essentially additional pressurized modules whose overall health should be monitored. Moreover, leaving a crew member on the Orbiter occupies a scarce resource that could prove invaluable for both nominal and contingency operations on the Space Station.

The current plan to have crew members translate through a fire, toxic spill, or other problem in a node to reach the safe haven food supplies does not seem to be well grounded. The argument that this "standardizes" the crew response is neither compelling nor correct. The typical human response is to retreat from an emergency condition rather than attempt to move through it. Moreover, the placement of all of the safe haven food on one side of the nodes can eliminate being able to use time to resolve the unsafe condition and restore access to the regular food supply.

Overall, the problems exhibited by the Space Station Freedom Program are relatively minor compared to the obvious progress the program has made. There is a definite *"when we fly"* attitude in evidence rather than the *"if we fly"* mood which had permeated the program for years. This is a healthy sign and bodes well for program success if funding remains sufficient and the program managers focus additional attention on the diminishing number of weak spots.

Ref: Finding #2

See the complete ACRV report in Appendix D.

Ref: Finding #3

The Space Station is dependent upon the use of robotics for assembly and maintenance to reduce extravehicular activities (EVAs) and minimize the crew time devoted to maintenance. This past year has seen important progress in defining the role of robotics in Space Station maintenance, including:

- International agreements on robot safety and compatibility issues.
- A maintenance study to examine the logistics and operations of Orbital Replaceable Unit (ORU) changeout over the 30-year life of the station.
- Design of a new ORU subcarrier and a robotic strategy that could triple (from 2 to 6) the number of ORUs an EVA astronaut could change in a single EVA.
- Analysis of the different phases of the detailed assembly sequence oriented toward: 1) determining what needs to be done to assure compatibility between components so that it is feasible to complete the assembly; and 2) determining what support capabilities must be initiated to allow the assembly operations to be accomplished.
- Considerable progress on developing robot-compatible ORUs, though there are still many ORUs that are not robot-compatible.
- An internal vehicle activity (IVA) maintenance study paralleling the Fisher-Price EVA study to examine the time required for internal maintenance operations. Preliminary results show that the tasks can be accomplished within the crew time budget.
- A feasibility study for using ground control of robots for accomplishing inspection and maintenance tasks found that this approach is feasible and should be pursued further.

Ref: Finding #4

Space Station automation activities during the past year fell into two major categories: 1) automation of fault detection, environment monitoring, and environment control, and 2) continued development of expert systems for fault isolation and recovery.

Considerable progress has been made in areas such as:

- Detection of hull leaks.
- Fire detection and protection.
- Pressure control.
- Trace contaminant monitoring.
- Water quality monitoring.
- Internal thermal control system leak detection.
- Demonstration of a prototype fault identification system for the thermal control system.
- Construction of a general DMS fault detection, isolation, and recovery (FDIR) prototype.
- FDIR activities for the power system.

The Panel was pleased to note that NASA has utilized a human factors expert in designing some of the user interfaces, with impressive results. However, areas of concern remain. Inclusion of the caution and warning system operation within the overall *Integrated Station Executive* software is not scheduled until Mission Build 17 and there are hints that this might be subject to future software reductions and prioritization. Further, NASA does not currently have an adequate means of integrating the simulation models and the rule-based fault isolation systems, as is needed for some aspects of FDIR. There is also a need for the capability to integrate the activities of multiple expert systems.

NASA needs to vigorously pursue the technical solutions to problems limiting the development of automatic fault detection, isolation, and recovery systems during the upcoming year, before the design progresses too far.

Ref: Findings #5 and #6

Major DMS organizational changes during the past 6 months include creation of an Avionics Systems Manager position. The current manager was given responsibility for program-wide avionics integration in addition to the Work Package 2 (WP-2) avionics responsibilities previously held. The Avionics Systems Manager has taken the positive step of creating a series of programwide mode and design teams. These include: 10 Software Mode Teams, a System Design Team, a System Management Team, a Program Data Architecture Team, a Software Design Architecture Team, a Software Integration Process Team, and an Avionics Architecture Team.

The DMS is presently in a high state of flux, with significant design changes in process at the time this report was being written. Those changes reviewed for this report, such as the channelized architecture, appear to be improvements over the previous design.

While detailed comments on the revised DMS design would be premature at this time, a few areas of concern can be noted. First, the centralization of software integration and testing has been an important step forward. However, the DMS equipment available for testing may be too limited to support all of the verification and validation activities necessary to ensure safety.

Second, the people developing the DMS centralized test facilities have as yet had little involvement with the payload developers. Payload developers need to be brought into the picture soon to ensure consistent development efforts and safety-related activities (e.g., caution and warning, FDIR) that are compatible with DMS capabilities. Further, it is not clear that the payload developers have adequate access to the facilities needed, e.g., DMS kits, emulators, or software development facilities. A recent utilization workshop was held, but a stronger effort is needed.

A system called *Timeliner* is being developed for scheduling activities on the Space Station. This system is effectively a high-level programming language that will be used on-line by the crew as well as from the ground. Neither the *Timeliner* system itself nor the scripts developed by it seem to be undergoing the same level of development review and scrutiny as the other software systems. Yet, *Timeliner* and its scripts appear to be very much an on-line control system. *Timeliner* scripts can change real-time object data base (RODB) values as well as inspect them, and the RODB values are used by other parts of the DMS system. Therefore, *Timeliner* scripts and their utilization should be subject to the same kinds of design reviews and verification and validation as other parts of the DMS.

Ref: Finding #7

The Software Support Environment (SSE) has been operational for the past year, and there are a number of work package contractors using it. The reports from Work Package 1 (WP-1) have been particularly favorable toward it, Work Package 4 (WP-4) is heavily dependent upon it, and WP-2 acceptance and use of the SSE is now progressing rapidly after a slow start.

The SSE serves very useful and necessary functions in Space Station software development, configuration management, and documentation control. It now appears to have cleared many of the obstacles that plagued its development and use in the past and is finally serving the function for which it was created. The importance of the SSE suggests that it is unlikely that the SSFP software development can be successfully completed without the type of tools the SSE offers.

Ref: Finding #8

Work is proceeding to identify the elements of the Integrated Logistic System (ILS) for the SSFP. Full advantage is being taken of the experience and facilities developed for the Space Shuttle at the Kennedy Space Center (KSC), although each Work Package develops and supports its own hardware. The Logistics Support Analysis base being evolved at KSC would make that Center responsible for operations and maintenance, spares, repairs, and consumable requirements and resource allocations.

The early development of an Logistics Support Analysis plan is a step in the right direction. Detailed contractor design studies of on-orbit maintenance including accessibility, replaceability, and human engineering also appear to be progressing well.

B. SPACE SHUTTLE PROGRAM

ORBITER

Ref: Finding #9

Continued operation of the Space Shuttle over the next 20 or more years leads to a high probability of the occurrence of one or more instances in which an automatic landing capability will be needed to minimize landing risk. At least two basic situations might result in the need for an automatic landing. The first would involve the inability of the crew to see the landing runway due to factors such as deteriorating weather in the landing site after the deorbit burn, a partially or fully obscured windshield, or smoke in the cockpit. The second would involve the inability of the crew to perform a safe landing due to subtle or obvious incapacitation. The requirements for an automatic landing system to meet these situations must encompass hardware, software, and flight rules that are appropriate in terms of functional capabilities and reliability for those flight conditions or scenarios deemed by analysis and risk management decisions to require automatic landings. However, NASA has yet to establish a complete set of flight rules and associated scenarios for the use of the automatic landing system. Crews do not presently train in the use of the automatic landing system through touchdown, and there are no defined performance or physiological measures to indicate when automatic landings should be made to minimize risk.

The cancellation of the detailed test objective (DTO) to test an automatic landing on STS-53 was a setback for the Space Shuttle Program. This DTO was extremely conservative and posed little additional risk for the STS-53 flight. It would have provided needed flight data to correlate with and validate the computer models and simulation experience. It would also have given the entire Space Shuttle team experience with and confidence in the use of the system when required. NASA should pursue a program leading to the full operational definition and certification of the Space Shuttle Automatic Landing System. This program should include:

- Enumeration of scenarios under which automatic landings might be required to ensure the safety of the crew and vehicle.
- Risk assessment of these scenarios and a determination of whether NASA is willing to accept the identified risk without use of an automatic landing system.
- Approval of the work already defined by Rockwell to quantify the existing system's performance limits if the risk studies indicate a benefit.
- Research on measures of crew and vehicle performance and the environment to establish criteria for when the automatic landing system should remain engaged.
- Determination of the need for additions to the system's capabilities, such as the inclusion of differential Global Positioning System capability and/or automating gear and air data probe deployment.
- A few automatic landings as defined in the DTO for STS-53. These are needed to correlate actual performance

data with the computer models used by NASA and Rockwell and to validate them.

- Specification of a final system configuration and operational rules for its use.

It is also worth noting that the automatic landing system employs the same guidance information that the crew uses with the exception of the actual scene of the runway and any landing aids such as Precision Approach Path Indicator (PAPI) lights. Thus, if the crew were unable to see the runway surface, the reliability of the existing automatic landing system and the crew flying only the guidance information would be similar. In fact, the automatic mode would theoretically have a higher reliability than the manual mode since any possible failures of the Rotational Hand Controller (RHC) would be irrelevant. The landing dispersions and, hence, operational safety of the Shuttle would undoubtedly be superior under limited visibility conditions when the automatic landing system is used.

The redundancy of the present system design does appear deficient with respect to the arrangement of the three receivers for the Microwave Scanning Beam Landing System (MSBLS). If one of these disagrees with the other two, it can be "voted out." However, if the remaining two disagree, the only prudent alternative is to disregard the MSBLS information and have the crew land using visual cues. A relatively simple enhancement of the MSBLS receiver redundancy arrangement has already been identified by Rockwell and, if incorporated, would eliminate this problem. The automatic system would then be fail-operational/fail-safe in accordance with the rest of the system. This would also eliminate the need for the extensive simulator and Space Shuttle Training Aircraft training on low altitude takeovers that was considered necessary in preparation for the STS-53 DTO.

It is logical to conclude that a reliable and safe automatic landing system is a "must" for the Space Shuttle Program and that little additional development is required for the existing system to provide the needed capability. If the need for extensive and costly pilot training to counter extremely unlikely fault conditions at critically low altitudes can be eliminated, automatic landings become a manageable adjunct to Space Shuttle operations that could improve future landing safety under certain extreme operational modes and conditions.

Ref: Finding #10

The Multi-Purpose Electronic Display System (MEDS) retrofit involves significant engineering, program management, and configuration control. The functionality of the existing instruments must be maintained or improved while substituting a digitally based display system for the older analog components. A significant challenge arises from the need to integrate the new displays with the existing analog data bus. In addition, the upgrade must be accomplished without an undue impact on Shuttle flight rates.

As part of the MEDS program, emphasis is being placed on avoiding mixed fleet operations. A decision has also been made to emulate the existing displays at the outset of the changeover. Both of these approaches may be too conservative and thereby delay the time when the program will obtain maximum benefits from the changeover. Many airlines fly the same aircraft types with and without glass cockpits and have cross-qualified their flight and maintenance crews. With the extensive pre-flight crew training for Space Shuttle flights and detailed paperwork for ground crews, a mixed fleet should not present a major problem.

The MEDS development and installation timeline is sufficiently long to permit formation of a task group to examine the issues of display contents and mixed fleet operations. It is theoretically possible to change displays easily in software. However, the history of software modifications within the Shuttle Program would suggest that they are often a pacing item.

Ref: Findings #11 and #12

A major revision of the Auxiliary Power Unit (APU) design has been introduced into the fleet. It has been designated the Improved APU (IAPU) and incorporates many changes to the original design including: a new turbine wheel, a "spring" gas generator, a quad redundant electronic controller, and a passive thermal control system that eliminates the need for water sprays onto the fuel pump and the Gas Generator Valve Module (GGVM) after shutdown. In addition, there are numerous changes in design details such as materials, seals, valve seats, and manufacturing processes and techniques.

While the upgrade to the IAPU is being accomplished, there is a possibility of reaching a situation in which the program will have zero spares. This might arise because of time restrictions on components such as the GGVM valve seat or because of the need to re-grease the shaft to prevent rust as discussed below. This increases the risk that cannibalization will be needed to assure a sufficient number of flightworthy units.

The new "75-hour" turbine wheel has eliminated the problem of turbine blade root cracks that had plagued the APU from the beginning and required extensive inspections and change-outs of APUs. The new wheel design eliminates the sharp corners of the original blade design and provides full shrouding of the blade tips, making the wheel a much more rugged device that is less susceptible to high-cycle fatigue problems. As a bonus, the new wheel provides about 5 percent improvement in operating efficiency.

The "spring gas generator" is an ingenious and simple mechanical design that keeps the catalyst bed under pressure, thus preventing the formation of voids as operating time is accumulated. Precluding the formation of voids eliminates the "roughness" experienced in the gas generation process (decomposition of hydrazine) when voids are present and makes for a smoother running APU.

The new electronic controller with its quad redundancy has minimized the concern about overspeeding of the 72,000 rpm turbine with consequent uncontained blade or wheel failure. The controller passed its certification program without significant problems. Unfortunately, during the design process, the nature of the interaction of the controller with the crew's APU Start/Run switch was overlooked. In the original controller, the overspeed and underspeed automatic shutdown functions closed the fuel tank isolation valve, overriding the flight deck fuel tank isolation valve switch. The overspeed and underspeed latches did not reset when the Start/Run switch was toggled on-off. With the new controller, these latches are reset automatically. Consequently, with the new controller, the crew procedures for normal and emergency APU shutdowns are not identical as had been the case with the original design. Because automatic closure and latching of the fuel tank isolation valve is required to prevent additional vehicle damage after APU loss due to mechanical failure, the system should be designed to use identical procedures. Fortunately, it was possible to effect a return to the original mode of crew operation with a very minor change to circuitry for the fuel isolation valve driver on the flight deck.

Another problem that has developed is the discovery of rust formation on the fuel pump's M-2 steel drive gear. The concern is potential combustion reaction between the hydrazine fuel and the rust. Extensive tests of the compatibility of the rust with the fuel under operational conditions have indicated a low potential for a major reaction. Nonetheless, for the short term, manufacturing, assembly, and storage processes have been revised to minimize the probability of rust formation, and coating of the affected parts with a special grease has been implemented. The grease application lasts 18 months, after which disassembly, cleaning, and re-greasing is required, a time-consuming and expensive process. A long-term solution of the problem is being pursued. The avenues being examined include different, longer lasting greases, and plating or coating of the steel.

Despite numerous design detail changes to the GGVM, there are still problems with durability and failure of the valve seat and other parts of the module mechanisms which apparently defy solution. Preliminary evaluation of a different valve module design shows promise. This avenue should be pursued actively.

Ref: Finding #13

Data taken during early flights of the Space Shuttle showed that the pre-flight calculations underestimated the ascent flight loads on the Orbiter. It was necessary to devise a system of arbitrary wing panel loads (so-called "collector" loads) to adjust calculated external loads so that they produced internal loads like those derived from flight measurements.

Subsequently, more strain gages and pressure sensors were installed, and data were taken over the time period between flights STS-28 and STS-50. The pressure data showed the presence of local shocks, and the magnitudes of the pressure data did not agree with those from wind tunnel tests. The wind tunnel data were adjusted to conform with those measured in flight, and an adjusted pressure distribution was developed. This adjusted pressure distribution was then used to predict the external loads during ascent.

After the data collection flights, wing strain gage calibration tests were conducted so that the flight strain data could be used to determine the bending moments, and shear and torsional loads in the wing box structure. Unfortunately, the data from the wing strain calibration tests did not satisfy the conditions needed to use the conventional method for ascertaining the bending moment, shear, and torsional loads. Instead, an "independent matrix" method was developed to enable the calculation of the direct problem, that is, the applied load/predicted section strain problem as well as the indirect problem, measured strain/predicted section load. This matrix method was used to compare loads obtained from flight test data with analytically predicted loads.

The results from flight data showed that the bending moment and shear was within five percent of the predicted values, using the adjusted wind tunnel data pressure distributions to obtain external loads. Torsion exceeded the predicted values by eight to 15 percent, however.

Predicted ascent loads using the "collector loads" technique envelop (are greater than) those obtained using measured pressure and strain data from flight. As the "collector loads" method [employing the Orbiter/Redesigned Solid Rocket Motor (RSRM) air load data base] is currently used to establish allowable flight conditions, the practice is conservative.

It has apparently been decided not to use additional strain calibration tests or additional pressure instrumentation to obtain data that could permit an expansion of the current flight envelope. Data will be taken, employing existing instrumentation on OV-102, on flights STS-52, -55, and -58 to obtain further substantiation of the calculations of applied and internal loads. This is especially important for loads on the tail where torsion plays a more significant role.

Pressure distribution data will be revised, however, to predict the airloads for the "ASRB Cycle 2" certification analysis during 1993 and 1994.

SPACE SHUTTLE MAIN ENGINES (SSME)

Ref: Findings #14 and #15

There are sufficient engines, spare engines, and spare parts on hand to allow careful inspections and tests when preparing engines for flight. There are still limitations on the service life of the High Pressure Fuel Turbopump (HPFTP) and severe limitations on the service life of the High Pressure Oxidizer Turbopump (HPOTP). The engines have performed well in flight. With diligent and scrupulous performance of all the precautionary tests and inspections, flights can continue at an acceptable level of risk.

To increase the ruggedness of the highly critical Space Shuttle Main Engine (SSME) and reduce its dependency on complex checkout procedures, a number of design modifications have been proposed or are in various stages of development. It is prudent to seek robust design solutions as a replacement for extensive reliance on personnel and procedures. When certified and installed in the fleet, these improvements will increase the operating margins of the SSME and thereby provide better risk management. The modifications include: a single-tube heat exchanger, a new HPOTP and HPFTP, a Large Throat Main Combustion Chamber (LTMCC), and a two-duct powerhead.

The two-duct powerhead and the single-tube heat exchanger went into the certification test program late in 1992 in an engine using a standard throat diameter main combustion chamber and the existing turbopumps.

The Alternate Turbopump Program (ATP) involves both the HPOTP and the HPFTP. The HPOTP has been placed into test and originally experienced a shaft dynamics problem. This has apparently been solved. The HPOTP still has a problem of premature pump-end bearing wear, but solutions are being tested. The HPOTP certification program is planned to begin in the spring or early summer of 1993.

As noted in last year's report, the development of the HPFTP had been placed on hold because of budgetary problems. It was possible, however, to install on one turbopump all but one of the design modifications needed to overcome the problems the HPFTP had experienced before work was stopped. This unit was subjected to three test runs on the Marshall Space Flight Center (MSFC) Technology Test Bed facility with excellent results. If the HPFTP program is reactivated, it would essentially be ready to enter certification testing as soon as the final turbine vane casting is produced.

The LTMCC is now a formal part of the SSME improvement program. However, the Congressional appropriations committees have recently denied funding for the LTMCC. The test results obtained to date, as reported last year, indicate that there is no loss and, perhaps, a slight gain of specific impulse (Isp), and that there is no evidence of combustion instability. In fact, the recovery time of the LTMCC is almost identical with that of the existing small throat Main Combustion Chamber (MCC). Use of the LTMCC provides significant increases in the operating margins of most of the SSME components, especially the high pressure turbopumps.

Unfortunately, the certification programs for these improvements are spread out over a 5-year period. Each of the components was treated as a separate development entity. As a result, certifications are being performed in engine configurations that, most probably, will never fly. For example, as noted above, the two-duct powerhead and single-tube heat exchanger are being certified with the small throat MCC. Devising an integrated modifications and certification program encompassing all the changes noted and aimed at producing a block upgrade of the engine would provide not only more realistic testing, but also potentially more efficient and effective use of resources.

SOLID ROCKET MOTORS

Ref: Finding #16

Performance of the RSRM has been repeatable and predictable. Thrust-time profiles of the more than 20 RSRM flights have all met specification limits. The rate of in-flight anomalies across 13 or more flights has been stabilized at 2 or fewer per flight. Appropriate corrective action has been taken in each instance.

Improvements in plant-wide cleanliness and the efficiency of RSRM manufacturing procedures are clearly evident. NASA and Thiokol have invested in facilities and processes that have reduced cost and increased product quality. Manufacturing has been organized into work centers with management, engineering, safety, quality assurance, and material co-located and assigned to supporting functions.

Flight Support Motors (FSMs) manufactured to the current RSRM configuration have proved their benefit to the program. The FSMs have allowed the program to confirm and validate process quality control, changes in materials and manufacturing procedures, and improvement in design. In response to the drive for cost reductions, however, it has been proposed to eliminate some or all of the FSMs for the RSRM program. The purported rationale for this proposed action is that the program is "mature" and no longer requires the degree of testing represented by a FSM.

The significant safety benefits of the continued use of FSMs in the RSRM program argues against the elimination of this type of testing. On the contrary, the need to introduce material and process changes and to qualify new suppliers as sources are lost, suggest that NASA should actively support the FSM program during the remaining production of the RSRM. In addition, the mandated elimination of toxic/hazardous chemicals, and, especially, the use of non-asbestos materials will require FSM testing to ensure safety. The FSM program is a prudent investment to maintain and provides confirmation for the changes that are deemed necessary.

Ref: Finding #17

There have been four instances of soot being found on the O-ring (gas paths) of nozzle joint numbers 1, 3, 4, and 5 during postflight examinations of 42 RSRMs. Thirty-five such gas paths were noted during the same inspections for nozzle joint number 2. All cases revealed no heat effects or blowby at primary seals. However, the relatively high rate of undesirable gas flow for joint number 2 has prompted the program to seek countermeasures. A new assembly sequence with Room Temperature Vulcanizer (RTV) backfill has been developed and is expected to reduce the problem incidence. However, this is a procedural solution to a problem that occurs often enough to suggest the need for a redesign.

Ref: Finding #18

Tests of the Structural Test Article 2 (STA-2) of the Solid Rocket Booster (SRB) aft skirt under the loads imposed by the original Solid Rocket Motor (SRM) demonstrated that a weld failed at a factor of safety (FOS) of 1.28 rather than the required FOS of 1.40. As a result, waivers are being processed for each flight to permit the use of skirts with the 1.28 factor of safety. The Space Shuttle Program has approved a development effort for an aft skirt modification consisting of the addition of an external bracket with the object of restoring a factor of safety of 1.40.

United States Boosters, Incorporated (USBI) conducted a finite element analysis (FEA) with a detailed submodel of the affected weld area on the aft skirt with the added external bracket. This bracket is intended to increase the moment of inertia of the cross-section and thereby reduce the stress due to bending. The analysis predicted a reduction in the strain at the outer surface of the weld of 35 percent at the aft edge and 69 percent at the aft ring centerline. This results in a *predicted* FOS in excess of 1.40.

It should be noted, however, that when the original aft ring was redesigned, the moment of inertia was calculated to be increased by 28 percent. A non-linear FEA showed a stress reduction in the weld of 14 percent, thus predicting a FOS greater than 1.40. Nevertheless, the STA-3 full scale test failed at 1.28 FOS. The added material to the ring, therefore, was not effective. Based on this experience, the use of the FEA global rigid beam model displacements to determine the boundary conditions for the external bracket test specimen must be questioned.

The latest NASTRAN non-linear analysis with an increased number of grid points and elements in the critical area shows the stresses to be maximum at the aft end of the skin and lower toward the centerline of the aft ring. The strain gage data from actual launches and the SRB aft skirt influence tests show just the opposite. The maximum stress occurs in the skin at the centerline of the aft ring and decreases toward the aft edge of the skin. In fact, the actual STA-3 test failure initiated 5 inches above the aft edge of the skin in the vicinity of the aft frame horizontal tab at its centerline.

In summary, the use of a segment of the aft skirt to test the proposed external bracket poses at least the following issues:

- The test specimen is a curved rigid beam, not a complete ring. This can result in strains and boundary conditions that cannot be properly duplicated. The 11- inch width of the test specimen may not be wide enough to represent accurately the aft skirt structure.

- In the actual aft skirt ring construction, the stresses in the welded area are due to moments, internal axial, and in-plane shear loads from each of the four holddown posts. The curved beam specimen test of the external bracket cannot produce the same strains as those in the full ring.

The effects of the external bracket could be better evaluated in the facility that was originally used for the influence testing of a full aft skirt. This would raise no significant questions about boundary conditions. The application of 200,000 lbs axially and 100,000 lbs radially used during the influence tests resulted in 20,000 to 27,000 psi stresses in the region of concern. These are large enough for a valid evaluation of the effects of the added external bracket.

Ref: Finding #19

The use of plasma arc welds on a case the size of the one for the Advanced Solid Rocket Motor (ASRM) is new to the rocket industry. As for all welds, residual stresses will occur in the vicinity of the weld. A design margin is provided in the ASRM for this residual stress by increasing the weld joint thickness to 1.25 times the membrane thickness. A stress relief treatment will be used to partially relieve these residual stresses.

It is anticipated that a number of start and stop areas including those from weld repairs will be made on the ASRM case segments. The residual stress peaks at the start and stop areas are different from the rest of the weld. The stress corrosion cracking (SCC) tests conducted to date show that earlier-than-expected failures have taken place in the 50-percent yield stress (YS) range. An SCC test program has been established to check the material's SCC performance and select the proper post weld heat treatment. An even more thorough evaluation of the SCC effect is required. Testing should include transverse and longitudinal specimens. The validity of the SCC tests will only be known when carried out on full scale (150-inch diameter) cylinders.

Ref: Finding #20

The ASRM Manufacturing Software System is intended to keep track of everything from complete component descriptions to the manufacturing history of each product produced, as well as overseeing the control of manufacturing operations. All of the components needed to meet the comprehensive specifications of the ASRM Manufacturing Software System are being purchased, rather than developed. The work currently under way is to integrate them. The emphasis to date seems to have focused more on the physical connections and data flow rather than the functional interrelationships.

A substantially standard NASA design and change review board process for all software developed has been adopted. The ASRM Program has also adopted a standard design methodology for software development. In addition, they have wisely adopted a formal technical review process that will be used not only for internal software developments, but also for vendor-developed software.

At the time of the Panel's examination, there was no complete, overarching requirements document for manufacturing software. The original top-level ASRM requirements were flexible enough that a detailed requirements document on the manufacturing system was not mandated.

The Program plans to make extensive use of commercial off-the-shelf (COTS) software in order to reduce substantially the amount of software that NASA and its contractors must write. However, this decision means that NASA has no control over the level of software quality assurance that the individual vendors apply. They must, therefore, depend upon evaluation of the vendor track record and the development of their own acceptance tests. The intent to perform acceptance tests is included in the ASRM Program, but little information on how these tests will be generated was available.

Also, at the time of the Panel review, an overall systems integration plan did not exist. A 17-week Conference Room Pilot Project had just been started that appeared to be loosely directed toward an integration plan, but was also focused heavily at the component level. The project was addressing issues such as how components work together, what operator displays will look like, and what changes are needed to the COTS software. However, no one with formal training in human factors was involved in the design of the operator displays and functions. Some of the COTS product vendors do, however, have well-tested systems for building operator interfaces.

As there is no systems integration plan, there is no system-level testing plan. Apparently, ad hoc testing was scheduled to occur during the Pathfinder Stage (scheduled for summer 1993). At that stage, all components were to be interconnected and inert materials produced. Pathfinder is intended to work out the kinks in the physical interconnections of the system. However, it may not be capable of testing the functional interconnections of the system as a whole. These considerations could become moot as the Program is seriously considering the cancellation of the Pathfinder. This raises concern about how integration and system-level testing will be performed.

LAUNCH AND LANDING

Ref: Findings #21 - #23

The Space Shuttle processing activities at the Kennedy Space Center (KSC) involve extensive scrutiny of individual operations by quality assurance (QA) personnel. This is time-consuming and may not be necessary in all cases. KSC has recently started a pilot Structured Surveillance Program. This program involves assigning an inspection level commensurate with the risk to safety or mission quality. It relies on the person performing the work for the primary quality control and uses contractor QA personnel as a redundant inspection of quality when risk warrants. Civil service QA personnel only become involved as a second, redundant inspection for those operations involving the highest risk.

The Structured Surveillance Program has the potential to improve greatly the efficiency of Shuttle processing operations by reducing the intrusiveness of QA activities. It also can assign quality responsibility to the most appropriate level. The pilot program must, however, be carefully evaluated to ensure that overall safety is enhanced or maintained despite the reduction in oversight inspections inherent in the Structured Surveillance approach.

Last year, the Panel commended the task team approach KSC had begun. During the current year, the use of task teams was expanded significantly with continuing positive results. Task teams are fast becoming an integral part of Shuttle turnaround processing. This bodes well for future safety and productivity at KSC. As with the Structured Surveillance Program, however, the task team effort needs continual appropriate evaluation to provide feedback for program improvement. Also, if the Structured Surveillance Program proves successful, effort might profitably be devoted to including its principles within the task team effort.

A third high bay Orbiter Processing Facility (OPF-3) was opened at KSC during the year. The design of this OPF took into account significant lessons learned from years of use of the other two OPFs. As a result, significant improvements were made in the support equipment installed and in the level and subjective quality of the ambient lighting.

Industrial engineering and human factors studies have generally shown that both safety and productivity can be enhanced by increased ambient light levels. The informal observations of the Panel members when touring OPF-3 as well as comments received from workers in the facility suggested that the lighting in the new building is far superior to that found in the older high bays. The difference in lighting across the facilities raises the concern that adaptation problems may arise for personnel who rotate among them.

The Panel was briefed that a request to upgrade the lighting in OPFs -1 and -2 to the level of OPF-3 has been made and is awaiting funding. Given the potential benefits of the upgrade and the possible problems inherent in operating functionally equivalent facilities with wide disparities in lighting levels, the upgrade should proceed as soon as possible.

LOGISTICS AND SUPPORT

Ref: Findings #24 and #25

The NASA Shuttle Logistics Depot is a large facility that has great potential for contributing to the logistics program. With this facility close at hand, unit turnaround times should be further reduced. However, the problem of coordination of the flow of line replaceable units needs to be improved. Units are held up for considerable periods of time awaiting failure analysis. The control of failure analysis is by a different organizational element (the Johnson Space Center) than that controlling the logistics flow (the Kennedy Space Center). The Space Shuttle Program's logistics would be significantly enhanced if line replaceable units were analyzed for failure and repaired with minimal time between removal of a unit, its failure analysis, repair, and return to inventory.

The Orbiter logistics and support activities appear to be under good management control, but certain measurement parameters, such as shelf stock life rates, loss of spare or repair capability, and manufacturer's service agency repair and turnaround times for some components are showing slightly adverse trends. Conversely, other parameters such as cannibalization have shown outstandingly low rates. General performance of the Shuttle logistics system is excellent and the difficulties, where they exist, are being diligently addressed and corrected.

The Orbiter logistics and support system together with the funding for its continuation at an appropriate level has evolved very successfully over the past 12 years. Progressive movement has led to the present efficient centralization of much of the directly supporting activity at the launch site. The system is still being fine-tuned by the orderly transfer of remaining activity components under the Logistics Management Responsibility Transfer program, and it is essential to continue this program to completion.

C. AERONAUTICS

Ref: Finding #26

The establishment of a NASA Headquarters Aircraft Management Office with a senior incumbent reporting directly to an Associate Administrator was an extremely positive step. This, in parallel with the promulgation in 1992 of a well-designed and comprehensive *NASA Aviation Safety Officers Reference Guide*, satisfies two longstanding Panel concerns. At the same time, continuation of the outstanding and dedicated services of the Intercenter Air Operations Panel as an independent entity virtually assures an effective NASA aviation safety effort.

Ref: Finding #27

NASA's aging aircraft inventory is a source of concern. Many NASA aircraft are flying a considerable number of hours and years beyond their originally estimated service lives. Many are also used for missions for which they were not originally designed. NASA aircraft operators and managers are sensitive to the potential difficulties and hazards attendant to flying aging aircraft and take prudent measures to preclude unsafe conditions. Inspections and tests appear to be appropriate, and no instances of operating unsafe equipment were uncovered. Nevertheless, as budgets shrink and pressures to continue to operate mount, there is a human tendency to stretch the rules. At the same time it is obvious that the costs of maintaining older aircraft may outstrip the cost of replacement. Attention to the details of extending service lives and to the costs of replacement is certainly warranted.

Ref: Finding #28

Since 1946 when the X-1 became the first research airplane program conducted from what was then known as the High Speed Flight Research Station – now the Dryden Flight Research Facility – NACA/NASA has conducted numerous flight investigations of experimental aircraft in conjunction with the Air Force and Navy with laudable success. The cautious and painstaking manner in which flight envelopes were approached and negotiated by these aircraft is a tribute to the efficiency and competence of the engineering and flight crews involved. Similar care and restraint in the conduct of flight programs are evident at other NACA/NASA installations such as the Langley, Lewis, and Ames Research Centers. In every Center, joint ventures with the Air Force, Navy, and the Army continue to be models of interagency collaboration.

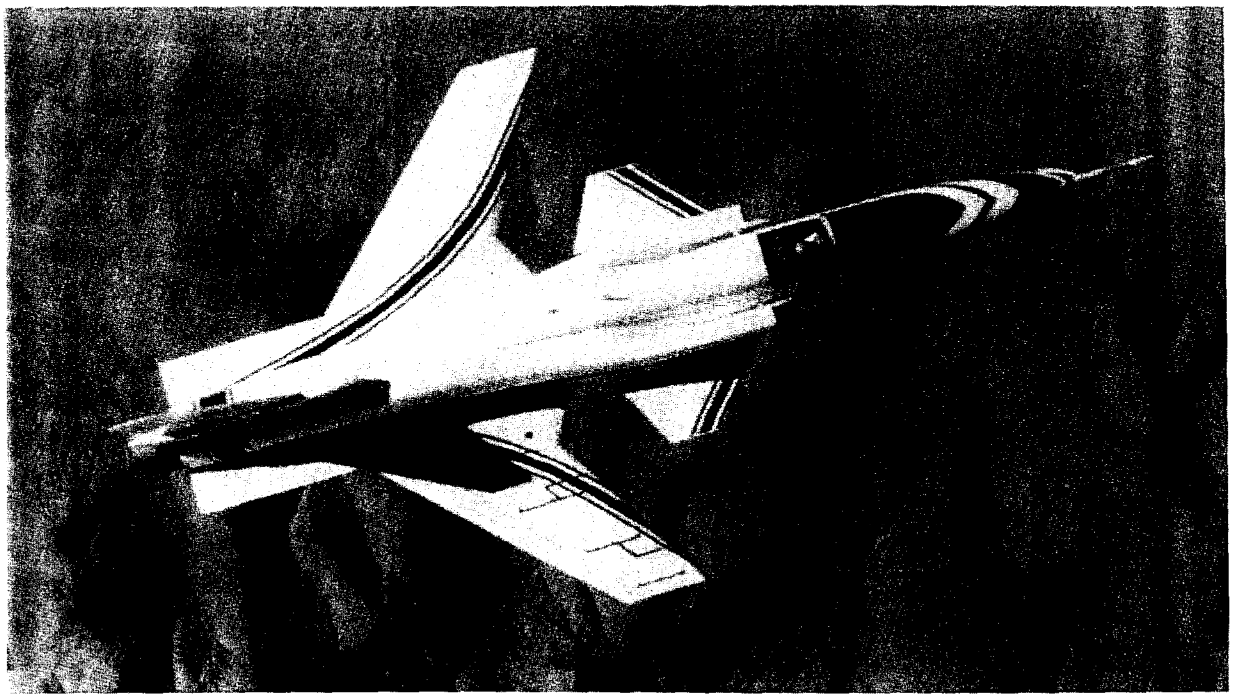
Program reviews of flight test activities were held during a visit to Dryden Flight Research Facility by the Panel. A wide variety of flight tests and technology evaluations are being conducted that utilize more than a dozen flight vehicles. In general, these flight test activities are for the purpose of validating and verifying concepts that have been developed by analysis and ground tests. There are inherent risks associated with these efforts that require constant attention to safety considerations. The Panel considers the flight phase of the overall NASA aeronautical research program as essential to maintaining and enhancing the nation's position in aeronautics.

By developing the appropriate control law software for an MD-11 transport aircraft, the Highly Integrated Digital Electronic Control (HIDEC) program has produced excellent results in defining the ability to control an aircraft with only the propulsion system. The F-15 Propulsion Controlled Aircraft (PCA) software has been validated, and flight tests are ready to be initiated that will include the critical landing phase. Due to obvious safety implications, the Panel will be reviewing this program more closely in the coming year.

The X-31 enhanced fighter maneuverability No. 2 aircraft experienced a Flight Control Computer (FCC) shutdown due to a data transfer (software) anomaly that could not be repeated during bench tests. The failure was compounded by causing the hydrazine Emergency Power Unit (EPU) to fire erroneously. Further analysis identified the problem as insufficient FCC computation time for certain failures. This problem clearly illustrates the value and need for rigorous pre-flight test evaluations and the problems inherent in software verification and validation.

The X-29 vortex flow control flight tests have demonstrated for the first time the ability to control an aircraft at high angles of attack (alpha) by use of controlled blowing over the nose of the aircraft. The problem being addressed is that at the high alpha the vertical fin is masked by the fuselage and becomes ineffective. The program was completed without significant problems and is a tribute to an excellent flight safety effort by the NASA/industry team.

The F-18 High Alpha Research Vehicle was committed to flight testing in September 1992 after a series of design reviews of the Remotely Augmented Vehicle, all software and the iron bird simulation. In addition to the Thrust Vector Control System interfaced with the engines, the aircraft has been equipped with nose strakes for enhanced roll control.



D. OTHER

Ref: Finding #29

In discussions with the Panel, the Administrator expressed concern about the interface responsibilities between the NASA Headquarters Office of Safety and Mission Quality and its counterparts at the NASA field Centers. Specifically, he asked the Panel to ponder two issues: (1) whether the Center safety and mission quality organization should be "solid lined" (i.e., report programmatically and administratively) to the Associate Administrator for Safety and Mission Quality or continue to be "dotted lined" (i.e., report only programmatically) as is the current practice; and (2) whether the performance evaluation of the chief Center safety and mission quality individual should be performed by the Associate Administrator for Safety and Mission Quality or continue to be carried out by the Center Directors.

In addressing these issues, the views of Center Directors, Associate Administrators, and other key managers involved with or affected by safety and mission quality activities, both at the Centers and in Headquarters, were solicited and recorded. This information together with material obtained in previous Panel examinations of the safety and mission quality function formed the basis for the findings and recommendations in the report submitted to the Administrator.

All the Center Directors and Program Associate Administrators interviewed endorsed the current relationships and advocated their continuation, but with some clarification where necessary. An anomaly exists, for example, in the SSFP at Reston. The safety and mission quality functions of the Level II Reston office have been the responsibility of a Level I safety and mission quality individual at NASA Headquarters – thus blurring the distinction between line and staff functions.

During the review, it became apparent that there were some misconceptions and ambiguities defining the roles and responsibilities of Center Directors and Headquarter personnel in the management of safety and mission quality functions. The Panel suggests a clarification of their roles through revised NASA Management Instructions and a thorough communication of their content throughout NASA.

Ref: Finding #30

The Simplified Aid for EVA Rescue (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 return of an astronaut who becomes untethered from the Space Station or an Orbiter that could not move quickly, e.g., because it was attached to a satellite or Space Station assembly package. The probability of this problem arising is not considered great for a free-flying Orbiter, because it can maneuver immediately to retrieve an astronaut who is drifting away. However, Space Station assembly will involve considerable EVA time with the Orbiter essentially immobilized because of Space Station components attached to the cargo bay.

SAFER was developed in-house at JSC by the Automation and Robotics Division. They plan to build an engineering prototype and a flight unit for test on the Space Shuttle. After this test, they will use the data to develop detailed requirements.

As part of the SAFER program, a 3-degree motion simulation has been prepared on an air table. JSC has also developed an excellent fixed-base, three-dimensional computer graphics simulation that allows astronauts to "fly" the SAFER with a full 6-degrees of motion. Finally, they have adapted a "virtual reality" system to give potential crew members a realistic feeling for the visual inputs they would obtain when flying the SAFER. If the program proceeds, Weightlessness Evaluation Test Facility (WETF) testing is also planned.

SAFER is an excellent example of the type of program that is essential to NASA's success. The use of multiple types of simulation (air table, fixed base, virtual environment, WETF) is an extremely effective way to proceed and should help to avoid difficulties such as those encountered in the Intelsat rescue. Considering the potential safety (as well as operational) benefits of SAFER, it should be developed and tested as soon as possible.

Ref: Finding #31

Traditionally, three modes of simulator training have been used to prepare crews for space missions. These involve fixed base simulators, moving based simulators and the underwater test tank or WETF. The fixed based simulators are excellent for learning and practicing procedures that do not require significant motion cue feedback. Moving base simulators add vestibular cues to enhance fidelity in those situations in which a human derives significant information from the motion response of the system. WETF training uses neutral buoyancy to simulate the effects of weightlessness.

Although these three types of training cover much of the conditions an astronaut will experience during EVA, they do not adequately cover the dynamics of objects that the astronaut must maneuver. This is primarily because the water resistance in the WETF prevents a response to force inputs that realistically reflects the conditions in zero-g.

Recent advances in virtual reality systems make it possible to consider augmenting the three basic types of simulators with a fourth based on a virtual reality. Virtual reality systems are typically implemented through helmet-mounted video inputs to a user who can then interact with the "virtual" environment seen on the computer-generated display. By using position sensors and instrumented gloves, the trainee can actually "work" in the virtual environment which could be programmed to simulate accurately the motion of objects in zero-g.

The use of virtual reality for training is not without some technical problems. Primary among these is the fact that the ability to reflect accurately the forces imposed on objects and resulting from their motion is somewhat limited. Nevertheless, the technology has advanced enough and has sufficiently high potential that it can be productively used now. NASA is already doing this with the SAFER system discussed elsewhere in this report. The benefits of virtual reality training for Shuttle EVA activities and Space Station maintenance and repair strongly suggest that NASA should embark immediately on a research and development program for utilizing virtual reality in training.

Ref: Finding #32

The Panel has urged NASA to include greater consideration of human factors issues within the Space Shuttle and Space Station Programs for several years. In particular, utilizing the preeminent human factors capability within NASA's research centers in support of the programs would appear to hold a great potential for improving safety by reducing the risk of accidents and incidents due to human errors.

There has been an increase in efforts within NASA to incorporate more human factors expertise in program operations in the past year. However, they are not yet at a level that can produce a maximum benefit. On the contrary, several incidents during the last year suggest the need for an immediate increase in human factors oversight. These include two problems with the Space Shuttle Auxiliary Power Unit. The first involved a latching relay in the Improved Auxiliary Power Unit controller. The old controller shut down the APU and closed the fuel isolation valve when there was a problem. In order to reset the APU and isolation valve, the panel switch had to be changed from the start/run position to the off position and then back to the start/run position. In the new controller, turning the switch off reset the APU and opened the fuel isolation valve. This led to the possibility of the APU restarting after an overspeed failure unless the crew executed the added step of removing power from the isolation valve.

The second problem involved a change in the water deluge system for hot-starting the APU. The new design forced the crew into an unnatural and potentially dangerous set of procedures that could have been avoided by a properly human-engineered design. The crew was forced to use a three-position, center-off switch to control start/run, off, and water cooling deluge. This could lead to a high probability of errors under stressful conditions, e.g., throwing the switch in the wrong direction. This design was adopted even though the sensors and valves already existed to automate the water deluge as part of a hot-start procedure to eliminate the possibility of crew error.

Both APU problems were eventually recognized, and workarounds were developed. However, the fact that these problems reached the point of a final design implementation suggests that both the NASA and contractor design, safety, and human factors functions were not performing adequately. The latching problem with the controller should have been discovered during the design process since it was a baseline requirement. The hot-start process was made a crew procedure on the erroneous assumption that the crew does not fail. In fact, a single-point hardware failure with a known low probability of occurrence was replaced with a crew procedure with an unknown and highly variable probability of occurrence.

On the positive side, the Space Station Work Packages are allocating significant effort to human factors issues within their purview. For example, Work Package-2 (WP-2) is doing a commendable job of designing the crew interface for the habitat and laboratory modules. They have assembled a multi-disciplinary team that includes participation from McDonnell Douglas human factors experts. Unfortunately, there is no similar team on the NASA side. Thus, the human factors interface requirements are *only* flowing upwards from Level IV.

The absence of a definitive crew interface design agreement between NASA and the international Space Station partners is worrisome. It is not prudent to permit interface differences among the various modules. It is definitely ***not*** sufficient to say that, for example, that European crew members will never work in the U.S. or Japanese modules. There is apparently a tentative agreement to standardize on the backup caution and warning system (EMADS) design being developed by WP-2. However, the crew workstations and their associated information input/output requirements will likely not be standardized. This leads to a higher than necessary probability of human errors over a 30-year operational life of the Space Station.

Ref: Finding #33

In addition to the in-house and work package verification and validation performed, independent verification and validation (IV&V) is performed for the Space Station by Draper Labs and the Space Station Engineering Integration Contractor (SSEIC). Some confusion has arisen over the detailed nature of the verification and validation work and whether these activities really are independent of the principal development contractor. As the IV&V question arises frequently, NASA would be well served if it had a clear statement of what is meant by IV&V in the context of each of its programs.

The terms *verification* and *validation* can be used to denote a variety of related, but different activities. There should be a clear understanding of what is needed to assure safety. For example, IV&V work could take the form of repeating tests, independently generating tests, or reviewing the processes used by NASA (or its contractors) to develop and perform verification and validation testing. NASA's use of these terms should be sufficiently standard that the definition is accepted by the community at large. The term *independent* also needs clarification. No verification and validation are ever completely independent. There is always some level at which common reporting occurs. This level needs to be clearly identified and consistently applied across the agency.

Ref: Finding #34

In October 1992, the Administrator stated that NASA's infrastructure is critical to meeting its mission goals. The Panel agrees with this, but submits that the importance of infrastructure goes far beyond meeting NASA's mission goals. Indeed, NASA infrastructure is a national asset, key to the continuance of the United States' leadership in space and aeronautics. Regrettably, some of that infrastructure is not being adequately maintained, and new, state-of-the-art facilities are not being introduced at the rate they are needed. Launch facilities, laboratories, and NASA wind tunnels all fit this description. Already, some American aerospace companies are forced to use foreign facilities. Not only does this impact on intangibles such as prestige, but it can affect the balance of payments, technological leadership, and, at some point, safety. NASA needs to exercise continuing surveillance over its infrastructure and implement timely maintenance modifications and new facilities.

Ref: Finding #35

The Tethered Satellite System (TSS) consists of a fixed base pallet which includes a 12-meter, extendable and retractable boom to launch and dock the satellite at a safe distance from the Orbiter. The system is designed to fly the satellite up to 62 km, either above or below the Orbiter while connected to a boom by a 2.5-mm-diameter conductive tether. The satellite is equipped with reaction thrusters to provide in-line, out-of-plane, and yaw control. The in-line thrusters provide positive tension on the tether in a situation where the tether slacks. This could happen if the reel should jam and may result in the loss of satellite attitude stability, and a potential impact with or entanglement of the Orbiter.

The first TSS mission that flew on STS-46 was programmed to deploy the satellite to 20 km above the Orbiter to verify control, operation and the retrieval characteristics of the system. Limited scientific investigations were to be conducted in the general areas of tether dynamics, spacecraft environment, and space plasma effects of electrical power generation by the conductive tether. Several problems that occurred during the attempted deployment of the satellite included: (1) a stuck power and data umbilical, (2) binding of the upper tether control mechanism, and (3) interference of a bolt with the level wind mechanism. As a result, the satellite initially failed to deploy, then stopped at 179 meters, at which point manual control was used to maximize the satellite momentum to continue deployment. It stopped again at 256 meters. When it was reeled back to 224 meters, it failed to move in either direction and was retrieved after clearing of the jam by partial retraction of the boom. As a result of these problems, no further deployments were attempted.

The principal cause of the deployment problem was that a bolt used to attach a modification to the tether structure extended into the path of the level wind arm and jammed the reel assembly. This modification was to relieve additional stresses due to higher design loads, which were only identified close to the time of launch. The modification was judged to have no effect on the operation of the reel assembly. As a result, the installation was conducted in the field without proper systems analysis or verification, and the interference problem of the bolt with the reel mechanism went undetected. The lesson to be learned is there is no substitute for good engineering design and judgment, review, and, when possible, rigorous testing of the total system.

Ref: Finding #36

NASA has embraced Total Quality Management (TQM). Because TQM has such potential for not only better leadership and management but also for safer operations, the Panel has taken an interest in its implementation within NASA. The impression from the reviews the Panel received is that acceptance and understanding of TQM is mixed, at best. Several of the major NASA contractors have truly outstanding programs, enthusiastically received by all employees. Within NASA itself, however, the program appears to be focusing mainly on the TQM process rather than on achieving meaningful change. The Panel has little hands-on TQM experience itself, but is concerned that unless the NASA program gets moving soon, it may result in no more than a diversion of scarce resources from other efforts. There are a number of appropriate statements from top management extant, and there are "TQM Managers" who can deliver enthusiastic motivational speeches. Nevertheless, the TQM implementations within NASA facilities appear to be lagging those in place at contractor facilities.

Ref: Finding #37

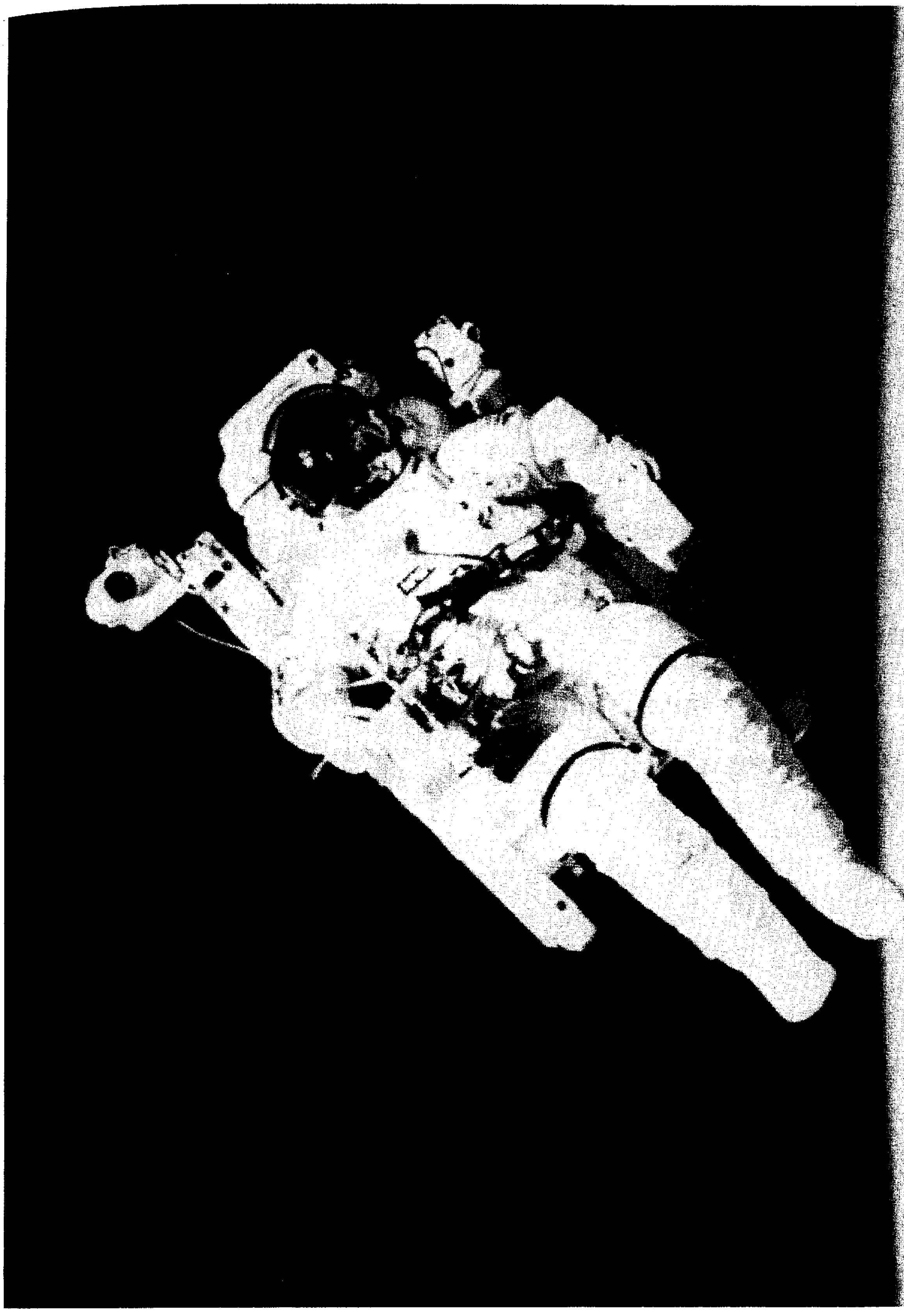
During the next several decades, our nation – perhaps with others – will embark on extended duration human exploration in space. Such an endeavor requires the ability to maintain crew health and performance in spacecraft, during extravehicular activities, on planetary surfaces, and upon return to earth. This goal can be achieved only through focused research and technological developments. The Aerospace Medicine Advisory Committee (AMAC) report entitled, "Strategic Considerations for Support of Humans in Space and Moon/Mars Exploration Missions (Life Sciences Research and Technology Programs, Volume 1)," provides the basis for setting research priorities and making decisions to enable extended duration human exploration missions.

The AMAC report expands the recommendations of several previous advisory committees. It is based on the results of comprehensive studies conducted by Life Sciences Discipline Working Groups (DWGs). These DWGs – 12 in number – are listed here to show the scope and extent of the AMAC undertaking:

- Behavior, Performance, and Human Factors
- Regulatory Physiology
- Cardiopulmonary
- Environmental Health
- Musculoskeletal
- Neuroscience
- Radiation Health
- Cell and Developmental Biology
- Plant Biology
- Life Support
- Planetary Protection
- Exobiology.

The DWGs, in conjunction with NASA, attempted to define the unresolved issues considered critical to the advancement of knowledge in their disciplines.

The AMAC concluded that, within the current confines of knowledge, no issue precludes human exploration of the Moon and Mars if appropriate research is conducted and enabling technologies are developed. However, experimentation in space, AMAC cautions, may disclose unexpected difficulties that will require reassessment of this conclusion.



IV. APPENDICES

APPENDIX A
NASA AEROSPACE SAFETY ADVISORY PANEL MEMBERSHIP

CHAIRPERSON

MR. NORMAN R. PARMET
Aerospace Consultant
Former Vice President, Engineering
Trans World Airlines

MEMBERS

MR. RICHARD D. BLOMBERG
President
Dunlap and Associates, Inc.

MR. CHARLES J. DONLAN
Aerospace Consultant
Former Deputy Director
NASA Langley Research Center

VADM ROBERT F. DUNN
Former Assistant Chief of Naval
Operations, Air Warfare, Pentagon

DR. GEORGE J. GLEGHORN
Former VP and Chief Engineer
TRW Space and Technology Group

MR. PAUL M. JOHNSTONE
Consultant, Former Senior Vice
President, Operations Services
Eastern Airlines

DR. NORRIS J. KRONE
President
University Research Foundation

MR. MELVIN STONE
Aerospace Consultant
Former Director of Structures
McDonnell Douglas Corporation

DR. RICHARD A. VOLZ
Chairman, Department of
Computer Sciences
Texas A&M University

CONSULTANTS

MR. JOHN A. GORHAM
Aerospace Engineering
Gorham Associates

DR. SEYMOUR C. HIMMEL
Aerospace Consultant
Former Associate Director
NASA Lewis Research Center

MR. JOHN F. MCDONALD
Former Vice President
Technical Services
TigerAir, Inc.

DR. JOHN G. STEWART
Vice President, Valley Resources
Resource Group
Tennessee Valley Authority

DR. WALTER C. WILLIAMS
Aerospace Consultant
Former Chief Engineer
NASA Headquarters

EX-OFFICIO MEMBER

COL. FREDERICK GREGORY
Associate Administrator for
Safety and Mission Quality
NASA Headquarters

STAFF

MR. ARTHUR V. PALMER
Staff Director

MS. PATRICIA M. HARMAN
Staff Assistant

APPENDIX B
NASA RESPONSE TO MARCH 1992 ANNUAL REPORT

SUMMARY

In accordance with the Panel's letter of transmittal, NASA responded on October 20, 1992 to the "Findings and Recommendations" from the March 1992 Annual Report. This response was considerably delayed compared to previous years. As a result, some of NASA's responses were no longer relevant due to programmatic changes or the completion of the event at issue.

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.

Based on the Panel's review of the NASA response and the information gathered during the 1992 period, the Panel considers that the following is the status of the recommendations made in the 1992 Report:

RECOMMENDATION		
NUMBER	SUBJECT	STATUS
1	Space Station Freedom (SSF) safety and risk considerations	CLOSED
2	SSF systems engineering and integration	CONTINUING
3	SSF assured return capability	CLOSED
4	Use of preintegrated truss sections for SSF	CLOSED
5	SSF Data Management System software	CLOSED
6	Orbiter body flap	CONTINUING
7	Shuttle Modal Inspection System	CLOSED
8	Orbiter thermal protection system inspectors	CONTINUING
9	Orbiter maintenance	CLOSED
10	Orbiter Autoland System	OPEN
11	Software independent verification and validation	CONTINUING
12	Space Shuttle general purpose computer system	OPEN

RECOMMENDATION		
NUMBER	**SUBJECT**	**STATUS**
13	Automation of Space Shuttle crew procedures	CONTINUING
14	Number of flightworthy Space Shuttle Main Engines (SSME)	CLOSED
15	SSME component reliability and safety improvement program	CONTINUING
16	Large throat main combustion chamber and SSME Advanced Fabrication Process	OPEN
17	Alternate HPFTP development restoration	OPEN
18	ASRM O-ring material	CONTINUING
19	ASRM propellant manufacturing plant scale-up	CONTINUING
20	ASRM propellant manufacturing plant operator interface	CONTINUING
21	ASRM case development test program	CONTINUING
22	Aft skirt loads/strains monitoring	CONTINUING
23	ASRM logistics	CONTINUING
24	Orbiter landing performance analysis	CLOSED
25	Launch processing	CONTINUING
26	Launch processing personnel morale	CLOSED
27	Operations and Maintenance Instructions quality improvement	CONTINUING
28	Use of task teams at KSC	CLOSED
29	Corrective action for KSC hardware problems	CONTINUING
30	Shuttle Processing Data Management System II	OPEN
31	Orbiter logistics and support program	CLOSED
32	Integrated Logistics Panel	CLOSED
33	Logistics Management Responsibility Transfer Program	CLOSED
34	NASA Shuttle Logistics Depot support	CLOSED
35	Orbiter parts cannibalization	CONTINUING
36	Repair turnaround time control	CONTINUING

RECOMMENDATION		
NUMBER	**SUBJECT**	**STATUS**
37	Stocking recovery program establishment	CONTINUING
38	Management of replacement/substitute parts levels	CONTINUING
39	Incorporation of aviation safety in the Basic Safety Manual (now called the Safety Policy and Requirements Document) (NHB 1700.1)	CLOSED
40	Aeronautical flight research program safety	CLOSED
41	Space Shuttle crew circadian rhythm problems	CONTINUING
42	Space flight risk assessment and accident avoidance involving human factors	CONTINUING
43	Human-error reporting	OPEN
44	Tethered Satellite System quality assurance program	OPEN
45	Development of a new space suit and extravehicular mobility unit	OPEN
46	Extravehicular activity bends risk	CONTINUING

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Office of the Administrator

OCT 20 1992

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 1992 Aerospace Safety Advisory Panel (ASAP) Annual Report, enclosed is NASA's detailed response to Section II, "Findings and Recommendations."

The ASAP's commitment to assist NASA in maintaining the highest possible safety standards is commendable. Your recommendations play an important role in risk reduction in NASA programs and are greatly appreciated.

We thank you and your Panel members for your valuable contributions. ASAP recommendations are highly regarded and receive the full attention of NASA senior management. We look forward to working with you.

Sincerely,

Daniel S. Goldin

Daniel S. Goldin
Administrator

Enclosure

1992 AEROSPACE SAFETY ADVISORY PANEL REPORT FINDINGS AND RECOMMENDATIONS

A. SPACE STATION FREEDOM PROGRAM

Finding #1: During the past 1½ years, Space Station Freedom (SSF) has undergone a reconfiguration involving many technical changes and program deferrals. These changes were highlighted in the Aerospace Safety Advisory Panel's (ASAP's) March 1991 report. Some of the changes affect risk and safety while others influence serviceability and usefulness. Nevertheless, the SSF design that has emerged is more realistic and capable of supporting a stable development program.

Recommendation #1: Safety and risk considerations should remain of paramount importance in the development of the reconfigured Space Station.

NASA Response: Concur. Safety and risk considerations are central to successful development and operations.

Finding #2: The ASAP March 1991 Annual Report characterized the Space Station Freedom Program (SSFP) as plagued with technical and managerial difficulties and lacking an effective systems engineering and integration organization. Significant developments have occurred in the ensuing year. In particular, there has been a clarification of system engineering and systems integration responsibilities among NASA Headquarters and the Centers. Also, key managerial assignments have been delegated to appropriate Centers. The new arrangement benefits the program by drawing on the substantial technical expertise of the Centers' staff members not specifically assigned to the SSFP.

Recommendation #2: The changes introduced in the systems engineering and integration management areas should be monitored to ensure that the new arrangement is effective and that maximum use is made of each Center's particular capabilities.

NASA Response: Concur. The clarification of systems engineering and systems integration has resulted in a well-structured engineering organization across the SSFP. The changes introduced will continue to be monitored by the Space Station Freedom Program Office (SSFPO) for effectiveness and efficient use of each Center's capabilities.

Finding #3: NASA's current policy is not to leave a crew on the Space Station without an attached Space Shuttle or other assured return capability. At present, there is no program to develop a dedicated assured return vehicle. However, using an Orbiter as an assured return vehicle on long-duration missions reduces the number of Space Shuttles available for other purposes and raises potential safety and reliability issues.