and safely. However, the work environment at KSC needs greater management attention to continue moving towards one that minimizes the potential for human error today and in the future as the flight rate increases. The goal of "zero incidents," although extremely difficult to achieve, must nonetheless be the driving force of KSC management and the Shuttle Processing Contractor.

"Waivers" are defined as a written authorization to accept designated items which, during production or after having been submitted for inspection, are found to depart from specifications, but nevertheless are considered suitable for use "as is" or after rework by an approved method.

It would appear, that at this time the world of waivers might well benefit from a concentrated review; and where necessary, appropriate specification changes should be made to eliminate the need for repetitive waivers.

MISSION OPERATIONS
(Ref: Finding #19)

When the Mission Control Center was first activated in the early 1960s, it was considered a technical marvel. However, this original architecture has received only modest upgrades since the Apollo Program days. Until recently, it maintained a single mainframe based architecture that displayed data and largely left the job of data analysis and trend determination to the flight controller teams monitoring the consoles. The display technology utilized in this system is monochrome and primarily displays text information. The job of turning data into information upon which flight decisions could be made is performed by the controllers through interpretation of the incoming numeric data. In cases where it was determined that additional computational support was required, small off-line personal computers were added. The controllers manually copied data from the console display screens and entered it into the small computers to perform off-line analysis.

Although this system is technologically outdated, it contains years of customizing efforts and has served NASA well through Space Shuttle Program missions to date. Several factors are now driving NASA to change the architecture of the Mission Control Center operations. First, the primary reason seems to be to control costs. Second, automation available today can be used to expand the capabilities of controllers by eliminating some of the data reduction tasks they must perform and by increasing the amount of information they can utilize in making decisions. Third, the time required to obtain information for decision-making can be substantially reduced. Finally, there is continuing concern over the loss of corporate knowledge due to retirements and personnel turnover in conjunction with hiring freezes.

These factors have resulted in efforts by NASA to utilize the present generation in engineering workstations, on-line real-time expert systems, and traditional automation to allow flight controllers to perform more tasks and to capture the corporate knowledge of senior personnel. A prototype system called the Real-Time Data System has demonstrated the feasibility of achieving new levels of decision support. The Real-Time Data System also provides a technique to isolate applications so that new applications can be added without endangering the previously established base of flight critical code.

This Real-Time Data System effort, for example, has resulted in the ability to have a graphic display of a number of engine parameters as a function of time into flight. Further, key flight parameters can be displayed in easily read formats with color used to convey criticality. Previously, the engine data was displayed in tabular form, and the flight controllers had to apply mental gymnastics to determine what was happening. The key parameters were displayed only in code, and the flight controllers had to mentally convert these to their actual meanings. Moreover, the new technology is capable of obtaining and displaying this more easily used information up to 4 seconds faster than the old control room computers.

Thus, as described to the Panel, the advances in workstations and real-time expert systems have enabled small programming teams to implement new real-time data reduction techniques that have made major improvements in NASA space operations. Unfortunately, now that the basic capabilities have been demonstrated, they are not being incorporated into the flight control system in a manner that optimizes productivity. For example:

- The fact that the Real-Time Data System is 4 seconds faster than the mainframe is good only if the Real-Time Data System is the decision-making system. At present, it is not. When both systems are used simultaneously, as is presently done, a 4-second difference between the two systems (old and new) could actually cause an operational problem because of the time lag between the Real-Time Data System and the older system that is used for decision-making.

- There does not appear to be any discipline imposed with respect to which system is used. It appears that the older, more experienced flight controllers, prefer the current mainframe/ monochrome system while the new controllers prefer the Real-Time Data System color workstations. Established policy is to make all decisions (calls) using the old, slower system. Controllers, therefore, have access to two sets of information from the same source but displayed in different formats and with a 4-second time lag. The use of such things as "notes taped on the consoles" is not an adequate replacement for appropriate management control or an orderly process for the introduction of change.

- The way in which the two systems are being used may actually increase console operator workload. The scan patterns required to see both the old and the new displays becomes very complex. The very fact that two screens are available at the same console can cause difficulties during times of stress.

- Having color, graphics workstations emulate the old displays wastes much of their capability. The displays must present a large and potentially bewildering amount of information to the controller and, therefore, could benefit from human factors/ performance-oriented inputs.

- One of the inherent benefits of the new technology used in the Real-Time Data System is the ability to calculate and display trend information. In some situations, the availability of trend information can be invaluable because it increases the time available for decision-making. Greater incorporation of various projection and trend analysis in the design of the Mission Control Center would likely be very helpful.

The Real-Time Data System has demonstrated some excellent concepts, and the control room certainly could benefit from updating. However, the Real-Time Data System has reached the stage of development at which a more structured plan for utilizing its capabilities should be followed. This plan should include:

- A requirements analysis of the operations including work flows and task analyses.
- A human factors analysis of the interface to determine the best display formats, while taking into account: current controller experience and expectations, transition and initial training requirements, information transfer rates, minimization of response time errors, and fatigue.
- A comprehensive test plan with acceptance criteria.
- A phase-in transition plan.
- Off-line testing with simulations.
- On-line testing in parallel with current system.
- An upgrade to provide for the inclusion of new technology and to compensate for future obsolescence.

At the completion of the above program, a new Mission Control system based upon the new workstation/expert system technology should be phased-in to replace the existing Mission Control Center.

ASSURED SHUTTLE AVAILABILITY PROGRAM
(Ref: Finding #20)

The many Space Shuttle flights over the past few years has yielded a much clearer understanding of the significant risks and margins of safety built into the current Shuttle system. The Congress took note of this in the House Multi-Year NASA Authorization Bill of 1989, which authorized funds for specific safety enhancements. NASA responded to this with a report "Space Shuttle Safety Enhancements" October 1990 to the United States House of Representatives and the United States Senate. The Panel has recommended that the Space Shuttle Program implement an organized, visible, and well-funded program of safety and reliability improvements for the Assured Shuttle Availability Program.

Now NASA has a program with the same title, Assured Shuttle Availability Program, but with a somewhat different focus, that is, life extension and elimination of obsolescence. While both are worthy objectives, they do not necessarily encompass those changes and updates required for the enhancement of safety and reliability. Further, the use of the same title covering two somewhat different sets of objectives can, and probably will lead to confusion and misinterpretation. It is the Panel's contention that there should be two programs. One should emphasize significant safety and reliability improvements, the second should deal with such things as reduced turnaround time between missions, higher levels of performance, and life extension. Priority should be given to risk reduction.

Many of the "Typical Space Shuttle Safety Enhancements" list items noted in the Panel's March 1989 Annual Report have been or are being developed for incorporation into the Space Shuttle systems. This is very encouraging and should be continued. This applies to such items as the improved APU, the SSME alternative turbopump hardware, the so-called "10K" high-pressure pumps, the new general purpose computers, more reliable instrumentation, structural "beef-up" of the Orbiters, and upgrading of KSC facilities.

All Space Shuttle elements should maintain a continuous study to identify those modifications that would provide risk reduction.

LOGISTICS AND SUPPORT PROGRAM
(Ref: Findings #21 through 25)

The logistics and support program for the Space Shuttle is continuing to develop. The problems that persist, in general, are well documented and understood. They do, however, need continuing attention if flight rates are to be maintained without compromising safety.

1. Integrated Logistics Panel (ILP) Activities

The Integrated Logistics Panel meetings appear to be expanding their effectiveness as a principal management tool for the coordination of logistics issues across all Space Shuttle elements. The Integrated Logistics Panel also is watching the OV-105 developments at Palmdale to ensure smooth integration of that vehicle into the fleet. The quarterly meetings rotate among the involved NASA Centers. They are chaired by JSC with KSC as a deputy chair function. Ad hoc sessions also are held at various locations for specialized purposes, and internal logistics audits are encouraged. The Integrated Logistics Panel concept seems to be working well and provides a forum for coordination among contractors and between the contractors and NASA. ASAP believes this process is crucial to the control of the necessarily extensive Space Shuttle logistics support program.

2. NASA Shuttle Logistics Depot (NSLD)

Development of the NASA Shuttle Logistics Depot, which is located in Cocoa Beach and operated by Rockwell, is proceeding very satisfactorily, and should provide overhaul and repair facilities for a large range of Shuttle components when it is fully developed and equipped. The main facility encompasses some 223,000 square feet, and an adjacent group of smaller buildings has 45,000 square feet. Among its several aims, the facility will permit more rapid turnaround of Line Replaceable Units, reduce spares inventory requirements, and provide insurance against the cessation of Original Equipment Manufacturer (OEM) overhaul services for certain obsolescent and unique components. The manufacture and repair of some items of Ground Support Equipment (GSE) also is being provided for, and the entire facility will form a very well-equipped "back shop" for the on-site support of the Shuttle programs. Completion of the required shop equipment, availability of fully trained personnel, provision of technical manuals, support, etc., for the overhaul of a chosen component earns a "certification" to perform the task. To date, some 100 certifications have been obtained involving 3,255 Line Replaceable Units. At present, the plan calls for 230 certifications to be valid by FY 1994 involving 3,795 Line Replaceable Units.

3. The Thermal Protection System (TPS) Manufacturing Facility

The nature of repair and replacement of elements of the Orbiter TPS led to a decision several years ago that this could best be performed on-site at KSC rather than remotely on the west coast.

The tiles presently are being made by Lockheed (west coast) and Rockwell at KSC. They are not now being carried as spares owing to fitting problems and, therefore, are being machined individually to suit each application. The flexible blanket replacements are handled similarly, and some of the thermal barriers also are made on demand, although a few are carried as spares. Some 7800 tiles, blankets, gap fillers, etc., have been manufactured or processed through the Thermal Protection Systems Facility at KSC during 1990. Development of the remaining equipment and staffing needs appear to be on target to completion in 1992.

4. Logistics Management Responsibility Transfer (LMRT)

The Panel previously has commented upon the activities of the Logistics Management Responsibility Transfer program and has noticed, with approbation, the repositioning of experienced management and other skills from the west coast to the KSC area, particularly with respect to the NASA Shuttle Logistics Depot facility at Cocoa Beach and the Thermal Protection Systems on-site facility at KSC. This Logistics Management Responsibility activity also is continuing on a broader front. A memorandum of agreement recently has been completed for issues affecting SSME logistics between KSC and MSFC.

5. Control and Communication Systems - Logistics

Systems for the control of the huge inventory and dollar amounts necessarily involved in the entire Shuttle logistics support system have grown with time and, it is hoped, are now near maturity. The root of these systems is to be found in the now well-established Program Compliance and Assurance System (PCASS), which currently is being augmented so that it will meet its design goals. The Integrated Management Information Center (IMIC) and the Meeting Support Environment (MSE) have been introduced. A file server will be installed at all sites enabling the Integrated Logistics Panel presentations to be viewed. All the logistics data requirements, e.g., specifications, maintenance manuals, etc., for the entire Shuttle system are collected under a series of document trees for easy retrieval. A logistics supportability alert system is being introduced to advise of major issues such as pending loss of suppliers and receipt of bogus parts. The alerts will be contained in the PCASS.

6. Cannibalization

Previous Panel reports have reviewed this important aspect of Orbiter vehicle safety and have observed the implementation of satisfactory control programs to keep cannibalization. The principal control measure is the restriction of component removal actions to those that are absolutely required. There also has been a change in the definition of cannibalization, which tends to artificially suppress the apparent cannibalization level.

The overall situation of cannibalization can be generally described as "reasonable" or "normal." Quite obviously, "zero canns" continues to be the goal to the extent that it is cost effective. Continuing to watch the rate of cannibalizations will provide NASA management with critical information on which components may be in short supply or might productively be the subject of life extension activities.

7. Component Repair Turnaround Times (RTAT)

The total elapsed Repair Turnaround Time still can be excessive with a resulting major impact on inventory management. There are several contributing causes for this that were discussed briefly in the 1990 Annual Report (p. 50), but one of the key issues is the average time involved in the engineering analysis of failed components. The overall trend of Repair Turnaround Time showed a significant improvement toward the end of the year, but in some cases, notably the components overhauled by the Original Equipment Manufacturers, is much too high. Management emphasis currently is being directed to the entire problem of reducing Repair Turnaround Time and should continue.

8. Out-of-Production Parts

Some of the Original Equipment Manufacturers are not providing sufficient support for out-of-production parts. NASA and its contractors have evolved good systems for identifying and tracking these problems, but the difficulties of ensuring continuing production with small batches of obsolescent or semi-obsolescent parts inevitably will increase with Orbiter age. The problem involves balancing the alternatives of purchasing and storage of excess parts, establishing manufacturing facilities and skills at KSC, or potentially facing critical shortages. The heart of the problem is that many manufacturers simply do not want to devote any more manpower or effort to revive production. The study of possible alternative source vendors for critical vendors continues but is necessarily a slow and complex process.

9. Scheduled Structural Overhaul of the Orbiter Fleet

NASA's response to the 1990 ASAP Annual Report concerned with structural overhaul (p. 51) dealt principally with the visit on OV-102 at the Rockwell Palmdale facility scheduled to begin in June 1991. A review of the major modifications necessary to bring OV-102 up to the standard of OV-105 was included. During the work on OV-102, a "3-year" and a "6-year" structural inspection will be performed. It is assumed that this will provide the information necessary to define a basic structural overhaul program. This program would then be fitted into available intervals in the launch program up to 1995 for all four Orbiters.

A second element of longer term maintenance program planning has been defined but apparently is not presently funded. It is known as "Orbiter Supportability Plan - Project 2020" and is intended to provide a basis for ensuring a rational program for orderly maintenance and support of the fleet through the assembly of the SSF. The outline of the plan properly embraces the interfaces of the existing major contractors and the operating NASA Centers, and outlines an organizational support formula. This formula includes detailed Line Replaceable Unit supportability and full structural integrity accountability. The ASAP has an interest in seeing this program go forward as planned.

10. Automatic Test Equipment (ATE)

The development of ATE and the recruitment of the necessary computer and engineering skills at the NASA Shuttle Logistics Depot is a valuable undertaking. The installation of the Hewlett Packard automatic test station and the two program development stations in the Cocoa Beach facility is praiseworthy. The eventual aim is to test 60 different Line Replaceable Unit types, including multiplexers/demultiplexers (MDMs) that tend to be troublesome, and to replace some 30 special purpose systems with automatic procedures. With full maturity, and perhaps later expansion of this medium, it is reasonable to expect much more rapid turnaround of difficult Line Replaceable Units as well as a more thorough and reliable individual test regime.

11. Advanced Solid Rocket Motor Logistics Program

An early start on logistics programs for the Advanced Solid Rocket Motor has been made, and includes the delineation of the support requirements for testing the 48-inch motors at MSFC. Shipping containers and transportation methods have been established for all elements, e.g., exit cones, nozzle assemblies, cases and segments, and the 48-inch motors. Raw materials logistics for the Advanced Solid Rocket Motor production have been similarly provided for.

B. SPACE STATION FREEDOM PROGRAM

(Ref: Finding #26)

The Space Station Freedom Program is currently undergoing redesign; therefore, no specific comments are offered. However, there are lessons learned that merit consideration.

- NASA should take a broader, longer term approach to the requirements for specific flight computers. The redesign efforts under way for Space Station, together with studies in progress in one of its research laboratories and the need to start planning now for the next change in Space Shuttle computer systems, make this a good time to consider changing the approach.

  NASA should embark upon an agency-wide, long-range plan for computer upgrades in long-term space programs. This should include not only hardware development, but software and testing issues as well.

  NASA should utilize efforts already under way in its Ames Research Center and make the effort an intercenter one, with use of the results, to the extent possible across the agency.

- NASA began development of a Technical and Management Information System (TMIS) as part of Space Station. While the ideas behind this system were laudable, it rapidly fell short of its promise largely through late deliveries. Nevertheless, many of the tools planned for the Technical and Management Information System are of general value to NASA and could be used on any project, not just the Space Station. If fully implemented with proper participation of users throughout NASA and if adopted across the agency, Technical and Management Information System could make integration of activities across Centers much easier as well as providing better support structure to project management.

C. AERONAUTICS-OPERATIONS

AIRCRAFT OPERATIONS
(Ref: Finding #27)

The Panel has for several years been concerned that NASA top management has not given adequate attention to matters of aircraft operations and aviation safety. One reason for the apparent lack of a common NASA-wide policy covering these activities is the diverse nature of NASA's aircraft uses. These fall into three categories: (1) research aircraft such as the X-29, (2) support and training aircraft such as the 747 Orbiter transport and the T-38s proficiency airplanes, and (3) administrative aircraft, i.e., the gulfstream for personnel transportation.

Frequent changes in Headquarters management and preoccupation with more intense issues has procrastinated decision-making in this area. However, based on recent discussions with the Administrator, the Panel has been requested to make a thorough study of these matters and to examine in detail the functions and responsibilities of the various Headquarters organizations involved, including the Intercenter Aircraft Operations Panel (IAOP). As regards to the Intercenter Aircraft Operations Panel, a Panel member has been appointed to attend its meetings and any other meetings dealing with aircraft operations and aircraft safety matters.

With this encouragement and mandate to examine the full range of NASA flight operations, it is believed that many of the concerns expressed in the past can be resolved.

RESEARCH AND TECHNOLOGY
(Ref: Finding #28)

The X-29 flight test program has been reviewed periodically by the ASAP since 1984. This aircraft incorporates advanced and unique aerodynamic, structural, configurational, and fly-by-wire flight control technology. With such a large number of untried technologies being flown for the first time, the safety risks have been high, and NASA has managed the program with a high priority placed on safety. By the end of the year, the two X-29 experimental aircraft had completed over 250 flights. The principal efforts were directed towards clearing the aircraft for its maximum speeds, mach number and altitudes, and for gathering data during high alpha maneuvering flight. The current flights of the second aircraft have been aimed at exploring various high alpha maneuvers (to levels greater than those demonstrated in the wind tunnel) and to evaluate the handling qualities during these severe flight conditions. Wind-up turns and asymmetric maneuvers have been accomplished. The software of the control laws has been undergoing a series of modifications to improve the flying qualities and the higher angles of attack capabilities.

The ASAP reviewed a number of research programs that have the potential for enhancing aviation flight safety. These included wind shear detection and warning, hazards of lightning strikes, heavy rain effects, aging commercial aircraft and airframe structural integrity, take-off performance monitoring, fault tolerant electronic controls, and activities to assist the air traffic control function by studying terminal approach and landing ground and cockpit concepts. The results of these types of programs will increase in importance as commercial air traffic continues to increase.

D. SAFETY AND RISK MANAGEMENT

MISSION SUPPORT
(Ref: Finding #29)

The fault tree analysis approach is a deductive analytical technique that supports detailed systems analyses, provides clear inputs for decision-making, and provides a rationale basis for communications. When used as a system safety analysis tool, as it was during the later stages of the hydrogen leak investigations in mid-1990, the fault tree highlights the interrelationships of those system events, which may result in the occurrence of an undesired event — in this case, the hydrogen leaks.

The fault tree approach combined with Failure Modes and Effects Analysis has the ability to help resolve significant problems that initially may elude traditional engineering solutions. It is logical and turns over "every stone" in the process of determining casual relationships within a system.

All engineers involved in any aspect of design, test, or operations of any aerospace system should be given at least a minimal grounding in these valuable tools.

TOTAL QUALITY MANAGEMENT (TQM) OBSERVATIONS
(Ref: Finding #30)

Over the years, there have been numerous "packaged" approaches to quality improvement. Some have worked, most have not. Often, these techniques have been little more than fads whose appeal faded when they did not turn out to be "miracle cures" for all management problems.

The Panel has been briefed on TQM activity at NASA Headquarters, NASA Centers, and NASA contractors, and there is no doubt that a great deal of enthusiasm is being attached to TQM. As often stated by TQM practitioners, results only will be achieved over a period of years and then must be sustained thereafter. Based on the material presented to the Panel, many of the TQM efforts were not in the mainstream of the ongoing work. There appears to be a need to bring the effort down to those who do the "hands-on" work. This includes the engineers, test personnel, technicians, schedulers, and quality assurance/inspectors. It is certainly essential to have the senior management throughout the organization involved, but the enthusiastic and practical day-to-day implementation of TQM philosophy needs nurturing at the hands-on level. There does not appear to be enough of this going on.

To meet the goals of TQM, it would be well to have additional attention given to the means by which the hands-on personnel can be made an integral part of the overall TQM activity. This includes having senior and middle management make it their business to get out onto the floor and provide a sincere effort to both understand and support the floor personnel.

TQM, by itself, is not a solution to quality problems. It is, however, a potentially effective amalgam of some of the latest techniques for fostering group interaction and team-building. If used as a tool by a concerned management dedicated to improving operations, TQM appears to be very effective. On the other hand, if it is imposed by management without adequate involvement or follow-up, it may be ineffective or even counterproductive. The aviation press over the past year has contained numerous references to the extensive problems experienced by one major contractor as a result of an over-zealous TQM program.

By far the most impressive TQM implementation seen by the Panel was the one at the Michoud Assembly Facility. This model program has generated significant enthusiasm among the personnel at the facility and has yielded impressive productivity improvements. NASA would do well to learn from this success and attempt to transfer it to other facilities by directly involving the Michoud staff responsible for their TQM program.

SAFETY REPORTING SYSTEMS
(Ref: Finding #31)

Accidents and near-misses or incidents are rarely the result of single causes. Rather, causation typically can be traced to a relatively complex combination of factors such as design defects, component malfunctions, and human errors. Therefore, the most effective accident and incident investigation techniques rely heavily on a multi-disciplinary approach combining investigators trained and experienced in the hardware, software, institutional, and human performance aspects of the involved system. This approach, perhaps, is exemplified best by the accident investigations conducted by the National Transportation Safety Board (NTSB).

NASA's Management Instruction on "Mishap Reporting and Investigation" provides a basis for investigating accidents and incidents, and acknowledges that human factors might be needed in some investigations. In fact, however, it may require initial analysis by a trained human factors specialist to determine if human performance considerations were germane to the incident. Since the vast majority of NASA's operations involve complex human-machine systems, it is reasonable to include a human performance specialist in the initial review of all serious incidents. This will help to determine the role that human error played in the incident and to identify the cause of any errors identified. This is consistent with the need to conduct accident and incident investigations with the objective of determining cause as well as responsibility.

Before lessons can be learned from an accident or incident, it must be brought to the attention of those responsible for investigations. Accidents and incidents with the potential for serious consequences are typically reported and, therefore, can be investigated in some detail. Incidents and close calls that do not result in injury or property damage, however, often go unreported even if they have the potential for serious loss or sufficient visibility to commend and investigate. Therefore, a complete incident investigation system must include a provision for collecting data on events that did not result in a loss or sufficient visibility to command and investigate.

NASA maintains the NASA Safety Reporting System, which has the objective of collecting anonymous data on incidents. It is patterned after the highly successful Aviation Safety Reporting System NASA operates for the Federal Aviation Administration (FAA). While the NASA Safety Reporting System has generated some information, it does not appear to be getting the widespread use characteristic of the Aviation Safety Reporting System. One reason may be the absence of a "buffer" between the responsible agency and data collection source. People reporting to the Aviation Safety Reporting System know that they are not sending potentially incriminating information to the cognizant regulatory agency (FAA has jurisdiction and the reports are submitted to NASA). With NASA Safety Reporting System, on the other hand, NASA fulfills both roles. This may be somewhat daunting to a NASA or contractor employee whose career advancement may depend on maintaining an incident-free record.

In light of these considerations, NASA should carefully review the operation of the NASA Safety Reporting System to determine if it is maximally effective. This review might profitably reexamine the notion of having this program run by an outside, "neutral" agency in an attempt to increase its effectiveness.

E. OTHER

NASA FACILITIES
(Ref: Finding #32)

NASA's Research and Technology and Research and Development programs depend greatly on the availability and productivity of its many unique test facilities. Many of these facilities are more than 40-years old and are showing the wear and tear of these years of use. This is particularly true of NASA's aeronautical facilities, some of which had deteriorated to the point that they were considered unsafe. Others still employed their original operating and control equipment which, now, are technologically obsolescent and cannot be repaired because their components are no longer manufactured. Obsolescence similarly affects the instrumentation and data systems of the facilities rendering them inefficient and limiting their productivity.

Recognizing these conditions, NASA chartered a committee (the Hopps Committee) to assess the situation and to recommend a course of action. The committee reported in 1987 and recommended that major refurbishments be undertaken for many of NASA's facilities in accordance with certain priorities. Responding to this report, NASA developed a 5-year plan to revitalize the highest priority facilities.

This program focuses primarily on the aeronautical facilities, which are the agency's oldest. It addresses wind tunnels, their support facilities, and their data acquisition and control equipment. Activity began in FY 1989, and the pace is accelerating. By FY 1994, the bulk of the planned renovation/restoration of these highest priority facilities should be completed. But the current program does not cover all of the needed renovation/restoration. By the time 1994 arrives, the facilities that had been assigned lower priority in the 1987 assessment will have aged another 7 years and, undoubtedly, will have suffered further deterioration in both safety and operational adequacy. The revitalization program should be extended to accommodate the facilities that did not make the "first cut".

Not only should the major renovations be extended, provision also must be made in planning and budgeting for a continuing program of major maintenance activities so as to preclude the sort of deterioration and obsolescence that has been experienced. Experience has shown that it is frequently much easier to obtain funding to build a new facility than it is to obtain support to properly maintain an existing one. This is sometimes humorously referred to as the "edifice complex" and is endemic throughout our society. This must not be permitted to take root again for NASA's facilities.

NASA is to be commended for its facility revitalization program. Certainly, it was long overdue. Now is the time for the agency to provide for the extension of the program to other facilities and to incorporate a continuing major maintenance program so that the degree of deterioration and obsolescence experienced in the past will not recur.

EXTRAVEHICULAR MOBILITY UNITS/SPACE SUITS
(Ref: Finding #33)

The current Space Shuttle space suit is approved for up to three EVAs from the Space Shuttle before requiring maintenance. There are plans to extend this number to 12 and even 24 when the suit is used during assembly and support of the Space Station. The current suit also requires extensive pre-breathing periods, which are tiring for the crew and limit the available EVA work time. The proposed high-pressure suit designs eliminated or reduced the need for pre-breathing and were intended to be certified for extensive reuse before refurbishment.

It now appears that development of the high-pressure suit designs has been suspended due to lack of funds. Also, some astronauts do not appear to want the new suit because the current suit is more flexible and less restrictive of torso motion. Some astronauts also stated that pre-breathing requirements with the existing suit are overly conservative and could be reduced as there has never been a decompressive sickness problem with any EVA to date. Pre-breathing also could be reduced by lowering Space Station ambient pressures to 10.2 psi, but that would be counterproductive to many of the experiments that are to be carried since their results are referenced to sea-level experience.

NASA has spent considerable efforts this past year determining the amount of EVA activity that would be required to maintain the Space Station. The results were shocking. Much more EVA time would be required than would be desireable. It also was concluded that greater use of robotics and automation together with some redesign to make such automation possible could greatly reduce the predicted EVA time, and make the resulting time acceptable.

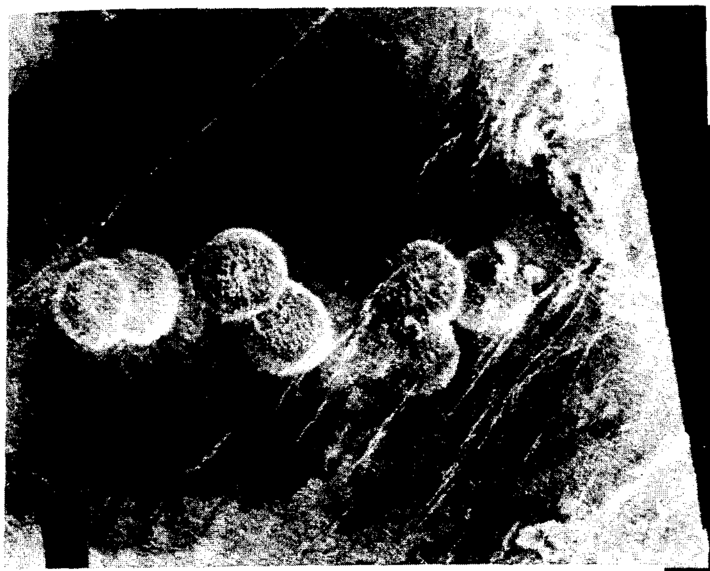
Other studies on possible major space missions the nation might undertake also concluded that these missions must rely heavily upon robotics and automation. Indeed, the missions considered are probably impossible without considerable use of robotics and automation in space. However, the development of new robotics and automation technology has proceeded more slowly than anticipated half a decade ago. The problems that have been encountered are complex and require expensive facilities to address. Progress has been made, and NASA has some very impressive results to show. Nevertheless, the progress has come in smaller steps and more slowly than expected.

In view of the criticality of these technologies to almost all possible future long-term NASA missions, it is important that efforts be continued, perhaps even increased, so that the needed robotic and automation technologies will be available when needed. However, it is realistic to assume that the state-of-the-art of robotics and automation will not be sufficient to replace all EVAs in the Space Station Program. Therefore, EVAs, both planned and contingency, will likely be required. Extensive work still remains to bring the amount of these EVAs down to manageable levels, and to find the maximally effective mix between robotics/automation and EVA.

TETHERED SATELLITE SYSTEM (TSS)
(Ref: Finding #34)

The Tethered Satellite System consists of a fixed base pallet, which includes a 12-meter extendable/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 the boom by a conductive tether having a diameter of 2.5 mm. The first mission will deploy the satellite to 20 km above the Orbiter to verify control, operation, and the retrieval characteristics of the system. Limited scientific investigations in the general areas of tether dynamics, spacecraft environment, and space plasma physics will be conducted.

The satellite is equipped with reaction thrusters to provide in-line, out-of-plane, and yaw control. The in-line thrusters are necessary to provide positive tension on the tether if there should be 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 the Shuttle or a wrap-around of the Shuttle.



MAGELLAN IMAGE OF VENUS' EASTERN EDGE OF ALPHA REGIO

MAGELLAN'S FULL-RESOLUTION MOSAICKED IMAGE DATA RECORD

HUBBLE PICTURE OF GASEOUS RING AROUND SUPERNOVA 1987A

IV. APPENDICES

A. NASA AEROSPACE SAFETY ADVISORY PANEL

CHAIRPERSON

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

MEMBERS

MR. RICHARD D. BLOMBERG
President
Dunlap and Associates

MR. CHARLES J. DONLAN
Consultant
Institute for Defense Analyses

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

DR. NORRIS J. KRONE
Executive Director
University Research Foundation
University of Maryland

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

DR. JOHN G. STEWART
Vice President
Resource Development
Tennessee Valley Authority

MR. MELVIN STONE
Aerospace Consultant
Former Director of Structures
Douglas Aircraft Company

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

CONSULTANTS

MR. I. GRANT HEDRICK
Senior Management Consultant
Grumman Corporation

DR. SEYMOUR C. HIMMEL
Aerospace Consultant, Former
Associate Director, NASA LeRC

MR. JOSEPH F. SUTTER
Former Executive Vice President
Boeing Commercial Airplane Company

DR. WALTER C. WILLIAMS
Aerospace Consultant
Former Consultant to
NASA Administrator

EX-OFFICIO MEMBER

MR. GEORGE A. RODNEY
Associate Administrator for
Safety and Mission Quality
NASA Headquarters

STAFF

MR. GILBERT L. ROTH
Staff Director

MR. ARTHUR V. PALMER
Staff Assistant

MS. PATRICIA M. HARMAN
Staff Assistant

B. NASA RESPONSE TO MARCH 1990 ANNUAL REPORT

SUMMARY

In accordance with the Panel's letter of transmittal, NASA's response dated July 18, 1990, covered the "Findings and Recommendations" from the March 1990 Annual Report.

Based on the Panel's review of that response and the information gathered during the 1990 period, the following items noted in the July 18th response are considered "open" at this time. There were 40 findings and recommendations and the following are considered open:

Finding/Recommendation No. and Subject		Comments
#2	Space Station Freedom Program Disruptions	Everyone agrees that "something" must and will be done. The Panel intends to exert its influence as appropriate.
#4	Augmentation of efforts regarding the many areas of life sciences/ human factors	The Panel will reexamine the various activities at NASA and its contractors to assess status and further requirements.
#7	Assured Shuttle Availability Program	The Panel intends to continue to review, assess, and make appropriate recommendations regarding this most important area.
#9	Orbiter vertical tail loads	As noted in this year's report, the Panel will complete its assessment.
#11	Orbiter OV-102 Instrumentation (Loads)	As noted previously, the Panel continues to review this work until there is satisfactory flight results. For example, if the calibration test is conducted only after collection of data, it may not obtain the required transfer functions, then some of the gages will have to be rearranged and the flight tests repeated. Note that the manufacturer's calibration of the strain gages before flight will only show that the gage will respond correctly to the application of loads at various points on the wing. The 263 strain gage channels on the wing should be enough to combine the proper gages mathematically and obtain influence coefficients if calibrated before the collection of flight test data.

Finding/Recommendation No. and Subject		Comments
#16	Solid Rocket Booster aft skirt	The Panel will continue to address this concern as noted in this current annual report.
#18	Solid Rocket Motor case-to-igniter and case-to-nozzle joints	These joints appear to be operating well, but recent evidence indicates that perhaps more attention may be needed regarding "layup" of the putty/sealing material.
#20	External tank waiver for tumble valve (but applies to waivers in general)	As noted in this year's report, the Panel will continue to examine the management of waivers and the like.
#24	Orbiter structural overhaul plans	The Panel will continue to monitor these activities.
All	Space Station Freedom Program	Panel activities will depend upon the disposition of the current reconfiguration and rephrasing activities.
#38	Risk Management and the use of Probabilistic Risk Assessment	The Panel will continue its review of these activities to ascertain possible strategies to use Probabilistic Risk Assessment or similar methodologies to gain more informed management and engineering decisions.

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Office of the Administrator

JUL 18 1990

Mr. Norman R. Parmet
Chairman
Aerospace Safety Advisory Panel
9311 Fauntleroy Way
Seattle, WA 98131

Dear Mr. ~~Parmet~~: Norm

In accordance with your introductory letter to the Aerospace Safety Advisory panel (ASAP) Annual Report dated March 1990, enclosed is NASA's detailed response to Section II, "Findings and Recommendations."

The ASAP's dedication to helping NASA continues to be commendable. Your recommendations have helped to reduce risk in NASA-wide manned and unmanned programs and projects and are greatly appreciated.

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

Sincerely,

Richard H. Truly
Administrator

Enclosure

NASA RESPONSE TO MARCH 1990 FINDINGS AND RECOMMENDATIONS

A. OFFICE OF SPACE FLIGHT

MANAGEMENT

Finding #1: Until November 1989, the two principal manned space flight programs--the Space Shuttle and Space Station Freedom--were managed independently, each under the cognizance of a separate Associate Administrator. Since the Challenger accident, Space Shuttle management has exhibited a noteworthy degree of effectiveness and stability. In contrast, Space Station Freedom management has suffered from a lack of continuity in its top-level personnel. Also, the independent status of both programs created some confusion concerning future operational responsibilities. The recent reorganization of the Office of Space Flight places both programs under one Associate Administrator. This change in NASA management is a positive step in seeking stability and cohesiveness in manned space flight activity, especially in flight operations and budgetary planning.

Recommendation #1: NASA, the Administration, and the Congress should support the recent reorganization of the Office of Space Flight and allow that office time to accomplish its objective of achieving a unified and cohesive manned space flight program.

NASA Response: NASA concurs with the finding regarding the recent reorganization and establishment of the Office of Space Flight under a single Associate Administrator. All necessary actions have been taken within Space Station Freedom Program (SSFP) elements to ensure the smooth transition of the organization involved so that the goal of a "unified and cohesive manned space flight program" can be achieved.

Finding #2: In addition to mandated changes in budget and scope, the Space Station Freedom Program has suffered from disruptions in management, especially at the Headquarters level.

While reviewing the work packages at the centers and contractors, the Panel was made aware of the lack or incompleteness of top-level controlling documents, both technical and managerial. The Panel expressed concern about this situation in last year's report. The recent reorganization of the Office of Space Flight offers promise for improving this situation.

Recommendation #2: NASA top management should encourage and provide full support for the new management and structure of the Space Station Freedom Program. Everything possible should be done to ensure technical and managerial continuity of the program.

NASA Response: NASA concurs with the recommendation that "everything possible should be done to ensure technical and managerial continuity of the program." Actions taken by the Office of Space Flight and the Program office in the recent past to bolster the organization and management team were taken specifically to achieve better stability. NASA will continue to strive to provide a viable environment to challenge and retain the leadership and workforce needed to deliver a useful and operational Space Station Freedom.

The problem stated in the finding ("lack or incompleteness of top-level controlling documents") and the related open issue from last years report (item B.1.a) have been extensively worked over the past several months. The result is a comprehensive update of the formal requirements documentation baseline for Space Station Freedom.

FLIGHT READINESS REVIEWS

Finding #3: The return-to-flight of the Space Shuttle has been characterized by extensive preflight reviews. The majority of these, including the roll-out, solid rocket booster/external tank mating, and flight readiness reviews have been conducted face-to-face at the Kennedy Space Center. With the increasing flight rate, the travel and scheduling involved in the multiplicity of meetings are becoming a financial and physical burden. Some of the reviews are being shifted to video or telephone conferences. These techniques conserve travel time and budget, but could reduce the effectiveness of the management review process.

Recommendation #3: The flight readiness, Launch-2 day, and Launch-1 day reviews should continue to be conducted as face-to-face meetings at the Kennedy Space Center. The balance of the prelaunch reviews for each flow may be conducted as either actual meetings or by remote conferencing techniques. This would depend upon interflight schedules and the number/importance of unique problems or issues associated with a particular flight.

NASA Response: NASA concurs with the recommendation. The Flight Readiness Review, and the Launch-2 Day and Launch-1 Day reviews will continue to be conducted as face-to-face reviews at the Kennedy Space Center. For the L-2/L-1 reviews, some JSC support elements (flight directors, weather, etc.) must remain at JSC to support, the terminal count. Therefore, some JSC elements have been supporting, and will continue to support the L-2 and L-1 reviews by telephone. The Level III project reviews, ET/SRB MATE Review, Orbiter OPF Rollout Review, and Launch Site Flow Reviews can be conducted by telephone with proper representation. Detail requirements, formats, and designated face-to-face meetings are contained within the NSTS 7000, Level I, Program Requirements Document, Appendix 8 (NSTS Operations).

TECHNICAL ISSUES

Finding #4: Many of NASA's currently planned activities such as extended duration orbiter, Space Station Freedom assembly operations, extended duration crew operations, and extended duration missions beyond earth orbit may face significant safety problems arising *from inadequate consideration of human performance and human capacity. Potential human performance problems can arise from either extended normal operations that exceed the knowledge base for humans in space or from unexpected (non-nominal), and even unforeseen events (unexpected and not part of the training syllabus), that will certainly occur during long-duration missions.*

Recommendation #4: NASA should embark upon a carefully planned research program to learn more about human performance during extended space operations. Specific attention should be given to the Space Shuttle crew's ability to land an orbiter safely after an extended duration mission. This program might be profitably modeled after the ongoing efforts to examine commercial flight crew workload and vigilance. Much of this work is being conducted at the NASA Ames Research Center and involves full mission simulation and the development of multidimensional measures of workload and reserve capacity.

NASA Response: NASA concurs with this recommendation and believes an augmentation of efforts currently underway will satisfy this recommendation. Under management by the Office of Space Science and Applications, the Life Sciences Division addresses issues of human performance in space, productivity, physiologic reserve, and crew health. A coordinated series of programs are planned to specifically support program development for extended duration orbiter (EDO), Space Station Freedom assembly and operations, and extended duration crew operations, as well as continued operations of the Space Shuttle.

Finding #5: Interruptions in Space Shuttle operations for any reason can have serious consequence to the Space Station Freedom assembly. The Panel, thus far, has seen little evidence of contingency planning by NASA for such eventualities. Contingency planning should extend through all phases of operation. The Panel believes this to be an important area for NASA to emphasize in operational planning.

Recommendation #5: NASA should develop a contingency plan that addresses the issues arising from possible interruptions of Space Shuttle operations during the assembly of Space Station Freedom.

NASA Response: NASA concurs and has actions presently underway. All of the Space Station Freedom stages prior to permanently manned capability (PMC) have an orbital lifetime of at least 1 year and generally closer to 2 years in the normal operating altitude. In the case of a Space Shuttle standdown, NASA could boost any of these stages to higher orbits with orbital lifetime of approximately 2 to 4 years, depending on solar cycle. After PMC, an Assured Crew Return Vehicle (ACRV) will be present; and in the event of a shuttle standdown, the crew could be returned via the ACRV and the station boosted to a higher orbit. These results will be reviewed during the Space Station Program preliminary design review in December.

Finding #6: The goals behind the Space Station Freedom Technical and Management Information System are laudable. It does not appear that this system has been developed in the form or time frame anticipated; nor has there been uniform acceptance of the system.

NASA centers that have been using computerized technical information systems have elected primarily to continue using their own (or their contractor's) system with an intent to convert the data to the Technical Management Information System format when and if the system is able to manage the data.

While a full Technical and Management Information System that is used by all of the Centers and contractors certainly would be an enormous improvement in NASA's operation, it appears that too much was promised and work was started too late with inadequate funding.

Recommendation #6: NASA should rethink the Technical and Management Information System plan and consider a program embodying the following characteristics:

- Whatever system is adopted must be deliverable according to a schedule that matches the need for it among the NASA Centers and contractors.
- Commitment to the system must be firm and the budget maintained regardless of other budgetary pressures.
- Use of the facilities provided must be made mandatory to all NASA Centers and contractors by Level II.

NASA Response: NASA concurs with the recommendations associated with this finding and have taken specific actions and others are in work. The Technical and Management Information Systems (TMIS) Control Board has been reconstituted and is chartered to review and approve information system developments across the program. Applicable Space Shuttle information systems are being adopted to accelerate the availability of needed capabilities and to foster integration with the shuttle program. TMIS has played a crucial role in the rebaselining activities over the past months and will be critical to the SSFP Preliminary Design Review (PDR) and future phases of SSFP operations.

The first phase of TMIS was to implement the Initial Operational Capabilities defined in TMIS functional requirements. In particular, TMIS implemented a network that supports message and file exchange facilities (including hosts distributed at the Centers) that are used extensively by over 2,500 users representing all elements of the program. These facilities support interchange of data between NASA management, contractors, the International Partners, and other users. Workstations supporting word processing, graphics, spreadsheets, scheduling, and project management for individual program participants have been deployed, and common facilities including high-speed printing and image processing capabilities were successfully distributed to all supported levels of the program.

Initial capabilities that supported the Preliminary Requirements Review phase of the program were then augmented by program-wide document management systems. TMIS now supports a Program Automated Library System (PALS), which today holds the baseline requirements documentation for SSFP, along with many working documents.

Collectively, these represent over 175,000 pages of text and graphics in over 1,600 documents. An Automated Requirements Management System (ARMS) maintains a database of linkages and relationships between the 50,000 various program requirements. These systems were critical tools that were used by Level III management at the Centers and by Level II personnel during the rebaseline effort completed in 1989. Additional administrative and management systems were then developed and deployed and are now in active use throughout the system. These include the Program Master Plan/Master Schedule (PMP/MS), Budget Resource and Information Management (BRIMS), Action Tracking System (ATS), and the NASA Automated RID (review) Tracking System (ARTS). An Engineering Data Base has been established, which today contains the critical Assembly Sequence and Resource Allocation (AS/AR) data (weight, power, volume, etc.) that are necessary for completion of the Level II integration responsibilities. All of the above systems are critical tools that are being used to support the PDR process and will be used during the Integrated System Program Design Review. Many also are being used directly during the Level III PDR activities, and some systems such as BRIMS are in constant use by the Centers for support of the NASA Program Operating Plan cycles.

Additional technical support systems, using the Engineering Data Base, are being implemented as required to support SSFP Critical Design Review (CDR) and other future phase requirements. These systems address Technical Planning and Scheduling, Commonality, Supportability, Flight and Orbital Support Equipment, Ground Support Equipment, Engineering Drawing Models, Design Knowledge Capture, Integrated Master Measurement Command List, Master Verification Database, and Integrated Risk Assessment [including Hazards, and Failure Modes and Effects Analysis (FMEA)] requirements. The implementation of these systems will be a major thrust of the Fiscal Year 1991 development efforts.

An Electric, Electronic and Electro-Mechanical (EEE) Parts Information Management System (EPIMS) has also been developed. This system has been designed to control the selection procurement, testing and application of EEE parts to the Space Station Freedom.

TMIS has completed procurement of a Computer Integrated Engineering (CIE) system which, when fully deployed, will become the central repository for design and "as-built" archival engineering data that will be obtained from the work package contractors as work in progress is completed. Such a common repository will complete the variety of CIE systems currently in use today by various elements of SSFP, and will be key to successful design, launch, operations, and on-orbit maintenance of Space Station Freedom. The TMIS CIE will be necessary to the integration of components from the Centers to ensure final fit and finish, since the Space Station will not and cannot be built in its entirety on-ground prior to its deployment on-orbit.

The Administration fully endorses the requirement for continued funding of TMIS at the appropriate level, and intends to deliver additional evolutionary systems and services to SSFP users throughout the life cycle of SSFP through TMIS.

B. SPACE SHUTTLE PROGRAM

ASSURED SHUTTLE AVAILABILITY PROGRAM

Finding #7: NASA management has proposed the Assured Shuttle Availability Program with excellent objectives. The goal of this program is to improve safety and reliability, replace obsolete equipment, achieve and improve flight rate, reduce recurring costs, and improve performance and capability to support NASA objectives. The steps being taken to enhance safety and reliability are of particular interest to the Panel, although it is somewhat difficult to address these two areas separately from the others. Full implementation of such a program would be a step forward in enhancing Space Shuttle safety.

Recommendation #7: The Assured Shuttle Availability Program should be formalized such that scheduled upper management reviews are conducted. Milestones should be established leading to change incorporation on a specific date. A specific budget item for the program should be established.

NASA Response: NASA concurs and action is in work. The Assured Availability Program, which had been proposed in NASA's FY91 budget, was deleted by the Office of Management and Budget. However, NASA continues to consider the primary objectives of the Assured Shuttle Availability (ASA) program to be essential to the successful long-term operation of the Space Shuttle. Actions have been taken by the Space Shuttle Program to preserve the option of implementing several of the more significant items while budget priorities are being reassessed. Proposed ASA changes have been identified and prioritized. The Space Shuttle Program has approved funding for studies and feasibility assessments of the following specific high priority items:

- Redesigned Orbiter Cockpit Displays
- SRB Control System Redesign
- Orbiter Integrated Orbital Maneuvering Subsystem/Reaction Control Subsystem (OMS/RCS)
- SRB Aft Skirt Redesign
- RSRM Igniter Joint Improvement.

These studies are scheduled for completion in late 1990. Implementation decisions and funding requirements will be based on the results of the studies. Similar studies for other important improvements, such as main engine advance fabrication, will be initiated as funding permits.

NASA is preparing rationale for a start of the ASA program in FY92. This funding approach will result in a strongly structured program with clearly defined objectives for implementation, as well as a well-defined management structure to ensure maximizing the gain for the available funding.

SPACE SHUTTLE ELEMENTS

Orbiter

Finding #8: Proposed modifications of certain wing structures to achieve a 1.4 factor of safety over a larger portion of the design flight envelope are being evaluated for cost and schedule effects.

Recommendation #8: The wing structure modifications should be incorporated as soon as possible.

NASA Response: Orbiter wing modifications identified as group 1, 2, and 3 have been accomplished. These modifications were based primarily on the first five Space Shuttle in-flight measured loads, which were higher for certain wing locations than prelaunch predictions (due to a small shift in the aerodynamic distribution caused by engine and SRB plumes). The modifications strengthened the structures in the wing's leading edge, but excluded the wing root (due to inaccessibility). Given the 1.4 factor of safety, the trajectory shape had to be changed to fly within the revised "q-alpha" and "q-beta" boundaries to ensure that an adequate safety margin was maintained. As a result of having to trade performance requirements against launch probability the concept of alternate I-loads (alternate trajectories) was developed to resolve this conflict. This concept has repeatedly provided high launch probabilities for very high performance missions.

Based on the 6.0 loads analysis, final trade-off studies of performance versus cost for the proposed wing modifications were conducted. The studies showed that the modifications would "round" a 45 degree edge of the envelope, which slightly increases the Orbiter flight capability. Based on the small increase in flight capability, it does not appear the wing modifications are warranted at this time. A safety factor of 1.4 or better is always maintained within the present flight envelope. High launch probabilities are obtainable within the present flight envelopes through the use of alternate I-Loads. In the future, higher launch probabilities may be obtainable through the use of day of launch (DOL) I-Loads presently under development.

Finding #9: A recalculation of the loads and stresses in the vertical tail using a revised aeroelastic math model resulted in a more than 20 percent reduction in the airloads on the tail. This enlarges the allowable flight envelope.

Recommendation #9: As the large reduction of airloads on the vertical tail has been obtained by a revised analysis only, the reduction should be confirmed by an independent means such as in-flight strain gage measurements or an independent analysis.

NASA Response: NASA agrees, instrumentation flown on Orbital Flight Test (OFT) is being reconnected to measure structural response in the vertical tail.

NASA has established a Modular Auxiliary Data System (MADS) Aero/Structures Instrumentation project to repair and channelize strain gages and pressure transducers on OV-102 for STS-35 and STS-40. After the instrumentation is repaired and tested to ensure proper operations, airloads on the vertical tail will be obtained. In addition, an independent analysis led by Charlie Blankenship of the Langley Research Center, will be initiated to confirm the vertical tail load reduction.

__Finding #10:__ It is planned to modify the Orbital Maneuvering System pod deck frames during 1991 and 1992 to provide the requisite factor of safety over a broadened flight envelope. Without such modification, an elaborate calculation to verify structural adequacy must be made for each flight.

__Recommendation #10:__ NASA should reexamine its plans for the incorporation of the Orbital Maneuvering System pod deck frame modification with a view towards implementation at an earlier date than currently planned.

__NASA Response:__ Any modification of the OMS pod deck frames (aft fuselage frame caps) will significantly impact Shuttle schedules because such a modification cannot be made for a given Orbiter between successive flights. Consequently, to preserve the current 1990/1991 flight schedule, the modifications for each vehicle will be done during the major modification period for that vehicle. However, modifications that include installation of vent valves on all Orbiters can be done between successive flights without schedule impact. Such changes are currently in progress. Until the major modification is complete, the vehicles will be flown protecting a 1.4 factor of safety using a load indicator calculation that is part of the computer program that evaluates loads based on measured winds. The installation of the valves will reduce the maximum pressure across the pod deck, mitigating the restrictions applied by the 6.0 loads analysis on the flight envelope.

__Finding #11:__ NASA plans to calibrate the OV-102 structural loads instrumentation (pressure and strain gage) well after the collection of flight data instead of immediately before the flight.

__Recommendation #11:__ As the proposed postflight calibration of loads instrumentation would compromise the validity of the data collected, an end-to-end calibration should be performed prior to the data collection flight.

__NASA Response:__ Starting with STS-32 (OV-102), pressure transducers and strain gages have been implemented on both wings, vertical tail, and other structural components of OV-102. Although all of this instrumentation is not completely operational, the Space Shuttle Program has approved and funded a dedicated instrumentation team to make all OV-102 instrumentation operational. This team has been in place since the beginning of the STS-35 KSC flow. The plan calls for this work to be completed during the STS-40 KSC flow. As part of the instrumentation activity, all pressure transducers are end-to-end calibrated prior to flight. The Kulite pressure transducers are calibrated prior to each flight and the Gould pressure transducers are calibrated before and after the first flight of each transducer. These calibrations provide for improved accuracy of Flight data and provide a status of the pressure instrumentation system health. Postflight quick look instrumentation reviews are conducted to identify all nonoperational instrumentation with corrective actions baselined by the Space Shuttle Program's Launch Site Flow Reviews.

The Space Shuttle Program also has approved and implemented strain gage instrumentation on OV-102. A load calibration of the strain gage instrumentation is planned for the OV-102 major modification period that is scheduled for 1991. The strain gage instrumentation system is used to gather data for two purposes. The near-term purpose is to compare measured strain to certified structural capability. The only calibration required for this purpose is the strain gage manufacturer's calibration that applies to the installed gage. These strain gage lot calibrations are stable and have adequate accuracy. The long-term purpose of the strain gage instrumentation system is to define external load distributions. To determine external load distributions requires that strain gage load calibration be conducted to define influence coefficient matrix. This calibration defines the influence coefficient matrix, which converts measured structural response (strain) to applied external loads. The calibration is conducted by applying known loads at a matrix of wing locations and measuring the strain gage output for each load application. This calibration can be conducted either before or after strain data are collected, as long as the strain gage measurement system remains stable. The purpose of the strain gage measurement system is to collect strain gage data from multiple flights. Because there are significant timed and vehicle access requirements associated with conducting the strain gage load calibrations, it is not practical to conduct the load calibration prior to each flight and is only required to be conducted one time. Although an end-to-end strain gage calibration prior to data collection may be desirable, experience with similar equipment and installation indicates that the characteristics of the strain gage system sensors and electronics should remain relatively stable from the time of data measurement until the OV-102 major modification period. The ultimate objective of the OV-102 instrumentation activity is to verify the Space Shuttle ascent aerodynamic pressure distribution that is the basis of the Space Shuttle structural capability. This objective will be accomplished by analyzing strain gage data and pressure transducer data gathered from all OV-102 flights prior to OV-102 major modification using the influence coefficient load calibration.

Finding #12: Review of the data from postflight inspections of orbiter windows indicates that frequency of damage to the windows is greater than previously believed.

Recommendation #12: NASA should consider incorporating thicker or improved glass to enhance the safety margin of the windows as well as implementation of operational techniques such as pre-selecting on-orbit attitudes and entry angle of attack to minimize exposure to debris or thermal effects.

NASA Response: Review of postflight inspections of orbiter window shows that frequency of damage to windows is well within values predicted by Rockwell at the beginning of the program. Thicker windows have been considered in the past as an improvement that would reduce turnaround time for the orbiter. Though improved glass will undoubtedly improve the thermal pane's ability to withstand impacts by reducing the