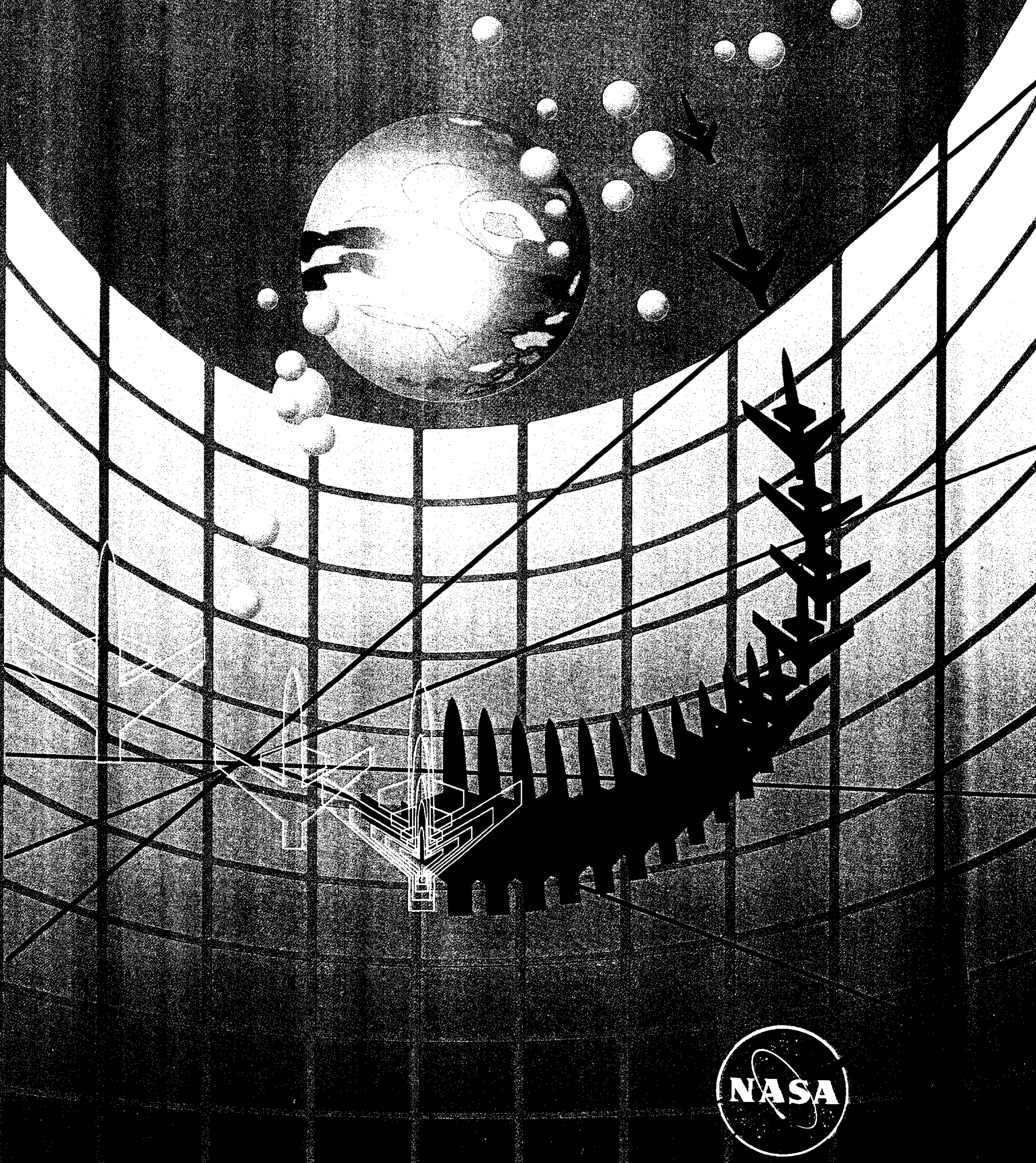
Aerospace Safety Advisory Panel

ANNUAL REPORT
MARCH 1993



NASA

National Aeronautics and
Space Administration

Aerospace Safety Advisory Panel

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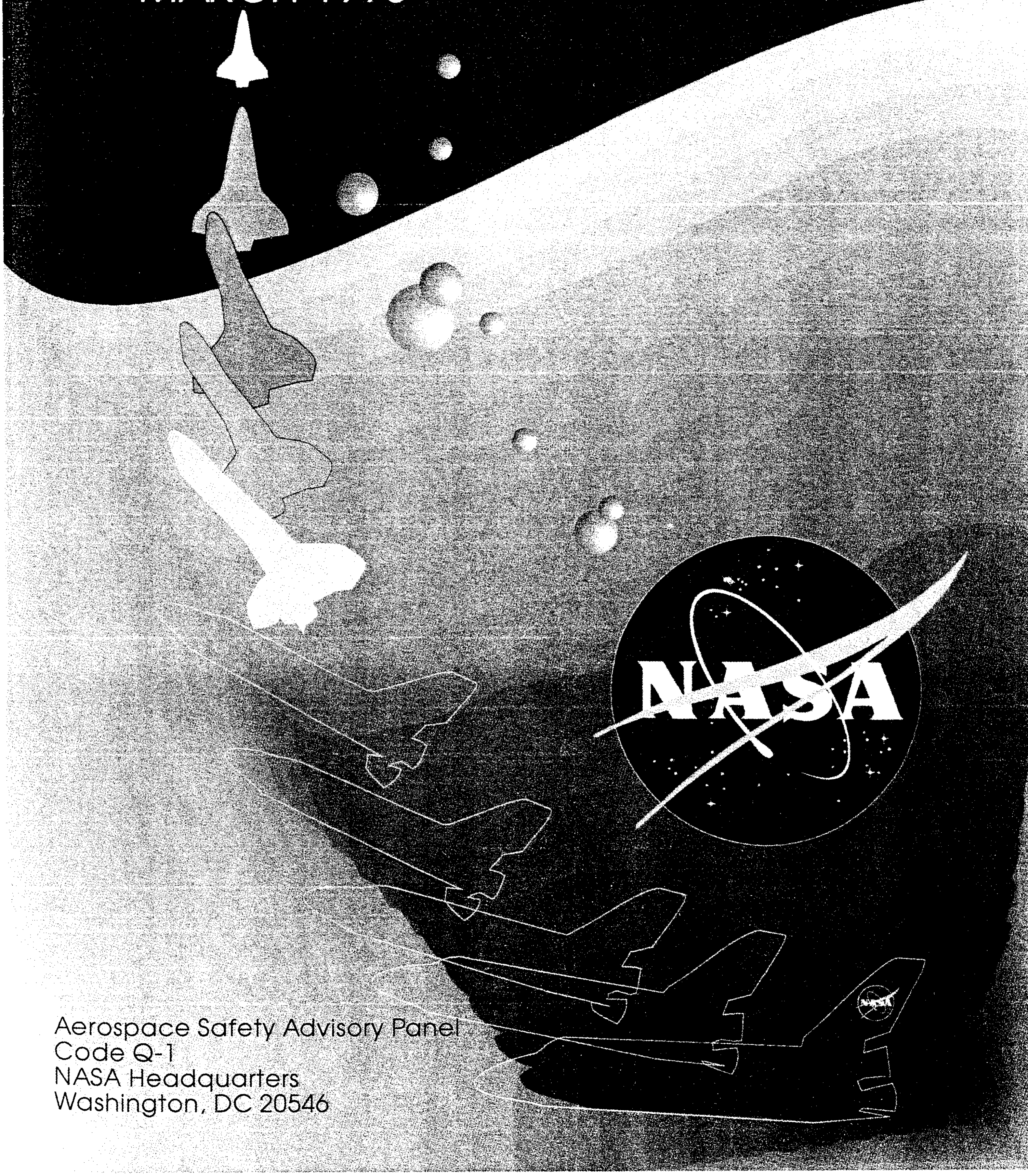

Aerospace Safety Advisory Panel
Code Q-1
NASA Headquarters
Washington, DC 20546

NASA
National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of: Q-1

March 1993

Honorable Daniel S. Goldin
Administrator
NASA
Washington, D.C. 20546

Dear Mr. Goldin:

The Aerospace Safety Advisory Panel is pleased to submit its Annual Report. This report covers the period from February 1992 through January 1993 and provides you with findings, recommendations, and supporting material. We ask you to respond only to Section II, "Findings and Recommendations." We also respectfully request your response, even in an interim form, within 3 months of receipt of the enclosed report. This will permit us to pursue open items in a timely manner.

Our relationship with NASA management over the past year has been most satisfactory. We are gratified by the confidence shown in us by you and your staff and the thoughtful consideration given to our analyses and recommendations. Over the next year, we plan to continue providing NASA with oversight on topics such as the impact of demanding schedules, Space Station Freedom organizational changes, the progress of the Station's data management system development, potential problems for the Space Shuttle and Space Station due to orbital debris, and the Space Shuttle major modification program.

We fully recognize that these are times of tight budgets and shifting priorities. Our Panel continues to believe that NASA's aeronautics and space programs, both manned and unmanned, are a vital national resource. We will do everything possible to assist you in assuring that these programs are pursued safely and productively.

Very truly yours,

Norman R. Parmet

Norman R. Parmet
Chairman
Aerospace Safety Advisory Panel

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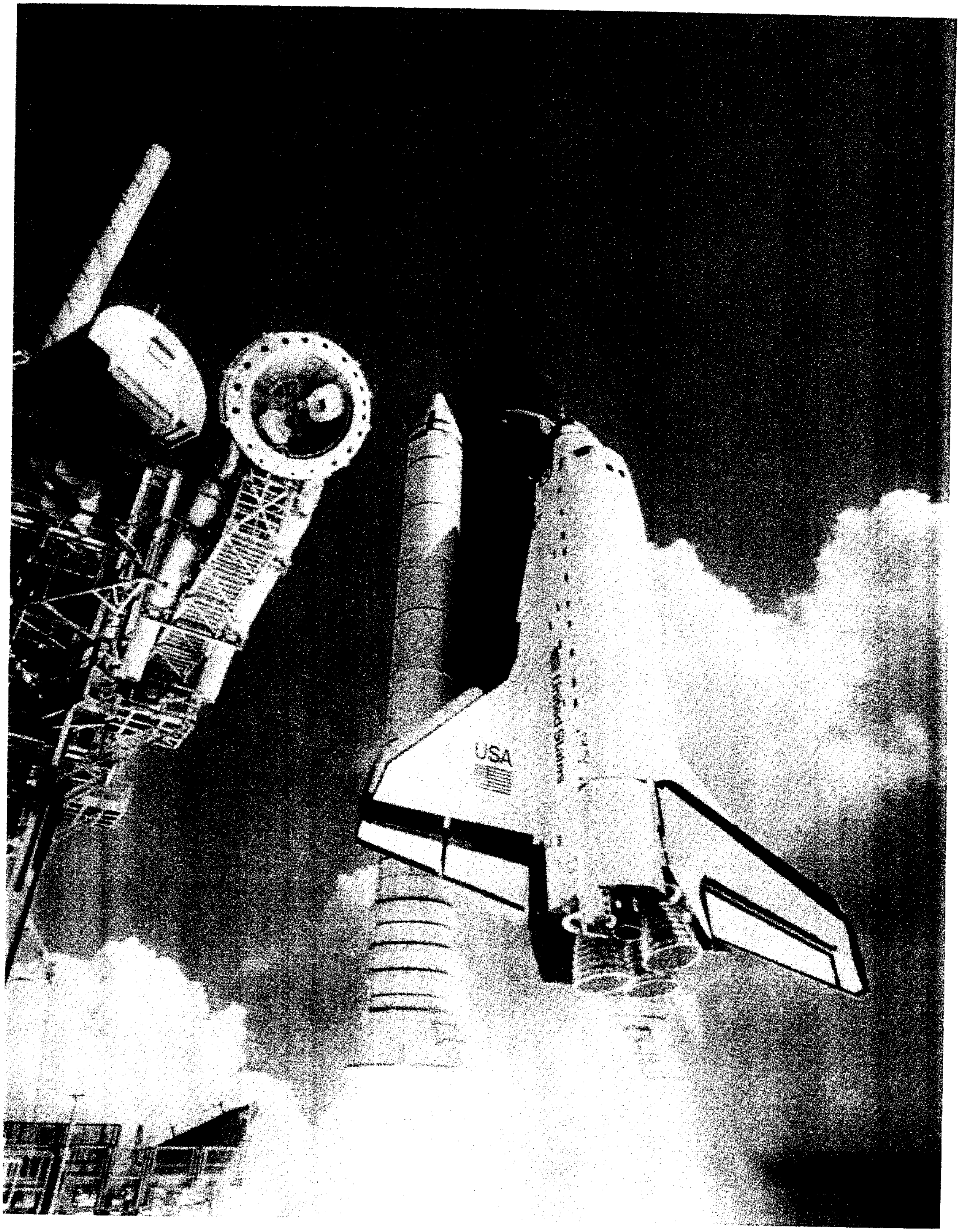


I. INTRODUCTION

I

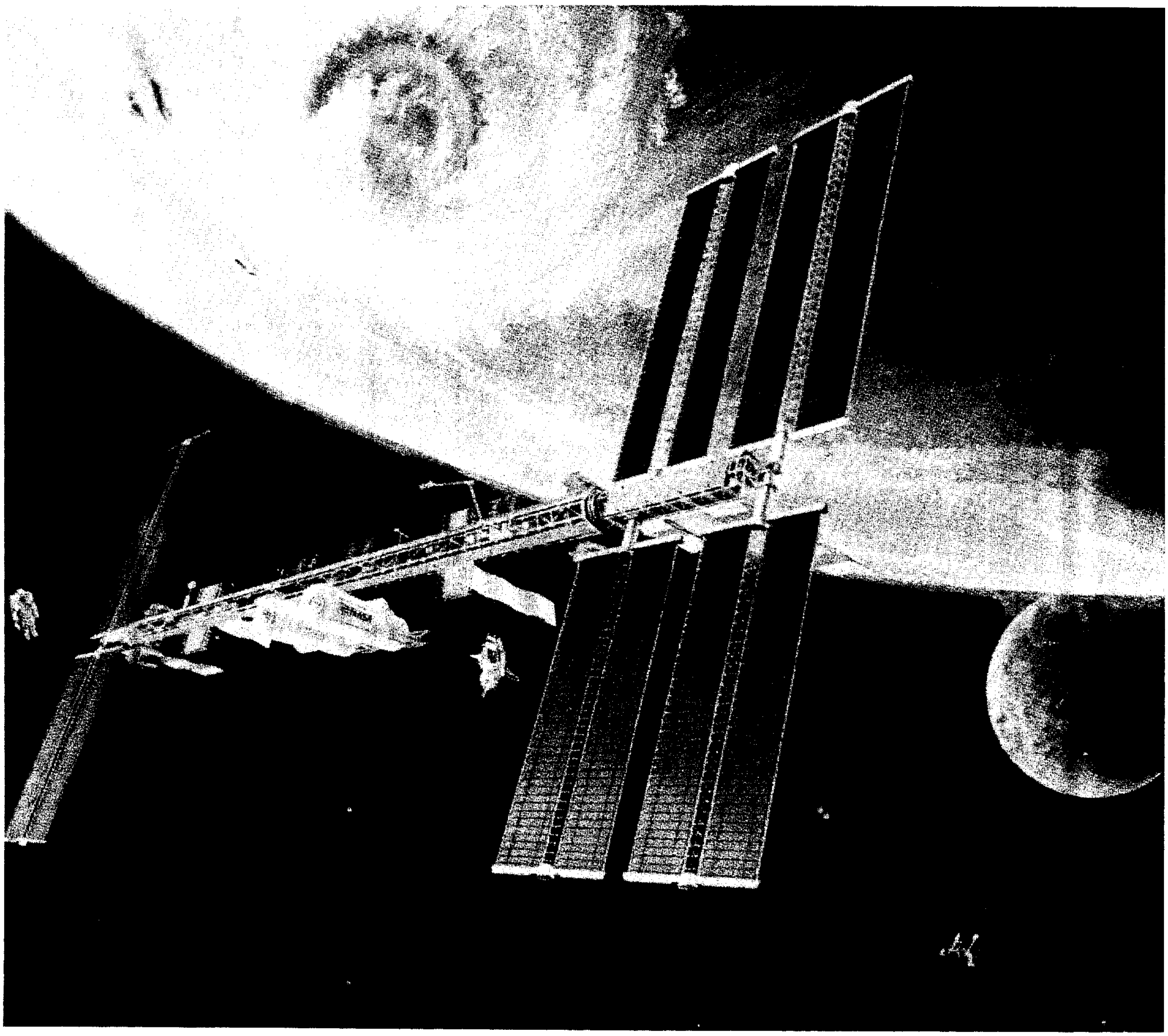
INTRODUCTION

The past year was one of significant accomplishments in many NASA programs. The Space Shuttle flew successfully and with greatly improved launch turnaround times. The Space Station Freedom Program emerged from its previous uncertainties and began to mature into a stable program. Much was learned about the ability of humans to work in space. Aeronautical research programs made significant advances that should yield benefits for both military and civilian aircraft programs.

As in past years, the Aerospace Safety Advisory Panel (ASAP) provided oversight on the safety aspects of many NASA programs. In addition, ASAP undertook three special studies. At the request of the Administrator, the Panel assessed the requirements for an Assured Crew Return Vehicle (ACRV) for the Space Station and reviewed the organization of the Safety and Mission Quality function within NASA. At the behest of the Congress, the Panel formed an independent, ad hoc, working group to examine the safety and reliability of the Space Shuttle Main Engine. Section II presents "Findings and Recommendations." Section III consists of "Information in Support of Findings and Recommendations" for the reader interested in more details. Appendices A, B, C and D, respectively, cover the Panel membership, the NASA response to the findings and recommendations in the March 1992 report, a chronology of the Panel's activities during the reporting period, and the entire ACRV study report.

The overall impression of the Panel is that the safety consciousness within NASA programs has continued the improvement trend highlighted last year. Nevertheless, sending humans into space and expanding the boundaries of atmospheric flight will always remain difficult and risky endeavors. NASA must continue its quest for risk reduction and for achieving the highest possible level of safety. Safety cannot be allowed to become "routine," but it also should not be permitted to paralyze unnecessarily a vital research venture. It is in this spirit that the ASAP presents its concerns. The Panel hopes to continue to play a role in NASA's safety efforts in the upcoming year by working closely with NASA and contractor personnel.

During 1992, Mr. I. Grant Hedrick retired after many years of service to the Panel. Mr. George A. Rodney retired as Associate Administrator for Safety and Mission Quality and ex-officio Panel Member and was replaced by Colonel Frederick D. Gregory. Mr. Paul M. Johnstone changed from consultant to member, and Dr. John G. Stewart and Mr. John F. McDonald changed from members to consultants. Dr. George Gleghorn was appointed to the Panel at the end of 1992.



II. FINDINGS AND RECOMMENDATIONS

II

FINDINGS AND RECOMMENDATIONS

A. SPACE STATION FREEDOM PROGRAM

Finding #1: The Space Station Freedom Program (SSFP) has progressed considerably in the past year. The entire effort now exhibits a degree of stability and continuity that has previously been absent. The program-level Safety and Mission Quality (S&MQ) function, however, is still not being addressed effectively.

Recommendation #1: NASA should place special emphasis on better integration of the S&MQ function into the overall Space Station Program. Attention should be given to assuring that the S&MQ function is an inherent part of the design and production processes. Areas to be addressed with significant urgency include software verification and validation, requirements for the caution and warning system, and normal and contingency operations planning.

Finding #2: The Space Station Freedom Program has established an Assured Crew Return Vehicle (ACRV) Project Office to develop requirements and manage the design of a "lifeboat" vehicle. The Panel examined the developed ACRV requirements in detail as part of a special study (see Appendix D). The ACRV Project Office has established excellent functional requirements which, if followed, should greatly reduce the risks inherent in leaving a crew on the Space Station without an attached Orbiter.

Recommendation #2: NASA should develop an Assured Crew Return Vehicle as a lifeboat in accordance with the ACRV Project system requirements and philosophy.

Finding #3: To allow robotic replacement of Orbital Replaceable Units (ORUs), the ORU designs must be robot-compatible. While progress is being made, the optimum level of robot compatibility has not yet been achieved.

Recommendation #3: NASA should set a goal of maximizing the number of robot-compatible Orbital Replaceable Units.

Finding #4: Considerable progress has been made in automation capabilities for Space Station Freedom. However, the inclusion of the caution and warning system operation within the overall *Integrated Station Executive* software is not scheduled until Mission Build 17, and there are hints that this plan might be subject to future software reductions and prioritization.

Recommendation #4: Because of the important safety role of the caution and warning system, NASA should provide for its operation under the *Integrated Station Executive* software as early as possible.

Finding #5: The central development facilities for the Data Management System (DMS) may not be adequate to support all of the software development and testing that will be required. Also, there is concern over the adequacy of the access of payload developers to the software development facilities.

Recommendation #5: NASA should review the capacity of its planned central development facilities for the Data Management System software to assure that adequate facilities are available to handle the load expected for SSF software development. NASA should also provide the payload community access to the DMS as quickly as possible and assure that payload developers have the facilities and information they need to complete their work safely and effectively.

Finding #6: Neither the *Timeliner* tool being developed for scheduling Space Station activities nor the scripts that will be developed using it appear to be receiving the same level of verification and validation as other Data Management System software.

Recommendation #6: The *Timeliner* software and the scripts created using it should be subjected to design verification and validation consistent with other mission-critical software.

Finding #7: The Software Support Environment (SSE) is of critical importance to the Space Station Freedom Program. Indeed, it is unlikely that the Space Station software can be successfully completed without the tools the SSE offers.

Recommendation #7: NASA should continue strong support of the development and use of the Software Support Environment.

Finding #8: The Space Station Freedom Program has begun the planning and development of an Integrated Logistics System, which coordinates the Work Packages and the Kennedy Space Center.

Recommendation #8: Continue working on the plan for the Integrated Logistics System.

B. SPACE SHUTTLE PROGRAM

ORBITER

Finding #9: The Space Shuttle automatic landing system needs only minimal additional analysis and a few system design changes to extend its performance limits and to support a complete definition of flight rules for its use. Cancellation of the detailed test objective for an automatic landing on the flight of STS-53 has further delayed the specification of these capabilities and the appropriate operational role of the automatic landing system.

Recommendation #9: Define the requirements and demonstrate the capability for an automatic landing system as soon as possible.

Finding #10: NASA has funded the development and installation of a Multi-Purpose Electronic Display System (MEDS) for retrofit into the Orbiter. This system will replace the conventional electro-mechanical instruments with flat panel displays. Commercial transports and military aircraft have been flying with MEDS-equivalent "glass cockpit" systems for some years, some converted from older, conventional cockpit displays.

Recommendation #10: The inherent operational and potential safety benefits of Multi-Purpose Electronic Display System warrant its installation in the Space Shuttle as soon as possible.

Finding #11: The inventory of Auxiliary Power Units is currently being upgraded to an Improved Auxiliary Power Unit configuration to improve reliability and service life. The upgrade program, however, projects a condition of zero spares in the future due to time limits on some parts.

Recommendation #11: NASA should take the steps necessary to preclude a situation of zero Improved Auxiliary Power Unit spares.

Finding #12: The Improved Auxiliary Power Unit represents a major improvement in durability and safety. However, the Gas Generator Valve Module (GGVM or "bang-bang" valve) continues to require frequent replacement because of the high-stress manner in which the valve operates. There are alternative valve designs that can be adapted to perform the same function.

Recommendation #12: NASA should continue to explore improved Gas Generator Valve Module designs with the goal of providing a replacement for the current configuration as soon as practicable.

Finding #13: The results of flight tests on the Orbiter *Columbia* (OV-102) using pressure and strain gage measurements on the wing showed that the calculated ascent loads on the wing are conservative. Additional flight tests to be conducted will measure the pressure distribution and strains on the wing and tail of OV-102. These data are required to substantiate that the predicted applied and internal loads on the wing and tail are conservative.

Recommendation #13: Conduct the planned tests as expeditiously as possible. Particular emphasis should be placed on the loads on the tail.

SPACE SHUTTLE MAIN ENGINES (SSME)

Finding #14: The Space Shuttle Main Engine program is doing well and has sufficient spares. However, the engines still require meticulous attention to detail in inspections and tests.

Recommendation #14: Continue the vigilant implementation of the inspection and test procedures while design solutions for known weaknesses are being addressed.

Finding #15: The individual major component improvement programs are making progress. However, a total engine upgrade is being delayed because the High Pressure Fuel Turbopump (HPFTP) part of the Advanced Turbopump Program (ATP) is on hold. The highly effective Large Throat Main Combustion Chamber (LTMCC) has finally been made a formal part of the Space Shuttle Main Engine program by NASA but has been denied appropriations by Congress. Schedule disparities among the various component improvements lead to interim certifications of components in engine configurations that will never fly and to unnecessary duplication of certification tests.

Recommendation #15: The identified Space Shuttle Main Engine design improvements are vital to the reduction of Space Shuttle operational risk. Therefore, NASA should reinstate the Advanced Turbopump Program High Pressure Fuel Turbopump development; continue to press for approval of the Large Throat Main Combustion Chamber; and examine carefully the benefits of integrating all the individual modifications into a block change program.

SOLID ROCKET MOTORS

Finding #16: Three Flight Support Motors have been used to date to verify quality and qualify design improvements, reproducibility, and replacement materials for the Redesigned Solid Rocket Motor (RSRM). In the near future, new materials will be needed in the RSRM to replace those eliminated for environmental or safety concerns. It will also be necessary to qualify new vendors to replace those who have left the industry or are no longer willing to supply components for the RSRM.

Recommendation #16: To maintain safety and performance, NASA should continue the use of Flight Support Motors for quality control, validation of design improvements, and qualification and verification of new materials, processes, facilities, and equipment.

Finding #17: Soot has been found on the O-rings serving the Redesigned Solid Rocket Motor nozzle internal joint number 2 significantly more frequently than on the similar O-rings for the other four joints combined. A new assembly sequence with Room Temperature Vulcanizer (RTV) backfill is being used to counter this problem.

Recommendation #17: The possibility of heat effect or blowby at the primary seal of nozzle joint number 2 is sufficiently high to suggest the need for a redesign of this joint to eliminate the present procedurally based solution.

Finding #18: The projected factor of safety of the aft skirt when used on the Advanced Solid Rocket Motor is less than specified. Installation of an external bracket has been proposed as a means of returning the factor of safety to the level in the design requirements. A segment of an aft skirt is to be used to test the effectiveness of the external bracket modification. The test of this 11-inch-wide specimen may not duplicate the actual strains and boundary conditions that would be experienced by a complete aft skirt and, therefore, may yield unreliable results.

Recommendation #18: The effects of the external bracket modification would be better evaluated if a full-scale skirt were tested in the facility that was previously used for the influence testing of a complete aft skirt.

Finding #19: Potential stress corrosion cracking of case welds on the Advanced Solid Rocket Motor is an acknowledged problem. The residual stress is not uniform over the entire weld. Residual stress peaks can occur at the start and stop of the welding process.

Recommendation #19: The Advanced Solid Rocket Motor Program should assess the adequacy of its stress corrosion cracking test plan to assure that sufficient pass/fail criteria tests are included.

Finding #20: The top-level requirements document for the Advanced Solid Rocket Motor manufacturing software is not scheduled to be available until July 1993. Also, systems integration and systems level testing plans for the ASRM manufacturing facility are not yet ready.

Recommendation #20: The overall Advanced Solid Rocket Motor manufacturing system software requirements document and systems integration and test plans are important parts of the system development. They should include a comprehensive test plan and an evaluation mechanism capable of tracking the system operation through its lifetime.

LAUNCH AND LANDING

Finding #21: The Kennedy Space Center has begun a pilot Structured Surveillance Program with the objective of increasing the efficiency of the quality control function in order to enhance launch turnaround processing. This program appears to have great potential.

Recommendation #21: Before Structured Surveillance can be fully implemented, it must be carefully evaluated to assure that it is fully supportive of safe flight operations.

Finding #22: The use of task teams at Kennedy Space Center has expanded with apparently successful results.

Recommendation #22: Continue to develop and use the task team concept. If Structured Surveillance proves successful, consideration should be given to integrating it with the task teams.

Finding #23: A new high bay Orbiter Processing Facility (OPF-3) has been opened at the Kennedy Space Center. In addition to advanced support equipment, OPF-3 has vastly improved lighting, which should decrease accident risk and increase productivity.

Recommendation #23: NASA should upgrade the lighting in the other Orbiter Processing Facilities as soon as possible to avoid differences across the high bays and maximize safety and productivity.

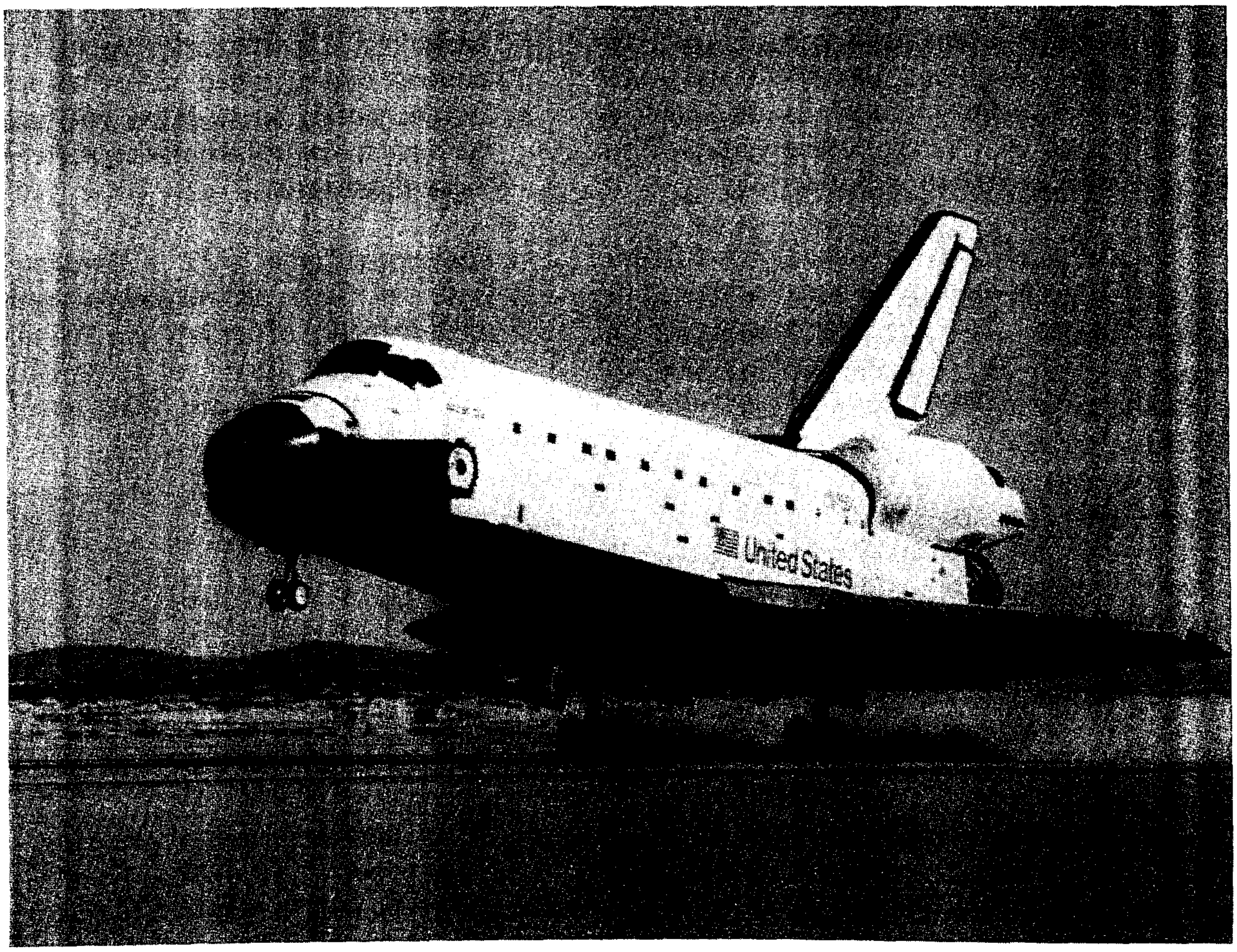
LOGISTICS AND SUPPORT

Finding #24: The NASA Shuttle Logistics Depot has great potential for improving repair turnaround times and enhancing the logistics program. At present, however, repair turnaround times are still significantly longer than desired due largely to protracted failure analysis times.

Recommendation #24: The Space Shuttle Program needs to establish a more effective method of moving units through the repair cycle in order to achieve the full potential of the NASA Shuttle Logistics Depot.

Finding #25: Performance of the Space Shuttle logistics system is excellent and difficulties such as loss of suppliers are being diligently addressed and corrected.

Recommendation #25: Continue placing the strongest possible emphasis upon controlling the growth in the number of below-minimum or zero stock levels. Where possible, alternative sources should be qualified or manufacturing and repair capabilities should be transferred to NASA facilities such as the NASA Shuttle Logistics Depot to compensate for the loss of suppliers.



C. AERONAUTICS

Finding #26: A NASA Headquarters Aircraft Management Office (AMO) has been established. The Office is headed by a senior manager reporting directly to an Associate Administrator. In addition, a new, comprehensive *NASA Aviation Safety Officers Reference Guide* has been promulgated.

Recommendation #26: NASA should continue to support a strong Aircraft Management Office and manage the NASA Aviation Safety Program in accordance with the *NASA Aviation Safety Officers Reference Guide*. The longstanding and dedicated Intercenter Air Operations Panel (IAOP) should be maintained as an independent entity. Together, the AMO and IAOP, guided by this reference guide, should be highly effective in maintaining the safety of NASA's aviation activities.

Finding #27: NASA maintains a fleet of aircraft for management and administrative purposes. Many of these aircraft are old, and some have even exceeded their originally specified service lives. Although excellent maintenance is currently coping with problems such as stress corrosion due to age, safety can be compromised if the level of maintenance decreases.

Recommendation #27: NASA should conduct a review of its aging aircraft and establish a coordinated program of upgrades, replacements, and appropriate additional safety inspections.

Finding #28: Flight research at the Dryden Flight Research Facility includes a number of test programs with aircraft, such as the F-15 and SR-71, that are potentially hazardous and therefore require a continuous and detailed safety effort. The Dryden safety procedures and activities continue to control the risks associated with these flight tests.

Recommendation #28: Dryden Flight Research Facility should maintain emphasis on the practice of periodic reviews of safety procedures to assure all reasonable risk reduction measures are being taken.

D. OTHER

Finding #29: At the request of the NASA Administrator, the Panel examined the organizational structure of the Office of Safety and Mission Quality and the counterpart organizations at NASA Centers. The study concluded that the current organizational arrangement provides an appropriate and effective relationship between NASA Headquarters and the Centers.

Recommendation #29: Maintain the current organizational structure, but clarify the functions and duties of the Headquarters Office of Safety and Mission Quality and those of Center Directors and, if necessary, issue revised NASA Management Instructions.

Finding #30: NASA has begun development of a Simplified Aid for EVA Rescue (SAFER). SAFER is a small maneuvering unit intended to fit at the bottom of the Portable Life Support System (PLSS) of an extravehicular activity (EVA) astronaut. Its main purpose would be to permit the safe recovery of an astronaut who becomes untethered from the Space Station or an Orbiter that was operating in a mode which prevented it from moving quickly for a recovery. SAFER also provides significant maneuverability for EVA astronauts, without the need to carry and deploy the larger and more complex Manned Maneuvering Unit (MMU). The SAFER concept has merit for enhancing safety and improving operational efficiency. The development program appears to have proceeded satisfactorily.

Recommendation #30: Because the requirement for a SAFER as a rescue unit appears to be well founded, and it has additional mission benefits, its full-scale development is recommended as soon as possible.

Finding #31: The Intelsat repair mission highlighted the need for additional types of crew training aids that can augment existing computerized and underwater simulators to provide better representation of the dynamics involved in EVA work efforts. The virtual reality systems being developed by NASA and others appear to offer significant promise for providing some of the additional training needs.

Recommendation #31: NASA should begin a program to assess the benefits of using virtual reality systems in more aspects of astronaut training.

Finding #32: In spite of some progress, the Space Shuttle and Space Station Freedom Programs are still not sufficiently addressing human factors issues. For example, the absence of a definitive user console layout standard between NASA and the International Partners for the Space Station could cause problems for training and on-orbit operations.

Recommendation #32: NASA management should encourage the active consideration of human factors issues within the Space Shuttle and Space Station Freedom Programs. This might be best accomplished by requiring the inclusion of someone with specific human factors training in decision-making at all levels.

Finding #33: Independent verification and validation (IV&V) of large software systems is considered critical to program success. There has been some confusion over the independent verification and validation activity for Space Station Freedom Program and the role of various groups in accomplishing it.

__Recommendation #33:__ NASA should develop a clear definition of what is meant by independent verification and validation. This definition should encompass both the activities to be performed as part of verification and validation and the degree of independence required.

__Finding #34:__ NASA research and test facilities are a national asset, key to the United States' continuing leadership in space and aeronautics. Regrettably, some of the infrastructure is not being adequately maintained, and the development of new, state-of-the-art facilities has been lagging.

__Recommendation #34:__ NASA should develop an integrated long-range infrastructure plan that assures the maintenance of existing assets and develops new facilities to continue American leadership in space and aeronautics research and development.

__Finding #35:__ The Tethered Satellite System deployment failed as a result of a field modification that was improperly controlled and tested. The change review process employed did not uncover the flaw.

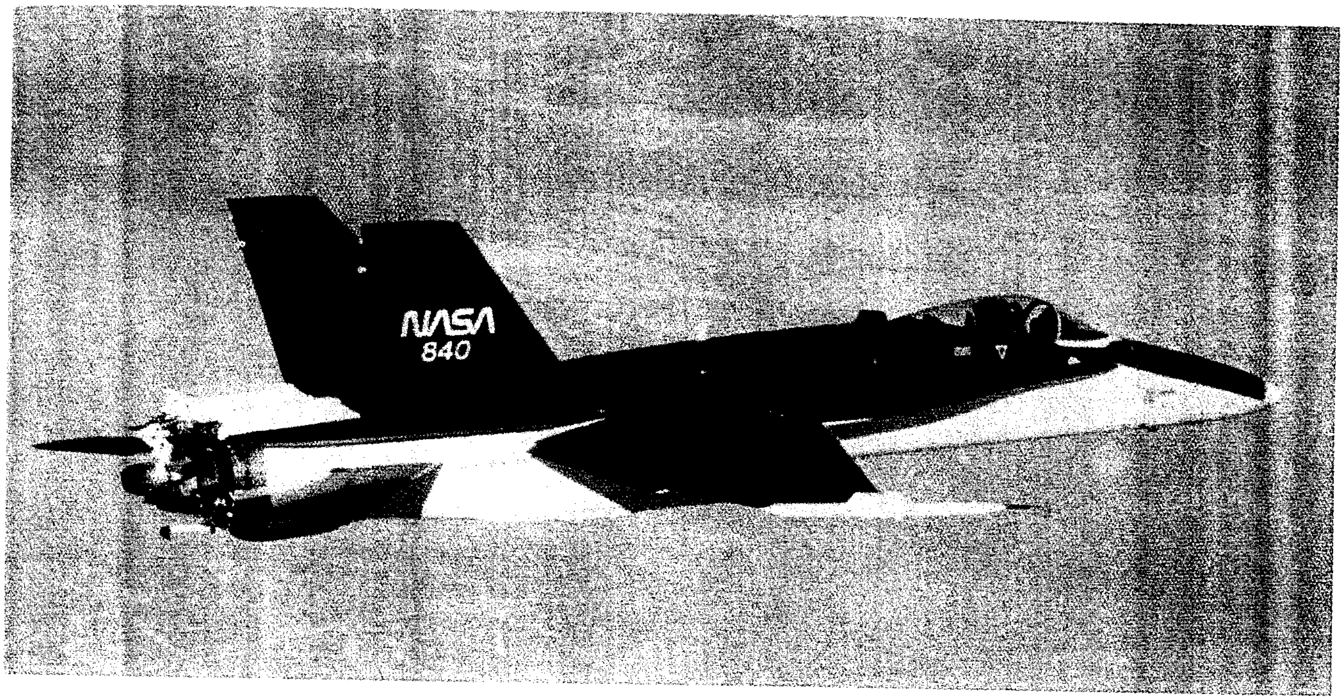
__Recommendation #35:__ NASA should increase its emphasis on complete system testing when feasible. In addition, care should be exercised to ensure that changes to flight systems between completion of the last total systems test and the flight of the equipment are properly analyzed, controlled, and executed.

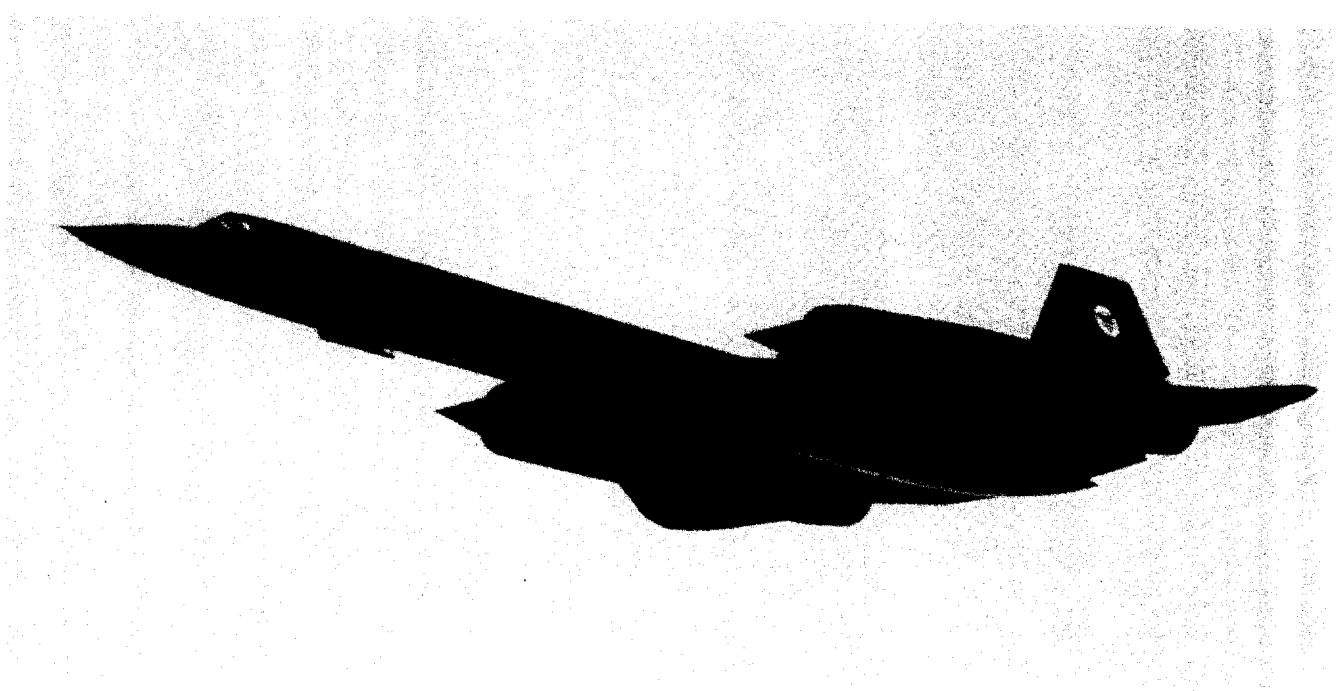
__Finding #36:__ NASA has embraced the concept of Total Quality Management (TQM). However, TQM implementation across NASA centers and contractors appears to vary from highly visible and apparently productive efforts to activities that seem to have more form than substance.

__Recommendation #36:__ NASA should review its internal Total Quality Management program to assure that it is properly structured as a support function and includes not only motivation, but also appropriate leadership and training for both TQM instructors and hands-on employees.

__Finding #37:__ The Aerospace Medicine Advisory Committee has produced a report entitled, "Strategic Considerations for Support of Humans in Space and Moon/Mars Exploration Missions (Life Sciences Research and Technology Program, Volume 1)." This excellent report contains a series of recommendations relating to human exploration in space that pinpoint areas that NASA should explore prior to embarking on extended duration space flight.

__Recommendation #37:__ NASA should address the recommendations contained in the referenced report in a timely fashion.





III. INFORMATION IN SUPPORT OF FINDINGS AND RECOMMENDATIONS

III

INFORMATION IN SUPPORT OF FINDINGS AND RECOMMENDATIONS

A. SPACE STATION FREEDOM PROGRAM

Ref: Finding #1

The Space Station Freedom Program (SSFP) briefings presented to the Panel during 1992 included several broad Program overviews as well as more in-depth explorations of specific areas such as the Data Management System (DMS) and Assured Crew Return Vehicle (ACRV). Overall, the information obtained highlighted how much the program has improved since the Panel's review last year. There is an obvious sense of stability and continuity that was previously lacking. The program organization and use of panels and working groups appear reasonable and capable of getting the job done. The definition of the role of the Safety and Mission Quality function, however, is still vague, and its integration into the project structure needs to be handled better for effective performance of its role. The effects of the shift of some responsibilities from Reston to the Johnson Space Center (JSC) announced late in the year will be monitored by the Panel in the upcoming year.

The SSFP appears to have a clear set of *functional* requirements *at the program level.* This, in turn, has resulted in excellent redundancy analyses and the definition of a good set of requirements documents. The current backlog of documents is scheduled to be "caught up" in the very near future. Unfortunately, the same level of functional analysis to support some of the subsystem requirements and designs is not in evidence. For example, the caution and warning and safe haven preliminary designs do not show the same depth of analysis as the major SSFP systems. The caution and warning system and backup Emergency Monitoring and Display System (EMADS) should be based on detailed consideration of the information the crew requires to be able to select among available countermeasure response options for each type of situation covered.

Progress has been made in the design and production of Space Station hardware. For example, two of the largest integrated-truss assembly structural bulkheads have been rough-machined. Structural test fixtures have been built, and some structural hardware has been manufactured for qualification testing. Also, electric power system components have entered functional tests.

The current design philosophy assumes that a docked Orbiter will be monitored by an on-board crew member because of an operations rule which dictates that at least one crew member will remain on an attached Shuttle at all times. It might be beneficial to include two-way monitoring of both an attached Orbiter and the ACRV in the caution and warning design. When these vehicles are at the Space Station, they are