NASA AEROSPACE PYROTECHNICALLY ACTUATED SYSTEMS

PROGRAM PLAN

National Aeronautics and Space Administration

Technical Standards Division
Office of Safety and Mission Quality
NASA Headquarters
Washington, DC 20546

February 1992

AEROSPACE PYROTECHNICALLY ACTUATED SYSTEMS PROGRAM PLAN

FOREWORD

This Plan identifies the activities to be accomplished by the NASA Aerospace Pyrotechnically Actuated Systems Program. The Plan defines efforts required to improve NASA's capabilities to design, develop, manufacture, and test pyrotechnically actuated systems used on NASA's programs. It responds to the issues raised by the NASA/DOD Aerospace Pyrotechnic Systems Steering Committee as presented in Appendix A. The actual projects undertaken by the Program, however, will be determined by the authorized funding level. Thus, the program actually implemented may not address all of the issues that have been raised. Therefore, projects are to be prioritized to address NASA's most critical needs.

The Program Plan is the top level controlling document for the Program. As such it forms the general structure upon which more detailed supporting tasks can be conducted. The program will be executed under the Program Implementation Plan (PIP), a second level detailed management document, requiring approval of the NASA Headquarters Program Manager, NASA Pyrotechnically Actuated Systems Program, Technical Standards Division. This will be a more detailed document that serves as the working plan. The Field Installations are to provide the Program with the necessary field resources to implement the Program's goals and to support the program management. The field resources include personnel, facilities, and travel costs on a priority basis.

Prepared by:

Norman R. Schulze

February 6, 1992
date

Norman R. Schulze, Program Manger
NASA Pyrotechnically Actuated Systems Program
Office of Safety and Mission Quality
NASA Headquarters

Approved by:

Daniel R Mulville

2/28/92
date

Daniel Mulville, Director
Technical Standards Division
Office of Safety and Mission Quality
NASA Headquarters

ii blank

TABLE OF CONTENTS

1.0 PURPOSE AND SCOPE

1.1 PURPOSE

The NASA Aerospace Pyrotechnically Actuated Systems (PAS) Program, a focused technology program, is being initiated to enhance the reliability, safety, and performance of pyrotechnically actuated systems. In broad terms, this Program Plan presents the approach that helps to resolve concerns raised by the NASA/DOD/DOE Aerospace Pyrotechnic Steering Committee, Appendix A.3. This Plan reflects key efforts needed in PAS technology. The resources committed to implement the Program will be identified in the PIP. A top level schedule is included along with major Program milestones and products. Responsibilities are defined in the PIP.

The Plan identifies the goals (Section 2.0) and detailed objectives (Section 3.0) which define how those goals are to be accomplished. The Program will improve NASA's capabilities to design, develop, manufacture, and test pyrotechnically actuated systems for NASA's programs. Program benefits include the following:

- Advanced pyrotechnic systems technology developed for NASA programs,
- Hands-on pyrotechnic systems expertise,
- Quick response capability to investigate and resolve pyrotechnic problems,
- Enhanced communications and intercenter support among the technical staff, and
- Government-industry PAS technical interchange.

The PAS Program produces useful products that are of a broad-based technology nature rather than activities intended to meet specific technology objectives for individual programs.

Four Program Elements have been established to accomplish the Program's goals and objectives. Within the Program Elements, necessary projects have been defined (Sections 4.0 and 5.0) to meet the Program Element objectives. These projects are structured to:

- assess NASA's pyrotechnic systems requirements periodically,
- improve design approaches,
- develop and characterize standardized hardware designs,
- develop improved test methods and approaches,
- understand more fully the intrinsic internal operational modes of pyrotechnic devices,
- characterize performance limitations,
- establish the effects of pyrotechnic device design and manufacturing variables on system performance, and
- advance applied PAS technology.

The deliverables that this Plan will provide are: recommended policies, improved design methods, specifications for standard hardware designs, system technical specifications, test approaches and methods, a data base, workshops, manuals, and catalogs.

The products from this program will provide guidance for NASA project and program managers. Furthermore, the Plan will provide for the timely identification of future technical needs in terms of PAS hardware development and will provide the formal basis for proceeding with the technical work. Recommendations for technology improvements will be coordinated with the affected NASA Headquarters program offices. Lastly, conducting this focused technology program will foster closer interactions and intercenter collaboration among the pyrotechnic staff.

1.2 SCOPE

The overall scope of the Program includes pyrotechnic devices, ground and flight programs, standards developments, and near term and far term program applications. All aspects of NASA aerospace pyrotechnic system activities that are essential for safe and reliable performance during ground and flight operations are to be addressed.

The types of Program activities encompass analysis, design, fabrication, testing, modeling, training, sponsorship of symposia or workshops, and the preparation of reports and other documentation.

For purposes of this plan, "pyrotechnically actuated systems" include not just pyrotechnic devices as separate entities but also those interfacing elements which could cause the pyrotechnic device itself to malfunction or to which the pyrotechnic systems could produce an otherwise unwanted effect. The Program will determine the system level performance that pyrotechnically actuated system designs are capable of meeting or delivering. The PAS Program is, for example, concerned with the initiation firing circuitry to establish reliability and performance characteristics under alternative power levels. Other system level operational aspects could include the following:

- Perform analyses and test confirmations that the proper ignition energy will be applied at the proper level and rate to assure that ignition and device function will reliably occur.
- Establish effects of the space operational environments that could cause break-up of the pyrotechnic device's charge at device functioning, thereby adversely altering its operational characteristics.
- Investigate the production of detrimental effects to the spacecraft or flight instruments such as shock loads, fragmentation, or chemical contamination from the reaction products.
- Analyze/test to determine whether safe and arm devices fail to unlock, thereby preventing the pyrotechnic device from firing when called upon, and consider/analyze/test whether the safe and arm could activate prematurely.

2.0 GOALS

This Program's basic goals are to:

- reduce program risk due to pyrotechnically initiated systems and
- improve NASA's aerospace pyrotechnic systems technology.

Risk reduction includes those activities that will produce greater potential for mission success, enhance personnel safety, and improve equipment safety. To improve the mission success posture of NASA's aerospace pyrotechnic systems technology, the Program includes projects that will provide NASA with PAS that are well characterized and have higher mass specific performance. The relationship of the Program goals to the Program products is depicted in Fig. 1.

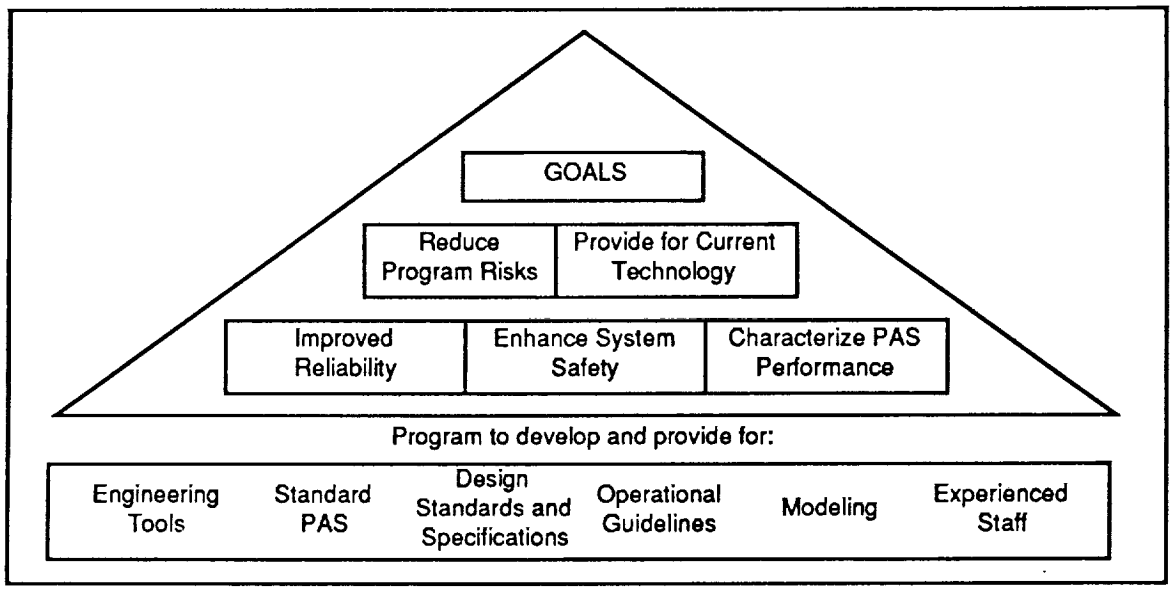

Fig. 1. Program goals and products.

These goals will be accomplished by structuring the PAS technology to:

1. Provide the engineering tools needed by the NASA pyrotechnic engineering staff to perform sound, updated, and advanced technical design approaches to meet pyrotechnic system requirements of NASA's mainline programs.
2. Develop standard pyrotechnic devices having well defined operational characteristics that have been controlled through proper technical specifications.
3. Develop well characterized pyrotechnic system design standards to provide assurance that consistent, high quality practices are employed throughout NASA.
4. Assist manufacturers by better characterizing the effects of variables associated with manufacturing process thereby helping to assure that hardware meets desired performance specifications.
5. Foster intercenter collaboration and provide for a well trained, experienced hands-on pyrotechnic technology engineering staff.

3.0 OBJECTIVES

This Program provides NASA with a focused pyrotechnic systems activity to:

- develop improved design methods, standards, specification, and approaches for pyrotechnically actuated systems,
- make policy recommendations regarding their use, and
- enhance NASA's technical capability in the application of the technology.

PAS technology must be developed into a well-understood science to provide NASA with the desired high quality capabilities in this technical field. In addition, resources must be available in terms of staff, equipment, and funding to properly use the science.

The Program accomplishes its goals by increasing PAS reliability through quality improvements. Quality is achieved by the application of standard designs that have been well authenticated by analysis and verified by qualification testing to the maximum anticipated operational level with a defined and understood margin. Quality is also achieved by designing in margins commensurate with intrinsic sensitivities of device performance to manufacturing tolerances. The attainment of high quality devices requires an understanding of those sensitivities to the manufacturing processes and tolerances. Also important to the program goals is having confidence that the product acceptance test procedures will adequately validate that the manufactured hardware is built per design. The Program's objectives are presented in Fig. 2.

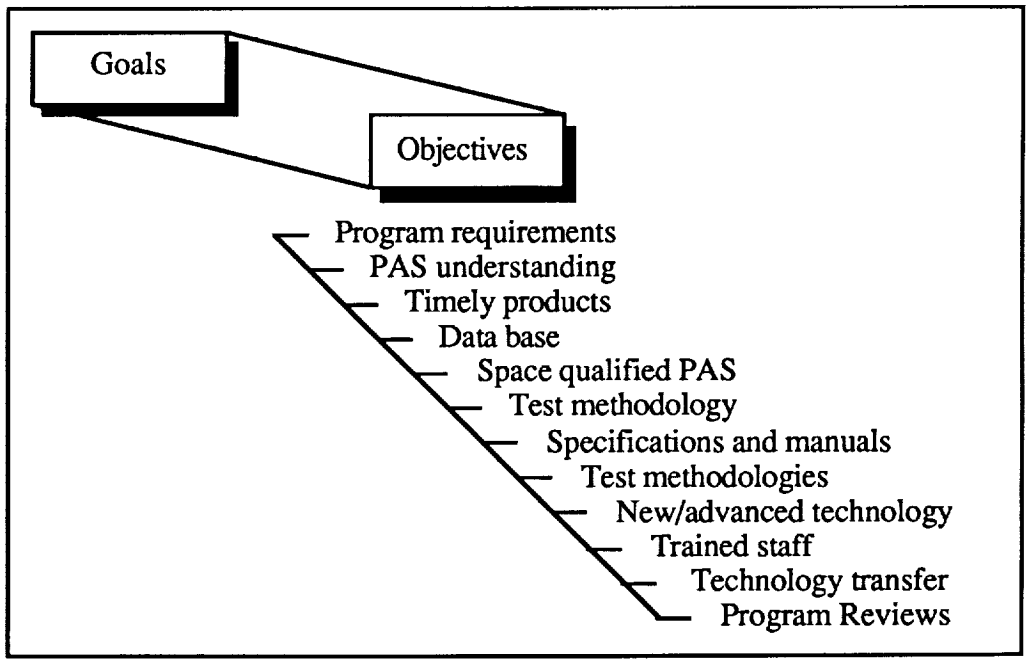

Fig. 2. PAS Program objectives.

This Program contains a comprehensive set of specific objectives to achieve its goals. These objectives are to:

1. Analyze NASA's future program needs in this technology to allow the conduct of a well planned, properly focused program.
2. Assist programs by assuring that dependable pyrotechnically actuated components and systems have been developed, characterized, and demonstrated for use with a minimum of risk, i.e., the Program will undertake projects that:
    a. provide for standardization of components and assemblies,
    b. improve current designs through better understanding of device internal functions,
    c. obtain an understanding of manufacturing processes and quantify the influence of key process parameters on device performance,
    d. conduct device modeling to reduce faults from design and manufacturing processes, and
    e. determine how to properly incorporate margins and/or redundancy into device designs and how to verify margin and redundancy.
3. Make well characterized, reliable advanced pyrotechnic technology hardware design approaches available on a timely basis for the benefit of future NASA programs.
4. Develop and maintain a PAS data base for design and operational aids and to identify areas in need of technology support.
5. Develop specifications with the required level of rigor to assure proper product control.
6. Improve test methodologies as a means to verify device performance upon design completion and to verify its quality conformance to the design upon manufacture.
7. Develop new and advanced technologies to support programs.
8. Ensure that NASA has a well-trained, functional hands-on capability using the latest technology for design tools and approaches to:
    a. attain and maintain the technical expertise for properly managing technical requirements in NASA's contracts which are essential for safety and mission success, and
    b. serve in an independent oversight function.
9. Ensure that proper updated tools are available to perform the necessary hands-on capabilities.
10. Interact with industry to provide and transfer updated technical information.
11. Conduct analyses and perform or sponsor independent technical reviews of pyrotechnic systems installed on flight and ground programs.

4.0 PROGRAM PLAN OVERVIEW

This NASA Aerospace Pyrotechnically Actuated Systems Program Plan is responsive to NASA's anticipated needs for high-performance systems as well as for safe and reliable pyrotechnically actuated systems both for the current program applications and for future program uses. PAS Program management reviews will be accomplished periodically to evaluate status. These reviews will serve to ensure that the stated goals and objectives are achieved on a timely basis, to coordinate interrelated PAS Program efforts, and to enhance technical communication among the affected governmental organizations.

The projects in this Plan insure the development of key PAS technologies and utilization of the Program's products. The plan by which this is to be accomplished is shown in Fig. 3.

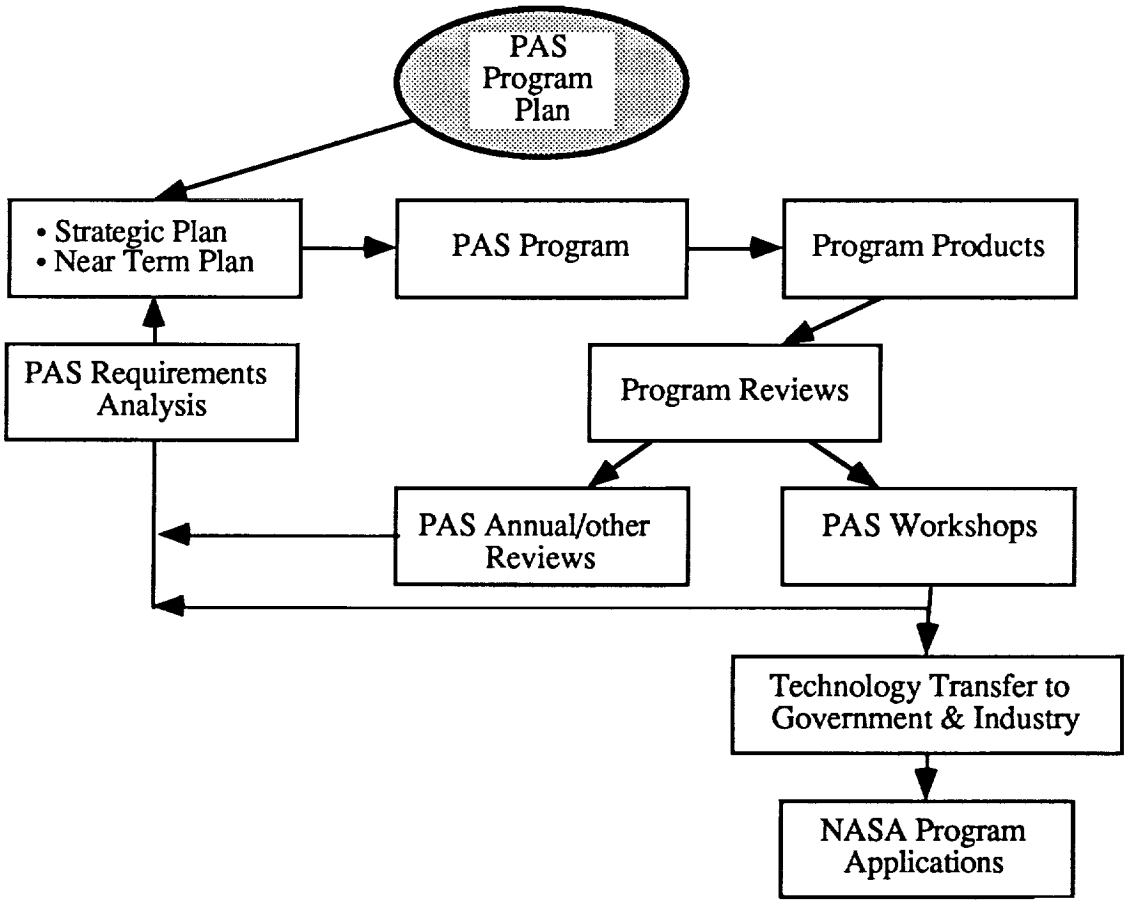

Fig. 3. Plan to assure use of Program products.

The Program Plan is, therefore, formally structured for strategic courses of action and to address near term objectives:

Strategic Plan

1. Assess NASA's overall program requirements for PAS.
2. Increase the number of well-characterized, standardized devices.
3. Improve guidelines and specifications for all aspects of system design, development, qualification testing, check-out testing, and acceptance testing.
4. Plan and implement PAS technology to meet future requirements of NASA's mainline programs.
5. Improve technical communications.
6. Expand and maintain an applied technology and experience base.
7. Provide a training and educational base, including hands-on experience.
8. Assure use of the technology developed.

Near Term Plan

1. Identify NASA's future program requirements for PAS.
2. Complete the Program Implementation Plan.
3. Initiate work on the most technically beneficial/high leverage hardware.
4. Develop critical policies and specifications.
5. Establish a data base, including:
   - current pyrotechnic designs,
   - applications, and
   - results of usage.
6. Emphasize interagency cooperation in sharing technology.
7. Transfer technology to other government agencies and to industry.

The interrelationships of this Program and its projects with the survey results (Appendix A), the NASA Program offices, and Code Q are shown in Fig. 4, the Pyrotechnically Actuated Systems Program master flow chart.

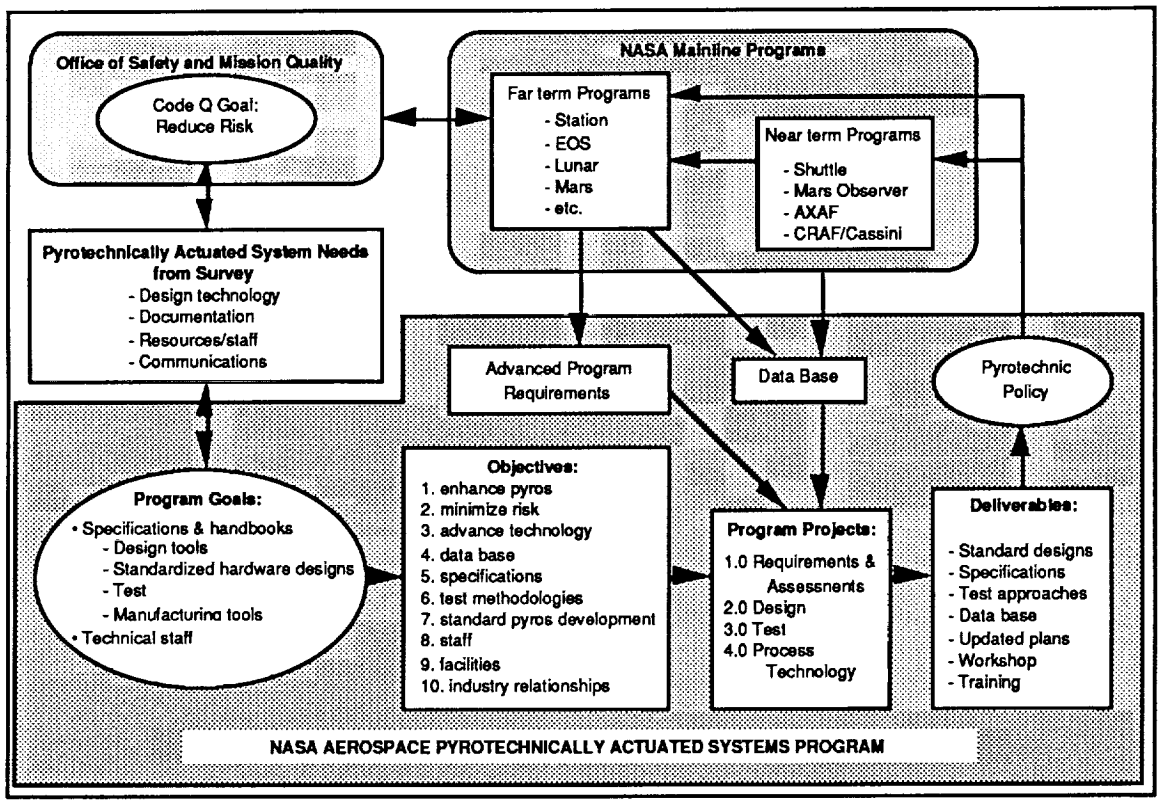

Fig. 4. Pyrotechnically Actuated Systems Program master flow chart.

The figure also presents the plan to ensure that the Program Plan is integrated with NASA's mainline program applications and that those programs will influence the PAS Program in an iterative process.

5.0 PROGRAM CONTENT

The Program is divided into four major Program Elements, each of which provides appropriate projects to accomplish the Program objectives (Fig. 5).

PROGRAM ELEMENTS	
1.0	Program Requirements and Assessments
2.0	Design Methodology
3.0	Test Techniques
4.0	Process Technology

Fig. 5. Program Elements, NASA Aerospace Pyrotechnically Actuated Systems.

The projects below are designed to improve both the near and long term pyrotechnic technology base—including components and systems—and to work toward the resolution of the problems summarized in Appendix A.3.

The Plan focuses upon the following specific remedies: design improvements, new and/or improved specifications, hardware standardization, an improved and expanded technology base, and enhancement of communications in the pyrotechnic community. Fig. 6 provides an overview of the Program content. The figure shows how the Program supports Code Q's functional role in NASA relative to design, test, and manufacturing.

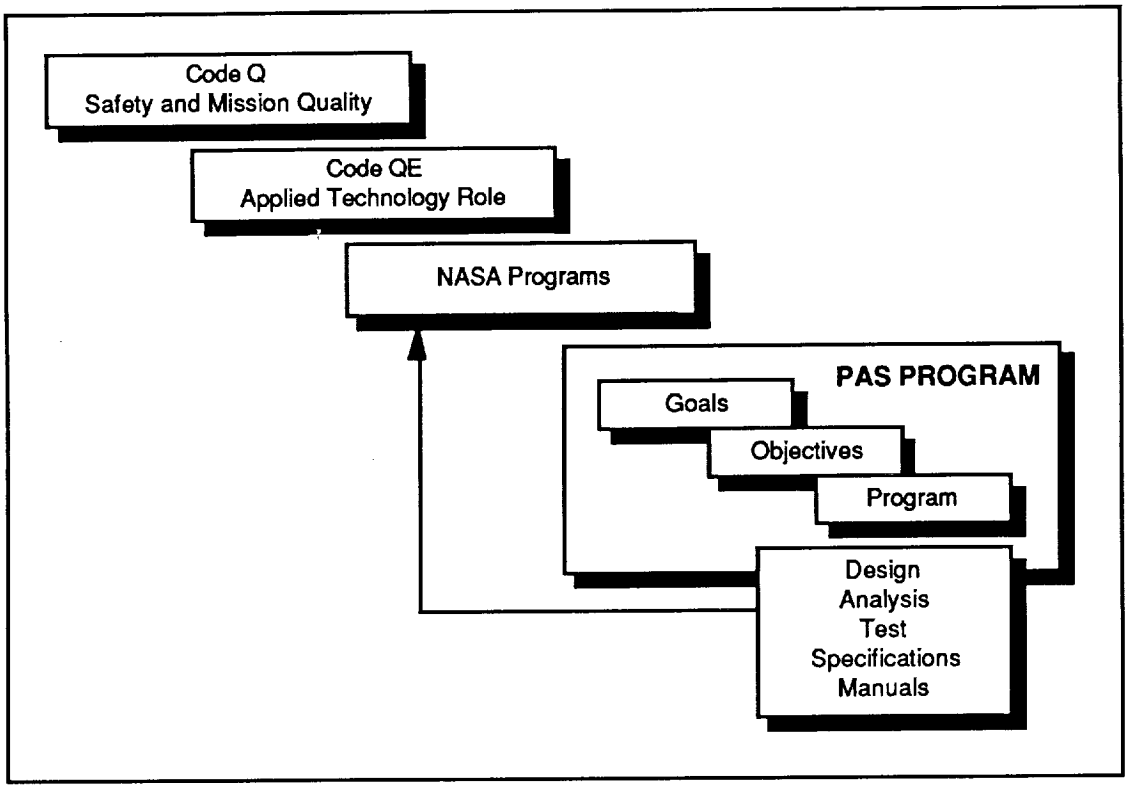

Fig. 6. Relationship of PAS Program to Code Q, QE, and NASA program roles.

Table 1 lists the projects recommended by the Steering Committee that the Program should accomplish. The text following the table describes in broad terms the function of each project and its products. The Program Implementation Plan provides greater detail concerning the project content. Project Plans will be prepared by the Project Managers. These plans will be very detailed documents, describing the project technical approach, implementation, milestones, etc.

Table 1. Pyrotechnically Actuated Systems Program Elements and Projects.

PROGRAM ELEMENT	PAS PROJECTS
1.0 Program Requirements & Assessment s	1.1 Future Pyrotechnic Requirements 1.2 Pyrotechnic Policy Preparation 1.3 PAS Technical Specification 1.4 PAS Data Base 1.5 Annual Program Review and Report 1.6 Program Implementation Plan 1.7 NASA PAS Manual 1.8 PAS Workshop 1.9 Training 1.10 Hardware System Reviews
2.0 Design Methodology	2.1 NASA Standard Gas Generator 2.2 Standard System Designs 2.3 NASA Standard Detonator 2.4 NASA Standard Laser Safe and Arm 2.5 Advanced PAS
3.0 Test Techniques	3.1 NSGG Performance 3.2 Standard Systems 3.3 NSD Performance 3.4 Safe and Arm Performance 3.5 Advanced PAS Performance 3.6 Service Life Aging Evaluations
4.0 Process Technology	4.1 NSGG Model Development 4.2 NASA Standard Initiator Model Development 4.3 NSD Model Development 4.4 Standard System Model Development

Funding levels limit the specific projects that the Program will undertake. The Code QE approved budget is identified in Section 7.0, Program Budget. The Program will be reviewed later to establish the funding of new projects and those projects that are identified herein but are currently unfunded.

1.0 PROGRAM REQUIREMENTS AND ASSESSMENTS ELEMENT

This Program Element implements those projects that are necessary to address the management aspects of the Program's objectives (Section 3.0). It particularly emphasizes the documentation and communications aspects. Policy and planning documents are prepared to ensure that the products of the Program will be used. The policy document, for example, will be in the format of a NASA Management Instruction that addresses PAS in a broad sense. Analyses of NASA's future program requirements and of current problems will enable appropriate revisions to the Program Implementation Plan. Problems, and the analyses thereof, will also be the subjects for final reports and the computer data base that will be developed. The Program Element includes analysis and design efforts needed to address the overall systems aspects of the Program and the documentation work that produces the reports and presentations associated with reviews, proceedings, analyses, etc.

A general description of the Projects in this Program Element and the major products follows.

1.1 Future Pyrotechnic Requirements

Project: New pyrotechnic technology requirements necessary for future missions will be studied. Programs are expected to require new mechanisms to meet more demanding environments and to extend service requirements further than previously accomplished. Functional understanding and new computational modeling capabilities will enhance PAS performance capabilities. The objective of the advanced planning is to define the efforts needed to improve and to verify the improvements in PAS quality. New diagnostic techniques, for example, will be evaluated.

Product: A report on an analysis of future requirements will be provided. It will be used by the Program's management to make revisions in the Program Implementation Plan or in this Plan. The PAS requirements report will be updated every two years.

1.2 Pyrotechnic Policy Preparation

Project: This Project will undertake preparation of an Agency-wide policy concerning pyrotechnic devices, their design, test requirements, operational use, and program application. The purpose is to place management controls into effect to assure the proper use of the work this Program will accomplish. There will be a general statement on NASA objectives, approach, requirements, and rationale for the application of pyrotechnically actuated systems.

Product: This effort will result in a draft NMI for approval.

1.3 PAS Technical Specification

Project: A technical specification applicable to design, development, demonstration, environmental qualification, lot acceptance testing, and documentation will be prepared. The specification will include improvements on the means for defining and demonstrating PAS functional margin. The specification will fulfill a void and will serve as a contractual reference document.

Product: The specification will be prepared as a NASA Technical Standard.

1.4 Pyrotechnically Actuated Systems Data Base

Project: This Project will develop and document the past and current programs in terms of system requirements, designs developed, performance achieved, lessons learned, and qualification status with sufficient detail to provide guidance for users. The data base structure and a user friendly interface will also be established. Documentation requirements to support the data base will be identified as part of a proposed NASA Pyrotechnic Policy document that the Program will prepare for review by the Steering Committee. These requirements will also be incorporated into device specifications. The

data base content includes data, reports, specifications, documents, etc. The catalog will list all past and presently available pyrotechnic devices. This project requires its project management to interact cooperatively with other NASA Centers, various DOD and DOE organizations, and private industry. Funding in later years is required to maintain the data base.

Product: The data base requirements will be established and published, a computer system selected, a user-friendly program developed, entries made, and training provided for users of the system. The catalog portion of the data base will be prepared as a NASA Handbook to provide designers with options in a single up-to-date reference document. This is to be a turn-key effort.

1.5 Program Reviews and Reports

Project: This effort provides important management information concerning the program status. Program status reports are prepared to provide program status and to discuss problems on a near-term basis. A minimum of two Program reviews will be held each year. One will be a formal program review to report on and to review the Program's accomplishments, status, plans, and problems. Another will be an annual review with the Associate Administrator for Safety and Mission Quality (Code Q) and the Director, Technical Standards Division (Code QE). Program office representatives from all Headquarters offices will be invited to the meeting for updates on Program accomplishments, status, and plans and for inputs from the program personnel to assure that the Program is responsive to the needs of NASA's programs. Additional reviews may be held at the direction of the PAS Program Manger.

Product: Program status reports are due quarterly with informal reporting biweekly. An annual technical summary will be completed for broad distribution to both NASA's management and the technical community. The annual summary report will identify and recommend new initiatives for PAS.

1.6 Program Implementation Plan

Project: This document provides the details necessary to implement the program. It will be more specific concerning the technical approach for each project. The Program Implementation Plan is the Program Manager's operating plan. It will be updated annually to assure currency. There will be flexibility to make changes within the Projects consistent with the content of the Program Plan.

Product: This will be prepared by Code QE and the lead center as an internal program management document.

1.7 NASA PAS Manual

Project: A detailed "how-to" document will be prepared providing guidance on all aspects of design, development, demonstration, qualification (environmental), acceptance testing, and margin demonstrations of

pyrotechnically actuated devices and systems. The manual's scope will be from the creation of the PAS/component design to final disposition of the device.

Product: This will be prepared as a NASA guidelines document that will be used for reference.

1.8 Pyrotechnically Actuated Systems Workshop/Symposium

Project: Technology exchanges at the national level will be achieved either through an affiliation with an existing symposium organization or through the creation of a separate pyrotechnic dedicated symposium. Presentations by government and industry personnel are to be encouraged as appropriate. The function of this Project is to perform the planning of the workshop for review by the Steering Committee.

Product: The workshop organization, preparations, implementation, and the preparation of the proceedings in a timely manner are all part of the responsibilities and products of this Project.

1.9 Training

Project: An education and training program will be established at both the engineering and technician level to ensure maximum utilization of the standards developed by this Program. Basic introductory courses will be available to meet the obvious need for pyrotechnic safety.

Product: An engineering training program will be developed for the benefit of current and future NASA personnel.

1.10 Hardware System Reviews

Project: Members of the NASA/DOD Pyrotechnic Steering Committee and the Program staff can be made available upon written request of the respective agency, NASA Headquarters, or any participating center for formal design reviews and for failure analysis. Problems will be worked either during regular committee meetings or on an ad-hoc basis as appropriate. Committee staff within NASA and the DOD or non-Committee members, including government and industry, may be involved in the review process.

Product: The product will be a summary report and presentation for each review.

2.0 DESIGN METHODOLOGY PROGRAM ELEMENT

The Design Methodology Program Element addresses those design deficiencies noted in the survey where the need was expressed to further understand current design limitations and to apply advanced design approaches. This element develops designs, tests hardware, and documents results. The primary Design Program Element's deliverables consist of design specifications or standards.

The projects performed here will develop hardware that advances basic research into operationally demonstrated technologies for performance characterization and for flight hardware applications. They will, therefore, more accurately define the device's ability to function under anticipated operational environments as well as operations in off-nominal conditions. Design limits of the device are to be determined. Recommendations for new applied technology projects will be provided by the Program staff for approval by the Director of the Technical Standards Division, Code QE. In the Design Methodology Program Element, hardware will be designed, manufactured, acceptance tested, and specifications prepared. Designs developed under Element 2.0 are tested under Element 3.0. This approach addresses a problem revealed in the survey (Appendix), emphasizes the importance of both design and test, and identifies separate budgets.

From the work in this Element, the PAS Program provides the guidelines, handbooks, and specifications for the design and development of pyrotechnic components and systems as required for the Program to accomplish its hardware focused goals (Section 2.0) and objectives (Section 3.0). The technical content for the appropriate documents will be developed for all aspects of pyrotechnic component and systems applications. Emphasis is to be placed on design standards and analytical techniques. The Program will conduct the applied technology necessary for supporting document preparation including verification of the accuracy of the specification values.

These projects are highly beneficial to NASA's programs because flight hardware characterization and applied technology developments will decrease the chance of failure of new hardware design approaches or of proven hardware in new operational regimes.

2.1 NASA Standard Gas Generator (NSGG)

Project: The NASA Standard Initiator (NSI) has been applied universally to serve both as an initiator and a gas generator. This has been found to contribute to functional failures (ref. 8). The NASA Standard Gas Generator will be, therefore, among the first hardware developed. The NSGG will be flight qualified, but its reliability will not be numerically proven due to the large number of samples required. The development of a NSGG has been assigned a high hardware priority since it has the widest pyrotechnic application.

Product: A qualified NSGG will be provided. A design specification will be developed as a NASA Technical Standard from data provided by the project. Test reports will be written.

2.2 Standard System Designs

Project: Improved, more reliable, high performance hardware is needed. Extensive background and operational experience will be evaluated preceding selections of candidates for NASA standard hardware designs. Functional performance, the effects of system variables, and scaling will be characterized. Process controls will be specified in detail to assure consistency and reliability

for all manufacturing lots. The systems to be studied include linear separation systems, pin pullers, etc.

Product: Qualified NASA standard system designs and design specifications will be developed as NASA Technical Standards from data provided by the project. Test reports will be written.

2.3 NASA Standard Detonator (NSD)

Project: This project undertakes the development of a NASA Standard Detonator. Explosive transfer technology in which high explosive charges initiate other charges across hermetically sealed interfaces is to be developed into an applied technology. The importance of this project is illustrated by the fact that two programs, the Delta launch vehicle and the Apollo Lunar Seismic Experiment (ref. 9), were forced into major redesign efforts because their detonators failed to reliably initiate the next item in the explosive train. A properly designed and applied standard detonator, the heart of all explosive transfer systems, would easily prevent such failures, actually require less explosive material, be less sophisticated, and reduce the destructive impact on the system.

Product: A qualified NSD and design specification will be developed as NASA Technical Standards from data provided by the project. Test reports will be written.

2.4 NASA Standard Laser Safe and Arm

Project: A wide variety of complex mechanisms currently exist to assure the inadvertent initiation of pyrotechnically actuated systems. As described in the Appendix, system interfaces often are not characterized properly to assure reliable performance. Standardized solid state approaches for safe and arm hardware and their interfaces would reduce risk considerably while enhancing functional reliability. This project will undertake the qualification of a solid state laser safe and arm for demonstration on the Pegasus launch vehicle. The design, integration, and operation aspects will be funded by the Small Launch Vehicle Program Office at NASA Headquarters.

Product: The Project will develop, qualify, and demonstrate in flight a standardizable solid state laser safe and arm system. Significant improvements are expected in size reduction, operational performance, power, and explosive containment. The latter will reduce hazards from debris. The results of this effort will be a performance demonstration and guidelines on how design features from this work can be incorporated into flight units. A design specification for a NASA standard laser safe and arm will be generated. Test reports will be written.

2.5 Advanced Pyrotechnically Actuated Systems (PAS)

Project: This project will define and pursue those advanced design concepts that are needed to bring NASA programs up to the state-of-the-art in

pyrotechnic technology and to maintain a state of currency. The first such activity concerns the development of a NASA Standard Laser Detonator. The second activity will be the development and qualification of a NASA Standard Laser Initiator.

Product: New, flight qualified, standard hardware will be built. Specifications will be prepared as NASA Technical Standards. Test reports will be written.

3.0 TEST TECHNIQUES PROGRAM ELEMENT

This program element addresses all aspects of testing: manufacturing, lot acceptance, qualification, margin validation, accelerated life, ground checkout, and in-flight checkout. Deficiencies will be addressed as noted in the survey where a need to improve upon pyrotechnic test methods was indicated and where it was considered necessary to develop test approaches that better characterize component and system performance.

Under these projects, the Program will test the hardware produced in Element 2.0. This Program Element will also develop new, improved, and appropriate test techniques to assure that the requirements imposed upon pyrotechnic devices are producing the specified performance required by NASA's programs. Of particular concern is the provision for sound technical approaches that verify the device's energy output and energy output rate. This element must provide the means to show that operational hardware can consistently meet specified design margins in a manner that is consistent with the manufacturing and process tolerances allowed by the specified manufacturing control documentation.

Guidelines, handbooks, manuals, and specifications will be produced for proper design practices, development, qualification, production (manufacture), and acceptance testing of pyrotechnic components and systems. The above will be developed for all aspects of pyrotechnic component and system applications. This Program Element will emphasize experimental and analytical developments to demonstrate functional margins. The technology needed to support the accurate preparation of appropriate documents will be developed.

3.1 NSGG Performance

Project: This Project will qualify the NSGG for flight. It will also develop test procedures for the NSGG that confirm its intended operation and quantify performance relative to the design specification, Project 2.1. Test data will be obtained to demonstrate the NSGG for flight. The data will also be used to update design specifications and for publishing test specifications.

Product: The results of the testing will be published as a test specification for use by programs. It is anticipated that new NASA standards will be developed as a result. A NSGG qualification test report will be prepared.

3.2 Standard System Performance

Project: Extensive background and operational experience will be obtained during qualification of standard designs selected for development in Project 2.2. Functional performance and the effects of system variables, including scaling, will be characterized.

Product: The results of the analysis will be published and incorporated into the Program planning activity. System designs will be flight qualified, and test reports will be prepared. Process controls will be specified in a detailed technical specification to assure consistency and reliability for all manufacturing lots. The initial system to be qualified will be a linear separation system (Project 2.2.1).

3.3 NSD Performance

Project: This Project will qualify the NSD developed in Project 2.3. Test procedures will be developed to confirm its intended operation and quantify performance relative to the design specification. Test data will be generated to qualify the NSD for flight. The data will also be used to prepare updated design specifications and for test specifications.

Product: Test and qualification reports will be prepared. Test results will be entered into the PAS Data Base and will be incorporated into the NSD design and test specifications.

3.4 Safe and Arm Performance

Project: Test procedures for the safe and arm devices will be developed that confirm intended operation and quantify performance relative to the design specification. Test data will be produced to qualify the safe and arm devices for flight. The data will also be used to update design specifications and for test specifications.

Product: Test and qualification reports will be prepared. Test results will be entered into the PAS Data Base and will be incorporated into the safe and arm design and test specifications.

3.5 Advanced PAS Performance

Project: This Project will test the performance of advanced pyrotechnic devices and systems. Highly relevant measurement approaches will be used to define device outputs and system functions. The data will also be used to update device specifications and to prepare manufacturing test specifications.

Product: The results of the testing accomplished will be published as a test specification for use by programs. New NASA standards will be developed. Qualification reports will be prepared.

3.6 Service Life Aging Evaluations

Project: The effects of aging on pyrotechnic devices and any degradation incurred as a result of storage and service in the intended operational environments will be evaluated. Relationships between storage environments and device shelf life will be determined. Approaches to accelerated life testing will be evaluated to find performance characteristics that can be measured during qualification to ensure that function and margins are not impaired by long periods of storage and service. The first activity under this project will use STS pyrotechnic devices removed during major overhall of Columbia.

Product: Guidelines will be provided for estimating device service life capability based on data obtained from test methods that measure performance after actual or accelerated storage conditions. Test reparts will be prepared.

4.0 PROCESS TECHNOLOGY PROGRAM ELEMENT

The Program includes projects necessary for developing approaches for analytically characterizing device performance sensitivities to manufacturing tolerances and "faults," or deviations, in component ingredients. It is necessary to develop test techniques that verify the analysis (Element 3.0). This Program Element will address the problems caused by inadequately controlled specifications or the introduction of unanticipated substances into the manufacturing process. This Element is expected to establish the proper degree of controls for assuring product quality and reliability.

Emphasis will be placed on process understanding and controls needed to assure that specified hardware performance is realized during manufacturing processes. The Program will conduct the necessary technology developments that support manufacturing processes. The means to validate that the critical manufacturing steps were all in place (product inspection) and that the delivered product performs per specification (acceptance testing) is of equal importance to understanding and adequately controlling processes. This relationship is shown in Fig. 7:

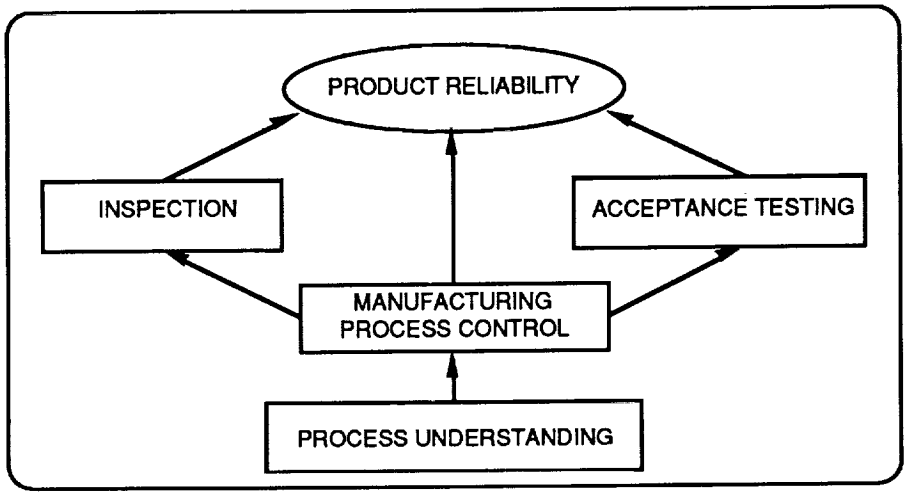

Fig. 7. Interrelationships between PAS Program and product reliability.

Guidelines, handbooks, and specifications will be provided for production (manufacture), and acceptance of pyrotechnic components and systems as required for the pyrotechnic discipline to accomplish its goals (Section 2.0). The appropriate guidelines, handbooks, and specifications will be developed for all aspects of pyrotechnic component and systems manufacturing.

4.1 NSGG Model Development

Project: This project will provide a better understanding of the effects of NSGG manufacturing process variables on performance. The model is to be verified by testing. This Project will present the technical details needed to control the device's function to a consistently high reliability level of performance. It will incorporate test results accomplished under Project 3.1.

Product: A user friendly model will be developed, and a report will be published describing the modeling in specification format for use by programs. The model is to be verified by testing. A NSI model will validate the Program's modeling techniques, since the NSI has an extensive data base.

4.2 NSI Model Development

Project: This project will provide a better understanding of the effects of process variables on the NSI's performance. It will be accomplished through the development of a model, the fidelity of which will be verified by testing. This Project will present the technical details needed to control the device's function to a consistently high reliability level of performance. This Project will verify the NSGG using the NSI's model.

Product: A user friendly NSI model will be developed, and a report will be published describing the modeling in specification format for use by programs.

4.3 NSD Model Development

Project: This project will provide a better understanding of the sensitivities of the NSD to process variable effects on performance. It follows validation of the modeling techniques for the NSI and the NSGG so that the effort needed to develop the modeling techniques should be well established at this phase of the Program. The model is to be verified by testing.

Product: A NSD model will be developed, and a report will be published describing the modeling in specification format for use by programs.

4.4 Standard System Model Development

Project: This Project will model the components developed in Project 2.2. The results will provide the technical details needed, including design content, form, fit, function, and application, to control the device to a consistently high reliability level of performance. It will incorporate the results of the

testing accomplished under Project 3.2. The modeling data here and the design activity, Project 2.2, will provide the specification contents for use by NASA's mainline programs. This project develops the analytical tools to provide the designer with a quantitative understanding of the necessary controls to manufacture high quality NASA standardized systems and components that will be developed and demonstrated under Projects 2.2 and 2.4. The models are to be verified by testing.

Product: A user friendly model for standardizable components will be developed, and a report will be published describing the modeling in specification format for use by programs.

6.0 MANAGEMENT ROLES AND RESPONSIBILITIES

This Program will be closely coordinated among all interested NASA Headquarters Offices and the NASA Field Installations. This coordination will be accomplished, in part, through the work of the Aerospace Pyrotechnic Systems Steering Committee. The Steering Committee will also provide Program review and oversight. During such reviews, coordination with relevant DOD and DOE organizations will take place.

The program will be managed by NASA Headquarters, Code QE. The projects within the Program will be the responsibility of the project managers at the designated centers.

All Program plans and activities will be submitted to NASA Headquarters for review and consideration in planning and budget cycles.

Individual organizational assignments are delineated below.

6.1 OFFICE OF SAFETY AND MISSION QUALITY, TECHNICAL STANDARDS DIVISION, CODE QE, NASA HEADQUARTERS

This office will be responsible for the management and execution of the Program as well as funding of this Plan.

6.2 OTHER NASA HEADQUARTERS OFFICES

The following offices are potential beneficiaries of the Program and can participate by providing guidance, technical coordination, and future requirements:

- Office of Space Sciences and Applications (OSSA), Code S,
- Office of Space Flight (OSF), Code M,
- Office of Space Systems Development (OSSD), Code D,
- Office of Aeronautics and Space Technology (OAST), Code R,
- Office of Space Communications (OSC), Code O, and
- Office of Commercial Programs, Code C.

6.3 NASA CENTER TASK ASSIGNMENTS

The center management assignments will be implemented per the Program Implementation Plan.

6.4 NASA AEROSPACE PYROTECHNIC STEERING COMMITTEE

This NASA Aerospace Pyrotechnic Systems Steering Committee will provide oversight and guidance for the implementation of the Program Plan. The Committee will identify needed technology and recommend priorities.

The Committee is chaired by the PAS Program Manager, Technical Standards Division, Code QE, Office of Safety and Mission Quality. Currently, membership is composed of pyrotechnic technology representatives from each of the NASA centers

24 blank

and delegates from the United States Air Force Space Division, the Naval Surface Warfare Center, and the Department of Energy. To the greatest possible extent, committee members and Program personnel are separate individuals in order to maintain a clear distinction between the functions of the two groups. Each Center designates one individual to serve as the installation representative.

6.4.1 Office of Space Division, Air Force Systems Command

This office participates in the Steering Committee to provide guidance and technical coordination.

6.4.2 Naval Surface Warfare Center

NSWC participates in the Steering Committee to provide guidance and technical coordination.

6.4.3 Sandia National Laboratory

Sandia National Laboratory participates in the Steering Committee to provide guidance and technical coordination.

7.0 BUDGET

Section 5.0 presents projects recommended by the Steering Committee. The work accomplished by the Program will be in accordance with the funding level provided by NASA Headquarters and will be in accordance with priorities as established by the Program Implementation Plan. The funding level by fiscal year is shown in Table 2.

Projects will be prioritized by the Program Manager using the advise and recommendations of the Steering Committee and approved in Annual Program Reviews with NASA Headquarters Code QE. The work that actually will be implemented and accomplished in the near term will be based upon Program urgency, personnel, and funding levels. A cost breakdown by Program Element and project is provided in the Program Implementation Plan.

Table 2. PAS Program Funding Level ($K)

FY 91	FY 92	FY 93	FY 94	FY 95	FY 96
100	600	800	980	600	200

8.0 MAJOR MILESTONES

A five year program schedule, showing the overall intent and scope of the planning activity, is provided in Fig. 8 and Table 3 below. Deliverables are listed in Table 4. The detailed program schedules will be presented in the Program Implementation Plan.

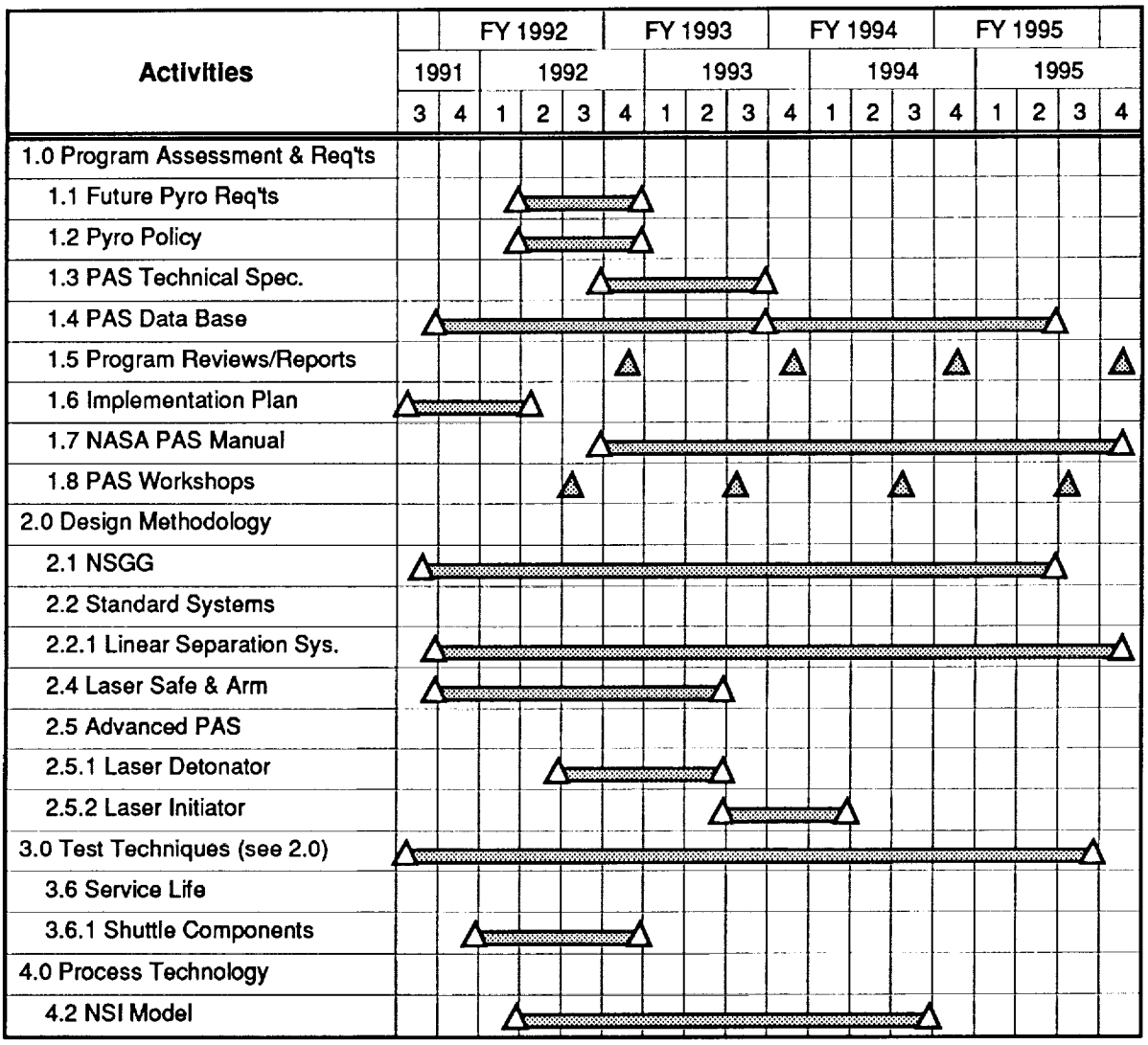

Fig. 8. PAS Program schedule.

28 blank

Table 3. Pyrotechnically Actuated Systems Program Milestones (typical only).

PROJECT #	MILESTONE
	FY 1991
	Commence program activities.
	FY 1992
1.1	Complete an analysis of pyrotechnic requirements for future flight programs.
1.4	Complete the Plan for NASA Pyrotechnic Data Base; initiate project.
1.6	Complete the Program Implementation Plan.
1.8	Conduct the first NASA Pyrotechnic Workshop and publish proceedings.
2.1	Complete the Development Plan for NSGG, and initiate project.
2.2.1	Complete the Development Plan for linear separation systems, and initiate project.
2.2.1	Complete linear separation system technical specification and issue RFP.
2.4	Complete Development Plan (Phase I) of laser safe and arm systems.
2.4	Conduct off limits and qualification tests of a laser safe and arm system.
2.4	Conduct flight demonstration of a laser safe and arm system.
2.5.1	Complete the Development Plan for laser-initiated detonators, and initiate project.
2.5.1	Conduct off limits, sensitivity, and qualification tests of laser-initiated detonators; publish results.
2.5.2	Complete the Development Plan for laser initiators.
3.6.1	Complete Development Plan for evaluating service life of Shuttle pyro devices.
3.6.1	Conduct service life tests of Shuttle pyro devices; publish results.
4.2	Complete the Development Plan for a NSI Model, and initiate project.
	FY 1993
1.1	Complete an analysis of pyrotechnic requirements for future flight programs.
1.2	Complete the draft NASA pyrotechnic policy document and initiate the approval process.
1.3	Complete the final Technical Specification for Pyrotechnically Actuated Systems.
1.4	Complete development of the NASA Pyrotechnic Data Base.
1.5	Publish an Annual Program Report.
1.7	Initiate development of the NASA Pyrotechnically Actuated Systems Manual.
1.8	Conduct the second NASA Pyrotechnic Workshop and publish proceedings.
2.1	Complete NSGG draft technical specification.
2.2.1	Evaluate contractors, procure hardware, and start testing first concept.
2.4	Publish Phase I results for laser safe and arm systems.
2.5.1	Complete laser-initiated detonator technical specification.
3.1	Complete NSGG performance and environmental qualification testing.
3.5.1	Complete laser-initiated detonator performance and environmental qualification testing.
4.2	Complete first simulation using the NSI Model.
	FY 1994
1.4	Update the NASA Pyrotechnic Data Base.
1.5	Publish an Annual Program Report.
1.7	Publish the draft NASA Pyrotechnically Actuated Systems Manual.
1.8	Conduct the third NASA Pyrotechnic Workshop and publish proceedings.
2.2.1	Procure hardware and start testing second concept.
4.2	Complete development and validation tests of the NSI Model. Publish results.
	FY 1995
1.4	Complete updating the NASA Pyrotechnic Data Base.
1.4	Publish the NASA Applications Catalog for Pyrotechnically Actuated Systems.
1.5	Publish an Annual Program Report.
1.8	Conduct the fourth NASA Pyrotechnic Workshop and publish proceedings.
2.2.1	Procure hardware and start testing third concept.
	FY 1996
1.5	Publish an Annual Program Report.
2.2.1	Publish a NASA Standard Linear Separation System specification and qualified vendor list.

Table 4. Pyrotechnically Actuated Systems Program Deliverables.

PROJECT #	DELIVERABLE
	FY 1992
1.4	Development Plan, *NASA Pyrotechnic System Data Base*
1.6	Program Implementation Plan
1.8	Proceedings, *First NASA Pyrotechnic Workshop*
2.1	Development Plan, *NASA Standard Gas Generators*
2.2.1	Development Plan, *NASA Standard Linear Separation Systems*
2.4	Development Plan (Phase I), *Laser Safe and Arm Systems*
2.4	Test Report, *Laser Safe and Arm System Qualification*
2.5.1	Development Plan, NASA Standard Laser-initiated Detonator
2.5.1	Test Report, NASA Standard Laser-initiated Detonator Qualification
2.5.2	Development Plan, NASA Standard Laser Initiator
3.6.1	Development Plan, evaluating service life of Shuttle pyro devices
3.6.1	Test Report, *Service Life of Shuttle Pyro Devices*
4.2	Development Plan, *NASA Standard Initiator Model*
	FY 1993
1.1	Report, *Projected Pyrotechnically Actuated System Requirements for NASA Programs*
1.2	NASA pyrotechnic policy document (draft)
1.3	Specification for Pyrotechnically Actuated Systems (draft)
1.4	Operational computer application of the NASA Pyrotechnic Data Base
1.5	Annual Program Report
1.8	Proceedings, *Second NASA Pyrotechnic Workshop*
2.1	*NSGG Design and Test Requirements, and Technical Specification* (draft)
2.2	Report, *Recommended Standard Hardware Designs*
2.5.1	*Laser-initiated Detonator Design and Test Requirements, and Technical Specification*
3.1	Test Report, *NSGG Performance and Environmental Qualification*
3.4	Test Report, *Laser Safe and Arm Flight Demonstration*
3.5.1	Test Report, *NASA Standard* Laser-initiated Detonator*Performance and Environmental Qualification*
4.2	Development Plan, NSI Model
	FY 1994
1.8	Proceedings, *Third NASA Pyrotechnic Workshop*
1.5	Annual Program Report
1.7	*NASA Pyrotechnically Actuated Systems Manual* (draft)
	FY 1995
1.4	Applications Catalog, *NASA Pyrotechnically Actuated Systems*
1.4	Update to NASA Pyrotechnic Data Base
1.5	Annual Program Report
1.7	*NASA Pyrotechnically Actuated Systems Manual* (final)
1.8	Proceedings, *Fourth NASA Pyrotechnic Workshop*
2.1	*NSGG Technical Specification* (final)
2.2.1	*Linear Separation System Design and Test Requirements, and Technical Specification*
3.2.1	Test Report, *Linear Separation System Performance and Environmental Qualification*
4.2	Report, *NSI model*
	FY 1995
1.5	Annual Program Report
2.2.1	Publish a NASA Standard Linear Separation System specification and qualified vendor list.

APPENDIX—PROGRAM BACKGROUND

A.1 STATEMENT OF THE PROBLEM

Pyrotechnic devices must accomplish mechanical functions that are critical to the success of aerospace programs and to the safety of both those individuals whose lives may depend upon the device's proper function as well as those who handle the devices. Pyrotechnic devices are usually considered to be immediately and readily available as off-the-shelf components by users. Consequently, little or no pyrotechnic engineering effort is expected from nor committed by program offices until problems develop. Since the technology is mature, no research program exists for pyrotechnic devices. Further, no technology developmental program exists either.

Although pyrotechnics are frequently required to demonstrate near perfect reliability in both manned and unmanned applications, serious problems on the ground and failures in-flight have occurred. The only technology efforts performed have been limited responses to specific program problems. That is in contrast with the preferred managerial approach of understanding device function to prevent problems by technically understanding pyrotechnic systems and their functions to achieve design and configuration control. That is preferred to the "design and shoot" approach. This situation, and indeed this approach used, has resulted in increased program cost for redesign, and in many instances, requalification, at even greater expense. From the information available at the time of the pyrotechnic systems study, the same situation applies outside NASA as well.

A significant need, therefore, exists in the discipline to significantly enhance the technical understanding of pyrotechnically actuated systems and to provide engineering tools, such as, standard design approaches, specifications, guidelines, analytical models, and manufacturing process criteria to prevent the recurrence of these problems. This program's fundamental purpose, therefore, is to rectify that situation by applying management attention to pyrotechnically actuated devices and the systems in which they are required to operate. This Program would serve as the instrument for correcting the undesirable situation. It will be of direct assistance to NASA's mainline programs by providing well defined, standard hardware design approaches and by maintaining the technology in a state of currency.

A.2 PROGRAM ORIGIN

In response to an expression of concern in 1986 by Mr. Norman R. Schulze of the Office of Chief Engineer at NASA Headquarters (ref. 1) to Mr. Swain of the Langley Research Center, a coordinated NASA effort was initiated to determine, study, and analyze problems and failures relating to pyrotechnic hardware, including interfaces with the system hardware. The results of the survey, performed by Mr. Lawrence Bement of the Langley Research Center, are summarized in the next section of this appendix. The detailed final report is reference 4.

An essential part of the survey effort was accomplished by the NASA/DOD Aerospace Pyrotechnic Systems Steering Committee. The Committee is composed of representatives from each of the NASA Field Installations, the Air Force Space

Division, and the Naval Surface Warfare Center. The Committee participated in the data collection and analysis, and in reviewing the final report. The pyrotechnic failure survey was the major subject for the initial meeting of the Aerospace Pyrotechnic Steering Committee that occurred on November 13 and 14, 1986. Two more Committee meetings were held in 1986 and 1987 to work on the survey and to consider recommended efforts to remedy the technology voids and which contributed significantly to the content of this Plan.

Cooperation among the NASA Centers and coordination with the DOD in the problem review and the recommended resolutions was considered essential because of the similarities in problems, program applications of pyrotechnics, and the desire to avoid a duplication of efforts. The value and effectiveness of intercenter and interagency coordination were proven by the highly successful "Shuttle/Centaur Super*Zip Separation Joint Failure Analysis and Resolution Program," conducted in 1984-85. The results are documented in "Investigation of Super*Zip Separation Joint" (ref. 6). In fact, the Steering Committee membership is composed of the same government members as the Working Group that had been established to resolve the Super*Zip separation system problem.

Because the survey results demonstrated the need for an applied engineering research and technology development program, a Program Plan was developed to define projects considered essential for improving NASA's capabilities to design, develop, and test pyrotechnically actuated systems for NASA's program applications. The Plan describes the program elements required to correct problems and deficiencies in the pyrotechnic technology as determined by the Committee's review of the technology status. The Plan was prepared by Mr. Norman R. Schulze, Office of Safety and Mission Quality (Code QE), NASA Headquarters, and with substantial assistance from Mr. Laurence J. Bement, Senior Pyrotechnic Engineer, Systems Engineering and Operations Directorate, NASA Langley Research Center, and from the NASA/DOD Aerospace Pyrotechnic Systems Steering Committee's recommendations. The Plan was originally submitted in 1988 and has subsequently been refined in response to inputs from NASA management.

On April 13, 1988, the Committee carried its concerns (ref. 5) forward to Mr. George A. Rodney, Associate Administrator for Safety, Reliability, Maintainability, and Quality Assurance (now the Office of Safety and Mission Quality) at NASA Headquarters, Code Q. Mr. Rodney requested that the Committee's recommended Program Plan be finalized and endorsed by all participating centers. In addition to the problems that the survey revealed, Mr. Rodney has also expressed concern over the problems that have been experienced with safe and arm devices that had not been included as part of the scope of the original survey. The overall system implications are sufficiently great that the Program scope should include the safe and arm types of mechanisms whether they include explosive trains, mechanical devices, or electromechanical devices. Action items were accomplished.

It is intended that the Committee continue to review the Program. As it becomes aware of the Program's status and products, use of the Program's technological developments will be assured. In addition, the Committee provides a forum for discussions to assure a common awareness of problems and to share benefits when problems are resolved. Those inputs will serve to strengthen the Program.

A.3 SUMMARY OF FAILURE SURVEY RESULTS, PROBLEM ASSESSMENT, AND RESOLUTIONS INDICATED

A.3.1 Survey of Problems

This section discusses the technical background and the causes of problems from which the Program Plan was developed. From a pyrotechnic failure survey and assessment, using the individual experiences of the Pyrotechnic Steering Committee members (ref. 4), a compilation was made of failures that occurred with hardware that had been at least through the design phase. The survey approach was used in the absence of a technical data base for pyrotechnic devices.

In summary, the survey, which covered a time frame of 24 years for NASA and DOD programs, revealed 84 significant failures, including 12 flight failures and 3 deaths. The underlying cause of those failures was attributed to the lack of a technological base.

Failures were considered, more specifically, to be the consequence of:

- lack of technical understanding of pyrotechnically actuated mechanisms,
- deficiency in designs, specifications, quality control, and procedures,
- lack of standardization,
- inadequate technology base for the pyrotechnic technology, including no technical data base,
- lack of resources for pyrotechnic technology funding, personnel, and facilities and,
- poor communications among centers.

A.3.2 Results of Survey: Summary of Deficiencies

Because these causes of failures define the problem areas experienced, they formed the basis for this Plan. Hence, it is considered essential to briefly discuss the key points on each of the noted deficient areas. For convenience in understanding, the failure causes are divided into four deficiency groups, each of which is summarized below:

- design technology
- documentation
- resources/staff
- communications.

A.3.2.1 Design Technology

The greatest cause of pyrotechnic failure has been the lack of understanding of pyrotechnically-powered mechanisms. However, a NASA or Air Force technology developmental and advancement program for the pyrotechnics discipline that could pursue device understandings is nonexistent. Individual pyrotechnically actuated devices are funded to meet only the needs of specific programs. The research and development activities that are accomplished are geared to the narrow bounds of program requirements, to the program schedule, and, of course, to the program's

budget priorities. There is little opportunity for thorough investigations of functional mechanisms or for the development of a basic understanding of operational parameters. The lack of technically proven and standardized test methodology was determined to be a frequent limiting factor in resolving problems or developing new designs as well as in problem prevention. Pyrotechnic modeling has not been developed; but it could be a key factor in reducing costs, understanding design margins, and enhancing safety and reliability.

That situation is resolved by the initiation of an applied technology program to focus on pyrotechnic device and system technology.

A.3.2.2 Documentation: Designs, Specifications, Quality Control, and Standardization

There are very limited guidelines and specifications for pyrotechnic design, hardware development, qualification, production, acceptance and system testing—none within NASA and only some generalized MIL STD's in DOD. For example, guidelines are not available that properly address: the selection of pyrotechnic approaches—including the use of previously qualified hardware, the best means to accommodate structural interfaces, how to achieve true redundancy, how to conduct proper testing, and how to achieve true reliability. The design of pyrotechnics has been and continues to be approached as an art rather than as a science. Empirical relationships between design, operation, and manufacturing controls have not been established. Flight programs cannot rely on meaningful statistically derived component test performance data through repetitive testing. Costs become prohibitive. Therefore, design remains an art; good modeling approaches have not been developed to take advantage of new analytical tools. There are no well defined and widely accepted means to demonstrate functional margin by testing. Hence, considerable developmental work that will establish a solid foundation for the development of meaningful specifications is needed.

A NASA generic specification that would provide guidance for all of these considerations would be of great benefit for program guidance. More standardized components with well-characterized functional performance characteristics would reduce design efforts and design problems since the standardized hardware designs would incorporate lessons learned and provide a wide data base. It would provide for better understanding of design margins, a key factor for enhanced safety, reliability, and performance assurance. A program is needed to identify enabling and enhancing pyrotechnic technology, to develop the identified critical technology, and, where feasible, to implement use of that technology by NASA's programs. One major program goal should be to make the design of pyrotechnically actuated systems a science. This will be aided by the advent and progress of modeling technology that has occurred in recent years. Particular emphasis should be given to the demonstration of functional margins through an understanding of the relative importance of system variables.

A significant example of a NASA problem reflecting the lack of attention to the pyrotechnic technology is the recent experience on what has been considered as the "best" pyrotechnic component. It has been mentioned that one major problem with pyrotechnic devices the technology void created by not understanding the effects that component ingredient variables have on performance. That situation is exemplified by the experience in flight applications and during ground testing with the NASA

Standard Initiator (NSI). In both uses it has failed to function in its operational thermal environment (–420 F, ref. 7) and in other situations where it exhibited low, erratic performance while serving as a gas generator to power mechanical devices. See reference 8. Those problems have occurred with the best developed and tested of all of NASA's pyrotechnic devices. There have been significant design changes deemed to be required after 20 years of application, covering a wide data base.

Whereas pyrotechnic devices usually have reliable performance, there has been no way to demonstrate the design margin in the operational environment. The effect of manufacturing changes on performance is an unknown. The effects of tolerance stack-up from variables within the system can be anticipated to result in unreliable devices.

Although flight data are not available, it is believed that a wiring error recently (1990) caused a major flight failure resulting in the loss of a commercial payload (Intelsat) due to the inability of the payload to separate from its upper stage of the commercial launch vehicle, the Titan. This is considered to be a system level problem that indicates the importance of the program taking system effects into account.

A.3.2.3 Resources/staff

To improve on the existing pyrotechnic devices, as well as to meet future program technical requirements, NASA needs more "hands-on," technology-oriented engineering personnel who have access to adequate test facilities. There is no NASA or DOD general fund source to meet these needs. As discussed in the previous section, design and problem solving are accomplished mainly by contractors under the management of specific individual program offices as needed. Very little formal pyrotechnic training or academic involvement is available. Thus, without the opportunity to gain experience in technology oriented facilities, government pyrotechnic personnel, of necessity, have placed a strong dependence on the manufacturer's expertise. The government's heavy reliance on the contractor's judgment concerning the product's performance obviously leads to an improper evaluation, or bias, regarding product adequacy for design considerations as well as for the conduct of failure analyses. The result is an inability to gain a valuable independent second technical judgment. Similar funding constraints in industry and product price competition have prevented industry from conducting a sound pyrotechnic technology program.

A.3.2.4 Communications

Intercenter communication, cooperation and support have been inadequate in exchanging and applying current pyrotechnic technology developments to all NASA programs. There are no libraries or central sources of information on this type of aerospace technology, particularly no data base of design information, test data, past problems, and failures. Indeed, the failure survey was necessarily conducted by polling the memory of senior, experienced individuals. Few papers on pyrotechnic failures are published; and few programs thoroughly document design information, functional performance properties, and physical characteristics in a format permitting engineers to conduct trade studies for subsequent programs. Furthermore, there have been no consistent, high-quality symposia, tailored to present data in a manner that meets the overall NASA needs to fill the stated voids. Most pyrotechnic efforts are done

independently with little intercenter cooperation or sharing of technical gains, problem and failure resolutions, and lessons learned. Thus, the pyrotechnic work has always been highly individualistic, program related, rather than a discipline oriented technology.

A.4 SUMMARY

> Not only is the government lacking good technical understandings of PAS that would be reflected by good specifications; but, in a highly competitive business world, the manufacturer also cannot afford to understand and characterize hardware commensurate with the high reliability demands placed upon it. The consequence is, the government has lost oversight; the manufacturer has lost insight; and the program risk is increased.

A focused program upon pyrotechnic technology can be expected to yield a large return in problem avoidance and problem resolution. The NASA Aerospace Pyrotechnically Actuated Systems Program can serve that role.

> One important point to remember is that these problems have been in existence for a very long period of time, and that their resolution will not be quick in coming.

It is anticipated that a **minimum of 5 years will be required** in order for this program to have a significant impact on NASA's mainline programs. Even after remedial measures have been developed, to be effective, it will be incumbent upon NASA to develop and implement an appropriate management instruction that takes advantage of the standardized hardware designs and technological developments that can be produced by this program. Each center will have a member of the Steering Committee who can assist in these matters.

DEFINITIONS AND ACRONYMS

Goal

The top level purpose of the program.

Near term

Activities having the highest urgency plus those required as a foundation for the strategic elements. This period of time is ~ 2-3 years.

NSD

NASA Standard Detonator

NSGG

NASA Standard Gas Generator

NSI

NASA Standard Initiator

Objective

Detailed focused activities to support the accomplishment of the program's goals.

PIP

Program Implementation Plan

Pyrotechnically Actuated Systems (PAS)

Include pyrotechnic devices and interfacing elements that could cause the pyrotechnic device itself to malfunction or for the pyrotechnics to influence an otherwise unwanted effect.

Pyrotechnic devices

Comprise explosive and propellant-actuated mechanisms excluding propulsion systems.

Qualification testing

Testing conducted to verify that factory manufactured hardware, when built to specification drawings and control documents, will meet specified performance requirements in the intended operational environment. The number of units tested will be sufficient to provide a representative sampling of the manufactured hardware.

Reliability testing

Testing conducted on the number of samples that is required in order to verify that factory manufactured hardware, when built to specification drawings and control documents, will meet specified failure rate requirements and performance requirements in the intended operational environment.

Specific performance

A higher level of output per unit input. In the case of pyrotechnics, it is the energy produced per unit mass.

Strategic

Long, 10-year, general purpose program plan to provide guidance for the properly directed development of the program in the future.

REFERENCES

1. Telecon—Mr. Norman R. Schulze of the Office of Chief Engineer, NASA Headquarters with Mr. Swain, Director, Systems Engineering and Operations, Langley Research Center, Hampton, VA, 1986.
2. Presentation by Aerospace Pyrotechnic Steering Committee, to the Associate Administrator for Safety, Reliability, Maintainability, and Quality Assurance, NASA Headquarters, April 13, 1988.
3. NASA survey entitled, "Solicitation of Interest in a Coordinated Pyrotechnic Technology Effort Among Centers," performed by the Langley Research Center, May 15, 1986.
4. Bement, L. J., "Pyrotechnic System Failures: Causes and Prevention," NASA TM-100633, Langley Research Center, Hampton, VA, June 1988.
5. NASA Aerospace Pyrotechnic Steering Committee meeting, Langley Research Center, Hampton, VA, November 13 and 14, 1986.
6. Bement, L. J. and Schimmel, M., NASA TM 4031, "Investigation of Super* Zip Separation Joint," Langley Research Center, Hampton, VA, May 1988.
7. NSI failure reports: JSCEP0083 (12/11/84), B00021 (1/31/86), HBC0108 (4/15/86),J00652 (7/18/86), JSCEP0006 (6/1/87), J00775 (11/13/87).
8. ALERT H5-A-89-01A. Explosives, Pyrotechnic Puller, Pin, Initiator, issued by Langley Research Center, Hampton, VA, June 2, 1989.
9. The Safety and Reliability of the Safe and Arm Mechanical Design for the NASA/LSFE Program, NOL TR 72-294, January 27, 1973.