structures, and has revitalized efforts at creating software assurance and development processes. This contemplated effort appears appropriate and should be put in place with the necessary resources as quickly as possible.

Ref: Finding #32

NASA has consolidated Life and Microgravity Sciences and Applications in NASA Headquarters Code U. Its responsibilities include human factors activities. A *Space Human Factors & Engineering Program Plan* is being prepared to guide future ***research*** activities. There remains, however, a clear need for more operational human factors input in both the Space Shuttle and Space Station programs.

NASA has needed a coordinated human factors effort for some time. The existence of a plan, however, is of little value unless it is adequately funded and universally accepted. At present, there are insufficient resources allocated to human factors to support either the long-term goals of the plan or the essential short-term integration of human factors within the operating space flight programs.

NASA's human factors ***research*** efforts, particularly at Langley and Ames, are excellent. These efforts, however, particularly related to space, are typically viewed as ***basic research*** by the operating programs and spaceflight centers. This assessment is partially true and partially the result of the "image" that human factors researchers within NASA have conveyed. The spaceflight programs must adopt a specific goal orientation with a decided "product" focus. The research programs are seen as a search for knowledge that sometimes leads to useful spinoffs but cannot be relied upon to meet deliverables and achieve budget or schedule targets.

While there may be some validity to these prevailing perceptions, there are also compelling counterexamples. The problem is that NASA human factors research and development efforts continue to focus primarily on long-term goals. What NASA needs ***immediately*** is the integration of its human factors expertise into the operating space programs. Prime examples of efforts that could benefit from human factors inputs are the Multipurpose Electronic Display System (MEDS) for the Orbiter and the Space Station systems integration. In spite of significant expenditures to retrofit flat panel displays into the Orbiters, no funds were allocated to designing optimum display content or format. There is essentially no human factors input to the MEDS program in spite of the fact that the NASA research centers have been studying aircraft display formats for a long time.

The *Space Human Factors & Engineering Program Plan* should be revised to ***include*** a focus on the short-term integration of NASA's human factors research assets into the operating space programs so that the plan is more responsive to NASA's needs. This should be its most immediate objective. In order to provide appropriate impetus to its growing human factors efforts, NASA needs to increase the number of trained human factors professionals available to the programs.

Ref: Finding #33

In the process of conducting other program- or activity-focused reviews, the Panel has encountered various applications of the Total Quality Management (TQM) approach. The Panel has also been asked by the NASA Administrator for its impressions concerning the application of TQM by NASA organizations and contractors. What follows is a summary of the observations and comments by ASAP members to this request and is not intended as a comprehensive review of NASA TQM activities.

Martin Marietta Michoud Assembly Facility. Two years ago, the Panel was first briefed on the TQM program being implemented by Martin Marietta Michoud Assembly Facility employees in constructing the External Tank (ET) for the Space Shuttle program. In May 1993, Panel representatives returned for an update. On both occasions, the Panel was extremely impressed with the structure, philosophy, and spirit of the Martin Marietta implementation effort.

The total effort has been renamed *Mission Success 2000*. In May, the Panel representatives were shown specific results of the work of a Performance Refinement Team (PRT) and a Application Process Team (APT) dealing with the application of the thermal protection system to the tank. Both teams have achieved significant and measurable advances as a result of their TQM efforts. The high morale among hands-on employees witnessed 2 years ago is still evident. It has been buttressed with the pride and recognition of accomplishment. This appears to have strengthened the process by reinforcing its benefits to the workforce.

Thiokol Corporation Solid Rocket Motor Facility (Utah). As an integral element in its RSRM program, Thiokol has committed itself to a comprehensive TQM effort to upgrade quality in manufacturing the motor segments and associated equipment and to ensure improved levels of industrial safety in the manufacturing process.

Thiokol has set up 24 improvement centers in the manufacturing process. Each center establishes and controls its own 3-year improvement plan. Each improvement center competes for a share of a significant monetary pool.

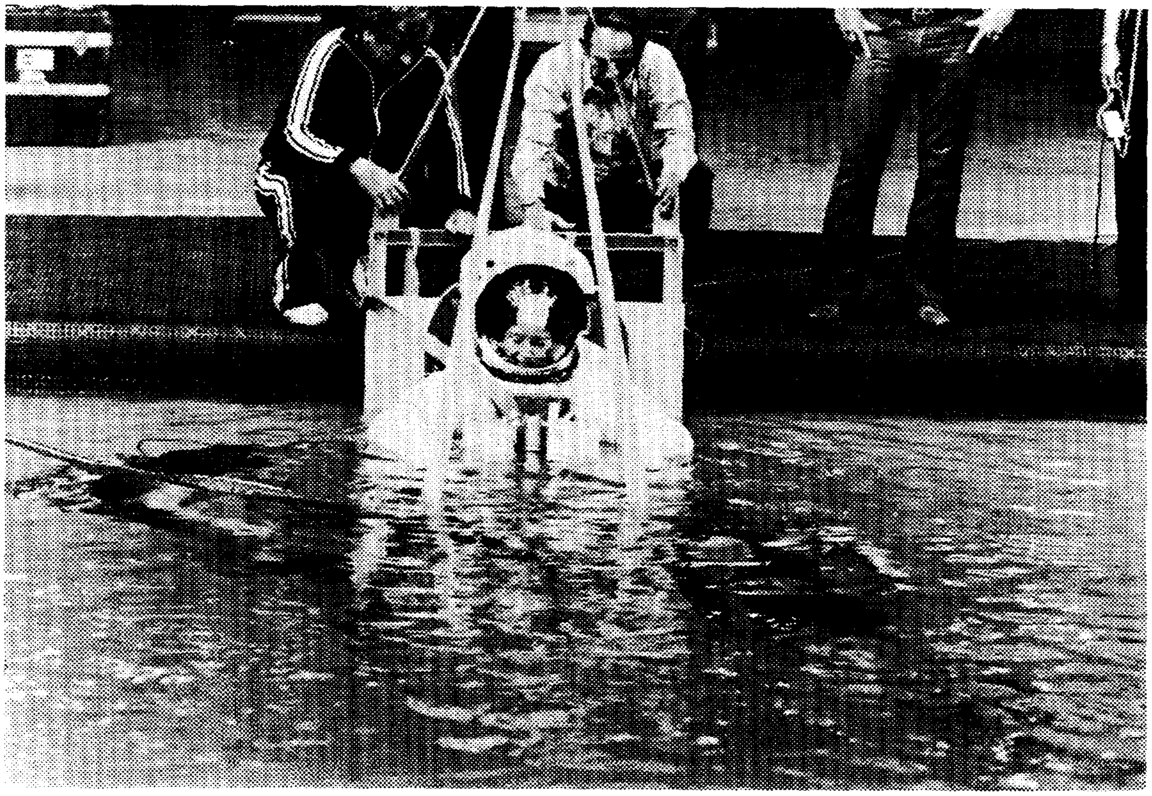
Results of the improvement process are displayed on the work floor. The excellent charts show a variety of ***quantitative*** measures, e.g., reduction of scrap, repair, rework, problem reports, and facility cleanliness, that are specific to each work center. A Safety Management System (SMS) has also been organized to prevent and control hazards at the point of manufacturing. Overall, quality has been improved, unnecessary inspection points eliminated, and Solid Rocket Booster stack time at KSC has been decreased.

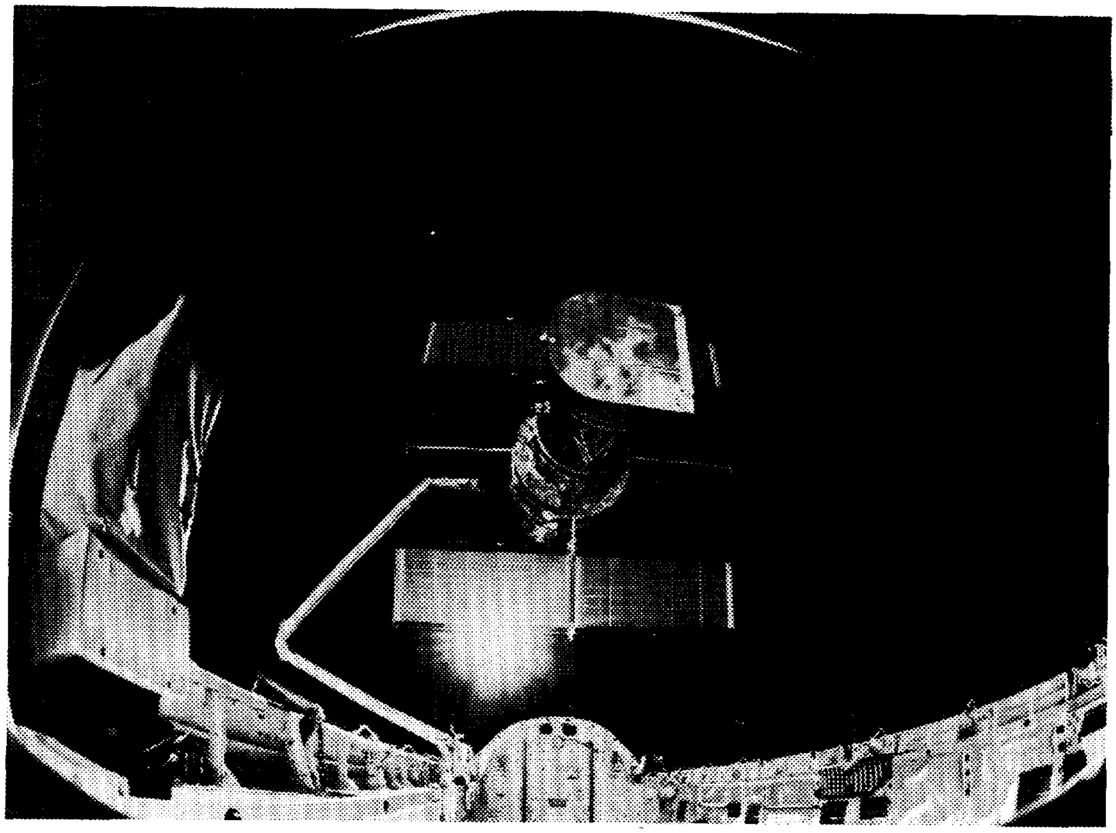
Rockwell Palmdale. Rockwell International (RI) has made a concerted effort to incorporate TQM principles into its operations. The major goals are productivity improvement in terms of cycle time and quality, and human/organizational improvement as reflected in commitment, assumption of responsibility, and flexibility of the workforce. It appears that the RI TQM program could benefit from the development and dissemination of additional performance measurements.

Shuttle Processing Contractor—Kennedy Space Center. The Lockheed Space Operations Company as the Shuttle Processing Contractor (SPC) has designed a continuous improvement process built around the functions of analysis, employee involvement, improvement, measurement, customer satisfaction, capabilities, and processes. These functions are carried out through a network of teams, beginning with the top management steering team and flowing through natural management teams, task teams, process improvement teams, and natural work teams. The SPC has invested in extensive employee training in implementing a task team concept. Various devices—"skip-level meetings" (bypassing immediate supervision), specialized newsletters, and program/corporate status reports—have focused on improving employee communications. To a much greater degree than previously, technicians, working in task teams, process improvement teams, and natural work teams, are actively engaged in developing more efficient and safer work procedures. Communications among shop floor technicians and engineering personnel have improved significantly. A shop floor data collection system is also beginning to develop reliable measures of problem areas and processing improvements.

Dryden Flight Research Facility. Without specifically referring to "TQM" by name, the basic principles of TQM are being effectively employed at DFRF. The management at Dryden has done an outstanding job of instilling a high degree of teamwork into the Facility's flight activities.

Summary. There is evidence of effective application of TQM principles and practices in various NASA activities. However, use of the term itself is of little value unless it is accompanied by top management's determination to make its application and implementation more than shallow, empty phrases. In particular, management must be committed to building a culture of trust and personal responsibility among the workforce. This requires leadership, training, innovation, patience, honesty, a willingness to change, a credible program of reward and recognition, and the commitment to performance measurement. This requires knowledge and application of the tools that bring about and validate meaningful performance and product improvement.





IV. APPENDICES

APPENDIX A
NASA AEROSPACE SAFETY ADVISORY PANEL MEMBERSHIP

CHAIRPERSON
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Aerospace Consultant
Former Vice President, Engineering
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MEMBERS

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Dunlap and Associates, Inc.

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EX-OFFICIO MEMBER
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Associate Administrator for
Safety and Mission Assurance
NASA Headquarters

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MR. FRANK L. MANNING
Staff Director

MS. PATRICIA M. HARMAN
Staff Assistant

APPENDIX B
NASA RESPONSE TO MARCH 1993 ANNUAL REPORT

SUMMARY

NASA responded on August 23, 1993 to the "Findings and Recommendations" from the March 1993 Annual Report. NASA's response to each report item was categorized by the Panel as "open," "continuing," or "closed." Open items are those on which the Panel differs with the NASA response in one or more respects. Continuing items involve concerns that are an inherent part of NASA operations or have not progressed sufficiently to permit a final determination by the Panel. These will remain a focus of the Panel's activities during the next year. Items considered answered adequately are deemed closed. Those items no longer applicable because of significant programmatic changes are denoted "N/A."

Based on the Panel's review of the NASA response and the information gathered during the 1993 period, the Panel considers that the following is the status of the recommendations made in the 1993 Report:

RECOMMENDATION		
NUMBER	SUBJECT	STATUS
1	Space Station Freedom (SSF) Program Safety and Mission Quality	N/A
2	SSF Assured Crew Return Vehicle	N/A
3	SSF Orbital Replaceable Units	CLOSED
4	SSF Integrated Station Executive software	CONTINUING
5	SSF Data Management System	N/A
6	SSF Timeliner software	N/A
7	SSF Software Support Environment	CLOSED
8	SSF Integrated Logistics System	CLOSED
9	Orbiter automated landing system (AUTOLAND)	CONTINUING
10	Shuttle Multipurpose Electronic Display System	CONTINUING
11	Shuttle Improved Auxiliary Power Unit (IAPU) spares	OPEN
12	IAPU Gas Generator Valve Module	CONTINUING
13	Orbiter pressure and strain gage measurements	CONTINUING

RECOMMENDATION		
NUMBER	SUBJECT	STATUS
14	Space Shuttle Main Engine (SSME) inspection and test procedures	CLOSED
15	SSME major component improvement programs	OPEN
16	Flight Support Motors	CLOSED
17	Redesigned Solid Rocket Motor nozzle O-ring sooting	CLOSED
18	Advance Solid Rocket Motor (ASRM) aft skirt factor of safety	N/A
19	ASRM stress corrosion cracking	N/A
20	ASRM manufacturing system software requirements document	N/A
21	KSC Structured Surveillance Program	CLOSED
22	Use of task teams at KSC	CLOSED
23	Orbiter Processing Facility lighting	CLOSED
24	NASA Shuttle Logistics Depot	CLOSED
25	Space Shuttle logistics system	CLOSED
26	NASA Headquarters Aircraft Management Office	CLOSED
27	Review of aging aircraft	CLOSED
28	Dryden Flight Research Facility risk reduction measures	CLOSED
29	Office of Safety and Mission Quality organization structure	CLOSED
30	Simplified Aid for EVA Rescue (SAFER)	CLOSED
31	Virtual reality systems	CLOSED
32	Human factors issues	OPEN
33	Software independent verification and validation	CONTINUING
34	Integrated long-range infrastructure plan	CONTINUING
35	Complete system testing	CLOSED
36	Total Quality Management	CONTINUING

RECOMMENDATION		
NUMBER	**SUBJECT**	**STATUS**
37	Strategic Considerations for Support of Humans in Space and Moon/Mars Exploration Mission (Life Sciences Research and Technology Program, Volume 1) report recommendations	CLOSED

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Office of the Administrator

AUG 23 1993

Mr. Norman R. Parmet
Chairman
Aerospace Safety Advisory Panel
5907 Sunrise Drive
Fairway, KS 66205

Dear Mr. Parmet:

In accordance with your introductory letter to the March 1993 Aerospace Safety Advisory Panel (ASAP) Annual Report, enclosed are NASA's detailed responses to Section II, "Findings and Recommendations." The responses reflect the status and intentions of NASA before Space Station redesign. Changes in Space Station design and management structure resulting from the work of the Redesign Team may dictate future changes in detail, if not in spirit, of the responses. In the case of the Advance Solid Rocket Motor (ASRM) program, the current prospects for funding are uncertain. If the program is terminated, the ASRM responses will no longer apply.

The dedication of the ASAP members to NASA continues to be commendable. Your recommendations have helped reduce risk and improve safety in NASA human/robotic programs and projects. Your efforts are greatly appreciated.

We thank you and your fellow Panel members for your valuable contributions and look forward to your next report. As always, ASAP recommendations are highly regarded and receive the full attention of our senior management personnel.

Sincerely,

Daniel S. Goldin
Administrator

Enclosure

1993 AEROSPACE SAFETY ADVISORY PANEL REPORT 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 (C&W) system, and normal and contingency operations planning.

NASA Response: The Space Station Redesign Team has defined a streamlined management structure that should result in significant safety and mission assurance (S&MA) cost savings during the program development and implementation phase. The Space Station program will fund the technical program requirements (reliability and safety engineering activities), while program oversight/assurance will be funded by the Headquarters Office of Safety and Mission Assurance (OSMA), or lead or host Center Directorate.

A formal Space Station Management Plan developed during the transition period will ensure a clear understanding of the new management structure. This plan will serve as a basic governing document that clearly defines all organizational roles and responsibilities.

The new S&MA structure will consist of two organizations: Assurance and Safety and Reliability Engineering. The Assurance organization will provide independent program assessment and will report directly to Headquarters OSMA. This organization, collocated at the host or lead Center, will support the Station Program Manager. Its primary responsibility will be an oversight function that encompasses establishment of safety and reliability requirements in concert with the Headquarters OSMA policies and guidelines, independent assessment and program risk analyses, quality assurance processes, and hardware/software certification, including independent verification and validation. The Safety and Reliability Engineering organization will be assigned to the Space Station program as part of the Systems Engineering organizations. It will ensure that the reliability and safety engineering function is inherent to the overall design process.

The new management structure will continue the effective level of involvement that the current program-level S&MA function (Level II Safety and Product Assurance (S&PA)

Division) provides in the current SSFP. S&PA holds membership, participates, and votes in all Space Station program software and Technical and Management Information System (TMIS) Control Boards. The Division participates in the development of program management and technical requirements for safety, reliability, maintainability and quality assurance (SRM&QA), and initiates/supports applicable change requests (CRs). S&PA reviews and recommends disposition for every CR evaluated by these Boards. S&PA has contributed to Level III, International Partner, and Level IV Design Reviews and the Man-Tended Capability (MTC) Phase Manager's Technical Integration Group, the lead Level II Design Review team. S&PA's expanded quality assurance integration efforts over the past year resulted in several program enhancements. S&PA also conducted audits and special topic studies.

In addition to these overall program integration efforts, S&PA has been intimately involved in reviewing requirements, plans, and designs for software verification and validation, the C&W system, and normal and contingency operations planning.

Finding #2: The SSFP 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 ACRV as a lifeboat in accordance with the ACRV project system requirements and philosophy.

NASA Response: Concur. The Space Station program plans to continue development of the ACRV. NASA is examining the acceptability of existing spacecraft from other countries in order to minimize cost and to assure that the ACRV will be available for use on Space Station Freedom in a timely manner. Provisions for the ACRV have been included in the NASA 5-year budget for the redesigned Space Station.

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 ORUs.

NASA Response: We concur that robotic compatibility is important to the design and operation of the Space Station. The SSFP established a Robotics Working Group which conducted an analysis to optimize the number of robot-compatible ORUs consistent with practical application and need. The Robotics Working Group is an active organization in which all work packages, operations, projects, international partners, and the Level II program participate. It has developed two robotics standards: (1) SSP 30550, Volume

I, "Space Station Robotics Systems Integration Standards: Robotic Accommodations Requirements"; and (2) SSP 30550, Volume II, "Space Station Robotics Systems Integration Standards: Robotics Interface Standards." The latter volume standardized hardware and equipment for the accommodation of robotics systems. The Robotics Working Group continues to work the addition of ORUs to the list of equipment designated to be robotic-compatible in SSP 30000, Section 3, "Space Station System Requirements," Table 3-55.

Only external, serviced ORUs are designated robot-compatible, because no internal robots are planned. ORU parameters influencing the specific design requirements include the physical geometry, mass properties, Mean Time Between Repairs, and Mean Time To Repair. ORU numbers, implementation costs, and unit interface and workstation environmental conditions are also considered in the design.

Finding #4: Considerable progress has been made in automation capabilities for Space Station Freedom. However, the inclusion of the C&W system operation within the overall *Integrated Station Executive* (ISE) software is not scheduled until Mission Build (MB) 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 C&W system, NASA should provide for its operation under the ISE software as early as possible.

NASA Response: The basic C&W is part of the Data Management System (DMS), not the ISE. C&W capabilities will be present in the DMS starting at MB 2 in the form of basic limit checking, and will be augmented by the ISE during subsequent assembly stages. DMS requirements in Section 3 of the Program Definition Requirements Document, Revision L, paragraph 3.2.5.1.1.25, specify that the DMS shall support a C&W system that continually monitors the safety conditions and critical functions and provides information to the flight and ground crews. ISE requirements in the paragraph 3.2.13.1.7 specify that the ISE shall augment the C&W capability accomplished by the systems, elements, and payloads via the DMS by providing C&W synthesis. These additional capabilities are stipulated in NASA-STD-3000, Volume IV, "Space Station Freedom Man-Systems Integration Standards." The additional capabilities include suppression of repetitive messages, annunciation of flood pattern recognition, and initiation of synthesized annunciation of conditions not recognizable by an individual system, element, or payload.

Finding #5: The central development facilities for the 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 DMS 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.

NASA Response: NASA has reviewed the capacity of the central facilities in order to verify their adequacy to support all required software development and testing. A recent loading analysis update was presented at the Central Facilities Delta Preliminary Design Review on April 26, 1993. The analysis shows a short period of need that exceeds availability for a two-shift, 5-day week. This will be accommodated by scheduling and additional shift work, as required. The Space Station program is continuing to study ways that could enhance the productivity and availability including more verification credit at the work packages.

The program intends to simplify payload interfaces with the core station such that payloads will not require the use of the central facility. However, those payloads with complex interfaces will have access. Change Request BB003472, "Add CSF/CAF Requirements to SSP 30000," approved April 7, 1993, ensures that payload software interfacing with core systems and software is accommodated. The DMS hardware and software and support equipment are in the central facilities to support payload interface verification; however, many potential payloads projects have emphasized that they require flexibility in selecting specific verification facility support.

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 DMS 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.

NASA Response: Timeliner is being procured through IBM and will receive the same level of validation and verification testing as other flight software. It has always been the intent for Timeliner to be subject to the same level of testing as any other flight software in accordance with SSP 30000, Section 12, "Space Station Program Master Verification Requirements," paragraphs 4.1.15 through 4.1.18. These paragraphs require verification of all flight software including in-line commercial-off-the-shelf (COTS) software.

Finding #7: The Software Support Environment (SSE) is of critical importance to the SSFP. 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 SSE.

NASA Response: Concur with the recommendation. The program will continue to support and monitor the SSE development and utilization.

Finding #8: The SSFP has begun the planning and development of an Integrated Logistics System (ILS), which coordinates the work packages and the Kennedy Space Center (KSC).

Recommendation #8: Continue working on the plan for the ILS.

NASA Response: Concur. The Space Station program is continuing development of the ILS at KSC. The program considers the ILS essential to the efficient and effective management of operations and maintenance, spares, repairs, consumable requirements, and resource allocations. It is also necessary for the planning and implementation of on-orbit quality assurance planning currently in work.

B. SPACE SHUTTLE PROGRAM

ORBITER

Finding #9: The Space Shuttle Automatic Landing (Autoland) 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 Development Test Objective (DTO) 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 Autoland System.

Recommendation #9: Define the requirements and demonstrate the capability for an Autoland System as soon as possible.

NASA Response: The orbiter currently has a capability for automatic landings, to be used as a contingency when the commander and the pilot are incapacitated or incapable of landing the orbiter using nominal Control Stick Steering (CSS). Certification of contingency Autoland has involved partial flight demonstration; on STS-2, -3, and -4 Autoland (automatic landing) was engaged from 10,000 ft. to as low as 125 ft. Further certification testing of contingency Autoland has not been identified as a requirement. Postflight data from each mission have been reviewed and indicate no instances of unexpected divergence by the nonactive contingency Autoland from the reference trajectory.

The requirements for demonstrating an automatic landing on the Shuttle have been developed as part of a DTO. However, this DTO is not currently scheduled. Reasonable mission rules, placards, microwave landing system calibration, and crew training requirements have been identified. Software changes desirable to enhance redundancy management of navigation sensors have been developed, though not yet implemented. Options for automation of landing gear deployment, air data probe deployment, braking, and nosewheel switching have been developed for incorporation in a long-duration orbiter program.

We currently have no plan to demonstrate the Autoland System. This policy is the same as not demonstrating a Return to Launch Site or Transatlantic Abort (RTLS or TAL). The policy is not to take any additional risk for demonstration purposes without a firm requirement.

As you know, the Office of Space Flight (OSF) is reviewing a crew exchange to preclude pilots from landing on long-duration flights to Space Station which extend beyond the crew's certified capability to land. Additionally, the OSF has developed an on-orbit simulator for practicing landings prior to entry. This will enhance crew performance during landing.

In summary, the program is reviewing the operational flight rules pertaining to Autoland, we have budgeted upgrades in software and hardware to improve the Autoland functionality, the life sciences organization is collecting physiological data and developing countermeasures to ensure adequate crew performance as the mission duration increases. We are confident with using Autoland in a contingency mode, but do not plan to demonstrate Autoland until a firm requirement mandates a demonstration.

Finding #10: NASA has funded the development and installation of a Multifunction 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 MEDS warrant its installation in the Space Shuttle as soon as possible.

NASA Response: The magnitude of the modifications to the orbiter vehicles to incorporate the MEDS is quite large. This is known to involve removal and installation of flight deck panels, installation of avionic Line Replaceable Unit (LRU) cooling ducts, and installation of new LRU wiring and the LRUs themselves. The nature of these modifications coupled with the subsystem development schedule, testing schedule, and delivery dates of MEDS hardware, warrant installation of the MEDS during orbiter maintenance/interval inspection down periods. First flight is scheduled in the fourth quarter of FY 1996.

Finding #11: The inventory of Auxiliary Power Units (APUs) is currently being upgraded to an Improved Auxiliary Power Unit (IAPUs) 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 IAPU spares.

NASA Response: The entire orbiter fleet will be upgraded to fly only IAPUs with the completion of the OV-104 Orbiter Maintenance Down Period (OMDP) 1. The spares posture is improving, but cannibalization will continue to be a possibility until all older APUs are upgraded to IAPUs and are available for installation in the field.

Finding #12: The IAPU 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 GGVM designs with the goal of providing a replacement for the current configuration as soon as practicable.

NASA Response: Development of an alternative GGVM design and vendor to provide a replacement for the current design has been implemented. First flight is scheduled for the fourth quarter of FY 1996.

Finding #13: The results of flight tests on the orbiter *Columbia* (OV-102) using pressure and strain gauge 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.

NASA Response: The Space Shuttle program has conducted a series of structural DTOs flights to collect the pressure and strain gage data on wing loads. Additional DTOs are planned for STS-55 and STS-58. The collected flight data will be used to verify the orbiter aerodynamic data base which has been used in loads analyses. Vehicle loads analyses are expected to be completed by October 1994.

SPACE SHUTTLE MAIN ENGINES (SSME)

Finding #14: The SSME 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.

NASA Response: The SSME program will continue vigilant implementation of improved inspection techniques and acceptance test procedures. Design solutions, recurrence controls, limitations, and product improvements are addressed routinely to assure and increase operating margins and safety margins.

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 Alternate Turbopump program (ATP) is on hold. The highly effective Large Throat Main Combustion Chamber (LTMCC) has finally been made a formal part of the SSME 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 SSME design improvements are vital to the reduction of Space Shuttle operational risk. Therefore, NASA should reinstate the ATP HPFTP development as well as continue to press for approval of the LTMCC, and examine carefully the benefits of integrating all the individual modifications into a block change program.

NASA Response: NASA fully agrees with the reduction of the operational risk by introducing the ATP pumps and the LTMCC into the SSME, and the Agency will continue to press for the go-ahead approval of the LTMCC and the ATP HPFTP.

Development and certification of two block changes will incorporate the safety features quickly and efficiently. Block I will include the ATP high pressure oxygen turbopump, the Phase II+ two-duct powerhead, and the single-coil heat exchanger. Block II will include the ATP HPFTP and the LTMCC. Funding for the ATP HPFTP and the LTMCC have been submitted in the President's FY 1994 budget. Following budget approval by Congress, these safety improvements will be aggressively pursued to accelerate implementation of the Block II changes.

SOLID ROCKET MOTORS

Finding #16: Three Flight Support Motors (FSMs) 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 FSMs for quality control, validation of design improvements, and qualification and verification of new materials, processes, facilities, and equipment.

NASA Response: It is NASA's intention to continue to qualify new materials or process changes incorporated into the RSRM via the FSM program. The next FSM is FSM-4, scheduled for November 1993. The timing of these changes and the subsequent qualification efforts are subject to budgetary constraints.

Finding #17: Soot has been found on the O-rings serving the RSRM nozzle internal joint number two 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 two is sufficiently high to suggest the need for a redesign of this joint to eliminate the present procedurally based solution.

NASA Response: The action which the Shuttle program is implementing to correct the deficiency of joint number two involves changing the assembly process. We believe, and the OSMA concurs, that the corrective action being taken is proper, recognizing the relatively minor consequences of the deficiency and the high cost and development risk which a redesign in this area might entail. Inspection of the first flight motor with the new process look favorable with blowhole occurrence reduced. We will continue to review this improvement.

During the redesign program following the Challenger accident, this joint was redesigned. The primary O-ring was added to make the seal redundant and also allow a leak check to be performed during nozzle assembly. There is a RTV sealant applied between the nose cap and cowl which is to prevent circulation of hot gas combustion gases in the joint. The joint is deficient because blow paths often occur in the RTV, allowing hot-gas penetration to the primary O-ring seal, the cowl-to-cowl housing bond, and to the joint metal parts. The sealing integrity of the primary O-ring has never been a concern to the Shuttle program, even with the many occurrences of gas paths to the seal, because the O-ring is a face seal fully enclosed within the O-ring groove and covered by the flex bearing flange, and because the joint is static and does not open with motor pressurization. There has never been erosion or heat effects observed on the O-ring or its sealing surfaces.

The finding of blow paths in the cowl-to-cowl housing bondline on STS-37 did, however, raise a concern for potential failure of that bond. The resulting analysis concluded that in the event of a failure of this bond, the leak path would be into the flex bearing/flex boot cavity which is not catastrophic. There is also a redundant mechanical attachment of the cowl to the cowl housing (36 steel shear pins) which would retain the cowl in the event of complete bond failure. This has been the basis for the flight rationale since STS-37.

In the current assembly procedure, an epoxy adhesive is applied to the cowl housing and RTV is applied to the nose cap at the same time. There is some mixing of the adhesives which prevents uniform curing, and air is sometimes trapped within the bondlines, leading to the formation of blow paths. The corrective action changes this procedure to separately bonding the cowl and cowl housing, installing the joint bolts, and then backfilling the RTV into the cowl/nose cap gap. This change is a low-risk improvement which has been thoroughly tested and is expected to significantly reduce the occurrence of hot-gas intrusion into the joint. The first flight of this change will be STS-57.

Finding #18: The projected factor of safety of the aft skirt when used on the Advanced Solid Rocket Motor (ASRM) 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.

NASA Response: Several testing options were evaluated for the external bracket concept. The first option was an influence test in which an aft skirt is loaded without and with the external bracket. This test would not destroy an aft skirt. The influence test option was eliminated because of the nonlinear behavior exhibited in weld region (the skirt will have to be loaded to high levels to obtain useful information). The next option considered was a full-scale aft skirt failure test. This type of test is limited in several ways. Only one holddown post can be taken to failure and provide useful test information. The magnitude of the test would result in a significant schedule impact. The complexity of an elaborate test setup would require a large engineering effort. The cost would approach that of a full Structural Test Article (STA) test.

The component test method was proposed to avoid the problems of the full-scale aft skirt test. The component concept allows the testing of up to four test articles to failure. Direct comparison between the external bracket concept and the baseline configuration under identical test conditions can be made. The component test concept requires a smaller and less complex test fixture than for a full-skirt test. The cost and schedule impact are much less than for a full-skirt test.

The validity of the component test concept depends on the ability to develop a load set that provides a proper state of stress in the area of the external bracket (critical weld region). Finite element analysis has determined that the external bracket does not effect the overall stiffness of the aft skirt. The regions affected by the bracket are included in the test article. Detailed finite element models were used to develop a set of test loads which will produce the STA-3 state of stress in and around the critical weld region. Furthermore, the STA-3 distribution has shown agreement with strain data from flight vehicles. The component test method is the preferred method of testing both from a technical and an economic point of view.

Finding #19: Potential stress-corrosion cracking of case welds on the ASRM 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 ASRM program should assess the adequacy of its stress-corrosion cracking test plan to assure that sufficient pass/fail criteria tests are included.

NASA Response: ASRM takes issue with this finding/recommendation. The project has conducted an extensive test program utilizing resources at Babcock and Wilcox, the University of Missouri, and the Marshall Space Flight Center (MSFC) Materials and Processes Laboratory with the goal of quantifying residual stresses as well as evaluating susceptibility to stress-corrosion cracking. This program is virtually complete and the Aerospace Safety Advisory Panel (ASAP) concerns are being shown to be nonproblems.

Finding #20: The top-level requirements document for the ASRM 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 ASRM 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.

NASA Response: ASRM currently has activities underway which address each of the ASAP concerns in these areas.

Overall ASRM manufacturing systems and integration requirements are being detailed in the Automated Manufacturing Systems (AMS) specification document which is currently under development and will be completed in July 1993. This document will define the total manufacturing computer system hardware and software requirements for ASRM.

An integrated test plan for the AMS software is also being developed and will be completed in the same timeframe. A manufacturing test bed is being built which will be utilized to verify AMS software requirements in accordance with the integrated test plan.

LAUNCH AND LANDING

Finding #21: The KSC 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.

NASA Response: The Structured Surveillance program is in the early stages of development with emphasis on maintaining safe flight operations. Operations and Maintenance Requirements Specifications (OMRSs) derived from Critical Items Lists (CILs) or Hazard Report acceptance rationale will continue to have the previous level of quality assurance inspections. Acceptance and installation of Criticality 1 hardware will also continue to have both contractor and NASA inspections. Evaluation of the results of the pilot program indicates increased efficiency of the processing effort and continued effectiveness of the quality assurance activities. We are moving slowly into this program with close management attention to assure safe flight operations.

Finding #22: The use of task teams at KSC 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.

NASA Response: The task teams will continue to be developed and used because of the positive results from this concept. The Structured Surveillance program is in the early stages of development and as it matures, consideration will be give to integrating it with the task teams.

Finding #23: A new high bay Orbiter Processing Facility (OPF-3) has been opened at the KSC. 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.

NASA Response: KSC acknowledges the findings and agrees with the recommendation. Actions are in process to improve the lighting disparities. Because the most significant differences are in platform configurations and light-reflective surfaces, all surfaces that can reflect light on High Bay 1 and 2 platforms are being painted white. The floors in High Bay 1 are also being painted white and those in High Bay 2 are scheduled to be painted white in August 1993.

LOGISTICS AND SUPPORT

Finding #24: The NASA Shuttle Logistics Depot (NSLD) 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 NSLD.

NASA Response: The protracted failure analysis times, especially those involving original equipment manufacturers (OEMs), are the most prominent contributors to the long repair turnaround times. Such turnaround times involving OEMs have averaged about four times those at the NSLD. The failure analysis capability at the NSLD has been enhanced during the past year. Initiatives are also underway with the Johnson Space Center (JSC) Orbiter and GFE project to improve the overall failure analysis process relative to identification of requirements as well as location where the analysis is performed. The increasing utilization of the KSC NSLD capability for both failure analysis and repair will significantly improve the average repair turnaround time and the overall logistics program in general.

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 NSLD to compensate for the loss of suppliers.

NASA Response: Emphasis has been placed on initiating additional transition of repairs to the NSLD and other Government facilities (i.e., White Sands) to compensate for supplier loss, high costs, and instability. A total of 19 certifications are planned this year and 20 vendors are being reviewed for future transition. Particular issues such as zero or below minimum stock levels are emphasized at the project level and reviewed routinely by the program for adverse trends.

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 Aircraft 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.

NASA Response: NASA agrees that a strong AMO and an independent IAOP will contribute to the safe and efficient operation of NASA aircraft and that the Aviation Safety program should be managed in accordance with the *NASA Aviation Safety Officers Reference Guide*. The guide was developed by the Headquarters OSMA to improve the NASA Aviation Safety program which is conducted according to the provisions of NASA Management Instruction (NMI) 7900.2A, "NASA Aircraft Operations Management"; NHB 7900.3 (V1), "Aircraft Operations Management Manual"; Chapter 7 of NHB 1700.1(V1-B), "NASA Safety Policy and Requirements Document (formerly the Basic Safety Manual)"; and other applicable NASA directives.

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.

NASA Response: Concur, the AMO is leading an Agencywide, multifaceted effort examining aging aircraft. The AMO is aggressively pursuing opportunities for obtaining newer, more efficient aircraft that become available as a result of the military drawdown. The AMO, in conjunction with the IAOP is developing a rigorous enhanced Gulfstream I Structural Corrosion Control Inspection to validate the integrity of these 30-year-old aircraft. This inspection program will be adapted to other older aircraft in the NASA fleet. NASA will continue to maintain all its aircraft to the highest standards to ensure safe, efficient, productive mission accomplishment.

Finding #28: Flight Research at the Dryden Flight Research Facility (DFRF) 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: DFRF should maintain emphasis on the practice of periodic reviews of safety procedures to ensure that all reasonable risk reduction measures are being taken.

NASA Response: DFRF procedures for flight program development, flight readiness reviews, and flight test operations have been long established and well proven. Safety assurance and risk management reviews are, and will continue to be conducted periodically by DFRF, Ames Research Center, the IAOP, and NASA Headquarters.

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 NMIs.

NASA Response: The role and responsibilities of the Headquarters Office of Safety and Mission Quality (Code Q) have been realigned as the result of the recent internal NASA Headquarters red team/blue team reviews. Based on the teams' findings, the name of Code Q has been changed to the "Office of Safety and Mission ***Assurance***" to more accurately reflect its function. Other changes have been instituted to streamline the overall activity and realign resources to better support the evolving needs of NASA programs and missions. A NMI incorporating these changes was signed on April 9, 1993.

Although the mandate of the OSMA will continue to emphasize its role as the Agency's "safety conscience," the changes ensure an appropriate and harmonious balance between Code Q's independent program oversight and support functions. The Office will provide an upfront contribution to programs (prevent problems by building in safety, reliability, and quality assurance at the earliest possible stage), focus efforts to manage the quality process for NASA payloads, and increase system engineering/concurrent engineering capabilities, while expanding risk-management capabilities to support program managers in meeting schedule and budget constraints during critical decisionmaking processes.

The strategic thrust of the Office over the next 2 years will be to: (1) Integrate SRM&QA requirements at the appropriate stage of a program; (2) Advocate SRM&QA oversight and assessment functions across the Agency; (3) Develop and promote NASA-wide risk-management practices; (4) Maintain a strong contributing SRM&QA presence in NASA programs and operations; and (5) Develop and advance engineering standards and practices.

Finding #30: NASA has begun development of a Simplified Aid for Extravehicular Activity (EVA) Rescue (SAFER). SAFER is a small maneuvering unit intended to fit at the bottom of the Portable Life Support System (PLSS) of an 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 would also provide 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.

NASA Response: SAFER design, study, and pre-production activity is continuing. A Project Management Plan for Phase I of the Flight Test project (FTP) has been written. Requirements validation for the SAFER has been established, and development testing of a prototype SAFER unit has been successfully conducted. A Flight Test Article (FTA) is being built at this time. Once built, the FTA will be flown on a Shuttle mission. This flight will be used to validate SAFER operating characteristics and ensure adequate engineering performance in a space environment. This type of activity is essential in confirming the accuracy of ground-based simulations. Results of this FTP will be used to refine the SAFER design prior to production. Manifest options for the FTA are currently being considered in the 1994 timeframe. Phase II of the project, the SAFER flight production project, will be initiated after completion of this activity.

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.

NASA Response: Virtual reality technology is currently being investigated for applicability to training by several Centers: JSC is developing a virtual reality training simulator to help prepare astronauts for Hubble-related maintenance; Ames Research Center is working with dynamic response of virtual environment spatial sensors, 3-D auditory displays for aeronautical applications, and extravehicular activity self rescue in virtual environments; Jet Propulsion Laboratory has developed interfaces with telerobotic control using virtual reality environments; MSFC is studying virtual reality applications to microgravity mobility and ergonomics; and Goddard Space Flight Center is investigating the use of virtual reality technology for telerobotics. All of these activities apply to the simulation and training of astronauts for Shuttle EVA and Space Station maintenance activities. A NASA technical report on virtual reality technology is expected to be published during the summer of 1993. This report will describe all Center research efforts and proposed applications of virtual environments. This report represents a major step toward the goal of providing a more realistic environment for 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 decisionmaking at all levels.

NASA Response: The panel's advocation of increased human factors involvement in NASA programs has not gone unheeded. NASA concurs that increased involvement of human factors professionals in the decisionmaking process is required. Human factors professionals from the crew systems organization at the JSC are deeply involved in the MEDS development project. Active involvement of human factors professionals in other recently initiated Space Shuttle improvement projects will also bear witness to our increased commitment to improved human factors. Additionally, the JSC Director recently highlighted the increased role that the Center needs to play in the area of human/machine interfaces on current and future NASA programs.

While the Space Station program is not staffed with human factors engineers, the crew systems and life sciences personnel perform this function at Level II with institutional support from JSC. The Safety Office performs oversight of the function as a safety concern.

Human factors requirements and their implementation are very high on the priority of the Space Station Freedom program. Human factors requirements are embedded in the SSP 30000, "Program Design Requirements Documents." Additionally, NASA Standard 30000, Volume IV, "Space Station Freedom Man-Systems Integration Standards," published by the JSC Crew Systems Division, is an applicable requirements document. This document has recently been updated to add common EVA workstation interfaces. The international partners have either accepted these requirements, or submitted their own human factors requirements document(s) for meets-or-exceeds negotiation per Memorandum of Understanding.

Implementation of these requirements is reviewed by several NASA groups, including the Extravehicular Activity System (EVAS) Working Group and Freedom Safety Review Panel. Mission Operations considers human factors when it reviews planned operations. The Milestone Design Reviews also address human factors. Priority for the implementation of commonality in design is based on the safety criticality of the function. In some cases, the program has determined that a commonality of a function is so critical that NASA makes its hardware available to the international partners. The Space Station will continue to emphasize human factors considerations in its design.

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 IV&V activity for SSFP and the role of various groups in accomplishing it.

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

NASA Response: In NSTS 08271, "Flight Software Verification and Validation Requirements," NASA formally defined an embedded process and requirements for the Space Shuttle program. This process includes maintenance of many detailed test procedures, and the SR&QA organization audits this process. NASA began a study to evaluate this embedded process relative to the need for IV&V and coordinated this activity with the National Research Council. Study results should be available in late 1993.

NASA will establish an IV&V facility in Fairmont, WV, later this year. At this facility, NASA will develop an Agencywide IV&V capability and provide IV&V support to programs, including Space Station. Through this effort, NASA will develop an Agencywide IV&V policy, conduct IV&V research, demonstrate tool/technique applications, and develop training requirements. The IV&V policy will include a clear definition of IV&V, identify the essential IV&V activities, and state the relationship of IV&V to other program activities.

SSP 30000, Section 12, paragraph 4.1.14, "Space Station Master Verification Requirements," requires IV&V of all flight software that supports Category 1, 1C, and 2S functions or is resident in Criticality 1 and 1R hardware. The program has been performing the IV&V functions; however, the process has not been formalized. SSF has utilized the Engineering Integration Contractor (EIC) as the program-level IV&V agent. The EIC is totally independent of all software developers in the program and reports directly to the Level II Program Office. Tasking is currently in place with EIC to perform typical design Phase IV&V tasks.

Tasks performed by EIC during the requirements phase of the program were specifically directed at requirement traceability analysis, review of requirements for consistency and completion, and independent assessments involving system performance projections and requirement correctness. The EIC has a track history of performing this IV&V function in every major software review and has provided numerous independent assessments to the Program Office. As the program enters the coding and test phases, new tasks will be issued to the EIC to conduct independent tests of each flight load for certification for flight readiness.

SSP 30666, Volume 4, Part 2, "Master Independent Verification and Validation Plan," will formally document this program-level software IV&V process. It should also be noted that each work package prime contractor has a verification and validation organization independent of the software development organization to provide the IV&V function at the work package level.

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.

NASA Response: NASA has embarked on a comprehensive study to develop a coordinated national plan for world-class aeronautical and space facilities that meets the current and projected need for commercial and Government-sponsored research and development, and for Government space operations. The plan will be coordinated with the Department of Defense, Department of Energy, Department of Commerce, Department of Transportation, and the National Science Foundation. Industry representatives have been contacted to ensure that private-sector interests are considered. The plan will address shortfalls in existing capability, new facility requirements, and consolidation and phaseout of existing facilities. The development of the Facility Plan will be accomplished by three task groups: Aeronautics R&D Facilities, Space R&D Facilities, and Space Operations Facilities; all three of which are of interest to constituencies in the private sector. The results of the study will be an essential component of our internal planning to improve and continue to maintain our facility infrastructure.

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.

NASA Response: NASA agrees. The OSMA is developing a NMI, "Verification of NASA Space Flight Systems." This NMI is applicable to NASA Headquarters and Field Installations, both to activities performed at NASA facilities and those performed at contractor sites in accordance with contract requirements. This NMI establishes policy and responsibilities for verifying that NASA Space Flight Systems meet performance and operational requirements. It includes requirements for verification program definition, planning, implementation risk evaluation, and independent assessment. The NMI specifically addresses problems like those encountered by the Tethered Satellite, by stating that all configuration changes made subsequent to qualification or acceptance testing shall require a system engineering evaluation and requalification by the same process initially used.

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 TQM 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.

NASA Response: NASA's Continual Improvement Office (Code T) is currently completing efforts to provide planning for a structured implementation of TQM. Coordination with points-of-contact at each NASA facility and outside industry experts has been conducted, and a NASA-wide Implementation Plan has been written. The plan provides for a phased program to examine established initiatives and approaches at all NASA Centers, benchmark successful activity, coordinate a consensus commitment across NASA, and achieve partnership working arrangement with outside organizations. Contractor/NASA metrics, and an internal/external Supplier Ratings System (SRS) have been developed using the guidelines and selected provisions of the Baldridge Award, President Award, NASA Low Trophy, and other similar criteria. These measures will be used to gauge the performance of NASA's Continual Improvement activities. Overall, this effort will result in a network of leadership, support, and training that meets the strategic goals and directions of the Agency.

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.

NASA Response: The report entitled, "Strategic Considerations for Support of Humans in Space and Moon/Mars Exploration Missions (Life Sciences Research and Technology Program, Volume 1)," includes a timeline for implementing the recommendations. The NASA Life Sciences organizations were an integral part of the Aerospace Medicine Advisory Committee efforts to define both their recommendations and the timeline to incorporate them. The Office of Life and Microgravity Sciences and Applications (Code U) incorporated those recommendations applicable to the life sciences, through the definition of science priorities and their discipline plans, within the last 2 years.

The report recommendations recognize that the space exploration program might be deferred to a future date. The timeline for incorporating space exploration recommendations will be modified to adapt to the goals of NASA.

APPENDIX C
AEROSPACE SAFETY ADVISORY PANEL ACTIVITIES
JANUARY 1993 - JANUARY 1994

JANUARY

15	Space Shuttle Main Engine Assessment, Marshall Space Flight Center
26	Assured Shuttle Availability Program Discussion with General Accounting Office, NASA Headquarters
27	Space Shuttle Main Engine Assessment Presentation to NASA Administrator, NASA Headquarters

FEBRUARY

11	STS-55 Flight Readiness Review, Kennedy Space Center
22-23	Aerospace Medicine Advisory Committee Meeting, NASA Headquarters
23-25	Integrated Logistics Panel Meeting, Marshall Space Flight Center

MARCH

17	Space Shuttle, Space Station and Russian Program Briefings, NASA Headquarters
18	Aerospace Safety Advisory Panel Annual Meeting, NASA Headquarters

APRIL

21	Auxiliary Power Unit Briefing, Sundstrand
22	Kennedy Space Center Operations Discussions, Kennedy Space Center
23-24	STS-55 L-2 and L-1 Day Review, Kennedy Space Center

MAY

3	Space Station Redesign Presentation, Crystal City, VA
4-6	Intercenter Aircraft Operations Panel Meeting, Tucson, AZ
11	Review of Space Shuttle Main Engine Firing and External Tank activities, Stennis Space Center
12	External Tank Briefing, Martin Marietta, Michoud Assembly Facility
17	Pre-Congressional Testimony Briefing with Associate Administrator for Safety and Mission Assurance, NASA Headquarters
18	Aerospace Safety Advisory Panel Annual Report Congressional Testimony, Washington, DC
25-26	Rocketdyne Procedures and Processes Study, Marshall Space Flight Center

JUNE

15-16	Procedures and Processes Study, Rocketdyne
22	F-15B Advanced Flight Test Fixture Flight Readiness Review Aerodynamic Flight Test, Dryden Flight Research Facility
25	National Research Council Committee Review of Space Shuttle Flight Software Process, Johnson Space Center
28-29	Kennedy Space Center Operations Review

JULY

13	Review of Flight Test Programs, Dryden Flight Research Facility
14	Orbiter 104 Review, Rockwell Palmdale Facility
15	Review of Orbiter Program Operations Safety Enhancements, Autoland, Rockwell Downey
21	Aerospace Medicine Advisory Committee Meeting, NASA Headquarters
22	X-31 Tactical Utility Testing Flight Readiness Review, Dryden Flight Research Facility

AUGUST

19 Discussions concerning Rocketdyne Procedures and Processes Study; ASAP Comments on General Accounting Office Space Shuttle Main Engine Report; and Kennedy Space Center Processing Procedures with Administrator, NASA Headquarters

26 Software Discussion/Teleconference with the Office of Safety and Mission Assurance

SEPTEMBER

8-9 Structured Surveillance Discussion, Kennedy Space Center

14-17 Integrated Logistics Panel Meeting, Kennedy Space Center

20 Rocketdyne Procedures and Processes for Space Shuttle Main Engine Presentation to Senior Management, NASA Headquarters

23-24 Structured Surveillance, Kennedy Space Center

29-30 Space Shuttle Program, Russian Program, Hubble Program Reviews, Johnson Space Center

OCTOBER

5 Awards Ceremony, NASA Headquarters
Software and Kennedy Space Center Processing Discussion with the Associate Administrator for Space Flight, NASA Headquarters

19-21 Shuttle Processing Reviews, Kennedy Space Center
Software Discussion with the Offices of Safety and Mission Assurance, and Space Flight, NASA Headquarters

NOVEMBER

2 Review of Space Shuttle Main Engine Program, Redesign Solid Rocket Motor Program, Lightweight External Tank Program and Space Station Alpha Program, Marshall Space Flight Center

16 Aeronautics Discussion with Associate Administrator for Aeronautics, NASA Headquarters

16 Flight Readiness Review on Use of Helmet Mounted Visual Audio Display, Dryden Flight Research Facility

DECEMBER

9 High Altitude Unmanned Vehicle Flight Readiness Review, Dryden Flight Research Facility

15 Total Quality Management Discussions with Associate Administrator for Continual Improvement, NASA Headquarters

16 Space Shuttle Discussion with General Accounting Office, NASA Headquarters

For Further Information
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