success. The assurance of adequate rigor must be retained, and changes of practice must be consciously considered, have a reasonable confidence of success, and have management consent. The result of this cultural transformation will be a workforce with a common lexicon, practices that are second nature, and an environment in which creativity and innovation can flourish to foster proactive management of NASA's programs and projects.

Theme V—Improving Communication

A recurring theme throughout the recommendations was the need to improve communication at all levels. Failures in communication are an endemic problem that constantly threatens organizations, and particularly large complex organizations like NASA. NIAT actions focus on two aspects of communication: a renewed emphasis on the improvement of organizational communication, and the capture and management of knowledge through information technology to make critical information readily available.

Efforts to improve communications and the tools that support it must have priority in the implementation of the actions. Without this emphasis, the understanding of the improvements will be lost and an opportunity will go unanswered. An organization and management team that communicates in an open environment and rewards the achievements resulting from that communication will set the path of success for others to follow.

<u>Overview of Actions</u>

The specific actions associated with each theme are given in Table 1.

Some actions are characterized as "Major New Improvements". These represent new initiatives requiring additional resources and planning. These are long-term and developmental in nature; such as, tools and approaches beyond current practice. As they mature and become fully deployed, the results of these initiatives will penetrate all levels of the organization, and thereby influence the manner in which programs and projects are executed. No immediate action is required by current programs and projects, except that portion of NIAT-9 associated with the need to evaluate and, when appropriate, conduct Independent Verification and Validation (IV&V) of critical mission software. Action related to such IV&V considerations has been underway well in advance of issuance of this report.

"Major Improvements Previously in Work" represent initiatives that were started prior to NIAT or shortly thereafter, based on early NIAT results. Their development does not require significant new resources beyond that which had already been planned. In the case of those initiatives started prior to NIAT, the NIAT action either validated the initial scope or provided refocus to ensure that identified shortcomings were being addressed. These initiatives are considered major because they address critically important improvements to the Agency approach to executing its programs and projects. The Health and Safety action (NIAT-1) and those associated with Delivering Advanced Technology (NIAT-4, 5, & 6) are long term in nature and do not require any immediate action by current programs and projects. Those associated with Understanding and Controlling Risk (NIAT-7 & 8) require evaluation by current projects for compliance with applicable elements of the actions. If needed, adjustments to current practice on those programs may be required.

Actions in the "Clarification and Verification" category represent straightforward actions that expand upon or modify existing Agency policy, requirements, and guidance or develop new ones to address identified shortcomings. This report provides the basis for those changes. The formal policy and requirements aspects of these actions will be effected in the near term. In addition, current programs and projects must evaluate their current practices for compliance with applicable elements of these actions and, if needed, adjust current practice.

The result of these actions will be to move NASA to the "required state," characterized by the right policies and practices, the right people with the right skills, supported by the right technologies.

Implementation

The Agency is firmly resolved to implement the actions contained in this report in a way that has a positive and lasting effect. In the process, we will enhance both the application of sound practice by project teams as they execute their activities and the supportive nature of the infrastructure and management team that must be attentive to the needs of the project team in order to enable them to be successful. Discussions at meetings of the Agency Senior

Table 1. Themes and Their Actions.

Actions		Major New Improve-ments	Major Improve-ments Previously in Work	Clarification and Verification
Developing and Supporting Exceptional People and Teams				
NIAT-1	Health and Safety		X	
NIAT-2	Development of the Workforce	X		
NIAT-3	Revitalizing Engineering Capability	X		
Delivering Advanced Technology				
NIAT-4	Balanced Technology Investment Strategy		X	
NIAT-5	Integrated Technology Planning Process		X	
NIAT-6	Technology Development and Infusion		X	
Understanding and Controlling Risk				
NIAT-7	Risk Identification, Assessment, and Management		X	
NIAT-8	Safety and Mission Assurance		X	
Ensuring Formulation Rigor and Implementation Discipline				
NIAT-9	Software Development and Assurance	X		
NIAT-10	Integrated Review Process			X
NIAT-11	Ensuring Adequate Resources			X
NIAT-12	Faster, Better, Cheaper			X
NIAT-13	Surveillance			X
NIAT-14	Verification and Validation			X
NIAT-15	Management Responsibility and Accountability			X
Improving Communication				
NIAT-16	Organizational Communication	X		
NIAT-17	Knowledge Management		X	

Management Council have emphasized the need for Senior Managers to commit to these objectives.

To that end, the Agency will consciously ensure that appropriate attention is being given to implementing and measuring the success of these actions through the following approach.

Overall responsibility for ensuring effective implementation of these actions throughout the Agency rests with the Associate Deputy Administrator (ADA). As the Agency's Chief Operating Officer, the ADA chairs the activities of both the Program Management Council and the Capitol Investment Council (CIC) that integrates all Agency budgetary requirements and develops recommendations for the Administrator. In addition, he oversees the activity of the Senior Management Council. He is, therefore, the appropriate person to see that implementation of these actions is appropriately integrated into the budget plan, that they proceed in a timely fashion, and that deployment plans and success metrics are defined. The long-term and development nature of actions identified as "Major New Improvements" will be phased in a manner consistent with the availability of resources identified by the CIC.

For each theme, a Headquarters office has been designated as a theme champion. These champions are responsible for ensuring consistency across the action set within the theme. These champions are the change agents that will guide the cultural change for improved performance, not just the completion of individual actions.

For each specific action, a lead Headquarters organization has been clearly defined (see Table 2). In addition, supporting individuals or organizations, and a target completion date for the essential elements of the action have been identified. The lead organization has the responsibility to involve additional organizations in the disposition of the action as needed. In addition, the lead organization must also identify intermediate milestones, define the plan for deployment of the actions, identify the metrics by which the success of that deployment can be measured, and serve as the advocate to the CIC for necessary funding.

The Office of the Chief Engineer will serve as the Agency's focal point for tracking these actions and reporting progress quarterly to the Agency's Senior Management. Periodic reports of progress also will be made to the NASA Advisory Council.

The responsibility for evaluating compliance of ongoing programs and projects against the provisions of applicable actions rests with the respective Enterprise Associate Administrators and Center Directors who, as a minimum, must evaluate the state of risk associated with such decisions related to adequacy of current practice. That assessment should consider the level of risk acceptable for the particular program or project, where the program or project is in its life cycle and the ability and desirability of making changes. The resources required and the benefit to the Agency are integral parts of determining and selecting specific solutions.

Summation

NASA is justifiably proud of its scientific and technological accomplishments, particularly during the past decade with its significant budgetary and workforce reductions. Nonetheless, NASA is a learning organization and continually strives to understand the present state of the Agency in terms of its people, policies, procedures, and capabilities to learn what is needed to improve in the future. To plan a path for improvement, it is critical to understand and communicate the required state.

The people of NASA and its partners are the linchpins of our present and future success. Challenging work, executed in a safe and productive environment, with manageable stress, by people that are well prepared for and supported in their work, is essential.

Well-defined and executed formulation and implementation is required to deliver safe, quality products that are responsive to the needs of the customer. Processes must be focused around sound decisionmaking, driven by thorough understanding and control of risks. Open, effective communication is essential to allow problems to be found early, at a time when the right people can more easily become involved and when the resources needed to solve them are less. The challenge is to allow and encourage innovation within a framework of sound management and engineering fundamentals.

A critical element is the access to state-of-the-art tools and methodologies. The cutting edge of space research and technology can only be achieved through advancing the way we do work, in parallel with the work itself. NASA will be continually evolving as new capabilities and methodologies are enabled by emerging technology.

Technology to enable revolution is the life's blood of NASA. It must be cutting edge with a healthy sustained pipeline that addresses the needs of today and the future. Planning must be strategic, as well as tactical, and be dynamic in response to needs of the Agency and the Nation. A sustained investment that makes the planning a reality is imperative. Effective infusion of the new technologies into NASA, academia, and industry is the engine that enables global competitiveness and leadership.

Failure provides us the stimulus to scrutinize the practices by which we strive to achieve our scientific and technological objectives. As we evaluate those practices, we do it with awareness of and respect for our considerable successes, using them to build the framework to guide future endeavors. As we go forward, we must continue to pursue bold challenges while pressing the boundaries on what is needed to accomplish them, and accepting prudent risks as we go. Along the way, it must be remembered that the inherent uncertainty associated with our business will occasionally result in failure.

This is the plan to take NASA into the future. Through it, we will further strengthen our ability to be effective stewards of the public trust. As we travel this road, we will, over the upcoming months, have increased dialog with our partners in industry and academia. Through this exchange, we can strengthen the entire community with shared experiences and lessons learned as we work together to better understand our respective contributions to our mutual success.

NASA Integrated Action Team (NIAT)
Action Descriptions

Introduction

Detailed descriptions of the NIAT actions within the themes described in the Executive Overview are contained in the following sections. Each description contains an assessment of the current state of NASA in that particular area, a figure containing the action and references to the report recommendations that it addresses, and a detailed explanation of the rationale and content of the action. Actions contain “minimum elements” that must be considered during implementation. Table II summarizes all actions and identifies the NASA Headquarters office responsible for serving as the Theme Champions and the Action Lead.

The NIAT, whose membership is shown in Appendix A, assessed 165 report findings and developed 17 actions containing minimum elements recommended to the Agency. Report findings are correlated with the actions and contained in Appendix B.

A list of acronyms is provided in Appendix C.

Table 2. NIAT Actions.

Theme I—Developing and Supporting Exceptional People and Teams (AE)

- ➢ NIAT-1 Health and Safety (AM)
- ➢ NIAT-2 Development of the Workforce (F)
  - • NIAT 2.1 Enabling Team Competency
  - • NIAT 2.2 Improving Workforce Development Capabilities
- ➢ NIAT-3 Revitalizing Engineering Capability (AE)

Theme II—Delivering Advanced Technology (R-CT)

- ➢ NIAT-4 Balanced Technology Investment Strategy (R-CT)
- ➢ NIAT-5 Integrated Technology Planning Process (R-CT)
- ➢ NIAT-6 Technology Development and Infusion (R-CT)

Theme III—Understanding and Controlling Risk (Q)

- ➢ NIAT-7 Risk Identification, Assessment, and Management (AE)
- ➢ NIAT-8 Safety and Mission Assurance (Q)

Theme IV—Ensuring Formulation Rigor and Implementation Discipline (AE)

- ➢ NIAT-9 Software Development and Assurance (AE)
- ➢ NIAT-10 Integrated Review Process (AE)
- ➢ NIAT-11 Ensuring Adequate Resources (B)
- ➢ NIAT-12 Faster, Better, Cheaper (AE)
- ➢ NIAT-13 Surveillance (AE)
- ➢ NIAT-14 Verification and Validation (AE)
- ➢ NIAT-15 Management Responsibility and Accountability (AE)

Theme V—Improving Communication (AE)

- ➢ NIAT-16 Organizational Communication (AE)
- ➢ NIAT-17 Knowledge Management (AO)

( )- Denotes responsible NASA Headquarters Organization

Theme I—Developing and Supporting Exceptional People and Teams

Introduction

The importance that NASA places on the health, safety, and personal and professional development of its people has always been a hallmark of the Agency. The intimate relationship of our personnel to the success of NASA is a principle that is woven throughout the NASA Strategic Plan. In that plan, we clearly state that "our greatest strength is our workforce." The Agency must properly invest in the maintenance and professional growth of this valuable resource—its human capital—through a combination of management approaches.

To support the full utilization of the NASA workforce in achieving NASA's strategic outcomes, the workforce must have the tools, skills, knowledge, and experience for optimal performance. This job performance enhancement is enabled by on-the-job work experience, supported by developmental assignments and training.

Project teams are comprised of civil service and partner individuals that must have the technical and interpersonal skills to work together effectively. Three actions describe what is needed to address critical aspects of developing and supporting exceptional people and teams, including the provision of a safe and healthy work environment conducive to mission success.

Health and Safety discusses how increased demands on employees have caused significant stresses on physical and psychological health and increase the potential for safety-related errors. The greatest factor contributing to this stress is not having enough people with the proper skills, combined with an increase in workload.

Developing the Workforce discusses how successful projects are based upon a strong foundation of competent and capable people. NASA must invest in enabling team competency and improving personnel development capability to ensure an adequate foundation for future programs and projects. Ensuring that the team has the right people with the right skills at critical times during the life of the project is essential.

Revitalizing Engineering Capability discusses the need for a comprehensive plan to ensure a world-class engineering capability that includes the development and application of advanced engineering tools and capabilities. Much of this effort will focus on strengthening capabilities in systems engineering. State-of-the-art integrated tools will support geographically dispersed project teams in an advanced engineering and project management environment. At the same time, the emergence of future technologies will stimulate improved design methodologies and enable the development of adaptive systems that are less susceptible to human error and more tolerant of unanticipated operational perturbations.

NIAT-1: Health and Safety

Current State

Over the past few years, while the NASA workforce has been reduced, the workload on employees has not comparably declined. The basic nature of the work of NASA—high visibility and high risk—can create stress that is further compounded by short deadlines, increasing hours, and fatigue. Stressful situations at work exact an emotional, physical, and productivity toll on the performance of NASA's employees and organizations. They also create the potential for safety-related errors.

Safety and health have been reaffirmed as NASA's highest core values, and NASA has emphasized the importance of every employee's involvement in the Agency Safety Initiative established in FY 1999. Promoting and maintaining health is a prerequisite to ensuring safety and productivity in the unique NASA work environment on the ground, in the air, and in space. The principal contributor to stress and health issues is too heavy a workload.

In FY 1998, a study was completed using focus groups to identify the possible sources of stress. The NASA Occupational Health and Safety Executive Board (OHSEB) developed recommendations for stress reduction. An expanded Employee Assistance Program (EAP) was established, providing after hours support to personnel. On May 1, 2000, the Administrator announced the creation of a new office, under the leadership of a Chief Health and Medical Officer, to increase the Agency's emphasis on health and safety. A NASA Health Council will be established to address the Agency's needs and investments in health, including strengthening external interfaces with other health agencies.

The reports validated the concerns of NASA and emphasized quality of life issues. It was recognized that the action required is more than training the workforce on "coping" skills but must include a focused effort on the part of Agency Senior Management to make decisions that result in a balanced workload.

NIAT-1 Action Summary

NASA should provide a physically and psychologically safe and healthy work environment for all its employees.

Recommendation Reference: SIA-4, FBC 35, also noted in other reports

NIAT-1 Action: Provide a physically and psychologically safe and healthy work environment for all NASA employees [***AM,*** Q, SMC, F, Center Directors; 6/01].

Minimum Elements:

A. Ensure continued implementation of the overarching actions of the Agency Safety Initiative

B. Implement key recommendations from the NASA Officials-in-Charge, prioritized by the Occupational Health and Safety Executive Board, for reducing stress

C. Develop training modules and train supervisors and employees to be aware of stress levels and mitigation.

D. Assess balance of workload and workforce capability and define an approach for achieving and maintaining balance.

Figure 1. Safe and Healthy Work Environment.

The objective of this action is to continue implementation of a series of ongoing and planned initiatives related to the safety and health of the NASA workforce such as Agency Safety Initiative and the Occupational Health and Safety Executive Board. The Office of the Chief Health and Medical Officer (Code AM) will continue to monitor various health indicators affecting the NASA workforce and recommend necessary mitigation and prevention efforts. To train supervisors and employees, Web-based training modules will be developed to help identify and manage stress.

The action requires an assessment of the current workload/workforce balance situation and a determination of specific remedies to control excessive stress on the workforce.

NIAT-2: Development of the Workforce

Introduction

Successful programs and projects are based upon a strong foundation of competent and capable people and teams. NASA has provided outstanding professional development opportunities that have facilitated the establishment of knowledgeable project teams whose skills have been developed through hands-on experience supplemented by training. The simultaneous increase in projects accompanied by a reduction in experienced practitioners demands greater attention to the process of developing and supporting the workforce.

Agency and Center leadership must ensure that development of people is a primary responsibility of management and that it cannot be compromised by short-term deadlines and requirements. Accelerated preparation requires more focused development and training that is planned between employee and manager. Management must personally support less experienced project managers during project execution as a real time hands-on learning experience and mentoring opportunity. Project teams need advanced job aids and tools accessible through the Web, and real-time performance support.

NIAT-2 is separated into two parts, one addressing the development of the team and the second aimed at improving the capabilities that enable and support development of individuals in the workforce.

NIAT-2.1 Enabling Team Competency

Current State

NASA has a standard of professional development called the Project Management Development Process (PMDP) that includes people in disciplines such as engineering, business management, safety, and procurement. The process defines the competencies necessary for success primarily through on-the-job work experiences augmented with training. Approximately 90 percent of the competency is acquired experientially and the remainder acquired through a variety of supportive education and training mechanisms tailored to the needs of the individual. This process imparts the basic knowledge of Agency practices in a way that enhances the value of on the job development experiences. Individuals can use the PMDP to identify competency requirements, establish a benchmark of current capability, and provide guidance for individual development plans.

Teams are successful when they have the right people with the right skills at the right time. The single, most important aspect of project success is the performance of the project team. The determination of project team membership is the responsibility of the Center Director, with key assignments usually being made within the Center. The right staffing of project teams includes consideration of technical skill, interpersonal skills, and resources.

The technical roles and responsibilities of the program and project managers is currently contained in NASA Program and Project Management Processes and Requirements (NPG 7120.5). The aspect of managing human resources is not addressed. The reports expressed concern as to the consistency of competency across teams in light of the need to establish teams that are multiskilled, including systems engineering, operations, and scientific expertise. A more indepth discussion of the team management role of the project manager as well as the potential for certification of program and project managers and teams was also suggested.

NIAT-2.1 Action Summary

Ensure that teams are composed of competent personnel through expansion and disciplined use of the PMDP, selecting the right team skills for the project's life cycle, and better defining the roles and responsibilities of the project manager as leader of the team.

Recommendation Reference: MCO-1, 2, 6, 7, 8, 9, 10, 11, 12, 14, 23, 29, 30; FBC-6, 8, 9, 35; SIA-2, 4,MPIA-1, 2, 3, 6, 9, 14, 15, 26, 27

NIAT-2.1 Action: Ensure that teams are composed of competent personnel through expanded and disciplined use of PMDP, selecting the right team skills for the project lifecycle, and better definition of the roles and responsibilities of the Project Manager as leader of the team.. [***F,*** AE***,*** H, PMCWG, Center Directors; 6/01].

Minimum Elements:

A. Designate PMDP as the Agencywide standard for program/project management competencies.
   - A.1 Review and upgrade PMDP standards for program/project management and enhance engineering development standards.
   - A.2 Ensure a disciplined approach to using PMDP competencies consistently as considerations for the selection, training, and assessment of key project personnel
   - A.3 Analyze and assess the need for Center-specific PMDP competencies.
   - A.4 Consider incorporating acquisition evaluation criteria for consistency/equivalency with PMDP competencies.

B. Evaluate the advisability of a formal NASA certification process for Program/Project Managers. Benchmark with industry and Government organizations that certify Program/Project Managers to determine options for NASA, considering industry standards, benefits and detriments to certification.

C. Develop a project lifecycle staffing guide tool, including all team disciplines and project timeframes, to assist Project Managers in developing:
   - Staffing plans
   - Team self-assessment and intact team training
   - Conducting gap analyses
   - Assigning roles and responsibilities to team members.

D. When practicable, publicize project manager and key positions to attract the best-qualified personnel across the Agency and beyond.

Figure 2. Enabling Team Competency.

E. Review successful practices to evaluate teams, define motivators for high team performance, and present recommendations for Agencywide implementation.
F. Develop an improved Rewards & Recognition process which emphasizes successful, high-performing teams.
G. Expand NPG 7120.5 to clarify PM roles and responsibilities for selecting and phasing the project team, and add project team definition (Appendix B) and human resource management (Chapter 4).

Figure 2. Enabling Team Competency (continued).

NASA will designate the PMDP as the Agencywide standard for program and project management professional competency and use them as considerations for selection, training, and assessment of key project personnel. The current process will simultaneously be reviewed and upgraded. Centers will analyze and assess the benefits of establishing more Center-specific PMDP competencies that complement and offer more specificity than the Agency-level process.

The issue of program and project management certification has been raised by several of the reports. Certification represents a more stringent and rigid application of professional development standards by requiring formal compliance of standards before an individual could be selected for a position. NASA recognizes both potential benefits and problems with certification. To make an informed decision, NASA will conduct a benchmark study with industry and Government organizations to understand their experiences and assessment of certification for program and project managers. The benchmark study will address the industry standards, the pros and cons for certification, and its potential impact to NASA. Options for addressing the issue of certification will be analyzed and submitted to the NASA Chief Engineer for consideration. A decision on whether or not to establish certification will be made based on Senior Management Council review of the findings and recommendations.

There is a risk in skills and staffing that need to be recognized as a project goes through several transitions in its life cycle. Some of these are the move from formulation into implementation and another is the transition from development into operations. The inherent risk in these transitions must be mitigated through the right staffing of the project teams as a function of project maturity. Specific considerations are needed for systems engineering skills at the "mission" level, and below, to ensure the "systems" perspective is maintained at all levels throughout the life cycle. The early and continuous involvement of the scientists or their representatives is needed so they may participate in trade studies and decisionmaking. Throughout the life cycle, operations skills are a critical element of the project team as well. The participation of operations personnel in the formulation of a project is essential for making the right architecture and concept decisions that consider the operational requirements and long-term costs. Integrating operations skills early in formulation also helps reinforces the systems perspective to the mission. As the project matures, the operations team has the depth of knowledge to execute the mission and address mission contingencies.

To support team formation, NASA will develop a staffing guide as a tool to assist Center leaders and project managers in developing staffing plans, conducting gap analyses, and assigning roles and responsibilities to team members. The staffing guide will identify key functional areas and expertise needed for a successful team. It is expected that this guide will serve as a tool for less experienced project managers as well as a staffing validation tool for any Project Manager. An Internet-based team self-assessment tool and intact team development support also will be made available to support the development of a cohesive and superior project team.

NASA will modify the current project management guidelines and policies to better reflect the central role of building an effective team. Resources and tools that support team performance will be made more widely available. In addition, the roles and responsibilities of the project manager will be clarified. It should be noted that an effective partnership between the project manager and line management is directly related to the potential for success. Line management support is addressed in NIAT actions 15 and 16.

NIAT-2.2 Improving Workforce Development Capabilities

Current State

The emphasis on project management and engineering training and development has accelerated significantly over the past decade. The establishment of the NASA Academy of Program/Project Leadership (APPL) underscored the importance and value in 1997. During the same time period, NASA established the engineering curriculum to provide similar support to the engineering community. Integrated directly into the NASA strategic management process, support is offered for *total team* and *individualized professional development* through training, developmental assignments, university partnerships, and advanced technology tools. Supervisors need to participate actively in determining the need for employee training to address particular competencies and to ensure training attendance.

The current environment requires timely development and training to effectively support the execution of NASA's complex engineering and project management tasks. The reports recommended an expansion of APPL and a more effective integration with the engineering curriculum. Hands-on experience through challenging assignments, as well as training support at the Center level, is seen as essential.

The reports recommended expanding training and improving training tools and methodologies through use of information systems technologies. Inclusion of the entire project team in training and an expert review of the training curriculum and methodology is also necessary.

During the last few years, a sizable portion of corporate knowledge, in the form of experienced practitioners, have left NASA due to normal attrition and planned buyouts. With the simultaneous increase in the number of projects, a less experienced workforce is being called upon to manage projects. These project managers and their teams need the insight and wisdom from experienced practitioners.

The report findings indicated a lack of availability of experienced personnel to advise and help the project team either by line management or mentors. Some pilot mentoring systems are in place and are proving to be valuable. However, a process is needed to be able to deliver this expertise on demand.

NIAT-2.2 Action Summary

Improve the hands-on experience, training curriculum, and mentoring for project managers and engineers.

Recommendation Reference: MCO-2,3,8; FBC- 1, 2, 3, 4,5, 6,7,8,9,11,29,35; SIA-2,4; MPIA-1,2,3,6, 9,14,15,26,27

NIAT-2.2 Action: Improve the hands-on experience, training curriculum and mentoring for project managers and engineers. [***F,*** AE, Center Directors, Project Managers, PMCWG; 9/01].

Minimum Elements:

A. Ensure line management is providing adequate hands-on experience and other training to support skills development.
B. Establish improved strategies and resources for training and development and accelerate required capability in advance of need, as appropriate, to include:
   - Alliances with universities, industry and other Government agencies to expand project and engineering joint training.
   - Just-in-time project team support
   - Project management automated/Web-based tools and technologies
   - Training tools that support NPG 7120.5.
   - Realistic scenario-based virtual training simulations
C. Establish a customer-focused Board of Directors to review project and engineering curriculum to assess the adequacy of course content.
D. Require project managers to estimate and plan for required training and support resources for intact team training.
E. Broaden existing mentoring programs to provide access to experienced and successful experts.
   - Establish a professional project network (ProNet) of experienced and talented practitioners who are willing to mentor at their Centers.
   - Expanded NASA Masters in Project Management Forum
   - Develop legislative proposal to reduce limitations on compensation of individual retirees to facilitate access to lost expertise and provide critical knowledge base for mentoring.

Figure 3. Improve Workforce Development Capabilities

Since on the job-experience is the primary source of training and development, it is imperative that line managers support development for their employees. Managers must work with their employees to determine the job-related knowledge, skills, abilities, and experience required for the work of their particular organization and their individual development objectives. This includes the short-term and long-term work assignments and classroom training needs.

Through alliances with universities, industry, and other Government agencies, NASA will develop improved workforce development capabilities. These capabilities will enhance professional readiness and competency of its program/project management and engineering communities through multiple strategies. This strategic approach must set priorities for training and development based upon customer-driven requirements and then match the availability of comprehensive services to those requirements. The enhanced portfolio emphasizes the need for training that minimizes time away from the job.

Project teams will have more "just-in-time" performance support tailored to meet the particular needs of the project at their site. Automated and Web-based project management tools will be expanded to provide closer links between training and practice. Virtual learning tools and simulations will provide interactive realistic scenarios to "practice" project management techniques and decisionmaking.

A closer integration between the program/project management and engineering development activities will ensure that project personnel and engineering practitioners are applying the same knowledge, concurrently. A customer-focused Board of Directors, supported by NASA senior managers, will review all courses in the project and engineering curriculum to recommend improvements. Program and project managers must estimate the resources and training requirements to support intact team training, and must incorporate these estimates into their program and project plans.

NASA will expand on existing project and engineering mentoring programs and will form a professional network of experienced and talented practitioners who are willing and capable of mentoring at their Center. The current NASA Masters in Project Management Forum will be used to help establish a "Leaders as Teachers and Mentors" initiative to increase the use of established project and engineering leaders for both teaching and mentoring. NASA also will increase its use of retired experts to supplement mentoring. Such mentoring activity will draw on expert experience regarding the objectives of effective and efficient program and project execution while recognizing the need to embrace an evolution in sound practice as it becomes enabled by emerging techniques.

The Internet-centered "Academy Sharing Knowledge" Web site will be used as a support for facilitating best practices and project knowledge sharing. The current tool, Project Manager Coach (PM Coach), will be upgraded to provide self-help guidance, self-assessment processes, tools, and job aids directly to the workforce. Legislative relief is needed to engage knowledgeable retirees without requiring financial sacrifice on their part.

NIAT-3: Revitalizing Engineering Capability

Current State

NASA takes great pride in possessing a knowledgeable and skilled engineering workforce capable of world-class performance in the development, integration, and operation of complex space systems and aerospace technologies. The sustainability of such capability is absolutely essential to NASA and the Nation.

Sustaining this end-to-end capability depends on robust hiring practices and development of new engineers, challenging experiences that include hands-on work, training, tools, mentoring, and management support. Engineers represent approximately 49 percent of the NASA workforce. They are the talent pool for providing experienced leaders in the engineering of complex space and technology systems, and in program, project, and institutional management.

The engineering workforce has decreased significantly over the last 8 years, with very limited hiring of fresh-outs. As a result, the Agency has lost significant corporate knowledge and critical skills, while the number of approved projects increased significantly. In addition, the program level architecture tradeoffs, mission options, and technology planning and execution needed to support the strategic plans of the Enterprises increased as well, placing even greater demand for skilled engineers, and in particular, systems engineers. The increased number of projects amplified the challenges on the systems engineering pool by placing equal demands for project managers from the same talent pool. Like other Government agencies, NASA faces an aging population, with a large percentage of the most experienced engineers eligible for retirement in the very near future.

The demand for experienced engineers is expected to remain high, and the complexity of the systems needing that expertise is expected to increase as we continue to push the envelope of science and technology. The development, infusion, and application of advanced tools and methodologies are essential to achieve the efficiencies necessary to be effective in this environment.

A third ingredient in the assessment of NASA's engineering capability is consistency in process, and execution. Over time, each of the NASA Centers has developed internal processes for systems engineering that have made them largely successful in their mission. However, as we strive for greater integration, consistency, and sharing of expertise among NASA Centers, industry, and academia in collaborative environments, it appears that the Agency could benefit from appropriate Agencywide standards in the systems engineering process.

NASA is committed to the revitalization and sustainability of its engineering capability. With the support of the Administration and Congress, NASA has started to fill critical engineering and other skills essential to health and safety of the Shuttle and ISS programs. In February 2000, the NASA Administrator created the position of Deputy Chief Engineer for Systems Engineering. This position was established to develop the vision, objectives, and strategies for the development and maintenance of the Agency's world-class engineering capability in the Agency.

NIAT-3 Action Summary

The purpose of this action is to establish the framework for a comprehensive assessment and definition of strategies to revitalize the engineering capability of the Agency in the formulation, implementation, and operation of space systems. This includes people, tools, and facilities. The assessment is intended to address adequacy of processes, the rigor of their execution, training and development of the workforce including hands-on experience, advanced tools and methodologies, and the use of metrics for continuous improvement. Advances in tools and methods are intended to enable rapid access of knowledge to perform engineering analyses, assess risk, and support decisions, including the cost, schedule, performance, and safety of increasingly complex systems. These ingredients are key to sustained excellence in the engineering capability within NASA.

Recommendation Reference: MPIA-7,11; MCO-21,25,27,71; FBC-19,36,43

NIAT-3 Action: Develop and implement a comprehensive plan to ensure excellence in Agency engineering capability, including hands-on work experience, and the development and application of advanced engineering tools and methodologies in an advanced engineering and program/project management environment [***AE***, EMC, F, Center Directors, Q; 6/01]

Minimum Elements:

A. Determine additional requirements to sustain a world-class capability, and develop options to address gaps between present state and needs.

B. Enhance education and training for engineering capability including real-world hardware experience and partnering with academia to develop curriculum such as systems engineering, advanced engineering environment, risk assessment, and cause-and-effect analysis tools and methods.

C. Review policy regarding the appropriate level of work to be performed in-house.

D. Develop Agency-wide process standards, requirements and guidelines for the effective implementation of systems engineering in programs and projects.

E. Develop near-term engineering and program/project management environment requirements:
- Assess current Agency investments in legacy systems, tools, and infrastructure
- Determine interim deliverables provided by the Intelligent Synthesis Environment
- Determine "capability gaps" and any areas of duplication across Centers.

F. Prioritize and fund an appropriate set of well-defined, near-term engineering and program/project management capabilities, and tools that draw on capabilities enabled by emerging technologies, particularly intelligent systems

G. Develop an improved tactical plan for infusing/deploying technologies, tools, and processes into Center infrastructure to address:
  G.1 Assure integration, interoperability, and efficiency in an improved standards-based, open, secure architecture for common infrastructure.

Figure 4. Revitalizing Engineering Capability.

<u>Minimum Elements (Continued)</u>:

- G.2 Develop tools and databases to support rapid design and transition to implementation.
  Evaluate feasibility of the recommended common, multi-Agency Internet Store for high-quality, modular, advanced components supplied by multiple vendors.
- G.3 Planning and timing considerations for transitioning new capabilities into Center infrastructure in a way that optimizes legacy systems and advanced tool integration. Transition plan should address resource planning, security, operations, and maintenance.
- G.4 Cultural changes needed to transition to new user environment, including training.
- G.5 Improved approaches for managing configuration and information across Centers and programs.

H. Establish improved process to guide and evaluate integration and use of near-term and advanced capabilities and tools

- H.1 Establish Customer-Based Steering Group(s) to provide guidance and coordination on near-term elements
  - Engineering Management Council for engineering-related environment capabilities
  - SMO for program/project management-related environment capabilities
  - Center institutional operations representatives for infrastructure-related capabilities.
- H.2 Establish metrics to evaluate the use and effectiveness of evolving suite of advanced engineering and program/project management environment capabilities.

Figure 4. Revitalizing Engineering Capability (continued).

Theme II—Delivering Advanced Technology

Introduction

NASA defines "technology" as the practical application of knowledge to create the capability to do something entirely new or in an entirely new way. This can be contrasted to "scientific research" which encompasses the discovery of new knowledge from which new technology is derived, and "engineering" which uses technology derived from this knowledge to solve specific problems.

In meeting NASA's imperative of working at the cutting edge, we depend on the use of advanced technologies to enable our missions. Highly intelligent, miniature, adaptable, self healing systems are being enabled by leveraging on discoveries in fundamental sciences such as biology, molecular science, and others to solve present day engineering problems, thus creating new ways to address the challenges of the future.

In recent years, NASA has undertaken sweeping changes to strengthen and highlight the role of advanced technology. In the past, NASA based mission selections on the desirability of proposed scientific objectives with insufficient regard for technology readiness or alternative mission concepts (i.e., technologies enabled by mission opportunities). A new paradigm has emerged where technology investments for generic classes of very challenging missions are made in advance, and where specific missions are not approved for development until the enabling technologies have matured (i.e., mission opportunities enabled by technologies). Developing advanced technologies before mission selection reduces the schedule and cost uncertainty associated with incorporating them into the mission, as well as significantly reducing the final mission development times.

NASA has also implemented new organizational structures and approaches to ensure that technology investments are closely aligned with mission needs. In February 2000, the NASA Chief Technologist and supporting office were merged within one of NASA's four Strategic Enterprises, the Office of Aerospace Technology, to better focus the Agency's strategy for maintaining its long-term technology base. The NASA Chief Technologist retains responsibility for serving as the Administrator's principal advisor on Agencywide technology issues, while also becoming the Associate Administrator for Aerospace Technology. This merger centralized planning and execution of Agency-level technology within one organization while still allowing Enterprise-specific mission technology development by each of the four respective Enterprises. NASA has also created the Technology Leadership Council, representing each of the Enterprises, Centers, and other key senior officials, to set the Agency's technology strategy, address critical issues, and formulate and advance NASA's vision for technology.

Delivering the right technologies to meet today's mission needs while maintaining a healthy, robust pipeline of new technologies, and pursuing new and emerging paradigms in science and engineering to enable the missions of the future is a complex management challenge. While a number of initiatives are underway to address this challenge, NASA will improve how it plans and manages the delivery of advanced technologies in three areas:

Balanced Technology Investment Strategy—A balanced investment strategy is crucial to maintaining a pipeline of demonstrated technologies that meets the needs of near- to mid-term missions, as well as the revolutionary capabilities needed to enable new classes of missions for the 21st century. A healthy technology pipeline is one that results in a balanced portfolio of technologies in various stages of development: advanced concepts, technologies in development, technologies that are flight qualified or tested, and technologies that have been proven or demonstrated in missions. Long-term and sustained internal investments are also needed to provide the necessary expertise and capabilities necessary in technology areas that are strategically critical to NASA, and to stimulate and enable new engineering approaches to address the unique challenges of space exploration.

Integrated Technology Planning Process—Identifying new technologies to invest in, defining new mission opportunities, and ensuring the efficient transition of new technologies into missions is a complex and iterative process. Responsibility for technology planning is shared among a wide range of Agency, Enterprise, and program players, each representing unique requirements, opportunities, time horizons, and risk perspectives. Improvements are needed to ensure an integrated, coordinated technology planning process that is responsive to customer needs, maximizes synergy among the Enterprise technology goals, and minimizes duplication of efforts. In addition, rapid advances and potential applications of new and emerging information technology, biology, and molecular science offer promising capabilities for NASA's missions. To take advantage of those capabilities, NASA needs specific plans for integrating NASA's information technology programs not only for enabling advanced engineering environments, but to address engineering design issues. Likewise, adequate planning and investment are needed to introduce biology and molecular science into the engineering mainstream.

Technology Development and Infusion—The technology life cycle begins with innovative ideas vetted through activities such as technology workshops, advanced concept studies, and mission studies. The technology life cycle ends with successful acceptance and use to accomplish a NASA mission. Dramatically shorter mission cycles and the growing frequency of mission launches makes it imperative that NASA find ways to accelerate the introduction of new technologies into missions. This imperative also applies to large programs that must address needs for critical technology early in the program life as well as needs for next-generation technologies in later program phases. Current processes for managing the full life cycle of technology development, maturation, and infusion need to be improved to enable the new levels of performance and capability required by current and planned missions. Improvements are needed to identify, develop, and infuse promising new technologies more effectively, reinforce collaborative relationships between technologists and project managers, and establish new forums for communicating information about technology initiatives.

The following three actions will be taken to address each of these opportunities for improvement. The plans should, however, be viewed as a holistic set of related actions that are tightly coupled. Integration, collaboration, coordination, proactive customer involvement, and balance are consistent principles throughout the plans. Demonstrating these principles is integral to the Agency's ability to improve strategic planning and implementation of technology programs aimed at meeting the needs of tomorrow's missions.

NIAT-4: Balanced Technology Investment Strategy

Current State

NASA invests approximately $2 billion annually in technology and technology-related investments to support space and aeronautics program areas, including long-term strategic technology efforts that will have broad impact across the spectrum of NASA activities.

The budget formulation process and the investment decisions and trades that are part of that dynamic process are inherently iterative and complex. Within this environment, investment decisions must result in a technology investment profile that delivers the technologies needed to meet near- and long-term mission needs. In addition, adequate investments in infrastructure must be sustained over time to ensure critically needed technology expertise and capabilities are available when needed. Investment decisions must balance a number of competing demands and requirements, including the following long-term implications on NASA's technology capability:

- Investment decisions must balance near-term mission requirements for technology and need for evolutionary improvements with the need for longer-term strategic technology investments that may be more revolutionary in nature.
- Investment decisions must balance among alternative providers of technology concepts and solutions. In many cases, industry, academia, and other Government agencies share technology challenges similar to NASA. NASA's approach for investment decisions is "buy when feasible, build when necessary." Capabilities that are available within NASA, industry, academia, and other Government entities must be preserved and used, where appropriate, to meet national technology requirements.
- Investment decisions must consider the long-term implications on NASA's capability to meet technology requirements. NASA must provide sufficient internal investments to sustain the core technology competencies and necessary expertise to provide leadership in areas that are strategically critical to the future of the Agency.
- Investment decisions must factor in the current maturity of technologies, what investments are required to mature a technology, and its expected maturation life cycle. The objective is to ensure a consistent pipeline of technology with no unplanned gaps or constrictions (e.g., appropriate level and type of advanced concept studies, technologies in development, demonstrated/tested technologies, flight-proven technologies, etc.) to assure that the right technology is available when it is needed by missions.

- Investment decisions must consider the perspectives of a wide range of customers and interests. The technology user must be involved as investment decisions are made to ensure the technologies selected for development and maturation are aligned with mission needs.
- Investment strategies must include the pursuit of new paradigms in biology, molecular science, information technologies and others, to stimulate revolutionary approaches to address the engineering problems of today and the future.

How are decisions for technology investments made? NASA has established organizational entities and defined processes for planning and formulating budgets and making investment decisions (reference the *NASA Strategic Management Handbook*, NPG 1000.2, February 2000). Agency, Enterprise, and program strategic directions, requirements, priorities for decisionmaking, and resource constraints are established annually as part of the budget formulation process to guide investment decisions. Specific to the Agency's technology investments, the NASA Technology Leadership Council, chaired by the Chief Technologist, is responsible for formulating and advancing NASA's vision for technology, establishing technology priorities, and recommending an Agencywide investment strategy to the CIC. The CIC is responsible for integrating and balancing among Enterprise program investments, crosscutting technology investments, and institutional investments.

Both the Faster, Better, Cheaper and Mars Climate Orbiter reports point out the criticality of adequate and stable technology funding that enables the availability of more technologies to reduce risk or reduce mission constraints. Technology funding needs to:

- Balance research and advanced technology with focused technology, and provide "seed corn" to trigger revolutionary approaches,
- Place higher priority on funding and support University research and advanced development,
- Balance competition of technology development along with sustainable technology development at NASA Centers, and
- Address broad Agency needs and reduce risks (increased Technology Readiness Level [TRL]) prior to project initiation, including flight opportunities such as the New Millennium program.

NIAT-4 Action Summary

NASA should invigorate the Agency's technology investment to ensure a balanced portfolio of evolutionary and revolutionary technology.

Recommendation Reference: FBC-31, 32, 36, 37, 38, 39, 40, 41, 45, 46; MCO-64,67,70

NIAT-4 Action: Invigorate the Agency's current technology investment to ensure that a balanced portfolio of existing, new, and emerging technology is available [***R-CT***, EAA, Center Directors, B; 4/01(Development Complete)].

Minimum Elements:

A. Assess Enterprise and mission-specific requirements and investments, including near-, mid-, and long-term balance, as well as internal/external participation balance.
B. Assess Agencywide (cross-Enterprise) requirements and investments, including near-, mid-, and long-term balance, as well as internal/external participation balance.
C. Complete the ongoing Technology Assessment, including human, physical, and financial resource model considerations.
D. Develop and implement the new Agency technology investment strategy that delineates optimum near-, mid-, and long-term, and internal/external participation balance.
E. Create a science and engineering research network for the pursuit of non-traditional engineering solutions based on emerging paradigms in biology, molecular science, information technology and others.

Figure 5. Balanced Technology Strategy.

The objective of the action is to undertake a thorough and explicit review of the Agency's technology portfolio and formulate an invigorated strategy that balances investments from a variety of perspectives. Enterprises will review near-, mid-, and long-term mission needs and identify the investments required to deliver technologies that will reduce life cycle cost and time, and improve safety and mission return. The NASA Chief Technologist will also review near-, mid-, and long-term needs for cross-Enterprise technology (i.e., not Enterprise-specific) and identify the investments required to deliver the revolutionary technologies needed to achieve NASA's strategic goals. These reviews will also determine whether NASA has an optimal distribution of investments in technology expertise and capabilities in the private sector, universities, other Government agencies, and NASA. In addition, NASA will complete the assessment of Center capabilities that support critical technologies and identify the level of long-term sustained funding necessary to support these areas. Based on the results of each of these assessments, NASA will develop an optimum and balanced technology investment strategy to be advocated as part of the FY 2003 budget process.

NIAT-5: Integrated Technology Planning Process

Current State

NASA's technology planning process is multifaceted and involves a wide range of organizations that are focused on delivering the technology needed to meet NASA's aggressive strategic goals. First, each Enterprise works with its respective customer and user community to translate broad strategic goals into Enterprise missions and their associated technology challenges. Enterprises then work with Centers to define and develop specific technology programs to meet the needs and technical challenges of the planned missions. This integration of technology within the Enterprise ensures that technology programs are closely aligned with Enterprise mission goals, frequently referred to as "mission pull." In addition, Enterprises are responsible for program formulation and funding for technology activities. This ensures that technology considerations are closely coupled with mission decisions, technologies are relevant to Enterprise needs, and mechanisms are provided to transfer successful maturing technologies into operational systems.

To ensure that NASA's technology investments do not evolve only toward near-term goals and incremental improvements, the NASA Chief Technologist addresses common technology requirements across Enterprises and commercial interests and identifies technology areas that may revolutionize the way missions are conducted. These strategic types of technologies are referred to as "technology push" investments. Today, the "technology push" areas that are strategically important to achieving ambitious future NASA mission areas are advanced miniaturization, intelligent systems, compact sensors and instruments, self-sustaining human support, deep space systems, and intelligent synthesis environments. Once Enterprise-specific and cross-Enterprise plans are prepared, they are reviewed by the Chief Technologist and the Technology Leadership Council, who then develop recommendations for budget and technical priorities as part of the annual budget cycle. Decisions and final plans that result from this process are documented in the *NASA Technology Plan*.

NASA's recent changes to technology planning and management processes are a significant improvement over historical approaches, but more improvements are needed. A shared vision for technology with clear and complementary roles and responsibilities that are well defined and supported is crucial to an integrated technology plan. Closer collaboration and more coordinated planning are needed to ensure that cross-Enterprise and Enterprise technology requirements, priorities, and investments will deliver the technologies needed to meet mission needs. Processes to transition promising technology from basic research to deployment in missions need to be well understood and broadly communicated. Finally, better ways to predict and evaluate the effectiveness of NASA technology investments are needed.

NASA's bold missions in space exploration and aeronautics will require advances in many areas of science and technology. An area that offers exciting promise is the rapid advances and potential applications of new information technology. NASA is significantly investing in information technology research to improve the Agency's core capabilities and to deliver promising new capabilities into programs and missions. Examples include:

- Intelligent Systems (IS) Program to provide critical new capabilities in automated reasoning, human-centered computing, intelligent data understanding, and revolutionary computing, and
- Intelligent Synthesis Environment (ISE) Program to research, develop, and implement tools and processes for revolutionary changes in engineering practice and science.

We will also be examining other programs to achieve ultrahigh levels of safety and mission success by fundamentally advancing NASA's system life cycle approach through infusion of advanced information technology in intelligent risk management, knowledge synthesis, and intelligent mitigation and self-healing technologies.

NASA needs to improve the planning, implementation, and application of the exciting promise that these new research areas have in the near and far term. Integrated planning and user-based pilot demonstrations for these important new technologies will enable NASA to exploit these advances and execute our missions with greater safety, performance, and robustness.

Report findings stress that integrated technology planning must balance evolutionary and revolutionary capability development and ensure early and continuous involvement of the end-user. Cost and risk must be reduced through aggressive integration of leading-edge technologies. Program management needs to review specific future mission needs and technology requirements early in the program development. Technology needs that reduce risk need to be expediently funded and more fully developed prior to project initiation. A better integrated technology (development) plan is needed as is an Integrated Information Technology Plan and Program that encompasses ISE, IS, and related Information Technology (IT) activities.

NIAT-5 Action Summary

NASA should strengthen its technology planning process and update the NASA Technology Plan.

Recommendation Reference: FBC-42, 46; MCO-66, 69, 72, 74, 75, 76, 77

NIAT-5 Action: Strengthen NASA's technology planning process and update the NASA Technology Plan [***R-CT***, TLC; 5/01].

Minimum Elements:

A. Clarify roles and responsibilities for defining cross-Enterprise needs and plans (e.g., IS, ISE, HPCC, 632, etc.) and Enterprise-specific requirements, and how they are integrated.
B. Establish criteria for identifying and prioritizing cross-Enterprise technologies that are relevant to future Enterprise needs.
C. Refine processes to "bridge the gap" between technology research and low-risk technology infusion into missions.
D. Improve processes and metrics for evaluating the effectiveness of NASA technology investments.
E. Update NASA Technology Plan to capture process improvements:
   - E.1 Clarify Technology Roles & Responsibilities and include Multi-Year Investment Profiles.
   - E.2 Develop clearer Enterprise and cross-Enterprise technology insertion roadmaps to identify multi-year maturation path and projected mission insertion points.

Figure 6. Integrated Technology Process.

The objective of the action is to position NASA to more aggressively integrate leading-edge technology into missions through improvements to the technology planning process. First, NASA will improve the management approach and mechanisms for conducting technology planning within the Agency. NASA will focus on a shared vision for technology development, and clearly define roles and responsibilities for integrating technology plans at all levels. The Chief Technologist and Technology Leadership Council will establish criteria for identifying and prioritizing cross-Enterprise technologies that are relevant to Enterprise strategic goals. In addition, NASA will improve its process for transferring technologies with broad Agency application to missions. The Agency will implement process improvements to help bridge the gap from technology research to mission use within allowable risk constraints. Finally, NASA will continue to refine its method for measuring the effectiveness of technology investments using metrics and other evaluative processes.

Based on these improvements and others, the *NASA Technology Plan* will be updated and improved to provide a more robust tool to manage and communicate technology plans and processes within NASA and with our external customers and partners. The updated *NASA Technology Plan* will reflect the clarified roles, responsibilities, and process improvements discussed above. In addition, multi-year investment profiles, technology maturation paths, projected mission insertion points, and anticipated benefits of the technology will be included to provide a long-term perspective of investments and timeframes when technologies are expected to be available for missions. The plan will clarify the objectives of the ISE, IS, and other potential programs and describe how they are integrated to yield high levels of safety and mission success through the infusion of advanced information technologies in the near term and beyond. In addition, NASA's current plans for other leading-edge technology areas and how they are being applied will be described. These include soft-computing technologies, autonomous operations and avionics technologies, and technologies which lead to improvement in aircraft, spacecraft, or aerospace vehicle design.

NIAT-6: Technology Development and Infusion

Current State

The development and infusion of new technologies is a crucial element of to the Faster, Better, Cheaper philosophy. A healthy technology pipeline is a continuum of activity that stretches from basic research through application of technology in flight. Dramatically shorter mission cycles and the growing frequency of mission launches makes it imperative that NASA find ways to accelerate the introduction of new technologies into missions. Current processes for managing the full life cycle of technology development, maturation, and infusion need to be improved to enable the new levels of performance and capabilities required by current and planned missions.

Technology is a complex and iterative activity that involves a continuous evolution and refinement of what is available, what is needed, and what could be available in the future. Processes and approaches for managing long-term research activities are quite different from those applied to mission development and operations programs; yet, elements of customer involvement, reviews, and oversight are common to the ultimate success of both.

In between technology concept and infusion, the technology must be matured—a process of testing and analysis that progressively reduces the programmatic risk of selecting that technology for an application and increases the readiness of that technology for use in a mission. Historically, "bridging the gap" between technology development and acceptance into mission applications has been the most difficult step in the technology development process. In addition, the length of time it takes to successfully mature technology varies, depending on the nature of the capability. For example, history has shown that it has taken decades to bring a new flight vehicle from the concept stage through development, design, manufacturing, and certification of the new aircraft. Yet, the life cycle of computer hardware or software may only be 3 to 4 years (and shrinking each day) and only have a useful life of 18 months. This rapidly changing state of technology complicates the timely delivery of new capabilities.

New technologies provide the innovations to find "win-win" solutions in the Faster, Better, Cheaper trade space. It has been said that technology development and infusion is a contact sport between technologists, who are more experimental by nature, and project managers, who face the reality of cost, schedule and performance challenges. Close collaboration and ongoing dialogue between the technologists and project managers throughout both the mission life cycle and the technology development cycle is critical for successful infusion of technology. There are two aspects to maximizing common understanding and supporting a team approach in identifying technology opportunities, needs, and solutions:

(1) Better information about technology requirements, investments, capabilities, and applications across the Agency that is comprehensive, integrated, and readily accessible. Better information will expose and educate program/project managers and engineers about available and future technology products and capabilities. NASA has recently launched a new NASA Technology Portal located at http://nasatechnology.nasa.gov/portal_main.cfm that provides a common entry point to a wide range of information on new technologies, and the Agencywide inventory of technology initiatives, and includes updates on technology news and events. This portal is an excellent step forward in providing an easy integrated access to needed technology information, but more is needed.

(2) Better guidance and requirements are needed for program/project managers on how to identify, evaluate and assess, select, develop where necessary, and infuse technology within their missions. The current set of guidance and requirements provided in NPG 7120.5 needs to be enhanced to be more specific on technology activities and their value. Better training for program/project managers to reflect improved guidance is also needed to heighten the awareness of benefits of new technologies and what program/project managers must do to incorporate them into missions.

The reports found that the end-to-end process for identifying, developing, demonstrating/ qualifying, and employing technologies in NASA missions must be improved. This can be accomplished through establishing technology requirements early, holding yearly "out-of-the-box" workshops, and engaging project and technologist teams early to facilitate acceptance. Technology needs should be expediently funded and matured compatible with project needs.

NIAT-6 Action Summary

Increase the speed and effectiveness of developing and infusing leading-edge technologies into missions.

Recommendation Reference: MCO-66, 67, 69, 72; SIA-26, FBC-40

NIAT-6 Action: Increase the speed and effectiveness of developing and infusing leading-edge technologies into missions [***R-CT***, AE, PMCWG, FT; 6/01].

Minimum Elements:

A. Clarify processes and requirements for managing long-term technology research and development programs/projects, to include the following points:
   - Customer focus and involvement to keep aligned with, and relevant to, Enterprises, programs, and projects;
   - Internal and external quality reviews to ensure technical excellence and feasibility;
   - Lifecycle systems analysis to assess impacts and payoffs;
   - Technology testbeds to support the "build a little, test a little" approach;
   - Ways to "bridge the gap" between technology research and infusion;
   - Maturity growth including ground qualification/space demonstration to facilitate infusion;
   - Documentation and oversight requirements to add rigor without stifling innovation;and
   - Capturing technology infusion lessons learned.

B. Establish a comprehensive environment and suite of tools to provide information about available technologies, opportunities, and needs.
   - B.1 Assess the use and utility of the NASA Technology Inventory database and other technology databases and sources (both internal and external to NASA) to provide information to program/project managers and systems engineers.
   - B.2 Establish a Web-based, interactive environment and suite of tools for program/project managers, engineers, and technologists to provide easy access to technology-related information, including:
     - Upcoming advanced and "out-of-the-box" technology workshops, conferences, and seminars;
     - Technology-related training and short courses;
     - Technology product availability and source/contact information, both internal and external to NASA;
     - Potential technology applications and benefits; and
     - Advanced concept mission study results.

C. Clarify NPG 7120.5 guidance and requirements to identify, evaluate/assess, select, develop, and infuse technology, to include:
   - Processes and requirements for assessing current/projected technology needs beginning at the earliest conceptual planning phases to ensure technology needs are met prior to infusion.
   - Tools, resources, and processes for identifying and tracking potential/available technologies.
   - Guidance on conducting technology assessments at key program/project phases to evaluate feasibility; readiness; and lifecycle costs, risks, and benefits.

Figure 7. Technology Development and Infusion.

<u>Minimum Elements</u> **<u>(Continued)</u>:**

- Strengthen requirements to reflect recurring nature of technology assessment processes.
- Guidance on how program/project manager provides feedback on program/project technology needs/plans into Agency technology planning processes.

D. Develop APPL curriculum that incorporates new and clarified guidance on technology processes and requirements.

Figure 7. Technology Development and Infusion (continued).

Three primary steps will be taken to increase the speed and effectiveness of developing and infusing leading-edge technologies into missions.

The first step addresses activities to clarify processes and requirements for managing long-term technology research. Steps will be taken to improve the way NASA manages these programs in a way that maintains customer focus, keeps alignment with missions objectives, and provides improved rigor and efficiency without stifling the creativity and innovation so integral for longer term research initiatives.

The second step includes activities to establish a comprehensive environment and suite of tools to provide information about available technologies, opportunities, needs, and significant events. NASA has a Technology Inventory database that describes technology tasks and how they are related to mission needs, and includes an indication of technology maturity and other key information. In addition, other technology databases exist, within NASA and commercially, as sources of technology information targeted to certain needs or locations. NASA will evaluate how these information sources and tools may be integrated and used more effectively to provide robust information about technology initiatives vital to program managers, technologists, and engineers. In addition, NASA will enhance the new NASA Technology Portal to include a content-rich, interactive environment and suite of tools for communities of interest on technology topics of key importance. For example, information on upcoming workshops, training sessions, product availability, and study results will be included and serve as a valuable resource to NASA missions and programs.

The third step addresses improvements that are needed to NASA's current guidance to program and project managers on the technology development and infusion process. Current guidance addresses the process of technology assessment and selection during the formulation phase of a program/project. Guidance on new tools and resources to support program/project managers on technology matters will be expanded. Roles and processes for how program/project managers identify technology requirements, how technology development programs are chosen, and how technology needs and requirements are fed back into the Agency's overall technology planning process also will be included. Training material will be added to the APPL curriculum on technology processes, requirements, and resources. This training will enhance a manager's ability to make the decisions for optimal application of new technology for cost and risk reduction and maximum return to their project.

Theme III—Understanding and Controlling Risk

Introduction

One of the critical elements for success in the Faster, Better, Cheaper approach is the project manager's ability to understand and control risk. In successful efforts, the project managers identify and accept (or mitigate) risks early in the project formulation and control the risks throughout the mission life cycle. They define and understand the criteria for mission success at the beginning of the effort.

NASA has always recognized risk management as a key factor in project management. Historically, effective risk management application was dependent on the specific background and experience of the project manager. With the downsizing in the late 1990's, much of this experience left the Agency, and with it, a loss of corporate knowledge on risk management.

In April 1998, NPG 7120.5A, "NASA Program and Project Management Processes and Requirements," established a disciplined, defined risk management process. This NPG requires all projects to develop a risk management plan that describes the process for risk identification, analysis, mitigation, tracking, and communication. In addition, projects must present their critical risk list during the formulation phase for Governing Program Management Council (GPMC) review. During the implementation phase, the knowledge and understanding of that accepted risk is carried into implementation. Where new risks arise, they are incorporated into the risk management process and reviewed by the GPMC.

Primary responsibility for effective management of risk rests squarely with the program and project manager. All members of the team must fully understand their role in identifying and controlling risk. With the increased emphasis on risk management, NASA's Safety and Mission Assurance (SMA) community takes on an important role in supporting the program and project managers. During the formulation phase, SMA provides guidance and assistance to the project team in the identification of risks and the development of the risk management plan. Once a project is underway, SMA provides independent assessment to ensure decisions and the decision process pay sufficient attention to risk. In addition, SMA assists the projects in using specialized tools, such as Fault Tree Analysis, Failure Modes and Effects Analysis, and Probabilistic Risk Assessment to identify and mitigate potential risk to success.

In the area of "Understanding and Control of Risk," the reports determined that improvements were needed in risk identification, assessment, and management; the definitions of acceptable risk and success criteria; and safety and mission assurance.

The following action summarizes the improved capabilities and performance needed in these areas.

NIAT-7: Risk Identification, Assessment, and Management

Current State

Although risk management guidance has been developed and requirements for risk management plans currently exist, the implementation is not uniform across the Agency.

NIAT-7 Action Summary

Improve and enhance the ability to identify, assess, mitigate, and track risk through the definition of success criteria and acceptable risk, utilization of tools and proper policy and guidance. Integral to this action is establishing an accurate, agreed-upon understanding of acceptable risk in the context of well-defined success criteria.

This action has three main objectives, each a critical part of technical and programmatic risk management. Understanding risk management requirements and tools focuses on ensuring that proper policy and guidance is in place and understood and that tools exist to facilitate the risk identification, assessment, mitigation, and communication process throughout the life of the project.

To ensure that risk management process is included in acquisition an interim rule change to the NASA Federal Acquisition Regulation (FAR) Supplement has been put in place. Additional changes to other acquisition mechanisms such as, Cooperative Agreements, Announcements of Opportunity, etc. will follow.

The application of new and existing tools for risk assessment will be improved by training the acquisition community and the program/project teams. In the near term, projects will be required to use currently available tools such as Fault Tree Analysis and Failure Mode Effects Analysis (FMEA), and, when appropriate, a more in-depth Probabilistic Risk Assessment to uncover risks and determine the robustness of risk mitigation. In the long term, intelligent systems based tools, enabled by emerging technologies, such as soft adaptive computing must be pursued to develop more rigorous risk assessment and management approaches.

Center Directors will ensure that the programs/projects address risk mitigation plans and progress at periodic GPMC reviews during the program and project life cycle in order to ensure that the job of meeting the success criteria is supported by the available resources, and that the budgetary and schedule reserves, as well as the design margins, are compatible with the risk posture.

The program/project team must develop clear “Success Criteria” during the formulation phase and that success criteria must be clearly communicated to all levels of the program and project organizations to define scope of the effort and to guide risk decisions. Furthermore, success criteria need to be developed at lower levels; e.g., system, subsystem, and component level to define trade space and support risk decisions. Success criteria will continue to evolve throughout the life cycle of the project. They may be modified through discussion and decisions related to risk, technology, program requirements, etc. as the project matures. It is imperative that the understanding of these criteria be communicated up and down the organization by project and line management to the entire team, including partners or contractors.

"Acceptable Risk" is defined in terms of the program/project management decision process. It is impossible to adequately define "categories" of risk and undesirable to move back to overly prescriptive rules for those categories. The variety of work within NASA makes this an impractical approach. This definition ensures that acceptable risk is properly identified by the program/project, drives the development of the risk management plan and future management decisions and is well communicated up and down the organization. The proposed definition is "Acceptable risk is the risk that is understood and agreed to by the program/project, GPMC, and the customer as sufficient to achieve defined success criteria within an approved level of resources." Each program/project must have sufficient information to make an informed decision on what is acceptable risk. The understanding of risk and risk management is an essential part of engineering from concept development through design and into operations. To support engineers and project managers, advanced quantitative tools are needed for risk analysis. When delivered, these tools will aid in the flow down of risk and support the assessment of success criteria at all levels.

Recommendation Reference: MCO-18, 19, 21, 22, 24, 25, 27, 31, 32, 33, 34, 35, 36, 37, 39; FBC-19, 21, 44; MPIA-4, 5, 8, 11, 13, 19; SIA-9, 10, 12, 15, 16, 18, 22

NIAT-7 Action: Improve and enhance NASA and contractor knowledge and ability to identify, assess, mitigate, and track risk through the definition of success criteria, acceptable risk, utilization of existing and new tools, and proper policy and guidance [***AE***, Q, H ,PMCWG, FT, Center Directors; 9/01].

Minimum Elements:

A. Ensure proper policy is in place and understood
- A.1 Use NPG 8705 to better communicate the risk management process.
- A.2 Develop an interim change or a Procurement Information Circular to explicitly address the AO/NRA process.
- A.3 Assess changes to the Grant and Cooperative Agreement Handbook to address RM for Cooperative Agreements.
- A.4 Implement a Risk-Based Acquisition Management activity for explicit safety and mission assurance guidance to RFP development, SOW development, source evaluation criteria, pre-award and post-award surveys.
- A.5 Strengthen NPG 7120.5 to reflect risk assessment by the entire team during formulation.
- A.6 Ensure that the GPMC's address risk mitigation plans and progress at program/project reviews.

B. Provide improved guidance on tools and techniques for risk assessment.
- B.1 Modify NPG7120.5A to include FMEA, FTA, and PRA to support risk assessment.

Figure 8. Risk Identification, Assessment, and Management.

Minimum Elements (Continued):

B.2 Develop a project management training module on PRA, FTA, FMEA.

B.3 Continue activity to expand NASA's peer reviewed "Quantitative Risk Assessment System (QRAS)" tool to include projects beyond the Space Shuttle. Evaluate other state-of-the-art tools that may be available.

C. Develop enhanced risk management methodology and tools that enable quantitative assessment of risk that can be flowed down and allocated, similar to a power or weight budget.
- Tool should allow assessment of system trade space and support design decisions.
- This allocated risk should be a contractor requirement.

D. Develop an improved methodology to provide enhanced risk tracking that alerts all levels of project management of possible problems.

D.1 Expand NPG 8705, current "Risk Profile" description to provide more detailed guidance into how to develop and maintain a risk tracking system.

D.2 Ensure risk tracking is in place for programs and projects.

E. Ensure that risk plans include intraprogrammatic considerations (e.g., spacecraft-to-spacecraft dependencies).

F. Define "Success Criteria." "Success criteria is that portion of the top level requirements that define what should be achieved to successfully satisfy the strategic plan objectives addressed by the program, project or technology demonstration." Additional considerations include the following:
- Success criteria are established during the Formulation subprocess to drive requirements, define allowable trade space, and guide risk and safety decisions. Success criteria are under change control.
- These criteria flow down from the overall requirements to the system/subsystem level to meet the overall objectives.

G. Ensure flow down of success criteria through the systems, system trades, and decision processes of current programs and projects and communicate the criteria to all team members.

H. Define "Acceptable Risk:" "Acceptable Risk is the risk that is understood and agreed to by the program/project, GPMC, and customer sufficient to achieve defined success criteria within an approved level of resources." Incorporate into NPG 7120.5.

I. Ensure that approval to initiate implementation includes management concurrence with a baseline risk management plan that defines the following:
- General risk mitigation strategies to be employed throughout program/project implementation.
- The initial set of identified risks and the risk mitigation/acceptance plan for each.
- The process to be used for continual assessment of risk posture.
- The approach to regularly communicating risk both internally to the project staff and throughout the management chain.

Figure 8. Risk Identification, Assessment, and Management (continued).

NIAT-8: Safety and Mission Assurance

Current State

Under cost and schedule pressure, involvement of SMA organization is frequently limited to only specific deliverables (e.g., review of a quality plan). Project managers sometimes do not plan for adequate SMA coverage, particularly after the formulation subprocess and into implementation including operations. Risks and margins are also factors that should be considered in the establishment of the right level of SMA involvement (e.g., surveillance, lessons learned). In addition, the processes at the Centers for the reporting of incidents, anomalies, etc. are not implemented uniformly well by all projects. The SMA organizations need to be engaged in this process to ensure the efficacy of the reporting system and the follow-up and closure of such events.

SMA organizations have trouble recruiting and retaining a skilled engineering staff due to the perception that these positions have a limited career path.

NIAT-8 Action Summary

NASA should enhance SMA presence and involvement throughout the program/project life cycle.

Recommendation Reference: MCO-26; FBC-15; SIA-7, 17, 19

NIAT-8 Action: Improve NASA Safety and Mission Assurance to provide lifecycle rigor in the formulation and implementation of flight systems [***Q***, Center Directors; 4/01].

Minimum Elements:
A. Ensure sufficient value added SMA involvement in programs/projects.
B. Define approaches to enhancing engineering skills of in-line assurance personnel through education, recognition, rotational assignments, improved career paths that enable greater growth, etc.
C. Ensure the SMA involvement in the oversight of the process of reporting incidents, anomalies, etc. and their responsibility in following through on these reports, ensuring close-out occurs.
D. Field Center ensure adequate training of personnel on problem reporting systems.

Figure 9. Safety and Mission Assurance.

The assessment of the situation in SMA support by the project managers, in conjunction with the GPMC, will identify any areas of concern on a project-specific basis. Relative to the incident reporting processes, Centers should ensure the process is working using SMA as an assessment agent. The SMA in partnership with the Centers, will define approaches for enhancing engineering skills of assurance personnel through various means such as education, recognition, rotational assignments, and improved career paths.

Theme IV—Ensuring Formulation Rigor and Implementation Discipline

Introduction

To successfully execute our programs and projects, NASA must exercise rigor and discipline in formulation and implementation. The processes and practices of good program and project management have long been understood by the Agency, but one of the findings of the reports is that on some projects those processes or practices have not been followed with sufficient discipline. A thorough formulation phase, confirmed to be such by rigorous independent assessment, is essential before initiating implementation of any program or project. Appropriate use of competition to further stimulate innovation of approach to accomplishing objectives with reduced, yet realistic resources must be considered.

During the last decade, NASA has been asked to do more with less. With a few exceptions, the Agency has delivered a greater number of programs and projects at lower cost and in a shorter development time. These projects have produced many exciting findings and have answered some of the fundamental questions that send us faring into space. In light of the recent problems, however, it is appropriate for NASA to revisit policies and procedures for formulating and implementing projects. Center Directors, Associate Administrators, and other senior managers must verify that all policy, procedures, and practices used by civil service and contractor personnel adhere to the fundamentals of sound management and engineering practice.

Additional clarification is needed to ensure common understanding of the Faster, Better, Cheaper management philosophy and the roles and responsibilities of the performing organizations in supporting mission success. This includes ensuring that adequate resources and margins are available and that sufficient rigor is being applied at all levels of the organization to deliver successful programs and projects.

The seven actions that follow, outline the steps needed to produce the common understanding of Agency policy and to ensure that NASA is routinely formulating and implementing its programs and projects in a rigorous and disciplined manner. The actions are intentionally not overly prescriptive. The ability to innovate and to tailor approaches to unique needs is recognized as an essential part of a team’s ability to meet their responsibilities and be accountable for their results. In so doing, however, changes to practice must be consciously considered such that reasonable assurance of adequate rigor is retained.

NIAT-9: Software Development and Assurance

Current State

Over the last decade, NASA has seen a dramatic increase in software needed for our missions and in particular a significant increase in on-board computational capability. As an example, Voyager had 3,000 lines of code on board compared to the 160,000 lines of code for Mars Pathfinder. In the future, we foresee exponential growth in software and software complexity within NASA as well as industry. For example, industry data indicate a growth in computer chip complexity by a factor of 2 every 18 months. Today, commercial packages such as operating systems, enterprise resource management systems, and telecommunications operations software are over 30 million lines of code.

Software is an increasingly difficult challenge to mission success. In general, the tools we have for developing and verifying software need improvement to prevent the systemic management and technical problems that traditionally occur in software development and verification. An independent study of over 8,000 software projects across all industries conducted in the mid-1990's showed that 31 percent of the projects were cancelled during development; 53 percent had major problems related to cost, delivery time, or performance capability; and only 16 percent were fully successful. For large software projects, only 8 percent were successful. Even then, there are typically 5 to 10 errors per 1,000 lines of code in commercial products.

NASA has many examples of excellence in software development process and performance such as the Space Shuttle software system. However, with the projected growth in software scope and complexity, NASA must take proactive steps to ensure software quality and reliability.

NIAT-9 Action Summary

NASA will improve the quality and reliability of software.

Recommendation Reference: MCO-28

NIAT-9 Action: Revolutionize the process of developing and delivering safe, reliable, quality software, and improve transfer of new software methods and tools into NASA practice [***AE***, FT; 6/01].

Minimum Elements:

A. Develop and implement a plan to move all critical software engineering development, management and assurance processes to a level commensurate with Capability Maturity Model (CMM) level 3.
B. Develop requirement for software-specific training as part of APPL curriculum commensurate with CMM level 3 goal.
C. Develop Agencywide requirements and guidelines for the development of software in Programs and Projects based on widely accepted industry standards.
D. Establish and apply basic metrics to assess performance in the development of software.
E. Establish process, criteria, and standards for V&V and IV&V emphasizing end-to-end system verification.
F. Emphasize fundamental software research in areas of reliability, error tolerance, automated reasoning, software reuse, and emerging paradigms (e.g., learning systems, and design for safety).
G. Develop a plan for the implementation of soft-computing methods in Programs and Projects.

Figure 10. Software Development and Assurance.

Because of our increased reliance on software and its critical role in mission success, NASA has begun an initiative to improve the quality and safety of software. This initiative will address process improvement, metrics, enhanced verification and validation, and fundamental software research applicable to verification and validation of software systems. The core capability in software Independent Verification and Validation (IV&V) represented by the NASA Fairmont IV&V Facility is expected to play a pivotal role in the Agency's thrust to ensure successful missions.

The action also sets the stage for the Agency to develop necessary requirements and guidance for the development and implementation of a plan that moves the Agency toward uniformly achieving a level of capability in critical software systems commensurate with the Carnegie Mellon/Software Engineering Institute level 3.

NIAT-10: Integrated Review Process

Current State

NPG 7120.5 provides the requirements and process for performing programmatic and technical reviews. The guidance provides the framework for knowledgeable practitioners to develop an effective, tailored set of reviews for each program and project. Systems Management Offices have been implemented at each of the Centers as a resource to assist Center management and program/project managers.

Inadequate review is a frequently cited theme in the recent mishap reports. The reports suggest that rigorous discipline must be routinely enforced in the review process. Projects should conduct a comprehensive program of thorough technical and programmatic reviews. The choice of experts to participate in reviews is critical to success. Continuity of review panels throughout the project life cycle is important. Complete, timely, and accurate reporting and closure of issues is required.

The guiding principles for reviews are articulated below. The major classes of reviews and how they fit into an integrated and comprehensive continuum of reviews also are defined.

Guiding Principles of Management and Technical Reviews

- <u>Reviews are a resource</u>. They offer an opportunity to add value to the products and to the sharing of knowledge by inviting outside experts that can provide confirmation of the approach and/or recommend options.

- <u>Reviews are a tool for communication</u>. They offer an opportunity to organize, assess, and communicate critical data and information between providers, customers, and stakeholders.

Major Classes of Reviews

The objectives and salient features of the four major review classes are provided to guide program/project managers in the formulation and implementation of an integrated and comprehensive continuum of reviews. The term “integrated and comprehensive continuum” is used to emphasize that there is both a life cycle relationship and a hierarchical relationship to these reviews. Reviews provide the opportunity to confirm the approach or offer options, if needed, and communicate progress and risks toward meeting the success criteria. Reviews also serve the needs of the various levels of the management hierarchy from those of an individual product lead on a project to those of the NASA Administrator. The products of these reviews (i.e., assessments, options, recommendations, and decisions) flow upward to subsequent reviews as appropriate to ensure alignment between providers, customers, and stakeholders, and ensure proper disposition of issues. It is up to the program or project manager to propose options to combine reviews to management, customers, and stakeholders, provided that the objectives of each are met. The goal is to enhance the probability of mission success through added value and efficiencies. The review program must be tailored to the needs of a program or project in a way that is compatible with acceptable risk.

- **<u>Product Integrity Reviews</u>** are an inclusive term for the variety of surveillance mechanisms employed by line management organizations to ensure the quality, viability, and safety of the products they provide. The expectation is that the supervisory chain of all performing organizations within NASA Centers, contractors, suppliers, universities, foreign partners, etc. exercises their responsibility for the integrity of the products and services their employees deliver to a project. The management and technical experts of the performing organizations conduct the reviews according to their internal processes. The ultimate customer is the project team member responsible for the delivery and performance of the product. This product lead is accountable to the project manager for ensuring that performing organizations understand and fulfill their accountability for the product.

- **<u>Engineering Peer Reviews</u>** are focused, in-depth technical reviews used to provide confirmation and offer options by bringing experts in as early as possible. A thoughtfully formulated, comprehensive set of Engineering Peer Reviews is a cornerstone of a successful project. The reviews provide a penetrating examination of design, analysis, manufacturing, integration, test and operational details, drawings, processes, and data. Engineering Peer Reviews are most frequently applied to subsystem or lower level development activities. They also are well suited for the evaluation of concepts, designs, and processes associated with combinations of subsystems and crosscutting functional subdivisions such as the end-to-end optical path, command and data pipeline, maneuver planning, or autonomous fault detection/correction system. Engineering Peer Reviews are most effective when accomplished with a small group of reviewers working around a table with the developers. Reviewers are experts independent of the project team, including experts from outside of the performing organization. Reviewers are appointed in collaboration with the product lead's line management. The customers are the product leads and the project manager. They are also accountable for the definition of review objectives and subsequent communication and closure of issues resulting from the reviews.

- **<u>Critical Milestone Reviews</u>** are the life cycle series of rigorous system-level technical and programmatic evaluations conducted at key formulation and implementation milestones. Key milestones in this context are the major transition points in the project life cycle, such as the transition from formulation to implementation, and the transition from the assembly and integration of components to system-level environmental testing. The purpose of a Critical Milestone Review is to assess the technical and programmatic health of a project or major element of a project with respect to the success criteria and acceptable risk. The reviews provide top-down systematic evaluations of the derivation and functional allocation of requirements, the engineering implementation to address the requirements, the validation and verification of the requirements, the preparation for mission operations and data analysis, and the system management processes that tie it all together. Critical Milestone Reviews should also address the resources (e.g., workforce, budget, schedule) required to implement the program/project, any associated resource constraints, issues/risks, and reserves. Reviewers are independent of the project and largely independent from the performing organization. They are chosen based on their combined expertise and their ability to assess the implementation of an entire system that employs numerous engineering and other disciplines. Review teams that provide continuity throughout the life cycle of the project is desirable to limit the amount of reeducation that must be done to get new members knowledgeable.

- **Independent Reviews** provide senior Agency managers with objective assessments of program/project planning, resource requirements, status, and risks. An independent review is generally requested by or on behalf of a Center Director, Enterprise Associate Administrator, or the NASA Administrator. Reviewers are experts from organizations outside of the advocacy chain of the program/project being reviewed. To the extent possible, continuity of review panel membership is maintained throughout the life cycle of the program/project.

NIAT-10 Action Summary

Define and rigorously implement a refined and reinvigorated NASA Integrated Review Process for programs/projects.

Recommendation Reference: MCO-41, 42, 43, 44, 45, 46, 47, 49, 51, 52, 58, 60, 61, 62, 63; FBC-17, 22, 23; SIA-20; MPIA-17, 21, 22, 24, 25

NIAT-10 Action: Define and rigorously implement a refined and reinvigorated NASA Integrated Review Process for Programs/Projects, which will:
[***AE***, PMCWG, Center Directors; 4/01]:

- Clarify an integrated continuum of reviews and associated rollup of value-added review products.
- Specify required reviews and classes of reviews for tailoring by Enterprise/Center/Program/Project including "peer" and "independent" reviews.
- Clarify objectives and expectations for each review/review class
- Identify the review "customer" and specify participants, roles, and responsibilities.
- Address independence and expertise requirements for reviewers, and the continuity and discipline area penetration assignments of reviewers.

Minimum Elements:

A. Revise NPG 7120.5 to guide program/project-defined technical and programmatic reviews.
   - Plan and conduct a comprehensive and rigorous review program tailored to add value to the program/project.
   - Increase attention to the selection and continuity of review panel members
   - Plan and allocate resources for the review process.
   - Complete timely and accurate reporting and closure of issues.

B. Confirm that all programs/projects currently in formulation and implementation have planned and are executing the appropriate technical and programmatic reviews.

C. Evaluate and update the technical and programmatic review processes at field Centers to ensure that each program/project plans and executes an effective, rigorous, and efficient review program, including the following:
   - Ensure that projects plan and conduct a comprehensive review program and that individual reviews are thorough.
   - Evaluate the execution of the formulation process including independent assessments of resource requirements
   - Ensure thorough engineering reviews by independent peers
   - Ensure that the selection of review panel membership is given a high priority and independently assessed.
   - Ensure that resources are planned and allocated for the review process.

Figure 11. Integrated Review Process.

This action requires the Office of the Chief Engineer and the Program Management Council Working Group (PMCWG) to refine Agency policy and procedures on reviews to provide clearer guidance to Agency, Center, and program and project managers.

Center Directors are asked to confirm that current projects are receiving adequate review and that Center policies and procedures on reviews are adequate to ensure that future programs and projects plan and execute an effective, rigorous, and efficient review program. An essential element of project success is the involvement of line management in the review and assessment of projects during formulation and implementation.

NIAT-11: Ensuring Adequate Resources

Current State

The budget process requires programs and projects to estimate their resource requirements approximately 18 months prior to the provision of appropriations. This lead time requires Enterprise or program, project managers to make assumptions about resource requirements very early in the formulation phase, when the system design and therefore the requirements are still immature. The uncertainty can be significant, especially for high risk leading edge endeavors, and thus without a clear understanding and communication of the same, unrealistic expectations may be set among customers and stake holders. As the program or project progresses through the formulation and into the implementation phase the uncertainty and the attendant risk in accomplishing those requirements are reduced as the initial assumptions are either validated, modified or discarded. Tools and methodologies for better estimation of the uncertainty in the resource requirements are required. Program and project managers must plan for and request resources that are adequate and commensurate with the scope, level of maturity, and understanding of the end to end system.

In the current constrained budgetary environment, it has been difficult for NASA to maintain robust margins. The Agency has taken a number of steps to get "the most bang for the buck:" reserves have been reduced, mission costs have been internally "capped," development schedules have been fixed, and reserves have sometimes been controlled at a program rather than project level and sometimes even eliminated altogether. While well intended, and often effective, such practices cannot be decoupled from the risk management process.

A primary finding of the Mars failure reports was that funding, including reserves, was inadequate to ensure mission success. The scope of the job and the allocated resources must be balanced throughout the life cycle. When circumstances warrant, balance must be restored. It must be recognized that, in such cases, additional funding is not the only alternative. Modifications in scope, leverage of other resources, or other potential solutions must also be considered as we strive to identify innovative ways to accomplish challenging mission objectives. Cancellation must be viewed as one alternative when resource needs are well beyond current allocations. Indeed, continuing an inadequately funded program or project may be worse than canceling the effort. Such decisions, when necessary, must be made as early as possible, a point that only further emphasizes the need to be continually aware of the balance between scope and resource.

NIAT-11 Action Summary

Throughout the life cycle NASA should ensure provision of program and project resources, including margins and reserves, that is compatible with the scope of the job.

Recommendation Reference: MCO-17; MPIA-12

NIAT-11 Action: Throughout the life cycle ensure provision of program and project resources that is compatible with the scope of the job. [***B***, EAA's, Center Directors; 4/01].

Minimum Elements:

A. Assess the adequacy of current program and project resources for the current scope of the job.
B. Verify the adequacy of program reserves and ensure reserves flow down to project managers.
C. In budget documents and external communications that are provided prior to program/project approval, clarify the preliminary character of lifecycle cost estimates to facilitate any required revision in cost, schedule, or scope.

Figure 12. Ensuring Adequate Resources.

The objective of the action is to ensure that adequate resources, including sufficient budget and schedule reserves and design margins to support the risk posture, are included in initial formulation estimates and maintained through the life cycle of the project or program. Appropriate utilization of competition must be recognized as a valuable method of effectively eliciting innovative approaches that require reduced, yet realistic resources to meet challenging mission needs. Scope must be well delineated at the time initial funding estimates are defined, and must be effectively controlled throughout execution. It is critical too, that the responsible project or program manager controls the reserves and margins. This will ensure timely response to issues. Center Directors will examine the adequacy of the margins and reserves for the programs and projects assigned to them. Associate Administrators will verify the adequacy of the margins and reserves and take steps to ensure timely release to the responsible program and project managers. The Office of the Chief Financial Officer will work with the appropriate Government entities to better inform stakeholders of the preliminary character of life cycle cost estimates generated during formulation and ensure realistic expectations of cost and performance.

NIAT-12: Faster, Better, Cheaper

Current State

In 1992, the NASA Administrator recognized that the Agency had been on a path that focused most of its resources on major projects and programs that took 7 to 10 years to complete. FBC was and is intended to stimulate innovation and provide challenge for bold new missions through application of technology, streamlined practices, managed risk, and accountable project teams. FBC has promoted taking risk with insufficient guidance as to the boundaries. Resources have been highly constrained and the impact on resultant risk has not always been mitigated.

In 1996, the Agency provided the guidance that moved project management from a strict “rule-based” approach to managing projects to a more flexible but structured process approach. This guidance was codified through the development of the NASA Procedures and Guidelines 7120.5, “NASA Program and Project Management Processes and Requirements”. Several of the findings of the failure reports identified the lack of a commonly held definition and process guidance as contributing factors to these early FBC missions.

NIAT-12 Action Summary

Define Faster, Better, Cheaper and appropriately incorporate the definition into NPG 7120.5.

The definition in Figure 13 below has been developed for inclusion in NPG 7120.5. This clarification will enable better understanding of the intent and environment of program/project management. Project success will be enabled by good planning and implementation per NPG 7120.5 and through the application of sound management and engineering practices.

Recommendation Reference: FBC-20

NIAT-12 Action: Define "Faster, Better, Cheaper" and incorporate into NPG 7120.5 [***AE***, PMCWG; 4/01].

Minimum Elements:
Define FBC. "Faster, Better, Cheaper is a management philosophy that promotes the acceptance of prudent mission risk while using sound and innovative approaches to safely accomplish bold mission objectives (better) while conserving time and money (faster, cheaper)."

To accomplish this, NASA:
- Emphasizes that safety of the public, its flight crews, its employees, and its critical assets are of paramount importance.
- Relies upon individual and organizational commitment to responsibility and accountability for doing it right the first time.
- Fosters efficiency in process, and the application of innovative methods and tools to greatly reduce product development cycle time and costs while ensuring that the risk is acceptable.
- Invests in an educated and empowered workforce to ensure the application of sound Project Management and Engineering practices.
- Invests in a sound technology program aimed at future needs, and encourages the infusion of those technologies.
- Recognizes that occasional mission failures will still occur.

Figure 13. Faster, Better, Cheaper.

The conclusions of the reports, and this NIAT assessment, are that the FBC principles are valid if properly applied. They apply in varying degrees to different programs recognizing that the portfolio of Agency missions covers a broad spectrum of activities for which the level of acceptable mission risk must be determined by mission unique considerations. The NASA and Enterprise strategic plans project a vision full of multiple challenging missions and technology developments that to become a reality in the present environment need sound application of the Faster, Better, Cheaper philosophy and its principles.

NIAT-13: Surveillance

Current State

The current NASA Procedures and Guidelines for the management of programs and projects define the responsibilities of management officials in the approval and ongoing surveillance of programs and projects. Responsibility for program management has been delegated to the Centers. A hierarchy of Program Management Councils has been established to ensure that Agency management is regularly engaged in the assessment of program and project status, issues, and risks. System Management Offices have recently been formed to assist Center Management in the execution of their surveillance responsibilities.

The delegation of program management authority, changes in day-to-day relationships with the contractor community, introduction of Principal Investigator-managed missions, other changes in project management, and the recent mission failures have raised issues relative to the adequacy of surveillance activities. The reports found that surveillance was sometimes inadequate and contributed to a lack of communication of issues among the project team, management, and contractors.

NIAT-13 Action Summary

Ensure that programs and projects receive adequate surveillance based on the understanding of risk and the ability of the supplier to deliver the product or service and that there is ample opportunity for the communication of issues and concerns.

Recommendation Reference: MCO-16, 40; FBC-18, 30, 33, 34; MPIA-10, 16, 22, 23

NIAT-13 Action: Ensure that programs and projects receive adequate surveillance based on risk knowledge and that there is ample opportunity for the communication of issues and concerns [***AE***, PMCWG, Center Directors; 6/01].

Minimum Elements:

A. Ensure that NPG 7120.5 clearly defines the hierarchy of management roles, surveillance, and planning documentation required relative to project risks. Incorporate any deficiencies into NPG 7120.5.
B. Review surveillance and reporting requirements and procedures at field Centers for ambiguities, conflicts, and omissions. Utilize risk to help determine appropriate surveillance and reporting requirements.
   - Confirm that appropriate surveillance and reporting is applied to projects including in-house, Government/contractor partnerships, and contractor advanced development activities.
   - Confirm that process and acquisition instruments enable the participation of all parties in open and frank communication and effective surveillance.
   - Confirm that appropriate mechanisms exist for program management to periodically review project decisions for program or mission-level impact.
   - Confirm that major issues identified in programmatic and technical reviews of projects are reported to senior management.
   - Provide for the periodic reassessment of the reporting process.
   - Integrate and maximize the efficiency of insight personnel.

Figure 14. Surveillance.

The action requires that current guidance and requirements be reviewed for adequacy, with revisions being provided if clarification is required. The first step will entail a review of NPG 7120.5 to ensure that:

- The hierarchy of management roles and responsibilities is clear,
- Project documentation and processes are structured to provide both planning for surveillance and mechanisms to communicate project status and risk.

Center Directors also will review their surveillance and reporting requirements and procedures for ambiguities, conflicts, and possible omissions to confirm that the appropriate reporting and surveillance is in place for current programs and projects. These processes should be part of every Center's Quality Management System.

Surveillance can be streamlined to be responsive to particular risk or skill issues specific to each project task or to specific suppliers. Efficiency can be realized by explicitly evaluating these and other factors to establish the right level of surveillance.

NIAT-14: Verification and Validation

Current State

Verification and validation activities are hierarchical in nature, building from the part level through the integrated system level. Verification typically includes use of breadboards, simulators, development hardware and software, and finally the flight articles themselves. NPG 7120.5 contains basic verification and validation requirements, but provides minimal detail on "how" or "how much." The fundamental assumption has been that each project would establish adequate verification requirements and conduct the testing necessary to ensure the success of the project, taking into consideration both the risk associated with the project and the performance and operational requirements. Approval of the plans by higher level authorities would constitute agreement with the assumptions and verification approach. However, constrained resources have sometimes caused projects to depart from the fundamental principle of "test as you fly and fly as you test."

NIAT-14 Action Summary

Ensure that all projects plan and execute a thorough verification and validation (V&V) program.

Recommendation Reference: MCO-50, 51, 53, 54, 57, 59; MPIA-20, 28; SIA-21

NIAT-14 Action: Ensure that all projects plan and execute a thorough verification and validation (V&V) program for hardware, software, and hardware/software systems [***AE***, Center Directors, PMCWG; 4/01].

Minimum Elements:

A. Revise NPG 7120.5 to provide additional guidance concerning V&V planning.
B. Conduct evaluation of V&V plans and execution for projects currently in implementation.
C. Review/update Center-level procedures and guidelines for V&V planning and execution.
  - Ensure that procedures and guidelines are sufficiently comprehensive in addressing hardware and software at all levels through the integrated system.
  - Confirm that review processes provide for thorough, independent assessment of the planning and execution of project V&V.

Figure 15. Verification and Validation.

NASA will revise NPG 7120.5 to provide additional guidance on V&V planning and execution.

In addition, Center Directors will conduct an evaluation of V&V plans and execution for projects currently in implementation. Center Directors will also review and update Center procedures and guidelines for V&V planning and execution. Emphasis should be given to thorough V&V of hardware, software, and integrated hardware/software systems, including use of simulations, when appropriate.

NIAT-15: Management Responsibility and Accountability

Current State

NASA deployed an Agencywide NASA Policy Directive (NPD) 7120.4 in November 1996 for Program/Project Management, and NPG 7120.5 in April 1998 for NASA Program and Project Management Processes and Requirements. The processes and requirements defined by these documents are an integral part of the Agency management system established to meet the goals of the NASA Strategic Plan. This management system provides the overall framework to govern the formulation, approval, implementation, and evaluation of NASA programs and projects.

Program/project management responsibility in NASA spans the management chain from the Administrator through the Associate Deputy Administrator, Associate Administrators, Center Directors, Program Managers, Project Managers, and other line management officials, each of whom has a role in ensuring consistency of program and project implementation with Agency policies and procedures.

The project manager is responsible for project success. In support of the project manager, line management has a responsibility for the technical accuracy of the project. This responsibility is exercised through management review (see NIAT-10) and frequent interaction with team members. Line management must also be knowledgeable of both technical information and the program/project management process to adequately support and advise their employees to proactively contribute to project success.

The report findings identify that management has the above responsibilities but that their implementation has not always been sufficiently rigorous.

NIAT-15 Action Summary

Senior and line management at performing organizations must be knowledgeable of Agency policies and guidelines and their traceability to Center specific processes, procedures and policies. They are also responsible for ensuring the application of sound engineering and management practices. This extends to providing all, but in particular less experienced, managers and other leads the support necessary for their development while ensuring that those practices are followed.

Management is ultimately accountable to implement the Agency's policies and procedures and provide guidance to others throughout the organization. They can only meet this responsibility through more direct involvement in programs and projects. To enhance their performance and improve support to the project teams, additional in-depth knowledge of the evolving terminology, methodology, and lessons learned is needed.

Senior and line management must work closely with the Systems Management Offices at each Center to provide continuous assessment and take proactive steps to support the project managers and project teams. The Office of the Chief Engineer, as steward of NPG 7120.5, will monitor the effectiveness of Agency policies and procedures in the support of management.

Recommendation Reference: MPIA-1, 3, 14, 15; FBC-10; MCO-14, 38; SIA-1

NIAT-15 Action: Ensure that Center senior and line management understand and effectively exercise their continual role in supporting Project Managers and Project Teams [***AE,*** Center Directors, PMCWG, FT; 6/01].

Minimum Elements:

A. Incorporate roles and responsibilities of Center senior and line management in NPG 7120.5.
B. Develop focused training materials and workshops/forums for senior and line management to become familiar with NPG 7120.5 and related documents.
C. Evaluate Center policies and processes to ensure traceability and consistency with NPG 7120.5 and related documents.
D. Develop and put in place an assessment methodology to ensure that Project Manager's and leads have the training and institutional support necessary for their success.

Figure 16. Management Responsibility and Accountability.

Theme V—Improving Communication

Introduction

The NASA team is comprised of a diverse group of highly skilled men and women located throughout the Nation with the charge to accomplish the Agency's mission, goals, and objectives. In most cases the team relies on multiple partners, including other Government agencies, industry, and academia. The Agency must have a culture of teamwork and open communications. To achieve that environment, we must continue to remove communication barriers and foster an inclusive environment where open and candid communication is the norm.

The essential knowledge for success is embedded in the systems and processes used within the Agency and the skills of NASA employees and partners. This knowledge is what makes NASA uniquely capable. It is not easy to capture and share information and key lessons across the Agency. To succeed, NASA must sustain an open learning environment that is facilitated through an effective communications process. This environment must capture and deliver lessons learned to effectively facilitate the sharing of information and expertise and enable knowledge management.

NIAT-16: Organizational Communication

Current State

With the diversity of needs, learning styles, and methods in place, the importance placed by people on an open communications process is inconsistent across organizations and organizational levels. NASA has a great challenge since our "can do" culture sometimes constrains the communications process, especially when issues and problems are involved. The spirit of "can do" drives employees to investigate all other avenues of solution until they have been exhausted. By this time, it is sometimes too late to effectively implement corrective or preventive actions. What enables our high rate of success also establishes barriers to an open communications process.

Most program and project teams include communication mechanisms within the team structure as a normal way of doing business. An example of a frequently used mechanism is that of project reviews. They currently provide a structured forum internal to the team. External to the team, they provide the project manager the opportunity to promote the understanding of requirements, to balance and understand risks, and to obtain expert advice on specific issues. Nevertheless, improvements are needed to strengthen communications both inside and outside the project structure.

One of the most important enablers to open communication is trust. Team members must feel free to express concerns without fear and openly communicate potential risks and issues. A key responsibility of program and project managers is to clearly communicate regularly to their management, as well as customers and stakeholders and they must ,therefore have that competency. In return, their management must be open to discussion and practice effective communication skills. Management must advocate prudent risk taking that does not compromise safety considerations as a tenet by which the Agency approaches its missions, and it must accept the occasional downside outcomes that may result from doing so. Barriers that can inhibit effective communication, such as lack of effective tools, travel constraints, organizational and cultural barriers, fear, and lack of trust, must be minimized.

NIAT-16 Action Summary

NASA should continue to remove communication barriers and foster an inclusive environment where open communication is the norm.

Recommendation Reference: MCO-4, 5, 8, 12, 13, 14; FBC-12; MPIA-18, 27; SIA-1

NIAT-16 Action: Continue to remove communication barriers and foster an inclusive environment where open and candid communication are the norm [***AE***, F, FT, Center Directors ,Project Managers; 6/01].

Minimum Elements:

A. Emphasize the importance of communication by developing a strategy similar to the NASA Safety Initiative to permeate the workforce culture.
B. Acquire expert advice and consultation on root causes and potential barriers to communication throughout the NASA organization.
C. Enhance PMDP competencies to include communication skills and best practices training.
D. Discuss with teams findings of the NASA Project Team Development study and utilize self-assessment tool available across the Internet, especially the effective communications indicator.
E. Consider implementation of feedback mechanisms (such as 360-degree appraisals) so employees can provide input on leader’s effectiveness in communication.
F. Hold periodic symposia to openly discuss issues, program status, and to highlight successful practices.
G. Educate all managers on the importance of totally supporting team members.
H. Expand development and implementation of training process for team facilitation to build more internal communication facilitators.

Figure 17. Organizational Communication.

The objective of this action is to establish an initiative similar to the Agency Safety Initiative where the importance of communication and a culture of trust and openness permeate all facets of the organization. Multiple processes to get the messages across the organizational structure need to be explored and encouraged. In addition, avenues to clearly define and communicate roles and responsibilities to all need to be developed. The Agency should solicit expert advice in identifying and removing barriers; provide tools, training and education; and the means to facilitate the communication process.

NIAT-17: Knowledge Management

Current State

NASA has long recognized the importance of managing its corporate knowledge. The processes of generating and communicating NASA's knowledge are considered core processes that cut across organizational boundaries. NASA has made strides toward improving the way in which knowledge is captured, organized, and stored. A NASA Knowledge Management (KM) Team, chartered by the Chief Information Officer with members from multiple disciplines, has been formed to develop an approach to KM. NASA has a set of KM activities led by this team, including some pilot projects. These pilots focus on:

- Increasing access to and archiving of information within communities across the Agency through customized portals,
- Improving the capture and reuse of lessons learned by augmenting the current Lessons Learned Information System (developed by NASA's SMA), and
- Locating experts across NASA.

In addition to the KM team's efforts, the Academy of Program/Project Leadership (APPL) has several KM efforts that are in their early stages of implementation. APPL's Project Management Coach online site includes guidance, points of contact, samples, templates, and training information on a variety of topics. APPL also provides a number of mechanisms for program and project managers to share experiences and knowledge through training classes and other forums.

Although NASA's efforts so far are commendable, the Agency must go further. In the current environment, effective management and sharing of knowledge is more critical than ever. The experience of prior managers is not uniformly well documented and made available for the benefit of newer or less experienced program and project managers to effectively utilize in their situations.

The report findings indicate a lack of access to and process for using lessons learned. Continuous knowledge capture was cited as necessary to promote communications and learning. In addition, checklists were recommended to facilitate the management and review of programs and projects.

NIAT-17 Action Summary

Promote the continuous capture, dissemination, and utilization of knowledge.

Recommendation Reference: MCO-15, 48, 55, 56, 68, 79; FBC-24, 25, 26, 27, 28, 29

NIAT-17 Action: Promote the continuous capture, dissemination and utilization of knowledge and make checklists available to support project managers. [***AO***, FT, Q, AE, Center Directors; 6/01].

Minimum Elements:

A. Develop, with customers, a new lessons learned tool to effectively capture and utilize lessons learned including:
   - Definition of the information (lessons and the project environment) that is relevant to the current environment.
   - Determination of how to capture and organize information for ready access
     - Reduce overhead and improve timeliness of posting.
     - Include mechanism for rapidly developing information in a useful and interesting format.
   - Identify external organizations which excel in knowledge management and determine best practices.
   - Select a pilot project to test and refine criteria, including a customer assessment
   - Address the cultural and process changes needed to encourage and reward knowledge sharing.
   - Incorporate into relevant training.

B. Capture checklists in LLIS database and APPL online tools to facilitate ready reference for project teams and independent reviewers.

Figure 18. Knowledge Management.

Better alignment of NASA's knowledge base with the needs of the Agency and its program and project managers, as well as its technical personnel, is required. NASA must ensure that its KM tools facilitate the capture of effective and appropriate information that can be reused in a beneficial way. Examples of the useful application of KM tools include:

- Providing tools and training to make the formal process for reporting problems and anomalies user friendly,
- Continuing Agency lessons learned symposia and working groups, and
- Maintaining a database of lessons learned and infusing the knowledge gained into the daily routines of NASA personnel.

The information gained in these KM activities will help NASA to understand how it can more aggressively proceed with managing and sharing its knowledge among employees and with external partners. The desired end-state is for NASA to become a true community of learning, where knowledge is used to help the Agency and its partners learn and progress. In order to achieve this, NASA must strive to promote a culture of knowledge sharing throughout the organization.

A primary mechanism for the promotion of knowledge management within the Agency will be improved lessons learned tools, developed in coordination with users of the system that draw on improved data base technology using advanced search engines. Three critical aspects are needed to ensure the success of the improved tool: input of new lessons learned information, knowledge of the environment and applicability of the lesson, and review of past lessons learned by programs and projects that will lead to changes in behavior. The system will capture lessons learned information from programs, projects, and missions, with the goal of ensuring that NASA does not have to keep “relearning” the lessons of the past. Further, the lessons learned system and process will be designed to affect changes in day-to-day operations and mission activities through ease of access and well organized information. For example, the application of previous lessons learned might lead to changes in current procedures, standards, and information management techniques in a new mission or project. The key to success in the application of lessons learned is communicating the lessons to people who will benefit from them.

To ensure successful deployment of the lessons learned tool, it will be developed first as a pilot project, allowing system users to provide feedback on the effectiveness of the system and the knowledge capture process. This pilot will also provide an opportunity to infuse lessons into everyday processes and systems. It will be important to avoid broadcast transmission of every lesson learned to every manager; targeting of communications to the appropriate persons will be crucial.

The lessons learned tool will constitute only one dimension of NASA’s expanded focus on KM. The Agency will benchmark other organizations that excel in the ability to share internal knowledge to provide measurable improvements. The Agency’s KM initiative will also identify best practices with applicability to the NASA environment. To bring about true change, NASA will promote an atmosphere of knowledge sharing in its formal and informal cultures and work processes, and reward the open dissemination and sharing of information. Finally, NASA will ensure that KM concepts in general, and the use of the lessons learned system in particular, are incorporated into Agency training classes and programs.

The continuous capture and application of project knowledge and lessons learned must become a core business process within the Agency’s program and project management environment. Regular input into NASA’s knowledge bases, such as the lessons learned database, should be emphasized. Programs and projects should implement a “document-as-you-go” philosophy, promoting continuous knowledge capture for the benefit of current and future missions. More importantly, program and project managers must regularly utilize the knowledge management tools to apply previous lessons learned to their own projects. The Agency can provide help for individuals to understand, learn from, and apply the lessons of others to their own work as part of a daily routine.

The NIAT recommends that checklists from the MCO report and others be made available to management and project teams. If readily available, Center management, project management, and others can develop project-unique checklists as an aid to internal and external communication. NIAT does not recommend an Agency-level requirement for the generation of checklists. The tendency could be to focus on the list exclusively and not be as aware of new issues as they arise.

Other Recommendations Assessed

Eleven recommendations considered by NIAT were found to be adequately addressed by existing NASA policy, policy changes in process, organizational changes already completed, and budgets already proposed. These recommendations and a description of the NIAT assessment are provided in Figure 19.

Recommendations Requiring No NIAT Action: FBC-13,16, 38, 45; MCO-20, 31, 33, 70; SIA-7, 18, 22,

- FBC 13 Continually evaluate the effectiveness of NASA policies, rules, procedures, etc., like what is being accomplished for NPG 7120.5.
  – In ISO formal process now in place at HQ and Centers. Specific issues addressed in other NIAT actions.
- FBC 16 Ensure that Programs and Projects develop the cost and schedule caps commensurate with mission scope by working their estimates from the bottom up with all members of the team participating, who then own the Project Plan.
  – Included in proposed changes in NPG 7120.5B 2.1.1.2.c; 3.1.1.2.b; 4.1.1; 4.3
- FBC 38 Form a Technology Office led by a results-oriented Chief Technologist Officer with as much stature and clout as Enterprises.
  - Effective 02/2000, Chief Technologist was also appointed Associate Administrator for Aerospace Technology Enterprise.
- FBC 45 Reduction of launch costs [must be] a national priority to drive FBC.
  - Space Transportation Architecture studies over the past 2 years in close concert with the Administration has produced NASA's Integrated Space Transportation Plan; a $4.5 billion multi-year investment submitted in the President's FY 2001 Budget.
- MCO 20 Define program architecture at the beginning of a program by means of a thorough mission formulation process.
  – See NPG 7120.5, Paragraph 2.1 and E.3.
- MCO 31 Each mission should maintain a formal record of risk factors to mission success in the form of a risk list.
  – See description of the risk management process NPG 7120.5B, 4.2.2.a & b.
- MCO 33 The risk management process should thoroughly address the question of "what could go wrong" early in the project.
  – See description of the risk management process in NPG 7120.5B, 4.2.2.a & b.
- MCO 70 The New Millennium Program or its equivalent should be adequately funded to provide flight testing opportunities.
  - FY01 Budget submission reflects restructured and adequately funded New Millennium Program. Program has been realigned to emphasize technology flight demonstration requirements over science data objectives in project selection.
- SIA 7, 22 Failure analysis and incident investigation should identify root cause and not be artificially limited to a subset of possible causes.
  – See NPG 8621.1.g., "Mishap Reporting and Corrective Action".
- SIA 18 Where redundancy is used to mitigate risk, it should be fully and carefully implemented and verified. If it cannot be fully implemented due to design constraints, other methods of risk mitigation must be utilized.
  – See description of the risk management process in NPG 7120.5B, 4.2.2

Figure 19. Recommendations Assessed by NIAT Requiring no Additional Action.

Conclusions

The NIAT has reviewed and assessed a total of 165 findings of the referenced reports. The product of that assessment is a set of 17 actions that provide an integrated framework for long-term improvement of the planning and execution of NASA's programs and projects. These actions will drive the Agency toward the required state of excellence through a continual improvement process that engages all levels of NASA. Our challenge is to clearly communicate not only the action statements, but also the intent behind them. This report endeavors to do that.

Excellence in communication is essential for the success of this effort, and any other, within the NASA community. Communication is the key ingredient in the understanding and control of prudent risk deemed acceptable in this challenging realm that must be at the forefront now and in the future.

We cannot hope to achieve the ambitious goals of the Strategic Plan without success in our programs and projects and the engagement of the entire team: NASA, contractors, partners, academia, customers, and stakeholders. NASA has a history of achievement. Our ability to continue that legacy is vested in the preparation, support, and performance of an excellent workforce. We must ensure, through careful planning and implementation, that we create the open environment for creativity, innovation, and challenge in which people thrive.

Appendix A—NIAT Membership

Carolyn Griner, Chair
Integration

Robert McBrayer, Orlando Figueroa, Keith Hudkins, Jo Gunderson, Marcus Watkins, Ed Hoffman, Nancy Kaplan

People	Process	Process Execution	Advanced Technology & Tools
Beth McCormick	Michael Greenfield	Richard Day	Andrea Norris
Olga D. Gonzalez-Sanabria	John Whiteley	Norm Haynes	Ron Johnson
Howell Hilton	Randy Taylor	Lia LaPiana	Rob Anderson
Anngie Johnson	Bill Piland	Gary Krier	Greg Reck
Renee Higgins	Lynn Bailets	Larry Schultz	Len Sirota
Tony Maturo	Harvey Schabes	Paul DeMinco	Jeanne Holm
Joanne Mueller	Keith Hudkins	Wally Sawyer	Chuck Smith
Ed Hoffman		Mike Conley	Michael Gilbert
		Jo Gunderson	Nicola Muscettola
			Gordon Johnston
			J.C. Duh
			Stephen Prusha
			Richard Gilbrech

Organizations:

2 Hq AE	2 Hq R	2 GSFC
2 Hq AO	2 Hq S	4 JPL
1 Hq R	1 Hq U/Z	2 JSC
2 Hq F	3 Hq Y	2 KSC
1 Hq H	2 ARC	3 LaRC
1 Hq Q	2 DRFC	4 MSFC
1 Hq M	2 GRC	1 SSC

Appendix B— NIAT Actions Versus Recommendations

Niat No.	Action/Objective	Recommend	Recommendation Text
NIAT-1.1	Provide a physically and psychologically safe and healthy work environment for all NASA	FBC-35	Balance Workload (number and/or scope of projects) to assure safety and rigor in execution
		SIA-4	Work teams should be supported through improved employee awareness of stresses and their effect on health and work, Workload and "overtime" pressures should be mitigated by more realistic planning and scheduling; a serious effort to preserve "quality of life" conditions should be
NIAT-2.1	Ensure that teams are composed of competent personnel through expanded and disciplined use of the PMDP, selecting the right team skills for the project life cycle, and better definition of the roles and responsibilities of the Project Manager as leader of the team.	FBC-6	Promote mobilization of key personnel among Centers and HQ
		FBC-8	Assign the HQ Safety and Mission Assurance Office the responsibility for an Industry/Academia Workshop to effect better NASA teaming arrangement – including contracting and incentives
		FBC-9	Form and motivate an excellent team, a mix of experience and bright energetic youth bringing enthusiasm and new methods
		FBC-35	Balance Workload (number and/or scope of projects) to assure safety and rigor in execution
		MCO-1	Project Managers selected based on experience gained on prior missions
		MCO-2	Provide on-the-job mentoring for Project Managers from experienced managers or retired experts
		MCO-6	Establish and fully staff a comprehensive systems engineering team at the start of each project
		MCO-7	Project Manager to determine and insist on an appropriate level of staffing in-house and at each contractor
		MCO-8	Increase inter-center participation and technology sharing on future projects at the system and subsystem levels, focused around Center of Excellence areas
		MCO-9	Ensure that teams foster an environment of commitment and ownership that team members that don't fit be replaced
		MCO-10	A cohesive team must be developed and involved in the project from inception to completion
		MCO-11	
		MCO-12	
		MCO-14	Roles, responsibilities and accountabilities must be made explicit and clear for all partners on a project and a visible leader appointed over the entire operation
		MCO-23	Assign adequate systems engineers not only at the project level, but also at the overall mission
		MCO-29	Engage operations personnel early in the project, preferably during the mission formulation phase
		MCO-30	The science representatives must be full members of each project's management team throughout the life cycle of the mission

Niat No.	Action/Objective	Recommend	Recommendation Text
NIAT-2.1	Ensure that teams are composed of competent personnel through expanded and disciplined use of the PMDP, selecting the right team skills for the project life cycle, and better definition of the roles and responsibilities of the Project Manager as leader of the team.	MPIA-1	The respective institutions are responsible for assuring that project managers are experienced, fully trained and/or a mentor is assigned to them
		MPIA-2	Ensure that the team has the right skills, is adequately staffed and can work together effectively.
		MPIA-3	Empower the project manager to access Agencywide institutional resources and capabilities to enhance mission success.
		MPIA-6	The project management should have end-to-end responsibility from concept formulation through development and operations for management of the total mission, and the effective assessment and management of risk
		MPIA-9	The Program Office must have the flexibility to realign and to adjust various science, technology, and flight project elements to meet the mission success criteria
		MPIA-14	Institutional management must be accountable for policies and procedures that assure a high level of mission success
		MPIA-15	Institutional management must assure project implementation is consistent with required policies and procedures
		MPIA-26	Scientists must participate in all stages of project formulation and implementation to ensure that science goals are understood and taken fully into account
		MPIA-27	Clear lines of responsibility and authority should be established at the initiation of each project
		SIA-2	Program/projects should assure that critical functional areas be staffed more than one deep
		SIA-4	Work teams should be supported through improved employee awareness of stresses and their effect on health and work, Workload and "overtime" pressures should be mitigated by more realistic planning and scheduling; a serious effort to preserve "quality of life" conditions should be
NIAT-2.2	Improve the hands-on experience, training curriculum and mentoring for project managers and engineers.	FBC-1	Certify Project Managers, and Teams as to experience and expertise
		FBC-2	Conduct the FBC Training Workshops throughout NASA Industry, Academia
		FBC-3	Expand the role and clout of NASA ‘s Academy of Program and Project Leadership
		FBC-4	Generating training material for FBC Training workshops for FBC Project Team leaders and teams which is first subjected to a "dry run" in front of experienced FBC Project managers from each Center, Industry and Academia
		FBC-5	NASA must retain the expertise to do in-house Projects. This "corporate history" represents a sustaining expertise that is the foundation for space exploration.
		FBC-6	Promote mobilization of key personnel among Centers and HQ
		FBC-7	Acquire outside help on cultural change, core competency, and organizational issues

Niat No.	Action/Objective	Recommend	Recommendation Text
NIAT-2.2	Improve the hands-on experience, training curriculum and mentoring for project managers and engineers.	FBC-8	Assign the HQ Safety and Mission Assurance Office the responsibility for an Industry/Academia Workshop to effect better NASA teaming arrangement – including contracting and incentives
		FBC-9	Form and motivate an excellent team, a mix of experience and bright energetic youth bringing enthusiasm and new methods
		FBC-11	Develop "Badges of Courage" for all Projects
		FBC-29	Continue symposiums on lessons learned, re-engineering, information technology cultural change, Teaming, etc., bringing in experts from within/outside NASA
		FBC-35	Balance Workload (number and/or scope of projects) to assure safety and rigor in execution
		MCO-2	Provide on-the-job mentoring for Project Managers from experienced managers or retired experts
		MCO-3	Formal certification training program in Project Management and other key positions such as Chief Systems Engineer, etc.
		MCO-8	Increase inter-center participation and technology sharing on future projects at the system and subsystem levels, focused around Center of Excellence areas
		MPIA-1	The respective institutions are responsible for assuring that project managers are experienced, fully trained and/or a mentor is assigned to them
		MPIA-2	Ensure that the team has the right skills, is adequately staffed and can work together effectively.
		MPIA-3	Empower the project manager to access Agencywide institutional resources and capabilities to enhance mission success.
		MPIA-6	The project management should have end-to-end responsibility from concept formulation through development and operations for management of the total mission, and the effective assessment and management of risk
		MPIA-9	The Program Office must have the flexibility to realign and to adjust various science, technology, and flight project elements to meet the mission success criteria
		MPIA-14	Institutional management must be accountable for policies and procedures that assure a high level of mission success
		MPIA-15	Institutional management must assure project implementation is consistent with required policies and procedures
		MPIA-26	Scientists must participate in all stages of project formulation and implementation to ensure that science goals are understood and taken fully into account
		MPIA-27	Clear lines of responsibility and authority should be established at the initiation of each project
		SIA-2	Program/projects should assure that critical functional areas be staffed more than one deep
		SIA-4	Work teams should be supported through improved employee awareness of stresses and their effect on health and work, Workload and "overtime" pressures should be mitigated by more realistic planning and scheduling; a serious effort to preserve "quality of life" conditions should be

Niat No.	Action/Objective	Recommend	Recommendation Text
NIAT-3.1	Develop and implement a comprehensive plan to ensure excellence in Agency engineering capability, including hands-on work experience, and the development and application of advanced engineering tools and methodologies in an advanced engineering and program/project management environment	FBC-19	Establish upfront agreements and maintain them
		FBC-36	Clearly define and resolve Center Core Competency and Center of Excellence role issues and operations including In-House work policy
		FBC-43	A common multi-Agency Internet Store for high quality, modular, advanced components supplied by multiple vendors a National Priority
		MCO-21	Changes to the baseline should be avoided to the maximum extent possible
		MCO-25	Systems engineer should ensure that project requirements are satisfied throughout the project
		MCO-27	Develop a comprehensive set of mission requirements early in the formulation phase. Perform a thorough flowdown of these requirements to the subsystem level
		MCO-71	Take advantage of useful Integrated Synthesis Environment capabilities as they become available
		MPIA-7	Appropriate levels of systems engineering need to be in place throughout the formulation and implementation phases of all projects
		MPIA-11	A clearly defined mission success criteria needs to be established early for all missions
NIAT-4.1	Invigorate the Agency's current technology investment to ensure that a balanced portfolio of existing, new and emerging technology is	FBC-31	Strengthen NASA HQ Management by assigning a NASA Center champion at NASA HQ to lead a NASA Center Teaming Office to bring NASA into the 21st Century , providing the "champions" as follows: Effective NASA HQ relationships with Centers, Bring NASA into 21st Century, Resolve Core Competency & Center of Excellence Issues and Operations
		FBC-32	Centers to focus on a few core competencies for which they are world class, and rely on other Centers, government agencies, industry and academia for other capabilities
		FBC-36	Clearly define and resolve Center Core Competency and Center of Excellence role issues and operations including In-House work policy
		FBC-37	Place higher priority on funding and supporting University research and advanced development and their space flight Missions
		FBC-38	Form a Technology Office led by a results-oriented Chief Technology Officer – must have as much stature/clout as Enterprises
		FBC-39	Balance research and advanced technology development with focused technology development. Provide "seed corn" for research and advanced development to trigger revolutionary
		FBC-40	Hold yearly "Out of the Box" technology workshops
		FBC-41	Balance competition of technology development with placing stable technology development at NASA Centers of Excellence.
		FBC-45	Reduction of Launch costs a National priority to drive FBC

Niat No.	Action/Objective	Recommend	Recommendation Text
NIAT-4.1	Invigorate the Agency's current technology investment to ensure that a balanced portfolio of existing, new and emerging technology is	FBC-46	Develop a NASA (Integrated) Information Technology Plan and Program that encompasses Intelligent Synthesis Environment, Information Technology, Intelligent Systems, Consolidate Super Computing Management Office, and all related IT activities.
		MCO-64	Adequate funding for technology development aimed at broad Agency needs
		MCO-67	Technology needs should be expediently funded and met prior to project initiation
		MCO-70	The New Millennium program or its equivalent should be adequately funded to provide flight testing opportunities
NIAT-5.1	Strengthen NASA's technology planning process and update the NASA Technology Plan.	FBC-42	Develop a better NASA Integrated Technology (Development) Plan.
		FBC-46	Develop a NASA (Integrated) Information Technology Plan and Program that encompasses Intelligent Synthesis Environment, Information Technology, Intelligent Systems, Consolidated Super Computing Management Office, and all related IT activities.
		MCO-66	Program management should review specific future mission needs and establish technology requirements early
		MCO-69	Technology needs, and risks, should be identified, funded, and met (i.e., risk reduced by increasing TRL to appropriate level) prior to project initiation. The goal should be that by the time a project starts, technology insertion should be low risk. (ATT Recom.)
		MCO-72	Missions should aggressively integrate leading-edge technology that may contribute to reducing cost and project risk. Specific examples are included recommendations MCO-73 through
		MCO-74	Pursue soft-computing software technology, such as neural networks and graphical models, that learn and adapt to changes in the environment.
		MCO-75	Develop autonomous operations and avionics technology, focused on saving operations costs and improving onboard fault detection and recovery.
		MCO-76	Pursue development of leading-edge technologies leading to multifunctional designs that enable cost-cutting measures and improve operating capability.
		MCO-77	Pursue development of leading-edge technologies leading to dramatic weight savings, such as those afforded by advanced propulsion systems and lightweight, smart structures.
NIAT-6.1	Increase the speed and effectiveness of developing and infusing leading-edge technologies into missions.	FBC-40	Hold yearly "Out of the Box" technology workshops
		MCO-66	Program management should review specific future mission needs and establish technology requirements early
		MCO-67	Technology needs should be expediently funded and met prior to project initiation
		MCO-69	Technology needs, and risks, should be identified, funded, and met (i.e., risk reduced by increasing TRL to appropriate level) prior to project initiation. The goal should be that by the time a project starts, technology insertion should be low risk. (ATT Recom.)
		MCO-72	Missions should aggressively integrate leading-edge technology that may contribute to reducing cost and project risk. Specific examples are included recommendations MCO-73 through

Niat No.	Action/Objective	Recommend	Recommendation Text
NIAT-6.1	Increase the speed and effectiveness of developing and infusing leading-edge technologies into missions.	SIA-26	Ensure early involvement of the project team with the technology team to facilitate acceptance and ownership of new technology by the projects.
NIAT-7.1	Improve and enhance NASA and contractor knowledge and the ability to identify, assess, mitigate and track risk through the definition of success criteria, acceptable risk, utilization of existing and new tools, and proper policy and guidance.	FBC-19	Establish upfront agreements and maintain them
		FBC-21	Define "Allowable Risk" as function of Program/Project
		FBC-44	Develop advanced tools to assess, analyze, manage, and mitigate risk.
		MCO-18	All critical flight phases be fully instrumented to support detailed real-time and post-flight analysis
		MCO-19	Establish a concise set of mission-success criteria early in the project life cycle
		MCO-21	Changes to the baseline should be avoided to the maximum extent possible
		MCO-22	Insertion of a new project definition phase, after the prime contractor is selected for a project, allows for a thorough reassessment of cost, schedule, content and risk prior to baselining
		MCO-24	Continually perform system analyses necessary to explicitly identify mission risks and communicate these risks to all segments of the project team and institutional management
		MCO-25	Systems engineer should ensure that project requirements are satisfied throughout the project
		MCO-27	Develop a comprehensive set of mission requirements early in the formulation phase. Perform a thorough flowdown of these requirements to the subsystem level
		MCO-31	Each mission should maintain a formal record of risk factors to mission success, in the form of a risk list
		MCO-32	Failure Mode and Effects Analysis, fault Tree Analysis and Probabilistic Risk Assessment tools should be used to develop quantitative risk estimates
		MCO-33	The risk management process should thoroughly address the question of "what could go wrong" early in the project
		MCO-34	Identify and control risk from the start of each project by tracking the overall risk profile over the course of the project
		MCO-35	The mission risk profile should become a part of each project plan and the risk profile should be reviewed at all periodic center and external reviews
		MCO-36	A team should be formed to refine the implementation of risk profile management techniques
		MCO-37	Acceptable risk must be defined and quantified, wherever possible, and disseminated throughout the team and the organization to guide all activities in the context of Mission Success First

Niat No.	Action/Objective	Recommend	Recommendation Text
NIAT-7.1	Improve and enhance NASA and contractor knowledge and the ability to identify, assess, mitigate and track risk through the definition of success criteria, acceptable risk, utilization of existing and new tools, and proper policy and guidance.	MCO-37	Acceptable risk must be defined and quantified, wherever possible, and disseminated throughout the team and the organization to guide all activities in the context of Mission Success First
		MCO-39	Projects and line organizations need to be extremely vigilant to ensure that a Mission Success First attitude propagates through all levels of the organization
		MPIA-4	Risk must be assessed and accepted by all accountable parties, including senior management, program management, and project management
		MPIA-5	All projects should utilize established risk management tools such as fault tree analysis and failure effects and criticality analysis
		MPIA-8	Each involved organization should establish a policy requiring telemetry data and coverage through mission-critical events
		MPIA-11	A clearly defined mission success criteria needs to be established early for all missions
		MPIA-13	Senior management needs to establish that risk associated with new high-return technology and innovation is acceptable as is risk associated with pursuing high-value science. Risk associated with deviating from sound management and engineering principles is unacceptable
		MPIA-19	Contractor responsibilities must include formal notification to the customer of project risk and deviations from acceptable practice
		SIA-9	Quantitative methods of risk assessment (likelihood of failure) should be developed
		SIA-10	Risk assessment matrix and Failure Modes and Effects Analysis should be updated based on flight failure experience, aging and maintenance history, and new information
		SIA-12	Quantitative methods of risk assessment and safety need to be integrated to develop the ability to perform trade-off studies on the effect of new technology, aging, upgrades, process changes, etc., upon vehicle risk
		SIA-15	NASA and NASA contractors should develop a Risk Management Plan and guidance for communicating risk as an integrated effort
		SIA-16	The Risk Management Plan would flow SSP expectations for risk management down to working level engineers and technicians, and provide insight and references to activities conducted to
		SIA-18	Where redundancy is used to mitigate risk, it should be fully and carefully implemented and verified. If it cannot be fully implemented due to design constraints, other methods of risk mitigation must be utilized
		SIA-22	Failure analysis and incident investigation should identify root cause and not be artificially limited to a sub-set of possible causes
NIAT-8.1	Improve NASA Safety and Mission Assurance to provide life cycle rigor in the formulation and implementation of flight systems.	FBC-15	Expand Safety and Mission Assurance responsibilities at NASA HQ and at the Centers for verifying: Team Certification, Risk Signatures, FBC Performance Metrics, Project Readiness for Start, Launch Operations, Compliance to FBC Lessons Learned

Niat No.	Action/Objective	Recommend	Recommendation Text
NIAT-8.1	Improve NASA Safety and Mission Assurance to provide life cycle rigor in the formulation and implementation of flight systems.	MCO-26	A strong mission assurance function should be present in all project phases
		SIA-7	The Safety & Mission Assurance role should include: mandatory participation on Prevention/Resolution Teams and in problem categorization, investigation of escapes and diving catches and dissemination of lessons learned
		SIA-17	Quantitative measures of safety (likelihood of error), including assessment surveying techniques should be developed, e.g., Occupational Stress Inventory and Maintenance Error Decision Aid
		SIA-19	NASA Safety and Mission Assurance oversight should be increased
NIAT-9.1	Revolutionize the process of developing and delivering safe, reliable, quality software and improve transfer of new software methods and tools into NASA practice.	MCO-28	The definition of mission-critical software for both ground and flight must be rigorous to allow the software development process to provide a check-and balance system
NIAT-10.1	Define and rigorously implement a refined and reinvigorated NASA Integrated Review Process for Programs/Projects, which will: – Clarify an integrated continuum of reviews and associated rollup of value-added review products – Specify required reviews and classes of reviews for tailoring by Enterprise/Center/Program/Project including “peer” and "independent” reviews – Clarify objectives and expectations for each review/review class – Identify the review “customer” and specify participants, roles, and responsibilities – Address independence and expertise requirements for reviewers; continuity and discipline area penetration assignments of	FBC-17	Establish better reality checks of the feasibility of implementing the Program/Projects for the resources allocated
		FBC-22	Consolidate all Independent Review objectives into one Independent Review per year for all Programs and Projects
		FBC-23	Ensure Careful upfront peer reviewed planning, design, and implementation.
		MCO-41	The choice in choosing the right experts to participate in reviews should be open to outside input as well as the project manager
		MCO-42	That a review no longer be checked off until the right people have participated
		MCO-43	Peer review results should be presented at all external reviews
		MCO-44	Standing external review boards should be appointed for each project, thereby ensuring continuity and greater familiarity with the subject matter
		MCO-45	Rigorous discipline must be enforced in the review process. Key reviews should have proper skill mix of personnel for all disciplines involved in the subject matter under review.

Niat No.	Action/Objective	Recommend	Recommendation Text
NIAT-10.1	Define and rigorously implement a refined and reinvigorated NASA Integrated Review Process for Programs/Projects, which will: – Clarify an integrated continuum of reviews and associated rollup of value-added review products – Specify required reviews and classes of reviews for tailoring by Enterprise/Center/Program/Project including “peer” and "independent” reviews – Clarify objectives and expectations for each review/review class – Identify the review “customer” and specify participants, roles, and responsibilities – Address independence and expertise requirements for reviewers; continuity and discipline area penetration assignments of	MCO-46	The external review process should include the reporting of the incidents, surprises, anomalies and other issues.
		MCO-47	Support from other centers for review teams should be increased. (Per 4/13 Telecon)
		MCO-49	Funding and schedule allocations for executing reviews and implementing recommendations resulting from reviews should be baselined at the start of the project. (Per 4/13 Telecon)
		MCO-51	Final end-to-end verification and validation of all mission-critical operational procedures must be performed
		MCO-52	All parties should make use of the project's established problem-reporting system to ensure resolution of all issues raised during reviews. (Per 4/13 Telecon)
		MCO-58	Before every launch, a full operations team should be assembled and trained in both nominal a and contingency operational scenarios
		MCO-60	A core set of operations personnel should be assigned to each project at its start
		MCO-61	A core set of development personnel should be defined for transition to support operations
		MCO-62	Appoint a deputy project manager for operations at the beginning of the project to ensure that trade studies properly consider the development and operations phases of the mission
		MCO-63	A core group of system developers and systems engineering personnel should assist the operations team in developing nominal and contingency procedures, mission rules and operational
		MPIA-17	Ensure that the best people are available and provide continuity through the review process. The team should be comprised of a combination of experienced experts and talented less
		MPIA-21	Conduct thorough technical and programmatic reviews beginning at the lowest levels of assembly and subsystem, and through the full up system.
		MPIA-22	All issues identified in programmatic and technical reviews must be tracked to the highest levels to ensure complete, timely and accurate closure.
		MPIA-24	Review teams should strive for continuity through the project life cycle

Niat No.	Action/Objective	Recommend	Recommendation Text
NIAT-10.1	Define and rigorously implement a refined and reinvigorated NASA Integrated Review Process for Programs/Projects, which will: – Clarify an integrated continuum of reviews and associated rollup of value-added review products – Specify required reviews and classes of reviews for tailoring by Enterprise/Center/Program/Project including “peer” and "independent” reviews – Clarify objectives and expectations for each review/review class – Identify the review “customer” and specify participants, roles, and responsibilities – Address independence and expertise requirements for reviewers; continuity and discipline area penetration assignments of	MPIA-25	Competent and efficient reviews of projects by experts from outside the projects and outside the implementing institutions should provide overall assessment of the projects and a thorough evaluation of risks
		SIA-20	An independent review process, utilizing NASA and other experts, should be institutionalized
NIAT-11.1	Ensure provision of adequate program and project resources throughout the life cycle.	MCO-17	Programs should be sufficiently funded to ensure mission and program success
		MPIA-12	Ensure that projects have adequate cost, schedule, and performance margins against the agreed upon baseline to meet the mission success criteria.
NIAT-12.1	Define “Faster, Better, Cheaper” and incorporate into NPG 7120.5	FBC-20	Define FBC and the application of it
NIAT-13.1	Ensure that programs and projects receive adequate surveillance based on risk knowledge and that there is ample opportunity for the communication of issues and concerns.	FBC-18	Treat "all" NASA work like Projects, including advanced development activities. Research schedule can be produced which targets periodic Peer Review assessing relevance and possible need for new direction
		FBC-30	Reporting requirements and processing and reporting procedures should be reviewed for ambiguities, conflicts, and omissions, and the audit or review of system implementation should be
		FBC-33	Address impact of erosion of Industry Capability and the balance of Government and Industry responsibilities and Oversight while allowing innovation to take place
		FBC-34	Maintain open communication relative to Risk and Effective Control of Resources (balance of sound Technical, Cost, Schedule)
		MCO-16	Representative of the program office periodically review all mission-related decisions
		MCO-40	A proper balance of contractor and project oversight by technical divisions at NASA field centers is required to ensure mission success and to develop a sense of ownership of the project by the institution
		MPIA-10	Ensure senior management is engaged in supporting project planning and execution
		MPIA-16	NASA Headquarters and Program management should have frank discussions when identifying objectives, requirements, constraints, and risk assessment throughout all phases of the program

Niat No.	Action/Objective	Recommend	Recommendation Text
NIAT-13.1	Ensure that programs and projects receive adequate surveillance based on risk knowledge and that there is ample opportunity for the communication of issues and concerns.	MPIA-22	All issues identified in programmatic and technical reviews must be tracked to the highest levels to ensure complete, timely and accurate closure.
		MPIA-23	Ensure that the appropriate level of oversight is employed on all projects
NIAT-14.1	Ensure that all projects plan and execute a thorough verification and validation (V&V) program for hardware, software and hardware/software systems.	MCO-50	From the simplest component or module to the most complex system, end-to-end verification and validation conducted via simulation or testing of hardware/software must be structured to permit tractability and compliance with mission and derived requirements
		MCO-51	Final end-to-end verification and validation of all mission-critical operational procedures must be performed
		MCO-53	Conduct extensive testing and simulation in conditions and environments as similar to actual flight conditions as possible
		MCO-54	Integrated tests across subsystems should be planned early in the project, using breadboards, development hardware and simulations
		MCO-57	Hardware/software integration tests should be performed using preliminary software drops to identify integration issues early in code development
		MCO-59	The operation team should use high-fidelity simulators to perform end-to-end simulations to validate all nominal and contingency procedures, assess system performance and demonstrate mission preparedness
		MPIA-20	Plan and execute a thorough verification and validation program starting with the lowest levels of assembly and through the full up system.
		MPIA-28	Perform independent verification and validation of critical elements (through test and analysis), including non-testable conditions (through thorough analysis).
		SIA-21	Testing must be carefully scrutinized to ensure adequate simulation of operating conditions, applicability to multiple sub-system, and complete documentation of results
NIAT-15.1	Ensure that Center senior and line management understand and effectively exercise their continual role in supporting Project Managers and Project Teams	FBC-10	Implement more effective NASA HQ relationships with the Centers
		MCO-14	Roles, responsibilities and accountabilities must be made explicit and clear for all partners on a project and a visible leader appointed over the entire operation
		MCO-38	The line organization managers and project managers be held equally accountable for the success or failure of a mission, within their appointed area of expertise
		MPIA-1	The respective institutions are responsible for assuring that project managers are experienced, fully trained and/or a mentor is assigned to them
		MPIA-3	Empower the project manager to access Agencywide institutional resources and capabilities to enhance mission success.
		MPIA-14	Institutional management must be accountable for policies and procedures that assure a high level of mission success

Niat No.	*Action/Objective*	*Recommend*	*Recommendation Text*
NIAT-15.1	Ensure that Center senior and line management understand and effectively exercise their continual role in supporting Project Managers and Project Teams	MPIA-15	Institutional management must assure project implementation is consistent with required policies and procedures
		SIA-1	Communications between the rank and file work force, supervisors, engineers and management should be improved
NIAT-16.1	Continue to remove communication barriers and foster an inclusive environment where open and candid communication are the norm.	FBC-12	Foster an environment where open, candid, thorough communications can take place by the FBC
		MCO-4	Ensure that teams maintain full communication with contractors and scientists without institutional or geographical barriers
		MCO-5	Workers should be trained to detect, broadcast, interpret and elevate problems to the highest level necessary until resolved
		MCO-8	Increase inter-center participation and technology sharing on future projects at the system and subsystem levels, focused around Center of Excellence areas
		MCO-12	Project Managers to foster an environment where problems are raised without fear of reprisal
		MCO-13	Communications meetings must be regular and frequent, and attendance must be open to the entire project team, including contractors and science elements
		MCO-14	Roles, responsibilities and accountabilities must be made explicit and clear for all partners on a project and a visible leader appointed over the entire operation
		MPIA-18	Senior management must be receptive to communications of problems and risks
		MPIA-27	Clear lines of responsibility and authority should be established at the initiation of each project
		SIA-1	Communications between the rank and file work force, supervisors, engineers and management should be improved
NIAT-17.1	Promote the continuous capture, dissemination and utilization of knowledge and make checklists available to support project managers.	FBC-24	Maintain database of lessons learned and communicate widely
		FBC-25	Consolidating the findings of this report with the Mars Program and Mars Climate Orbiter Investigation Reports, deriving composite FBC Project Lessons Learned, FBC Rules of Engagement and Project Implementation check lists
		FBC-26	Integrate Rules of Engagement Metric into regular review and reporting process for Programs and Projects
		FBC-27	Assign JPL the responsibility of conducting a NASA-Wide Methods Working Group to share and to further evolve re-engineering products. Use the NASA FBC Task Center Representatives already established.
		FBC-28	Keep lessons learned in front at all times and provide mentoring by experienced personnel
		FBC-29	Continue symposiums on lessons learned, re-engineering, information technology cultural change, Teaming, etc., bringing in experts from within/outside NASA

Niat No.	Action/Objective	Recommend	Recommendation Text
NIAT-17.1	Promote the continuous capture, dissemination and utilization of knowledge and make checklists available to support project managers.	MCO-15	Team members properly document lessons learned following a key mission event
		MCO-48	The projects should implement an "document-as-you-go" philosophy throughout the life cycle of the project to promote continuous knowledge capture
		MCO-55	Every negative response to a checklist question should be tracked from reporting to closure via action items, which have an associated timetable for resolution
		MCO-56	The checklist composed by the Mars Climate Orbiter Mishap Investigation Board should become apart of the project management process.
		MCO-68	Provide tools and training to make the formal process for reporting incidents, surprises and anomalies user-friendly
		MCO-79	The checklist should be maintained, expanded and shared
z-NAR		FBC-13	Continually evaluate the effectiveness of NASA policies, rules, procedures, etc. – like being accomplished for NASA 7120.5A
		FBC-16	Ensure that Programs and Projects develop the cost and schedule caps commensurate with mission scope by working their estimates from the bottoms up with all members of the team participating , who then own the Project Plan
		FBC-38	Form a technology office led by a results-oriented Chief Technologist Officer with as much stature and clout as Enterprises
		FBC-45	Reduction of Launch costs [must be] a National priority to drive FBC
		MCO-20	Define program architecture at the beginning of a proram by means of a thorough mission formulation process.
		MCO-31	Each mission should maintain a formal record of risk factors to mission success, in the form of a risk list.
		MCO-33	The risk management process should thoroughly address the question of "what could go wrong" early in the project.
		MCO-70	The new Millennium Program or its equivalent should be adequately funded to provide flight testing opportunities
		SIA-7	Failure analysis and incident investigation should identify root cause and not be artificially limited to a sub-set of possible causes
		SIA-18	Where redundancy is used to mitigate risk, it should be fully and carefully implemented and verified. If it cannot be fully implemented due to design constraints, other methods of risk mitigation must be utilized.
		SIA-22	Failure analysis and incident investigation should identify root cause and not be artificially limited to a sub-set of possible causes

Appendix C—Acronyms

ADA	Associate Deputy Administrator
AE	Office of the Chief Engineer
AM	Office of the Chief Health and Medical Officer
AO	Office of the Chief Information Officer
APPL	Academy of Program and Project Leadership
ARC	Ames Research Center
ASAP	Aerospace Safety Advisory Panel
ATT	Advanced Tools and Technology Team
B	Office of the Chief Financial Officer
C	Office of Headquarters Operations
CIC	Capital Investment Council
CMM	Capability Maturity Model
CoFR	Certification of Flight Readiness
DRFC	Dryden Flight Research Center
EAA	Enterprise Associate Administrator
EAP	Employee Assistance Program
ELV	Expendable Launch Vehicle
EMC	Engineering Management Council
EO	Equal Opportunity
F	Office of Human Resources and Education
FAR	Federal Acquisition Regulation
FBC	Faster, Better, Cheaper
FMEA	Failure Mode Effects Analysis
FRR	Flight Readiness Review
FT	Training and Development Division
FTA	Fault Tree Analysis
FY	Fiscal Year
GPMC	Governing Program Management Council
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
H	Office of Procurement
HPCC	High Performance Computing Capability
HQ	NASA Headquarters
IDP	Individual Development Plan
IS	Intelligent Systems
ISO	International Standards Organization
ISE	Intelligent Synthesis Environment
ISS	International Space Station
IT	Information Technology
IV&V	Independent Verification and Validation
JPL	Jet Propulsion Laboratory

JSC	Johnson Space Center
KM	Knowledge Management
KSC	Kennedy Space Center
LaRC	Langley Research Center
LLIS	Lessons Learned Information System
M	Office of Space Flight
MCO	Mars Climate Orbiter
MEDA	Maintenance Error Decision Aid
MPIA	Mars Program Independent Assessment
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NIAT	NASA Integrated Action Team
NPD	NASA Policy Directive
NPG	NASA Procedures and Guidelines
NRA	NASA Research Announcement
PM	Program/Project Manager
PMCWG	Program Management Council Working Group
PMDP	Project Management Development Process
PRA	Probabilistic Risk Assessment
Q	Office of Safety and Mission Assurance
QRAS	Quantitative Risk Assessment System
R	Office of Aerospace Technology
R-CT	Office of Aerospace Technology- Chief Technologist
RFP	Request For Proposal
RM	Risk Management
S	Office of Space Science
SIA	Shuttle Independent Assessment
SMA	Safety and Mission Assurance
SMO	System Management Office
SOW	Statement of Work
SSC	Stennis Space Center
SSP	Space Shuttle Program
TLC	Technology Leadership Panel
TRL	Technology Readiness Level
U	Office of Life and Microgravity Sciences and Applications (now Office of Biological and Physical Research)
Y	Office of Earth Science
Z	Office of Policy and Plans
V&V	Verification and Validation