stress on the pane's surface, there always will be a hypervelocity particle that can penetrate the pane. A redundant thermal pane window design may be feasible to incorporate within the vehicle to provide another layer of protection against the risk associated with a failed thermal pane.

Vehicle on-orbit operational attitudes that could minimize exposure to debris have been reviewed, though more work needs to be done. Uncertainties in the analysis data presented to date are greater than the risk reduction a different attitude would give. The probability of a particle large enough to penetrate the thermal pane is very small, about 10 to the minus 4 for a 7-day mission. Thus, the risk is small for continuing to operate without attitude restrictions. The effect on the vehicle during entry for the crack and/or loss of a thermal pane is being studied. Entry profiles that could be flown to minimize thermal stresses on a cracked window and surrounding structure will be evaluated once the damaged window study has been completed. Current mission rules require an orbiter entry at a cabin pressure of 10.2 psi for the loss of a thermal pane, thereby minimizing stresses on the remaining panes and window structure.

Finding #13: *During preparations for the launch of STS-29, an incorrect set of software for the ascent phase was produced and sent to the Kennedy Space Center. The error was caught by a comparison with an independently created "build" from Rockwell and IBM. The error was easily corrected once found.*

Recommendation #13: The incident emphasizes the need for an independent verification and validation system for software testing. Such a system should have the following attributes:

- Independent validation of the software generation procedures employed
- Independent check of the tests employed to verify the software generated
- Thorough validation of the software generation and check procedures from a safety point of view
- Traceability provisions
- Software failure modes and effects analysis.

NASA Response: NASA is meeting the intent of the recommendation for an independent verification and validation for software testing. The system did allow a software error in the software build to be sent to the KSC. The late parallel independent software check between Rockwell and IBM, that allowed this error to be sent to KSC, has been corrected. Key factors of the STS-29 Flight Software (FSW) incident are briefly described as follows:

- The STSOC FSW reconfiguration contractor omitted two SSME software patches from the STS-29 complementary FSW load delivered to KSC. This error pointed out a process problem in the STSOC complementary load build process particularly, as well as a process in the basic FSW reconfiguration process for Recon 1 and Final Load.

- IBM, the primary FSW development contractor, also performs what we call "Parallel Certification" of all mission integrated mass memory FSW reconfigured and produced by STSOC (RI-Downey, the backup FSW development contractor, also performs Parallel Certification of the mission backup FSW reconfigured by STSOC). IBM, in their Parallel Certification role, caught STSOC's omission of the SSME patches by comparison of STSOC's integrated mass memory with that independently built by IBM.

- The SASCB Chairman, per standard procedures, approved the Release Authorization Sheet (RAS) authorizing use of the STSOC complementary load in the field (KSC, SAIL, etc.). IBM Parallel Certification comparison results were not required to be completed before RAS authorization. Therefore, the RAS authorizing use of the STSOC complementary load was executed before knowledge of the Parallel Certification miscomparison.

A thorough review of the STSOC FSW reconfiguration process was conducted and all recommended process changes have been implemented. The Parallel Certification activity is still firmly involved in the FSW mission certification process. But ever since this STS-29 complementary load incident, RAS's require Parallel Certification statement regarding results of the bit-for-bit comparisons; therefore, no FSW product will be released to the field without confirmation from Parallel Certification with proper bit-for-bit comparisons.

Relative to ASAP's recommendation, the Space Shuttle Program totally concurs that the "Parallel Certification" activity performed by the FSW development contractors is required and plays a significant role in NASA's independent verification and validation (IV&V) system for software testing. This Parallel Certification/IV&V activity provides independent validation tests since Parallel Certification has developed their own FSW build procedures, builds their own integrated mass memory, and defines/conducts their own verification tests. Both STSOC and Parallel Certification have well documented audit/traceability systems in place. The JSC SR&QA provides an oversight of the FSW process--they are represented on the Shuttle Avionics Software Control Board (SASCB) and have their contractor (Ford Aerospace) perform independent requirement-to-code audits of the FSW. There is no classic FSW failure modes and effects analysis (FMEA), and both JSC-SR&QA and the Space Shuttle Program do not view this as necessary. Formal FSW analysis and discrepancy resolution is performed on all FSW. These analyses include test runs on multiple test facilities, e.g., SAIL, SMS, and SPF, as well as off-line processors and constitute a thorough assessment of the FSW.

In summary, the present FSW Parallel Certification process and SR&QA provide the program with all the necessary IV&V attributes recommended by ASAP. The program concurs with ASAP that this Parallel Certification IV&V activity is a significant element of the FSW process and must be continued. However, the FSW verification and testing eliminates any need for a FMEA.

<u>Finding #14</u>: NASA faces a significant problem with respect to its Space Shuttle computers that has not been addressed: a third generation of computers to replace the new computers to be installed in 1991. While it may seem premature to consider a third generation computer before the second generation has been installed, the rate at which computer technology is advancing compels such a consideration. Additionally, in the near future, NASA will have two major flight computer systems to manage (those of the Space Shuttle and Space Station). Both will be obsolete before the orbital assembly of the Space Station commences.

<u>Recommendation #14</u>: NASA should begin planning now for a process of regular upgrades to the Space Shuttle and the Space Station Freedom computers including, perhaps, a transition to the use of a common underlying computer architecture for the two systems.

<u>NASA Response</u>: NASA concurs with this recommendation for the long term but disagrees that this is a near-term issue. NASA believes that efforts currently underway are sufficient to identify and provide any necessary upgrades to the Space Shuttle and Space Station Freedom computing systems.

The new Space Shuttle General Purpose Computer (GPC) is scheduled for its first flight on STS-41 in October 1990. Design work for the new GPC began in January 1984, and the first new computers will be flown in late 1990 or early 1991. The calendar time required to design, test, and certify such a man-rated system practically assures that system to be technologically obsolete for most of its operational life. The expected life of the new GPCs is 15 years. Subsequent major changes to the computer system architecture would require revision of the complete avionics package. NASA believes that any consideration of possible further improvements to the GPCs or to the computer system should be an integral part of the Assured Shuttle Availability (ASA) Program.

The Space Station Freedom Program (SSFP) is planning for the upgrading of computers and/or software as improved technology permits. This planning, documented in its highest level program document, the Program Requirements Document (PRD), and in its second level requirements document, the Program Definition and Requirements Document (PDRD), is in two areas. First, the SSFP is planning for mainframe computer hardware and support software replacement every 7 years and workstation replacement every 5 years during the program's operational phase. Second, the program is establishing evolutionary requirements allowing the flexibility to upgrade to advance technology as it becomes available. As a result, requirements for the operational Space Station Information System require a design that isolates applications software (both flight and ground) from the underlying computing system. This promotes the migration of ground hardware and software to the flight systems or from facility to facility, and maximizes flexibility for replacement of flight hardware during the life of the program.

Transition to the use of a common computer architecture in both the Space Shuttle and Space Station is not considered feasible due to the differences in the underlying design philosophy of the two systems. The Space Shuttle, although relying on five computers (four primary and one backup), is essentially a centralized system fully integrated with the avionics package. Migrating the Space Shuttle computer architecture to some other design, such as that employed by the Space Station, would require the complete redesign of the avionics system. The Space Station, on the other hand, employs a decentralized system utilizing microcomputing technology as its driving force. Additionally, these systems employ radically different operating systems, programming languages, and are subject to different weight and volume constraints.

Space Shuttle Main Engine

Finding #15: The Space Shuttle Main Engines have continued to perform satisfactorily in flight. Operations are hindered, however, by the need to replace the high pressure oxidizer turbopump bearings after each flight. The impact of this requirement is mitigated by an increase in the number of spare turbopumps available. The flight bearing wear detection instrumentation that is being developed holds promise of permitting safe reuse of "healthy" bearings in the near term. Modifications of the bearing installation now in test have the potential for alleviating the high pressure oxidizer turbopump bearing wear problem.

The development of the two-duct power head (hot gas manifold) has continued with test results as good as, or better, than predicted. Incorporation of this change will alleviate some of the loads internal to the engine; specifically, those resulting from non-uniform velocity and pressure distributions in the flow passages caused by the present three-duct power head. Certification of the two-duct design is planned.

Work on the large-throat main combustion chamber has progressed slowly. Test data show that it provides major reductions in turbomachinery stress levels and environments. Combustion has been demonstrated to be stable and systems effects that would accompany its incorporation can be accommodated by straightforward modifications to other components; some of which are in work for other reasons. The large-throat main combustion chamber still is not a part of the engine improvement program even though it offers major increases in operating safety margins. The activity is treated as a technology program. Current opinion maintains that if the chamber is to be included in the engine improvement program, it should await other changes and be incorporated as part of a "block change" to the engine.

The alternate turbopump development program is nearing the major component test phase. The design is intended to incorporate the lessons learned from the development and operation of the current turbomachinery. The program also benefits from the ability to test individual turbopumps in a component test facility rather than on an all-up engine.

Recommendation #15: Since all of the engine modifications being developed enhance the safety margins of the system, these developments should be worked as expeditiously as possible. A much more aggressive development program should be instituted. This applies not only to the high pressure oxidizer turbopump bearing modification and the two-duct hot gas manifold, but also to the large-throat main combustion chamber. The latter modification should be made a formal part of the Space Shuttle Main Engine safety enhancement program; a segment of the Assured Shuttle Availability Program and its development and certification should not be constrained by other possible engine improvements. The pace of work on existing turbomachinery should not be decreased based on the anticipation of its replacement by alternate turbopumps, which are still in the early development stages.

NASA Response: A program plan has been developed by the SSME project in conjunction with the contractor and government technical experts, which addresses the identified limitations of the current engines and is structured to aggressively pursue enhancements for improving the engine. A formal program has been defined that includes enhancements to all items identified in the finding/recommendation; and in addition, addresses other concerns such as uninspectable welds in the current design.

In regard to the existing turbomachinery, health monitoring instrumentation modification to address the condition of oxidizer turbopump bearings after flight has been certified and incorporated on the flight pumps, which will permit two flights without removal, provided the bearing signatures are within acceptable limits. The modification was successfully flown on STS-31. The flight certification program to extend the Rocketdyne fuel and oxidizer turbopumps to at least five flights is being aggressively pursued and projected to be completed in 1991.

The near-term engine enhancement plan (FY94 fleet implementation) includes incorporating the phase II+ powerhead, which significantly reduces the severe hot gas flow environment, eliminates the preburner injector pins, incorporates the single tube internal heat exchanger (no interpropellant welds), and other design improvements, i.e., relocates a number of welds for producibility and inspectability. The other FY94 initiative is the implementation of the P&W alternate turbopumps, which significantly reduces the number of critical welds in each turbopump.

The long-range initiative, being pursued as a part of Assured Shuttle Availability (ASA), addresses other major concerns such as uninspectable welds in the MCC, nozzle, powerhead, and ducts, and takes advantage of advance fabrication techniques that will increase safety margins and significantly reduce manufacturing cost. The large throat MCC configuration with the main injector baffle and acoustic cavity elimination has completed characterization testing and appears to offer significant benefits in regard to reduction of the turbomachinery operating environments. The large throat MCC also will be implemented as a part of ASA. Although the large throat MCC and advanced fabrication are not constrained to be implemented together, that does appear to be the most favorable approach at this time.

The ground test hot fire exposure plan is extremely aggressive, and the proposed dates of incorporation into the fleet are largely limited by adequate ground test exposure. The plan is designed to upgrade via block change in 1994, and again in approximately 1996 and would result in an engine in the mid 90's, which positively addresses all known concerns.

Redesigned Solid Rocket Motor and Solid Rocket Booster

Finding #16: Static structural tests of the solid rocket booster aft skirt demonstrated that a weld cracked at a load equivalent to a 1.28 factor of safety on limit load. The aft skirt was able, however, to support a load equivalent to a 1.41 factor of safety without further failure. Waivers permitting the use of the aft skirt with a 1.28 factor of safety have been processed for each flight.

Recommendation #16: Despite the successful use of the current aft skirt, it would be advisable to improve the aft skirt in structural design and/or material so that it would demonstrate a 1.4 factor of safety. At a minimum, the analysis of the skirt structure should be improved to permit better comprehension of the load redistribution process after weld failure as well as the effects of the shock produced by weld failure on other booster systems attached to the skirt.

NASA Response: A number of inspection, testing, and analysis efforts are being performed to ensure that the existing aft skirt has adequate design margin and high reliability under all conditions. These efforts include both the normal activities associated with refurbishment and recertification as well as special testing programs to monitor aft skirt weld strains and applied loads during launch, and to develop methods and procedures for increasing the weld factor of safety.

Thus far. the results of the special testing efforts have been very positive, indicating that the aft skirt launch loads and weld stresses were below maximum design values, and that the weld factor of safety can be increased by using a skirt radial preload and careful booster stacking. In addition, a comparison of load-strain relationships from the launches with those from the structural tests suggests that the weld strains do not reach design limit. Therefore, the effective factor of safety for launch is 1.28 or greater. In addition to conducting special test programs, NASA has continued to study and refine the finite element structural models for the aft skirt and the Mobile Launch Platform (MLP) to better understand and model launch results and structural test results. Changes to the aft skirt and MLP models to incorporate moment transfers across the spherical bearing interfaces are in work to explain differences between launch and structural test load-strain results. Moment transfers at the support bearing interfaces (due to friction) may act to reduce weld strain and increase factor of safety. Test results indicate that a radial inward bias of the spherical bearings has the potential for reducing the critical weld stress on the aft skirt provided that bearing sleeve rotation can be controlled.

In addition, NASA is studying a potential new design of the aft skirt with "Assured Shuttle Availability" (ASA) funds, in the event that ASRM drives aft skirt loads above current requirements. The results of this design study, along with loads derived from the ASRM program, will be considered in determining the advantages of implementing a new aft skirt. In any event, the knowledge of the loads on the aft skirt are well understood, and the 1.28 factor of safety is adequate to ensure a safe flight.

<u>Finding #17:</u> The new field joint with capture feature and the "J" seal incorporated in the case insulation have demonstrated in test and flight that they prevent hot gases from reaching the primary O-ring of the joint. The joint heaters are subject to malfunction and the associated protection system can be a source of debris.

<u>Recommendation #17:</u> NASA should continue its search for an O-ring material with improved low temperature elasticity. Such a material would enable elimination of the joint heaters as well as a simplification of the joint protection system and its installation.

<u>NASA Response:</u> NASA concurs that the search for an O-ring material with improved low temperature resiliency should be continued, and is maintaining cognizance of new materials and process developments. However, recent material searches have resulted in no currently available materials, which constitute an improvement over the material now being used. Fluorocarbon STW 4-3339 is the O-ring material that has been selected after extensive testing of numerous material candidates. This material is an improved version (by omission of a filler material) of the Viton 747 Fluorocarbon that was used in the SRM/HPM.

Fluorocarbon STW 4-3339 has the following favorable characteristics: it is compatible with the HD-2 corrosion preventative grease environment in which it must operate, does not significantly absorb nitrogen gas, has acceptable squeeze and resilience properties, functions well in high temperature environments, has good surface hardness for assembly requirements, has consistent and acceptable general materials properties, and has good spliceability. Other candidate materials are significantly deficient by comparison. The silicones nick easily, are not sufficiently rigid, and are hard to assemble. The polysulfones react with lubricants and swell. They can be coated with a barrier layer, but this introduces coating problems, potential delamination, and another failure mode.

The joint heater system is working well with the baseline O-rings, and NASA plans to continue flying this configuration unless a new O-ring material becomes available.

<u>Finding #18:</u> The case-to-igniter and case-to-nozzle joints continue to require extreme care in assembly and installation to ensure a leak-free joint. There is still concern about control and reproducibility in the installation of the igniter joint putty and case/nozzle polysulfide sealant materials. New designs exist for these joints which provide joint closure upon case pressurization and eliminate the need for igniter joint heaters and case/nozzle radial bolts. Such designs have been proposed for the advanced solid rocket motors.

<u>Recommendation #18:</u> NASA should undertake a program to develop and implement the new case-to-nozzle and igniter-to-case joints. This will improve the safety of the redesigned solid rocket motor and simplify its assembly.

<u>NASA Response:</u> Regarding the igniter joint, assembly technique improvements have been incorporated that will reduce the potential for getting putty on the elastomer seals of the gask-o-seal. In addition, higher preloads have been incorporated for the attaching bolts to reduce the gapping at both joints. These modifications are now in place and they should alleviate some of the present concerns regarding the igniter joints until

redesigned igniters become available. The igniter joints are in the process of being redesigned per recommendation #18. The goals of the redesign are to make the joints less sensitive to manufacturing and assembly errors, to ensure the joints remain closed so there is no gapping at the seal at limit load, and to improve the insulation system. To accomplish these goals, the redesign will use a thicker adapter plat and longer bolts, and the gask-o-seals will be replaced with O-rings. These changes also will allow for the deletion of the heater. The putty will be replaced by a J-leg type pressure actuated insulation system. Preliminary estimates indicate this redesign can be manufactured, tested, and certified for flight in approximately 1 year.

A redesign of the case-to-nozzle joint, however, is judged to be a substantially more complex and time consuming task than the igniter joint. It is expected that such a major change to the RSRM could not be accomplished much in advance of the planned availability of the ASRM. The preload in the axial and redial bolts is being increased starting with the 14th flight set (STS-41) to enhance the sealing capability of the secondary O-ring. There has been no indication of anomalous conditions with this joint for the first 10 flights.

Advanced Solid Rocket Motor

Finding #19: A major premise in the advanced solid rocket motor program is the automation of the solid rocket motor case insulation process, and of continuous propellant mixing and casting processes. These automated process systems and software do not exist in the forms planned for use. One of the major impediments to successfully achieving such levels of automation has been the difficulty and cost of adapting automation from one application to another. It is not clear from the information provided whether adequate time, research, and budget had been included in the program to develop the level of automation planned.

Recommendation #19: NASA should conduct a thorough review of the plans for automation in the advanced solid rocket motor program. Particular attention should be given to: (1) the level of technical advancement required to achieve the degree of automation specified, and (2) the cost and time required to achieve the automation specified. This should be done by comparison with costs and schedule other industries have experienced when making similar advances.

NASA Response: NASA has reviewed the planned facilities and equipment for the automation in the ASRM program and plans to continue to thoroughly review those plans, with emphasis on the level of technical advancement, cost, and time required to achieve the degree of automation specified. High-level management visibility on automation has been established to assure proper planning and visibility into achieving the degree of automation specified. NASA concurs that care must be taken to ensure that the planned level of automation can be achieved on a realistic schedule within budget constraints. A review panel has assessed the automation of the ASRM in terms of industry experience, cost, and schedule. It is anticipated that this type of assessment will continue as deemed necessary throughout the program.

External Tank

Finding #20: The desire to eliminate the tumble valve has resulted in carrying a waiver for each flight since STS-27. The tumble valve has been disengaged for a number of flights and this has not resulted in External Tank debris footprints outside acceptable limits.

Recommendation #20: The program should either remove the tumble valves in their entirety and eliminate the specification requirement or conduct a process by which waivers are no longer needed for each flight.

NASA Response: In all flights where the tumble valve has been activated, the reentry footprint has remained typical of a tumbling tank and outside the geographical limits of 25 nautical miles from United States landmass and 200 nautical miles from foreign land masses. Mission specific analyses are performed to assure that predicted ET reentry footprints are satisfactory and to establish any risk associated with contingency aborts. The tumble valve will be disabled for missions where the footprint is such that the tumble valve is not required. NASA and DoD Range Safety agree the footprint uncertainties pose no risk to adjacent landmarks. When generic certification of ET entries without an active tumble valve is complete, the tumble valve system will be removed. This generic certification is planned to be completed by the end of FY91 and would enable NASA to eliminate this critical flight hardware from the External Tank.

Launch, Landing, Mission Operations

Finding #21: There is clear evidence that many of the problems that hampered launch processing prior to the Challenger accident are being addressed such as excessive overtime, lack of clarity in work instructions, shortage of spare parts, and heavy paperwork burden. However, these pre-Challenger problems have not been totally eliminated.

Recommendation #21: NASA and the Shuttle Processing Contractor must work diligently to eliminate deviations and errors that still occur frequently in the processing activities. Communications between the Shuttle Processing Contractor middle management and hands-on technicians must be continually improved.

NASA Response: NASA and the Shuttle Processing Contractor (SPC) realize that to safely process vehicles in support of the planned flight rate, occurrences of worker error must be further reduced. To decrease the likelihood of worker fatigue contributing to processing mistakes, the KSC continues to strictly adhere to the overtime policy outlined in Kennedy Management Instruction (KMI) 1700.2. Over the past year, less than 1 percent overtime exceeded the 60 hour/week criteria outlined in the KMI.

In May 1989, NASA/SPC formed a joint Processing Enhancement Team (PET) to reevaluate overall processing procedures. Efforts have focused on three major areas. First, the PET is working to assure that the work task preparation is complete, i.e., all documentation, people, and parts are available when required. Second, the team is working to guarantee that the right people and equipment are available to resolve processing problems as they occur. And third, the PET has found that to enhance processing, standardization is required of planning and scheduling procedures. These representative steps are aimed at clarifying instructions that each worker must abide by in safely completing his task.

Availability of spare parts has improved markedly since return-to-flight. The Line Replacement Unit (LRU) fill rate is roughly 89 percent compared to an average of 80 percent prior to STS-51L. The transition of logistics management responsibility to KSC has greatly improved the support posture. Steps also have been taken in this area by placing commonly used items in the OPF to assure availability to workers. Reduction in the amount of technician downtime has resulted.

The Shuttle Processing and Data Management System II (SPDMS II) is the descriptive title for a computer hardware, software, documentation, and processing system that will provide technical and management information support to shuttle ground processing activities. The project will significantly improve the work control system at KSC by providing faster, more accurate work scheduling, tracking, and approval to support the projected flight rate. Initial phases of this project are now being implemented, with continued incorporation planned over the next 2 years.

NASA/SPC believes the steps summarized above will mitigate the potential for processing errors. A system has been set up by the PET whereby workers can communicate their concerns and ideas about the specific processing tasks to appropriate directorate representatives. Managers continue to emphasize that safety will not be compromised to meet launch schedules. NASA/SPC remains committed to continue improving workmanship and strengthening communication channels between managers and hands-on technicians.

LOGISTICS AND SUPPORT

Finding #22: Continuing review of the overall orbiter logistics and support systems shows that the attention being given by NASA to the development of orderly management and control systems is yielding noticeable improvements. An excellent team spirit has evolved at the Kennedy Space Center among all the contractors and NASA. The virtual completion of the transfer of the Rockwell management and technical group to the Kennedy Space Center area enhances liaison with the Shuttle Processing Contractor (Lockheed) and the Kennedy Space Center logistics authorities. Development of physical stocking facilities and computerized control systems at the Kennedy Space Center is impressive.

Recommendation #22: Keep up the good work and maintain management attention to ensure continuing or better level of work.

NASA Response: KSC is continuing to improve the logistics support for the Space Shuttle program. Program requirements are presented to the top management levels in the program. Cannibalization rates have been reduced to near zero, and the POS rate is above 90 percent. The logistics budget has been supported by management, therefore, NASA expects logistics support to be maintained at the current levels.

__Finding #23:__ The Space Shuttle Main Engine spare availability is marginal as evidenced by the paucity of high pressure turbomachinery. This has lead to complex juggling of main engines to meet operational requirements.

__Recommendation #23:__ Incorporation of Space Shuttle Main Engine reliability and life enhancements should be accelerated to reduce the pressure for spares availability.

__NASA Response:__ The high pressure pumps with extended life capability are in testing and should be available for fleet implementation in FY91. The P&W pumps have just started developmental testing, and are planned for fleet implementation in FY94.

A block change is in the planning stages to minimize welds and use advanced fabrication techniques that will make a safer, more producible, engine. This will reduce the need for spares in the future.

Accelerating these schedules is not considered feasible in that the testing program is the critical element, and it is very difficult to speed up the testing significantly.

__Finding #24:__ The current documentation does not provide a proper plan for scheduled structural overhaul for the orbiter fleet.

__Recommendation #24:__ Provide a structural overhaul plan for the orbiter fleet, which should draw upon pertinent portions of plans of the Air Transport Association for aging commercial aircraft.

__NASA Response:__ NASA, with the assistance of Pan American Airlines, has developed a set of structural inspection requirements for the Orbiter vehicles. The requirements are documented in the Orbiter Maintenance Requirements and Specifications Document (OMRSD), NSTS 08178, File III, Vol 30. These identify the areas to be inspected, the inspection technique, and the inspection interval. Inspection intervals are based on the type of structure involved, the nature of degrading influences (e.g., fatigue, corrosion, temperature), and the results of previous inspections. These inspections are grouped into intervals of every flight, every five flights, every nine flights, etc. All vehicles were inspected during the post STS 51-L down period. In addition, the flight manifest includes provisions for major structural inspection periods to include those areas not accessible during normal turnaround operations. The next will occur on OV-102 (Columbia) in the summer of 1991.

__Finding #25:__ While the logistics management responsibility transfer has worked well for the Space Shuttle orbiter, little or no progress has been made in the transfer of responsibility for propulsion (MSFC elements) and orbiter GFE spare hardware necessary for the assembly of these elements into a complete system. These pieces are mostly small hardware items such as bolts, nuts, covers, and lubricants.

__Recommendation #25:__ All of the spare parts needed to mate the Space Shuttle elements at the Kennedy Space Center should become the responsibility of the Kennedy Space Center logistics function.

NASA Response: NASA's current Level I policy (NSTS 7000, Appendix 12) was updated in July 1989 after a complete program review. The policy directs that management responsibility for logistics support of the flight elements systems and their GSE be transitioned from the flight element project office to KSC, "without impacting the Space Shuttle Program safety, reliability, or launch schedules." KSC will negotiate a Logistics Management Responsibility Transfer (LMRT) agreement with each flight element project office. It is the Space Shuttle Program's intent to transfer those items that make sense from both the hardware project and KSC's vantage point. It does not necessarily mean that all of the spare parts needed to mate the Shuttle elements will be transferred. This is an area that will be reviewed on a continuous basis to insure that items are transferred when appropriate.

C. SPACE STATION FREEDOM PROGRAM

PROGRAM CONTENT

Finding #26: The reduced funding in the FY 1990 budget has required NASA to reexamine the content of the technical baseline of the Space Station Freedom Program and make decisions as to what should be retained or postponed for later consideration. A new management team and a reorganization of the program office, particularly the systems engineering and integration activity, should allow for the unimpeded conduct of preliminary design work leading to the preliminary design review scheduled for December 1990.

Recommendation #26: There are no specific recommendations other than to give appropriate attention during the coming year to those changes and deferrals having the most impact on system safety and reliability.

NASA Response: NASA concurs with the concept that safety and reliability must be recertified after any technical or design change. The SSFP has been rephased without compromising safety and reliability. The program is committed to resolve any safety or reliability issues that are identified, and it will be a specific focus on the upcoming PDR. In addition, specific studies have been commissioned to review various technical areas, and as the findings mature, actions will be taken to resolve all safety and reliability issues.

TECHNICAL ISSUES

Finding #27: Space environmental factors, including orbital debris and radiation, are critical to the design of the hardware and basic station configuration as well as operations during and after assembly. No previous manned space vehicle has been subject to such environmental factors over extended periods of time.

Recommendation #27: Since much attention continues to be given to orbital debris and radiation issues (accentuated by the return of the Long-Duration Exposure Facility), early decisions should be made regarding design and operating requirements to support hardware design and required test program.

NASA Response: NASA concurs and has actions underway. NASA agrees that the Space Station Freedom will be exposed to the space environment for a longer period of time than any previous manned spacecraft. NASA recognizes that the Long-Duration Exposure Facility (LDEF) provides a unique opportunity to examine long-duration, synergistic space exposure effects; and to enhance understanding of space environments definition, effects, and mechanisms. As a consequence, an LDEF Data Analysis Project Office has been established. The work of the Project is carried out by special investigative teams and LDEF Principal Investigators. Special investigative teams have been formed on micrometeoroids and orbital debris, radiation, materials and systems. The teams have placed highest priority on:

- Those analysis most relevant to spacecraft design and operations issues
- Understanding the context of LDEF findings with regard to changing environments during various phases of the LDEF mission
- Performing appropriate extrapolations for usage in other contexts, e.g., Space Station Freedom

Team members have been drawn from experts in the four discipline areas and represent multiple institutions and programs within NASA and DoD. These teams are structured to provide the desired "peer review" for evaluation of the implications of LDEF analyses. The LDEF analyses are examined within the context of other ground-based and flight data analyses to verify and improve ground-based simulations, testing and modeling. The LDEF analyses is also used to investigate accelerated testing methodologies. SSF representatives on each of these teams play a vital role in planning, implementing, integrating, and utilizing LDEF analyses to serve immediate and long-term SSF interests. Incorporation of LDEF information into the design and operating requirements of Space Station is an ongoing process. There is superb recognition within the LDEF investigator community of the urgent need for their analyses. This has resulted in unprecedented levels of cooperation and informal communication of LDEF results. The first major LDEF data workshop will be held in October 1990.

Finding #28: Ingress/egress to and from the Space Station Freedom poses several issues: Space Shuttle docking, extravehicular activity airlocks, and intermodule movement; each of which has safety ramifications. The current design has two Space Shuttle docking hatches; however, it is not possible for two Space Shuttles to be docked simultaneously because the docking ports are too close together. A failure that prevents separation of the orbiter and station could result in an emergency situation. Since the second airlock has been removed, this creates a critical single-failure-point and may elevate the criticality of other areas in that the crew will possibly have to move through a very difficult path to reach the single airlock in the event of an emergency.

Recommendation #28: Because of the criticality of the airlocks, the Panel believes that the reduction to a single airlock is an unacceptable risk. NASA should reconsider the decision to eliminate the second airlock and add it back into the configuration. NASA also should reexamine the entire issue of crew egress under a wide range of credible component and operational failures.

NASA Response: The current design requirements are being met with the single airlock. These requirements will be reviewed carefully, both in the multiple Level III PDR's and in the Integrated System PDR, which will occur in December 1990. Should the more detailed assessments reveal that a second airlock is required, then it will be incorporated into the baseline prior to the commencement of detailed design. Assessment of several emergency situations is also a part of the PDR process and the Design Reference

Missions (DRM), as well as the traditional Failure Modes and Effects Analyses (FMEA) and hazard analysis. In all of these assessments, crew egress will be evaluated as to its adequacy for evacuating any dangerous area of the Space Station Freedom.

Finding #29: Safety of the internal environment deals with toxic and hazardous spills, fire, and depressurization/repressurization. Although many precautions are to be employed during the handling and storage of toxic or hazardous materials (which should prevent most spills or atmospheric contamination), it is not enough to assume ***no*** *spills will occur. For a planned 30-year life, fire safety is a critical aspect of design. Protecting and maintaining a safe internal environment in the station currently includes the ability to repressurize the modules one time after a deliberate depressurization.*

Recommendation #29: Even though provisions are being made to handle spills, fire and depressurization, specificity is necessary in the requirements to accomplish hardware design and proper integration with other safety-critical functions and systems. A better understanding of fire initiation, propagation and extinguishment in a zero-g environment is required. Therefore, NASA should assure that a coordinated program is available to support fire safety activities.

NASA Response: NASA concurs and has actions underway and planned. Regarding hazardous spills, an ad hoc working group has begun definition of appropriate spill kits to manage spills should they occur. Preliminary definition suggests that a modest number of such kits will control the identified hazardous material on the station. NASA recognizes that fire initiation, propagation, and suppression is different aloft than in the terrestrial setting. It also is acknowledged that specific combustion experiments in weightlessness would yield useful data relative to the fire detection and suppression on the Space Station Freedom. The present preliminary design for fire detection and suppression will be reviewed at the Integrated System PDR in December 1990

Depending on the outcome of this review, specific studies will be undertaken to verify that the current design will accomplish fire detection and suppression as the designers originally envisioned. These studies would likely commence as early as the summer of 1991, and would logically include whatever combustion experiments were thought necessary to be performed in weightlessness.

Finding #30: The Space Station Freedom is supposed to have common berthing mechanisms throughout. Currently, the design calls for 24 active-rigid, 12 passive-rigid, and 6 passive-flexible mechanisms. These are essential to station assembly and operations, including those with NASA's international partners.

Recommendation #30: Multiple interfaces among these berthing mechanisms require close attention by the work package organizations (NASA and contractor), systems engineering and integration organizations as well as with the international partners. Thoroughly defined specifications and drawing requirements must be provided and maintained to assure compatibility.

NASA Response: NASA concurs and a common berthing mechanism will be used throughout Space Station Freedom. The Work Package 1 prime contractor, Boeing Aerospace Company, is responsible for design and certification of all berthing mechanisms employed on Space Station Freedom.

Finding #31: Extravehicular activities are heavily involved in Space Station Freedom assembly and operation, maintenance/repair, and emergency actions; and with the flight telerobotic system. The decision has been made to use the current Space Shuttle space suit for the foreseeable future.

Recommendation #31: Because of the limitation of the current space suit, operational timeliness and support training require close coordination between the JSC Flight Crew Operations Directorate and all the work package organizations. Particular emphasis should be placed on the work of the Space Station Freedom assembly sequence planning groups and their interaction with the human factors people and crew training curriculum.

NASA Response: NASA concurs and actions are underway. NASA acknowledges that the successful completion of the assembly process is challenging. It is recognized that the most effective and efficient use of orbiter-based Extravehicular Activity (EVA) necessarily involves close cooperation with the crew in terms of planning, training, human factors, and performance considerations. A specific group, the Assembly Planning Review, has been established at the Johnson Space Center to consider the details of the assembly process with an emphasis on operational issues. The group is chaired by an astronaut, Capt. David Walker. This group was established in 1988, and has functioned well in terms of incorporating crew considerations into the design process. NASA is expending a significant effort into task analysis for the robotics for Space Station Freedom, particularly the Canadian remote manipulator system.

Finding #32: In the safety and product assurance area, the Level II, III and IV organizations have begun to achieve a more coordinated and effective working relationship during this past year. They now work directly with the Space Station Freedom Program office as team members in performing their engineering and systems safety work. They also provide independent assessments to assure that safety and product assurance are being given proper consideration.

Recommendation #32: Maintain and enhance the current collaborative relationship between safety and product assurance organizations and the program/element offices. There is a need to formalize the various safety and product assurance documents as soon as possible to assure that such requirements and methodologies are in place and will support the activities leading to the preliminary design review.

NASA Response: NASA concurs and has actions underway. As the SSFP matures, the relationship between program/element offices also is maturing. Cooperation/coordination among and between the organizations continues to improve. Charters for the Safety and Product Assurance Panel, the System Safety Review Panel, and associated subpanels have been proposed for approval by the MS/Deputy Director and should further the amalgamation of the safety and engineering tasks that need to be performed.

Safety and product assurance requirements and process documents are being updated to better fit the needs of the program. Specifically, the overall Safety and Product Assurance Requirements, Section 9 of the Program Definition and Requirements Document (PDRD) (SSP 30000), have been recently revised. The Safety Analysis and Risk Assessment Requirements document (SSP 30309) also has been revised. The Problem Reporting and Corrective Action Procedures (SSP 30223) are currently scheduled for Space Station Control Board (SSCB) action, and NASA will be processing the FMEA Procedures (SSP 30234) within the near future.

Finding #33: Work continues on defining practical contingency models and their effect on overall Space Station Freedom design. Certain attributes of the contingencies may be design drivers as was the case on the Space Shuttle. Emergency operations may dictate requirements such for redundancy, location of equipment, configuration of a rescue vehicle, and design of the caution and warning system.

Recommendation #33: Develop selected scenarios to a sufficient level of detail to identify the significant ground rules and assumptions for this activity. This would include crew and ground responses for immediate safing action, subsequent isolation of the problem, and restorative or rescue actions.

NASA Response: NASA concurs with the finding and has actions underway. Space Station Freedom Contingency Operations Scenarios have been developed by the JSC Operations Integration Office with direct support from mission operations, flight crew operations, and prime contractor personnel. Specific contingencies are identified along with safing and isolation actions. Changes to design requirements are being developed to ensure implementation of identified operations. Contingency Recovery Scenarios are scheduled and will define restoration or rescue actions as required.

Finding #34: There appears to be no standard program-wide list of safety-critical functions for the Space Station Freedom. Such a list is required to support thorough hazard analyses and risk assessment. The crew's ability to egress from the station is an example of a safety-critical function.

Recommendation #34: The Space Station Freedom Program safety and product assurance organization, along with the engineering and operations organizations, should develop a program-wide list of safety-critical functions. Consideration should be given to including waste management in the list.

NASA Response: NASA concurs and is following the recommendation. A list of safety critical functions will be identified in the PDRD prior to the Integrated System PDR.

Finding #35: The Space Station Freedom will be highly dependent upon computers for its operation, and will have a very large complement of software to run them. The hardware and software will have to be upgraded occasionally without being returned to the ground, and flight experiments will require regular changes to the distributed computer system. Original plans for Space Station Freedom software testing included building a large test facility in which software could be tested in an environment that would represent the station.

The test facility apparently has been scaled back by substituting simulation for actual hardware.

Recommendation #35: NASA should institute a full-scale software testing environment for the Space Station Freedom and that facility should include as much actual flight hardware as possible.

NASA Response: NASA concurs with the finding and has actions underway. NASA concurs with the recommendation that a full-scale software testing environment for the Space Station Freedom be developed. NASA also agrees that the facility should include as much hardware as possible to lessen dependence on simulations. Since January 1990, there has been an action underway to consider this issue. A Verification Steering Committee led by the Deputy Manager for Program and Operations is reviewing and assessing the current Space Station Freedom verification approach. One of the areas being worked at this time is that of the necessity and characterization of a central facility for integrated software testing. Funding has been set aside for the construction and outfitting of this facility. A final recommendation is expected by the end of the third quarter of Fiscal Year 1990.

LOGISTICS AND SUPPORT

The Panel is concerned about this area but have not received sufficient information on the logistics associated with assembly and resupply; consequently, there are no findings or recommendations. However, a discussion of this vital program area is found in Section III.

NASA Response: The Space Station Freedom Logistics Program is characterized by a three-phase approach--acquisition, assembly, and operational support. The acquisition phase is managed by the program office and implemented by the design centers. A key function for logistics in this phase is the use of a Logistic Support Analysis process to analyze and influence the hardware for a more supportable and maintainable station. This process is based on a Department of Defense approach that has been tailored to ensure consideration for limited on-orbit resources during the design effort. A logistics panel, chaired by the program office and with members from NASA Centers, international partners, and contractors, is the forum used to integrate the various logistics activities and identify concerns. During this phase, detailed requirements and plans are being put in place to transfer design center logistics responsibilities (spares projection, procurement management, depot maintenance, etc.) to the launch site.

The Space Station assembly and operation era logistics support will be characterized by the human, material, and information resources and associated activities required to transport material to and from orbit, repair and maintain flight hardware, and to repair and maintain the ground systems. The maintenance of program hardware and the resupply/return of consumable supplies, experiment hardware, maintenance and repair materials, tools, manpower, and the transfer of crew personnel will constitute a major portion (at least 50 percent) of the operational era costs.

To manage the operational logistics task, a Logistics Operations Center (LOC) will be established. Reporting to the program office at NASA Headquarters and located at Kennedy Space Center (KSC), the LOC will provide the execution level integration needed to assure total integrated logistics support to the Space Station and to provide strategic, tactical, and execution level planning support to the appropriate levels of management. An onsite intermediate/depot level repair facility will be constructed at KSC to perform failure analyses, manage the repair process, and to recertify station hardware for flight. A program-wide Logistics Information System will allow timely coordination of direct support, planning, and analyses activities among the LOC, Space Station Control Center at JSC, and engineering support centers located at the original design centers.

D. AERONAUTICS

AIRCRAFT MANAGEMENT

Finding #36: *NASA has downgraded the level of the Headquarters Aircraft Management Office. This action has made it more difficult for the Aircraft Management Office to coordinate the development of aircraft operation policy for astronaut training and administrative aircraft.*

Recommendation #36: NASA should reestablish the Headquarters Aircraft Management Office at a level where it can coordinate and establish policy for all types of flight operations throughout NASA.

NASA Response: In its role as the Headquarters focal point for agency-wide aircraft operations and management, the Aircraft Management Office (AMO) in the Office of Management is responsible for the development of policy and oversight of its implementation as regards aircraft acquisition, operation, and maintenance and in the areas of flight crew qualifications and training. The change in management structure was initiated to assure additional senior management daily attention and emphasis on these important policy-making functions and on aviation safety where the Office of Management is responsible for assisting the Office of Safety and Mission Quality (OSMQ) in the development of aircraft safety policy and oversight of its implementation. We know of no cases where this new management structure has made it more difficult for the AMO to coordinate the development of an aircraft operations policy for astronaut training or administrative aircraft as stated in the finding. On the contrary, the additional daily attention provided by the Director, Logistics, Aircraft and Security Office accompanied by the continuing close attention of both the Associate Administrator for Management and his Deputy has expedited the implementation of a major effort to update NASA's aircraft policies. This process has been thoroughly coordinated with both the OSMQ and the institutional program offices and has included several briefings to the new NASA Administrator.

Finding #37: *Flight recorders for nonresearch aircraft again have been removed from the budget because of fiscal constraints. These recorders have been proposed for installation in all nonresearch aircraft (where recorders are not already installed) as a means of accident prevention and as a tool for accident analysis.*

Recommendation #37: Reinstate the program to obtain and install flight data recorders suitable for aircraft trend analysis as well as for accident resolution. Further, a program should be established for regular analysis of the data provided.

NASA Response: The value of flight data recorders as a means of accident analysis is well recognized. The installation of recorders in the JSC's fleet of aircraft that do not already have recorders: 28 T-38's, the KC-135, the Super Guppy, and 2 WB-57 aircraft, is estimated to cost in excess of $1.7 million.

Considering the Agency's overall budget constraints, and in turn the fiscal limitations of the aircraft program, the installation of flight recorders must be weighed against safety requirements and other requirements for improvements and needed modifications for the aircraft. Because of the relatively small and diverse aircraft fleet in NASA, flight recorder usefulness within NASA for trend analysis is uncertain.

Consequently, the value of recorders is recognized but must be prioritized, considering all safety-related requirements.

AERONAUTICAL RESEARCH

There were no findings or recommendations under Aeronautical Research.

E. RISK MANAGEMENT

Finding #38: NASA has taken the position that a lack of maturity, insufficient data base, and lack of funds associated with quantitative risk assessment limits its usefulness during the preliminary design of the Space Station Freedom. Specifically, the Space Station Freedom Program Office is relegating decisions regarding the use of quantitative risk assessment (or similar techniques) to the various work package managers and contractors rather than to institute a common approach.

Recommendation #38: The NASA management should develop and adopt a policy with appropriate methodology for performing quantitative risk assessment at the outset of large space ventures such as the Space Station Freedom Program.

NASA Response: NASA concurs and has actions presently underway. The Safety Analysis and Risk Assessment Requirements document (SSP 30309) for the SSFP has been approved by the SSCB and will be presented to the Program Control Board. It establishes a common approach to the use of risk assessment. More specifically, SSP 30309 requires the development of event scenarios (event trees) at the subsystem functional level and at the component failure mode, operations, and crew actions level. These event scenarios are part of the overall safety risk assessment and are developed during design and review phases. Scenarios are quantified when one or more of the following conditions hold:

- There exists significant uncertainty about the severity and/or likelihood of occurrence of a scenario
- A scenario is judged, by qualitative means, to have a catastrophic or critical severity and a high likelihood of occurrence, and has not already become a constraint to flight by a qualitative assessment
- Controls to prevent the hazard scenario are the least effective features of the Hazard Reduction Procedure Sequence (i.e., warning systems for hazard control rather than design for minimum hazard occurrence).

Finding #39: A new contractor has been selected by NASA Johnson Space Center to provide safety, reliability, maintainability and quality assurance support services to the Johnson Space Center. This contractor transition began February 1, 1990. The number of contractor personnel involved is approximately 350, many of whom will be new to the program.

Recommendation #39: NASA management should monitor this changeover closely so that the necessary level and types of service are maintained.

NASA Response: NASA fully concurs with the recommendation and has put mechanisms in place to carefully manage and oversee the changeover process. The changeover was initiated by the normal Government competitive procurement process in which Ford

Aerospace Corporation was selected to replace the long-term incumbent (Boeing Aerospace Operations). The loss of continuity was a concern to JSC management when the selection was made, and several actions were put into place to closely monitor and manage the contractor transition process.

Beginning about 5 weeks before the transition was to officially take place, a weekly review of transition planning and implementation activities with the Director and key staff of the Safety, Reliability, and Quality Assurance (SR&QA) organization was established. The purpose of this weekly review was to stay abreast of any problems or issues that came up during the transition process and to be able to quickly resolve stumbling blocks or problems dealing with the actual transition activities. Detailed schedules were developed to maintain control and status of the actual work. At these meetings, priorities were set to ensure that any effort needed to continue to support Space Shuttle flight preparation activities was in place and was being accomplished on a timely basis. Management from all functional areas of both the support contractor and NASA participated and worked together as a team to resolve any issues identified. These formal weekly reviews continued until May 3, 1990, wherein most of the significant transition issues were closed, and any open work remaining was placed on the weekly review of the SR&QA product and task schedules.

Another more detailed team was established to define all of the task orders that assign work to the support contractor and to deal with the very detailed transition issues associated with work processes. This, too, is a joint activity between NASA and the contractor. This activity is still in place with the current plan to have completed all the detailed work in the July 1990, time frame and is going well. Since the formal transition was initiated on February 1, 1990, the new contractor has successfully supported two Space Shuttle flights, as well as the preparation activities for the succeeding flights. In addition to the intensive effort provided to facilitate the transition, JSC SR&QA management conducts monthly formal Technical and Management Review meetings with the contractor management to go over the performance evaluation of the contractor for that month. A comprehensive evaluation by NASA, with a self evaluation by the contractor, is made of all task orders each month. The Director, SR&QA, makes regular reports on the progress of the contractor transition to the JSC Center Director, to provide additional management visibility.

NASA believes that the proper mechanisms have been put in place and that adequate attention is being paid to this very important contractor changeover.

Finding #40: *There is a need to monitor the aging and reliability of components as a function of time in service. Typically, monitoring is accomplished with fleet leader statistics. Unfortunately, as presently employed, fleet leader numbers can be relatively uninformative or even misleading. For example, these data do not permit managers to assess whether the fleet leader is representative of the entire system or simply an outlier.*

Recommendation #40: Statistics on single fleet leaders should be augmented by simple data that identify the distribution of the entire fleet. For items that have been procured in relatively large numbers, this might be expressed as percentages. For relatively unique items, information on the three or four of the oldest and youngest items might be provided.

NASA Response: NASA agrees. Historically, fleet leader statistics were used almost exclusively; however, this is not the case today. The SSME is the only item using a modified fleet leader concept in that it uses multiple fleet leaders to obtain a more representative sample of the fleet distribution. This minimizes the likelihood of a single fleet leader being an outlier. Use of a single fleet leader is atypical rather than typical. Fleet leader information is supplemented by such techniques and data sources as stress analysis, fracture analysis, qualification test results, life limit tests, and additional inspections of critical hardware. The process is no longer restricted solely to the fleet leader statistics. Initially, the fleet leader is the prime source of data defining the anticipated fleet distribution. However, as additional devices are built, tested and put into operation additional data becomes available to "temper" the initial judgement of the initial fleet distribution. Information is retained at the contractors on each device and these statistics are compared using in-house studies to guide judgement on retention of items and the flight worthiness of them. These data are reviewed prior to each flight and bear heavily on the decisions to retain/reuse items and on the ultimate launch decision.

C. AEROSPACE SAFETY ADVISORY PANEL ACTIVITIES

FEBRUARY 1990 - JANUARY 1991

FEBRUARY

7-10	-	STS-32 Flight Readiness Review, Kennedy Space Center
13-14	-	Space Station Advisory Committee Meeting, Washington, DC
20-22	-	STS-32 Launch-2 and -1 Day Reviews, Kennedy Space Center
21-24	-	Aerospace Medicine Advisory Committee Meeting, Johnson Space Center
21	-	Space Station Hearing/Chm Nelson, Washington, DC
23	-	Alternate Turbopump Programs by Pratt & Whitney, West Palm Beach, FL
27	-	Intercenter Aircraft Operations Panel Meeting, Lancaster, CA

MARCH

9	-	Congressional Staff, Washington, DC
9	-	Space Shuttle Main Engine, NASA Headquarters
22	-	Space Station Work Package #4, Rocketdyne, Canoga Park, CA

APRIL

5	-	Space Shuttle and Space Station Computer Issues, Johnson Space Center
11	-	Human Performance Research Laboratory Activities, Ames Research Center
13	-	Aerospace Safety Advisory Panel Annual Meeting, NASA Headquarters
26-27	-	Tethered Satellite System, Marshall Space Flight Center

MAY

1	-	SSME Turbopump, Aerojet Corp., Cleveland, OH
2	-	Human Performance, Ames Research Center
4	-	Office of Management and Budget, Washington, DC
8-9	-	Space Station Work Package #1, Boeing Space Co., Huntsville, AL
10	-	Space Shuttle Main Engine, Marshall Space Flight Center
10	-	Human Performance, NASA Headquarters

JUNE

11-13	-	Bio-Med Meeting, Aerospace Medicine Advisory Board, Washington, DC
19-20	-	Office of Space Flight Review of Space Shuttle and Space Station, NASA Headquarters/Reston
26-28	-	Alternate Turbo Pump Development Program, Pratt & Whitney, West Palm Beach, FL
26-28	-	Army/Navy/Air Crew/Aircraft Integration Program Activities, Ames Research Center

JULY

16-18	-	26th AIAA/SAE/ASME/ASEE Joint Propulsion Conference, Orlando, FL
18	-	Space Station Work Package #4 Review, Lewis Research Center
25-27	-	OAET and OSSA Activities, NASA Headquarters

AUGUST

3	-	Space Station Work Package #4, Lewis Research Center
8-9	-	GPC and SE&I, Johnson Space Center
16-17	-	Aeronautical Activities, Langley Research Center
22-24	-	Manned Space Activities, Johnson Space Center

SEPTEMBER

12-13	-	GPC Memory and SE&I, Johnson Space Center
24-28	-	Aeronautical, Human Performance, Space Activities, Ames Research Center

OCTOBER

30-11/2	-	Shuttle Launch and Landing Processing, Kennedy Space Center

NOVEMBER

2	-	Shuttle/Station Logistics, Kennedy Space Center
13-14	-	Advanced Solid Rocket Motor, Marshall Space Flight Center
14	-	SSME, Marshall Space Flight Center
13-15	-	Aviation Safety Reporting System Symposium, Reston, Virginia

DECEMBER

4-7	-	Safety and TQM Activities, Stennis Space Center and Michoud Assembly Facility
20	-	Aircraft Operations, NASA Headquarters

JANUARY

3	-	Aircraft Operations, NASA Headquarters
8	-	Shuttle Processing Operations, Kennedy Space Center
15	-	Congressional Staff, Washington, DC

For Further Information
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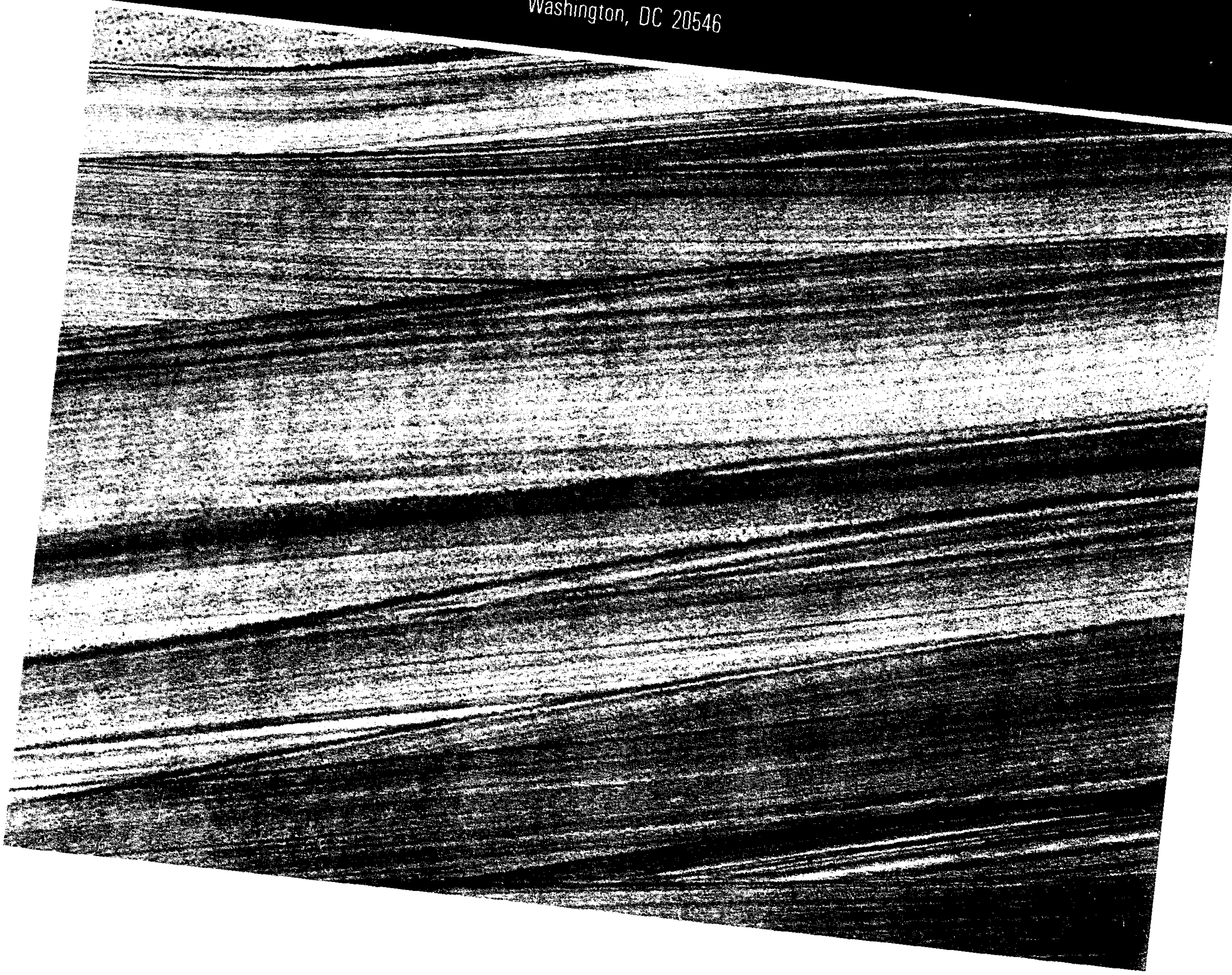

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