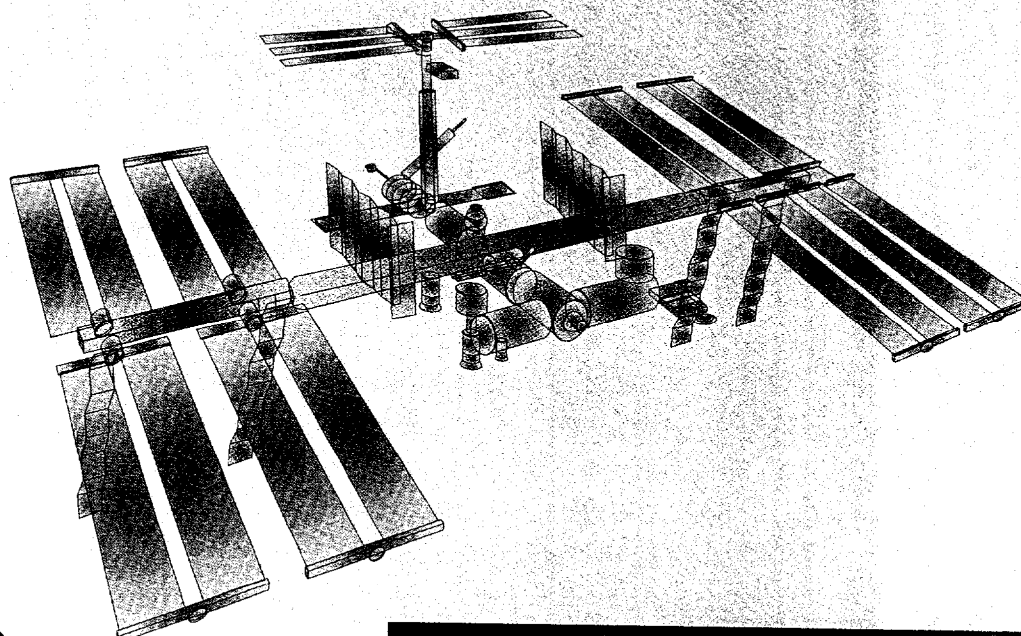
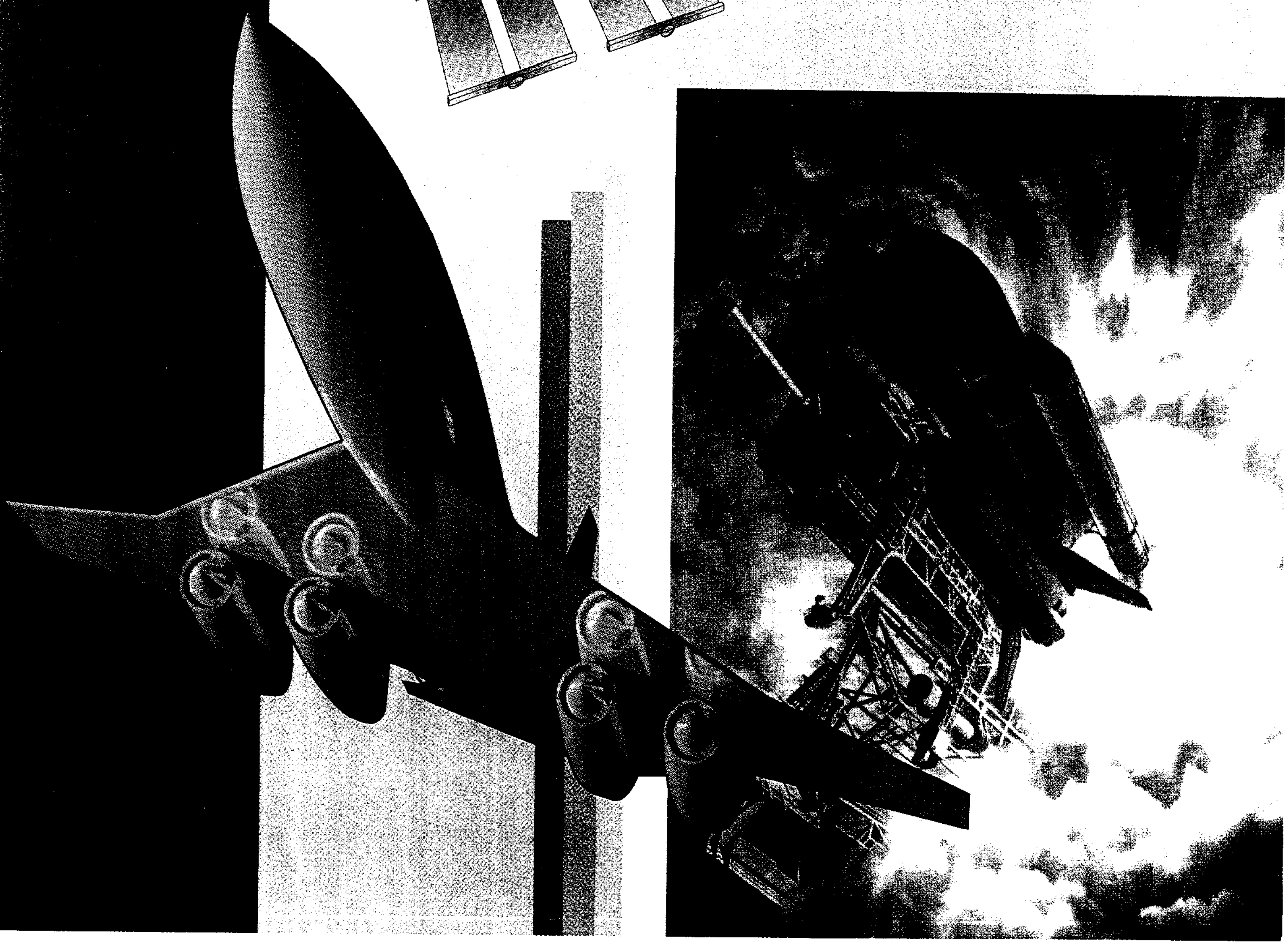
AEROSPACE SAFETY ADVISORY PANEL

Annual Report March 1995

National
Aeronautics and
Space
Administration





"The Panel shall review safety studies and operations plans referred to it and shall make reports thereon, shall advise the Administrator with respect to the hazards of proposed or existing facilities and proposed operations and with respect to the adequacy of proposed or existing safety standards and shall perform such other duties as the Administrator may request."

(NASA Authorization Act of 1968, Public Law 90-67, 42 U.S.C. 2477)

Aerospace Safety Advisory Panel

Annual Report

March 1995

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

Tel: (202) 358-0914

National Aeronautic and
Space Administration

Headquarters
Washington, DC 20546-001

Reply to Attn of: Q-1

March 1995

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

Dear Mr. Goldin:

The Aerospace Safety Advisory Panel (ASAP) is pleased to submit its annual report covering the period from February 1994 through January 1995. Overall, the Panel uncovered no "show stoppers" related to safety which is indicative of NASA's continuing commitment to risk management and reduction.

NASA's programs made significant advances during the past year. We are particularly pleased that all of the components of the Block II Space Shuttle Main Engine modifications are now underway and making good progress. Nevertheless, the safety impact of severe budget cutbacks and the departures of key personnel, particularly on labor-intensive operations such as Space Shuttle processing, continue to warrant the Panel's attention.

We remain concerned about the effective implementation of the joint U.S./Russian safety requirements. It has been difficult for us to obtain the timely and in-depth information needed to become comfortable in our oversight role of these programs. We will continue to follow the NASA collaboration with the Russians in the year to come with the specific goal of obtaining a better understanding of the joint safety processes.

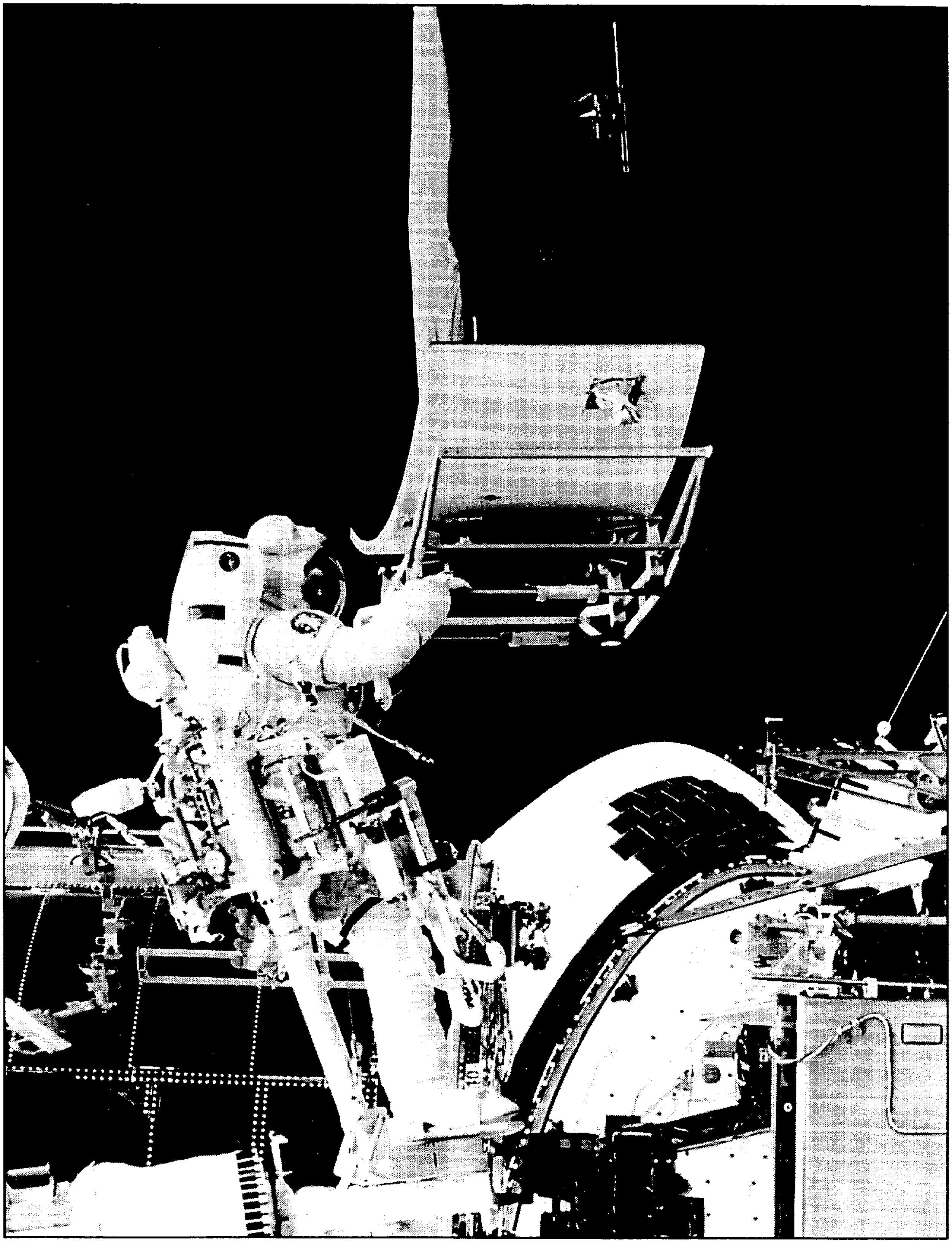
The Aerospace Safety Advisory Panel appreciates the support received from NASA and its contractors. We are also grateful for NASA's timely response to last year's report. This permitted us to pursue open items in an expeditious manner. As in the past, we ask that you respond only to Section II, "Findings and Recommendations," of the current submission.

Very truly yours,

Norman R. Parmet
Chairman
Aerospace Safety Advisory Panel

TABLE OF CONTENTS

I. INTRODUCTION



I. INTRODUCTION

NASA continued its safe and productive space and aeronautics programs over the past year in spite of budget cutbacks and political uncertainties. Seven successful Space Shuttle missions added significant knowledge in science and technology and on the ability of humans to adapt to space. These flights included the repair of the Hubble Space Telescope and also laid the groundwork for rendezvous and docking with the Russian Mir Space Station. The Langley Research Center completed its work on the joint NASA/Federal Aviation Administration wind shear detection program. The results were rapidly transferred to safety improvements throughout the world. The International Space Station (ISS) began to take shape during the year as designs matured and the cooperative agreements with the Russian Space Agency and its contractors were clarified. In all, it was a year of significant incremental accomplishments, progress on long-term programs and, most importantly, safe aircraft and spacecraft operations.

The Aerospace Safety Advisory Panel (ASAP) monitored NASA's activities and provided feedback to the NASA Administrator, other NASA officials and the Congress throughout the year. Particular attention was paid to the Space Shuttle, its launch processing and planned and potential safety improvements. The Panel monitored Space Shuttle processing at the Kennedy Space Center (KSC) and will continue to follow it as personnel reductions are implemented. There is particular concern that upgrades in hardware, software and operations with the potential for significant risk reduction not be overlooked due to the extraordinary budget pressures facing the agency. The authorization of all of the Space Shuttle Main Engine (SSME) Block II components portends future Space Shuttle operations at lower risk levels and with greater margins for handling unplanned ascent events. On the other hand, delaying the incorporation of Global Positioning System (GPS) capability in the Orbiter represents a significant lost opportunity for safety enhancements.

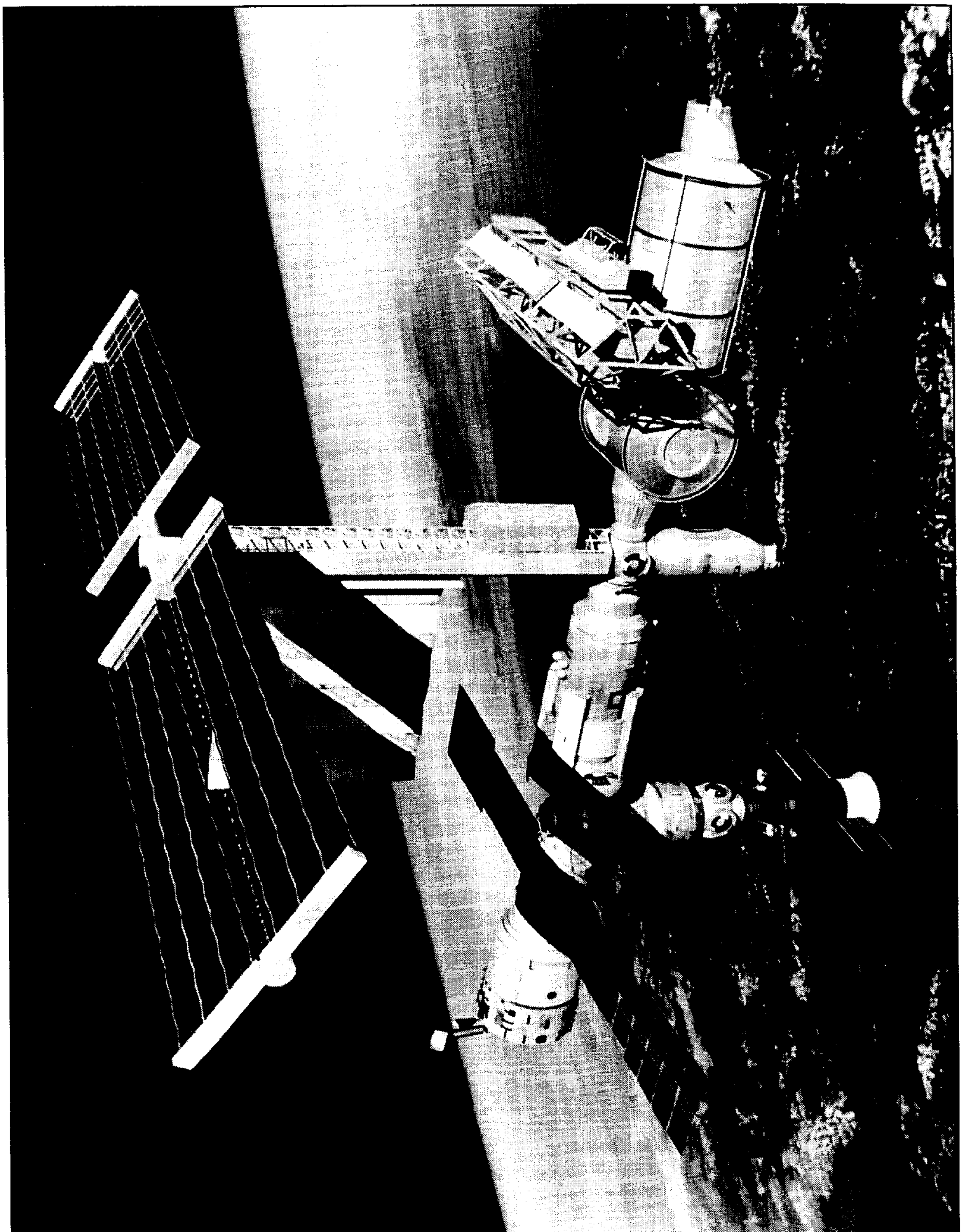
Throughout the year, the Panel attempted to monitor the safety activities related to the Russian involvement in both space and aeronautics programs. This proved difficult as the working relationships between NASA and the Russians were still being defined as the year unfolded. NASA's concern for the unique safety problems inherent in a multi-national endeavor appears appropriate. Actions are underway or contemplated which should be capable of identifying and rectifying problem areas. The Panel will monitor the joint NASA/Russian effort closely in the upcoming year. Particular emphasis will be placed on the potential for an increase in launch schedule pressure as the Shuttle/Mir missions begin. NASA must renew efforts to resist pressures to assign a launch schedule priority so high that safety may be compromised.

In the coming year, the ASAP will extend and adapt its oversight activities as needed to cover the new and revised safety challenges inherent in the continued U.S. leadership in aeronautics and the expanded habitation of space by humans.

During the year, Mr. Charles J. Donlan retired as a Panel member and became a consultant to the ASAP. Ms. Yvonne C. Brill was appointed as a member of the Panel. Mr. Paul M. Johnstone, a member of the Panel, was made deputy chairman and chairman designate.

The balance of this report presents "Findings and Recommendations" (Section II), "Information in Support of Findings and Recommendations" (Section III) and Appendices describing Panel membership, the NASA response to the March 1994 ASAP report and a chronology of the Panel's activities during the reporting period (Section IV).

II. FINDINGS AND RECOMMENDATIONS



II. FINDINGS AND RECOMMENDATIONS

A. SPACE STATION PROGRAM

Finding #1
The original organization of the International Space Station (ISS) Program included an independent safety assessment function reporting directly to the Program Manager.Subsequently, this was changed so that independent assessment reported directly to the Associate Administrator for Safety and Mission Assurance.

Recommendation #1
Maintain the true independence of the safety assessment function by ensuring that it reports outside the Space Station Program.

Finding #2
The ISS Program has committed to providing an assured crew return capability. This will initially be accomplished by using a combination of docked Space Shuttles and Soyuz capsules. Once the ISS is permanently and fully staffed, a newly designed Assured Crew Return Vehicle (ACRV) will be deployed.

Recommendation #2
The use of the Space Shuttle and Soyuz as an interim measure is an expedient. The planned new ACRV is definitely needed to support safety in the long term. The design of this permanent ACRV, regardless of where and when it is built, should be consistent with the design reference missions and systems requirements previously defined by the ACRV Office of the Space Station Freedom.

Finding #3
The architecture of the ISS contains a Caution and Warning (C&W) system to detect and warn of malfunctions and emergencies, including toxic spills, depressurization and fire. The system makes use of laptop computers for localization of faults.

Recommendation #3
Careful consideration should be given to the appropriateness of using laptop computers for a task as time critical as localizing life-threatening emergencies. The entire fault detection and localization process should use dedicated equipment to minimize response time.

Finding #4
The absence of experimental data for fire suppression effectiveness of the carbon dioxide extinguishers selected for use on the ISS under weightless conditions is a source of concern.

Recommendation #4
Appropriate ground-based and in-flight research to confirm the suitability of the use of pressurized carbon dioxide fire extinguishers under weightlessness should be conducted.

Finding #5
The present procedures for monitoring or controlling hazardous materials and procedures used in ISS experiments are dependent on the experiment supplier complying with Station requirements and specifications.

Recommendation #5
NASA should establish a positive system of compliance assurance modeled after the one used by the Space Shuttle Program. This system should consider the entire service life of the experiment and its deactivation when completed.

Finding #6
Good progress has been made in defining the threat from orbital debris and in demonstrating efficient shielding configurations. A technical basis for a debris protection specification for ISS is emerging.

Recommendation #6
Continue design with emphasis on: structural integrity of habitable modules and pressure vessels; identification of the damage potential from direct impact and other depressurization events; and definition and development of operational procedures and policies.

B. SHUTTLE/MIR (PHASE ONE) PROGRAM

Finding #7
The Russian Androgynous Peripheral Docking System (APDS) for docking the Space Shuttle with the Mir uses 12 active hooks on the Space Shuttle side which mate with an equal number of passive hooks on the Mir. The design currently provides no positive means of determining whether any or all of the hooks are secured. NASA has decided it is an acceptable risk to fly the first docking mission, STS-71, without an indicator.

Recommendation #7
NASA should develop an indicator system.

Finding #8
If the primary system fails, the first backup separation system for the APDS is a set of pyro bolts which disengage the 12 active hooks. Having to rely on the pyros as presently supplied by the Russian Space Agency poses risk because of lack of knowledge relating to the pyros' pedigree and certification. A second contingency demate procedure is available involving the Extravehicular Activity (EVA) removal of 96 bolts at a different interface. Implementing either backup method to separate Shuttle from Mir may leave the Mir port unusable for future dockings.

Recommendation #8
NASA should emphasize increasing the reliability of the primary mating/demating mechanisms in order to reduce the likelihood of having to use either of the backups. NASA should also obtain an acceptable certification of the supplied pyro bolts. Failing that, NASA should procure fully certified substitute bolts.

C. SPACE SHUTTLE PROGRAM

ORBITER

Finding #9
Significant additional payload mass capability is required to meet the demands of the ISS assembly and supply plans. Much of the needed increase in capacity will be achieved through weight reduction programs on a number of Space Shuttle elements and subsystems. The large number of simultaneous changes creates potential tracking and communication problems among system managers.

Recommendation #9
Emphasis should be placed on the adequate integration of all of the changes into the total system.

Finding #10
The New Gas Generator Valve Module (NGGVM), when certified and retrofitted to the fleet, should mitigate many of the problems with the current Improved Gas Generator Valve Module in the Improved Auxiliary Power Unit (IAPU). The NGGVM development program is proceeding well.

Recommendation #10
NASA should attempt to introduce the NGGVM into the fleet as soon as possible as a safety and logistics improvement.

Finding #11
The decision has been made to install the entire Multi-Function Electronic Display System (MEDS) in each Orbiter during a single Orbiter Maintenance and Down Period (OMDP). An Advanced Orbiter Displays/System Working Group has been formed to plan for the next generation of MEDS formats and display enhancements.

Recommendation #11
NASA should support the Advanced Orbiter Displays/System Working Group and set a timetable for the introduction of enhanced display formats which will improve both safety and operability. It should also maintain its commitment to completing the MEDS installations during a single OMDP.

Finding #12
The Tactical Air Control and Navigation (TACAN) and Microwave Scanning Beam Landing System (MSBLS) on-board receivers are obsolescent and increasingly difficult to maintain. The MSBLS receivers also have known design problems which can lead to erroneous guidance information if the Orbiter is operating with only two of the three receiver complement. A Global Positioning System (GPS) test is underway on one of the Orbiters using the backup flight software and computer. The use of GPS could replace both the TACAN and MSBLS systems as well as assisting ascent and on-orbit operations.

Recommendation #12
Given the potential of GPS to improve safety and reliability, reduce weight and avoid obsolescence and the many existing and potential problems with the use of TACAN and MSBLS, a full GPS implementation on the Orbiter should be accomplished as soon as possible.

Finding #13
Growth in the requirements for on-board data processing will continue as the Space Shuttle is used in support of Shuttle/Mir, ISS and other future missions. The length of time over which the General Purpose Computer and its software will be able to meet these growing needs effectively is likely inadequate.

Recommendation #13
NASA should expedite a long-range strategic hardware and software planning effort to identify ways to supply future computational needs of the Space Shuttle throughout its lifetime. Postponing this activity invites a critical situation in the future.

Finding #14
The STS-64 mission involved a higher than usual level of windshield hazing which could have led to a situation in which the astronauts' view of the landing runway was obscured. MSBLS and TACAN are obsolescent. There is also the possibility that false indications by MSBLS under certain scenarios could result in an unacceptable risk of a landing mishap. Thus, there is a clear need for early upgrade of Orbiter and support facility autoland equipment and crew flight rules and training improvement.

Recommendation #14
NASA should improve the autoland equipment on the Orbiter; for example, replacing MSBLS and TACAN with GPS. In the interim, NASA should ensure that operations and failure modes of MSBLS are fully examined and understood. NASA should also reexamine the training of crews for executing automatic landings, including autoland system familiarization. Astronaut commanders and pilots should discuss circumstances which might warrant autoland use prior to each mission and be prepared for all reasonable contingencies in its operation.

SPACE SHUTTLE MAIN ENGINE (SSME)

Finding #15
It has become necessary to execute a partial disassembly of both the engines and turbopumps after each flight because of the accumulation of special inspection requirements and service life limits on components of the current (Phase II) SSMEs. These inspections are performed with rigor and appropriate attention to detail.

Recommendation #15
In order to control risk, NASA must maintain the present level of strict discipline and attention to detail in carrying out inspection and assembly processes to ensure the reliability and safety of the SSMEs even after the Block I and Block II upgrades are introduced.

Finding #16
The re-start of the Advanced Turbopump Program (ATP) High Pressure Fuel Turbopump (HPFTP) and the start of the Large Throat Main Combustion Chamber (LTMCC) developments were authorized in the spring of 1994. Combined with the ongoing component developments of the Block I engine, this will produce a Block II engine which will contain all of the major component improvements that have been recommended over the past decade to enhance the safety and reliability of the SSME. Both the Block I and Block II programs have made excellent progress during the current year and are meeting their technical objectives.

Recommendation #16
Continue the development of the Block II modifications for introduction at the earliest possible time.

Finding #17
In order to provide an engine health monitoring system that can significantly enhance the safety of the SSME, improvements must be made in the reliability of the engine sensors and the computational capacity of the controller. It is also essential to eliminate the difficulties with the cables and connectors of the Flight Accelerometer Safety Cut-Off System (FASCOS) so that vibration data can be included in the parameters used in the algorithms that determine engine health.

Recommendation #17
Expand and emphasize the program to improve engine health monitoring. Continue the program of sensor improvements. Vigorously address and solve the cable and connector problems that exist in FASCOS. Continue the development of health monitoring algorithms which reduce false alarms and increase the detectability of true failures.

Finding #18
The Block II SSME can improve safety if an abort is required because it can be operated

more confidently at a higher thrust level. This will permit greater flexibility in the selection among abort modes.

Recommendation #18
NASA should reexamine the relative risks of the various abort types given the projected operating characteristics of the Block II SSMEs. Particular emphasis should be placed on the possibility of eliminating or significantly reducing exposure to a Return to Launch Site abort.

EXTERNAL TANK

Finding #19
The liquid oxygen tank aft dome gore panel thickness of the Super Lightweight Tank (SLWT) has been reduced significantly on the basis of analyses. To stiffen the dome, a rib was added. The current plan to verify the strength of the aft dome involves a proof test only to limit load. Buckling phenomena cannot be extrapolated with confidence between limit and ultimate loads.

Recommendation #19
The SLWT aft dome should either be tested to ultimate loads or its strength should be increased to account for the uncertainties in extrapolation.

SOLID ROCKET BOOSTER (SRB)

Finding #20
The structural tests of a segment of an SRB aft skirt in the baseline configuration did not duplicate the strains and stresses previously measured in the tests of the full-scale aft skirt Structural Test Article (STA-3). This suggests that segment testing of the proposed bracket modification to improve the aft skirt's factor of safety may not be valid.

Recommendation #20
NASA should reassess the use of the segment test method and reconsider the use of a full scale test article for qualifying the proposed bracket reinforcement.

LOGISTICS AND SUPPORT

Finding #21
The effort by the NASA logistics organization and its principal contractors has resulted in satisfactory performance. There remain a few problems, such as a tendency towards increased cannibalization, which still require attention.

Recommendation #21
Every effort should be made to avoid cannibalizations, particularly on critical components such as the SSME and the IAPU.

Finding #22
The Integrated Logistics Panel (ILP) continues to meet at six-month intervals, usually at the Kennedy Space Center (KSC) or the Marshall Space Flight Center. The ILP serves a valuable coordinating and liaison function for the entire logistics operation. Its personnel complement has been reduced as part of the overall NASA staff cutbacks.

Recommendation #22
NASA should maintain support of an effective ILP.

Finding #23
There is a plan to consolidate all logistics elements at KSC except Spacelab over the next three or four years. This should unify the entire logistics and supply organization. The realignments are intended to eliminate duplication of effort, gain efficiency in support and materially reduce the cost of operation.

Recommendation #23
Proceed as outlined in the NASA plan.

D. AERONAUTICS

Finding #24
NASA has entered into a contract with the Tupolev Design Bureau of Russia to support flights of a TU-144 supersonic airplane for a joint U.S./Russian research program. The TU-144 has a questionable safety record, and the particular airplane to be used has not been flown for a number of years. The level of assurance available for this flight project may not be equivalent to that typically associated with NASA's flight research programs.

Recommendation #24
NASA should assure that all design and safety data and operational characteristics of this vehicle have been fully explored.

Finding #25
Wind shear encounters, while infrequent, constitute a highly significant aviation hazard that has been a causal factor in major crashes. A joint NASA/Federal Aviation Administration (FAA) Airborne Wind Shear Sensor Program has developed methods, already being implemented, for providing timely warning to aircraft in danger of encountering such atmospheric conditions.

Recommendation #25
Continue research relating to wind shear and other aircraft-threatening phenomena, such as wake vortices, and the transfer of related technologies to users.

Finding #26
NASA has a coordinated program of tire research operating from the Langley Research and Dryden Flight Research Centers. This program has the capability to provide significant safety improvements for present and future aircraft and spacecraft.

Recommendation #26
In addition to supporting the Space Shuttle and other research programs such as the High Speed Civil Transport, NASA should continue to emphasize and transfer lessons learned in the tire research effort to all segments of the user community.

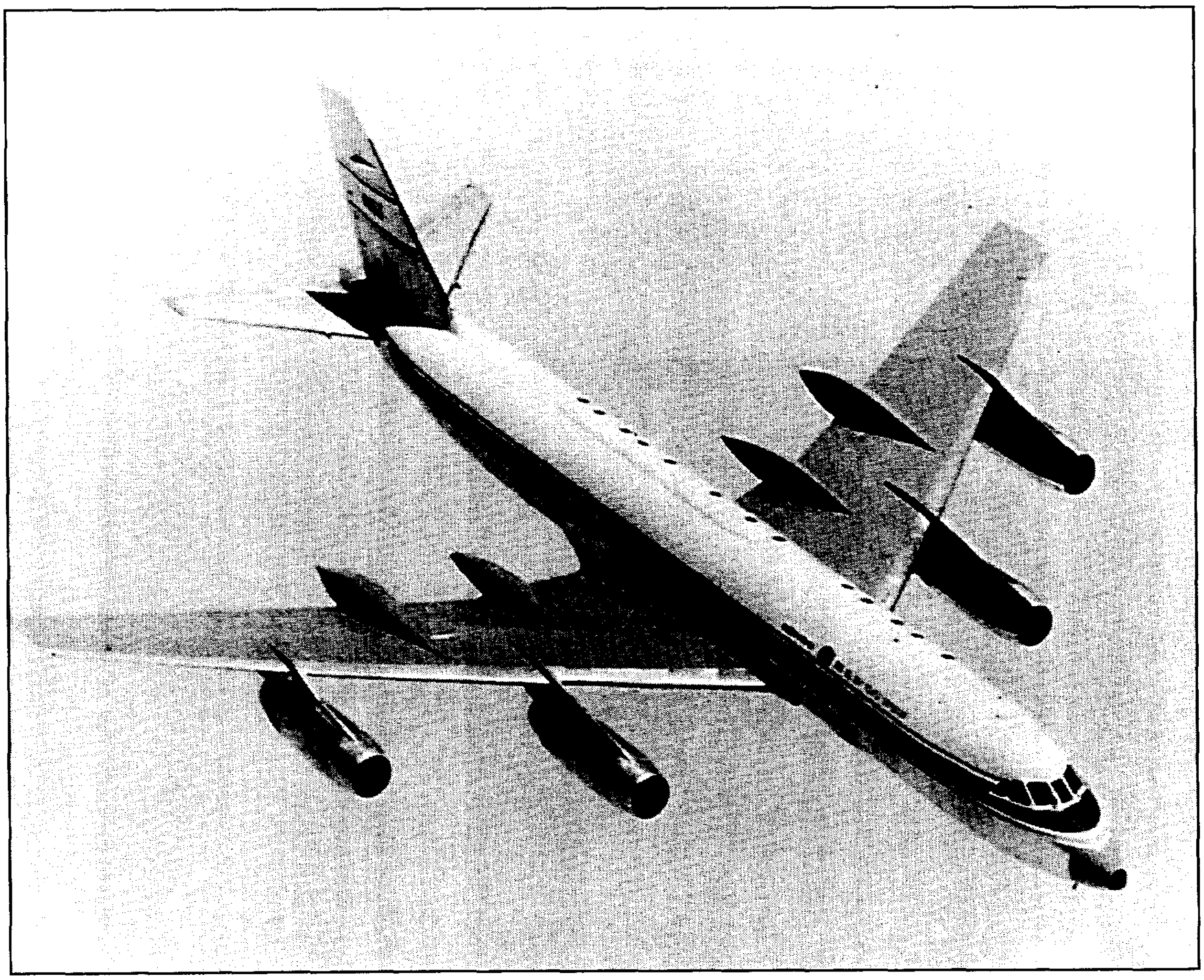
Finding #27
The Dryden Flight Research Center (DFRC) has completed a demonstration of the concept of a Propulsion Controlled Aircraft (PCA) system using an F-15 aircraft flight test and an

MD-11 simulator demonstration. This system permits an aircraft to be guided to a landing in an emergency using only thrust for flight path control. DFRC is now exploring a joint program with industry to extend the demonstration to a flight test on a large commercial aircraft. Although the PCA concept has been proved, the pilot control interface aspects of the design have yet to be systematically addressed.

Recommendation #27
Any flight test program on a large commercial aircraft should include a strong focus on selecting the optimum pilot control interface for the system.

Finding #28
The range safety policy for Unmanned Aerial Vehicle (UAV) operations within the Edwards Air Force Base range worked when the Perseus Program suffered an in-flight failure. Range safety for Perseus flights outside of the restricted Edwards airspace has yet to be addressed.

Recommendation #28
Consideration should now be given to establishing a UAV policy to cover Perseus flights conducted outside of controlled airspace at Edwards.



E. OTHER

Finding #29
The Simplified Aid for EVA Rescue (SAFER) was successfully flight tested on the STS-64 mission. Although designed as a rescue device for an astronaut who becomes untethered, SAFER has demonstrated its potential to assist in other safety-critical situations such as contingency EVAs. Five SAFER flight units have been ordered. Plans are to deploy them on Mir and Space Station as well as to carry them on the Space Shuttle only when an EVA is planned.

Recommendation #29
Once the flight units are available, NASA should consider routinely flying SAFER units on all Space Shuttle missions which do not have severe weight limitations. This will permit them to be used for those contingency EVAs in which safety can be improved by giving crew members the capability to translate to the location of a problem to make an inspection or effect a repair.

Finding #30
NASA has established a Software Process Action Team (SPAT) to review and develop plans for addressing the software concerns that have been raised within NASA and by several review boards including the National Research Council and the Aerospace Safety Advisory Panel. While NASA has extensive procedures for addressing software issues in some arenas, these issues have not received uniform recognition of their importance throughout the agency.

Recommendation #30
NASA should ensure that computer software issues are given high priority throughout the agency and that those addressing these issues are given the support needed to produce adequate ways of dealing with them. The creation of the SPAT was an important initial step toward dealing with complex safety critical problems, but much more needs to be done.

Finding #31
There were several in-flight and ground-based episodes in which astronauts developed adverse reactions to substances used in human experiments. Although the researchers guiding these experiments submit their protocols to a standard Institutional Review Board (IRB) process, there is no independent oversight of the safety of human experiments within NASA.

Recommendation #31
NASA should provide independent oversight of human experimentation by establishing a review process in addition to the standard IRB and ensuring that the Space Shuttle and Space Station systems requirements provide sufficient equipment, staffing and training to react appropriately to any problems which might be experienced.

Finding #32
The number of reports submitted to the Aviation Safety Reporting System (ASRS) has nearly doubled since 1988 and has consistently been above the levels projected when the system was started. In these same years, budgetary resources have remained flat so that, even with significant productivity increases, the portion of incidents that receive detailed analysis has declined. In addition, ASRS has not been able to develop cost-effective electronic dissemination of advisories or a program of educational outreach to expand use of ASRS by the aviation community, both of which would be significant safety enhancements.

Recommendation #32
NASA and the FAA should restore the full capability of analysis, interpretation, and dissemination of the ASRS and promote electronic dissemination and expanded educational outreach.

Finding #33

For many years, NACA and NASA aeronautical research and flight safety benefitted from the advice and counsel provided by an advisory group of aircraft operations specialists consisting of representatives from civil and military aviation and manufacturers of aircraft, engines and accessories as well as NACA/NASA personnel.

Recommendation #33

NASA should restore the previous capacity to capture the operational experience it found useful in improving its research focus and flight safety.

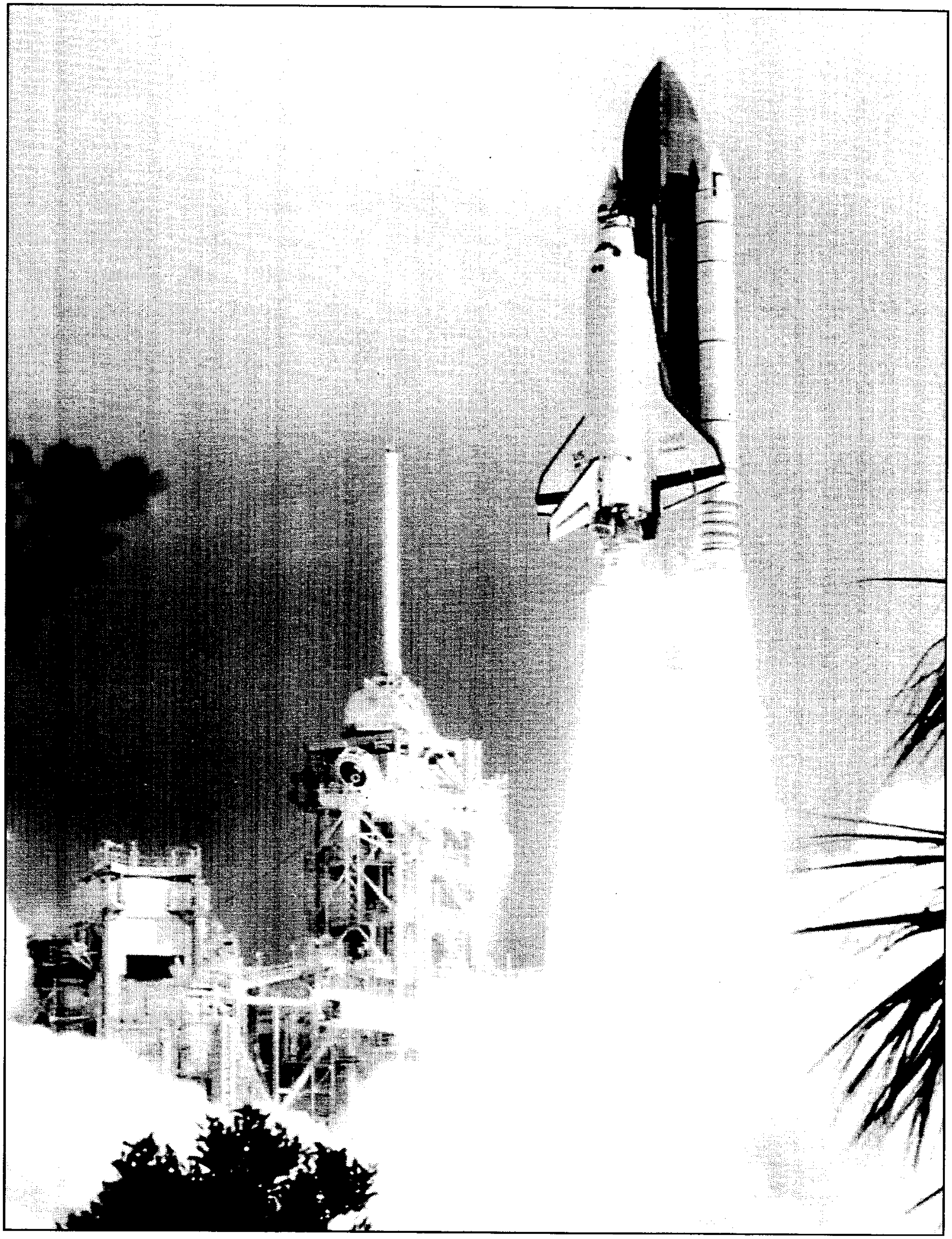
Finding #34

Total Quality Management (TQM) is an established philosophy within NASA and among its principal contractors, and implementations continue to improve.

Recommendation #34

None.

III. INFORMATION IN SUPPORT OF FINDINGS AND RECOMMENDATIONS



III. INFORMATION IN SUPPORT OF FINDINGS AND RECOMMENDATIONS

A. SPACE STATION PROGRAM

Ref: Finding #1

The initial organization of the International Space Station (ISS) as presented to the Panel at the Johnson Space Center (JSC) placed the independent safety assessment function under the program manager. In actual fact, an independent assessment function can only be truly independent if the director of that function is established on the same organizational level as the program manager. In that way, any dispute automatically elevates to the next higher level (Associate Administrator) for resolution.

After this was brought to the attention of NASA management, the organizational structure was changed so that the head of independent assessment reported directly to the Associate Administrator for Safety and Mission Assurance (S&MA). This provides true independence for this critical function.

Ref: Finding #2

The Space Station Freedom (SSF) Program formed an Assured Crew Return Vehicle (ACRV) office to examine requirements for a dedicated spacecraft to return the crew from an orbiting space station in the event of an emergency. Three Design Reference Missions (DRMs) were identified including a medical emergency, an evacuation due to the loss of habitability of the station and a lapse in Space Shuttle logistics support. These DRMs were used to develop a set of performance requirements for an ACRV to be deployed on the Space Station Freedom when permanently crewed.

The International Space Station is a different design from SSF. Nevertheless, the DRMs remain valid as they were generic to any crewed orbiting platform serviced by launch vehicles from the earth. Likewise, the ACRV system requirements generated from the DRMs also offer valid guidance for any ACRV to be built in support of ISS.

At present, NASA has made the decision to support initial crew return efforts with a mixture of docked Orbiters and Soyuz capsules. This interim approach does not fully meet the previously defined requirements for an ACRV. For example, a single Soyuz cannot accommodate the complement of a fully staffed station and has only about a six month service life on orbit. Nevertheless, this appears to be a reasonable compromise as an expedient. The long-range NASA plan is to deploy a newly designed ACRV in approximately the year 2002 when the ISS is completed and fully staffed. This vehicle, which may be U.S. built or supplied by one of the international partners, is vitally important for safety. Regardless of where it is built, its design should adhere to the systems requirements developed for the SSF ACRV. These requirements are complete and appear fully applicable as a starting point for any new ACRV. Also, in order to be available by the target date, a commitment to starting this vehicle must be made in the near future.

Ref: Findings #3 and #4

The ISS design includes systems and procedures to warn of, localize and react to a variety of malfunctions and emergencies that may occur during Station operation. The heart of these provisions is the Caution and Warning (C&W) system. This system consists of sensors distributed throughout the station which are designed to detect such things as temperatures, pressures and the presence of particulate matter within both racks and the general areas of the modules. Signals from the sensors are sent to a Multiplexer/Demultiplexer (MDM) which, acting as a data processor, discriminates between normal and abnormal conditions. The results of these analyses are sent to a set of redundant "command and control" MDMs via a digital data bus. These MDMs are, in turn, programmed to determine the nature and level of caution or warning to be issued. The resulting signals are sent to other MDMs which drive an annunciator panel in each of the five modules of the Station as well as to associated audio systems which sound alarms as required. The panels contain five lights, three of which are programmed to indicate a specific type of emergency: fire, toxic environment and depressurization, but not the location of the emergency. In the present design, localization must be accomplished by connecting a laptop computer (via a computer port at the panel) programmed to be able to query the system as to the location and nature of the problem.

The layout of the system is reasonably straightforward and is independent of the Station's Data Management System. The fact that the laptop is apparently not dedicated to the fault localization process is a source of concern. Certainly, the time lost in making the computer connection and running the program would appear to be a waste of a precious commodity in an emergency. Also, all software used in any laptop on ISS must be configuration controlled and subjected to appropriate levels of Independent Verification and Validation.

Active attention is being paid to the possibility of a toxic spill in the station. Every precaution is to be taken in the design of containers for and in the handling of toxic substances; requirements for these safety aspects have been developed and documented and are to be levied on all users. Contingency procedures are being developed in the event of a spill and are to be part of the training program for crew members.

The possibility of fire in the Station is always present, and combustion detectors are among the sensors in the caution and warning system. Research into combustion phenomena under weightless conditions has been conducted for a number of years, and the processes are reasonably well understood. At this time the Station has selected hand-held pressurized carbon dioxide extinguishers for fire suppression. These are to be used after air circulation within a rack, for example, has been stopped. There are, however, no experimental data on the effectiveness of such extinguishers in the environment of the Station. Experiments should be devised for both ground and flight tests to verify the effectiveness of this fire suppression technique. These can be relatively simple and straightforward with the sole objective of verifying the suppression capability of carbon dioxide in weightless conditions.

Ref: Finding #5

The Space Station's major reason for existence is to provide a platform for experimentation in space. As such, there will be great emphasis on obtaining experiments from diverse sources. These will likely include the aerospace industry, which is intimately familiar with the unforgiving nature and limitations of space, as well as sources which may or may not have any concept of the criticality of strict compliance with the requirements involved. NASA will make a grave error if inadequate means are provided to inspect and monitor the payload/experiment supplier. The Space Shuttle and some of its major payloads, such as Spacelab, already have excellent programs for specifying requirements and verifying compliance. These existing programs can serve as models for a similar ISS system.

Ref: Finding #6

Progress has been made this year in several areas related to the hazard to the ISS from orbital debris. A new assessment of the debris environment at ISS orbital altitude has led to a revised specification of the flux levels to be used for design. This specification is in the process of approval by both U.S. and Russian participants.

Several "campaigns" have been carried out this year to measure the flux of debris in Low Earth Orbit (LEO). The Haystack radar and other radars and optical sensors based at several latitudes have been employed to amass statistical data on the flux of particles 1 cm in diameter and larger in LEO. In addition, good data were obtained by launching calibration spheres in the Orbital Debris Radar Calibration

Spheres (ODERACS) experiment deployed from STS 60 in February 1994 and tracking them until they decayed from orbit. This experiment improved the ability to assess particle size on the order of 30%. Further experiments are planned for the near future to refine these figures and to introduce dipoles to better calibrate the radars in all polarizations. The overall result has been that the measured debris environment appears to be a factor of two lower at ISS altitudes (350-500 km) and somewhat higher near the 1,000 km altitude than in previously published NASA models.

The approach to evaluating probability of critical impact has been modified to account separately for each of the inhabited modules and to take notice of the reduced (compared to SSF) projected area of the current design and revised flux levels. These changes bring the "Probability of No Critical Penetration" to near acceptable levels.

NASA carried out a series of tests in the Spring of 1994 firing projectiles at hypersonic velocities (11.0 to 11.5km/sec) into shield samples. The results of this program have led to the decision that the "Stuffed Whipple Shield" will be the standard for ISS. The Stuffed Whipple Shield is a standard Whipple shield, a thin metal plate mounted on stand-offs in front of the protected surface, modified by inserting a layer of Nextel AF62 and Kevlar midway between the plate and the surface. Such a shield proves to be superior, with respect to mass versus penetration damage, to an alternate design incorporating additional aluminum plates. This approach seems promising for protecting the ISS within mass constraints.

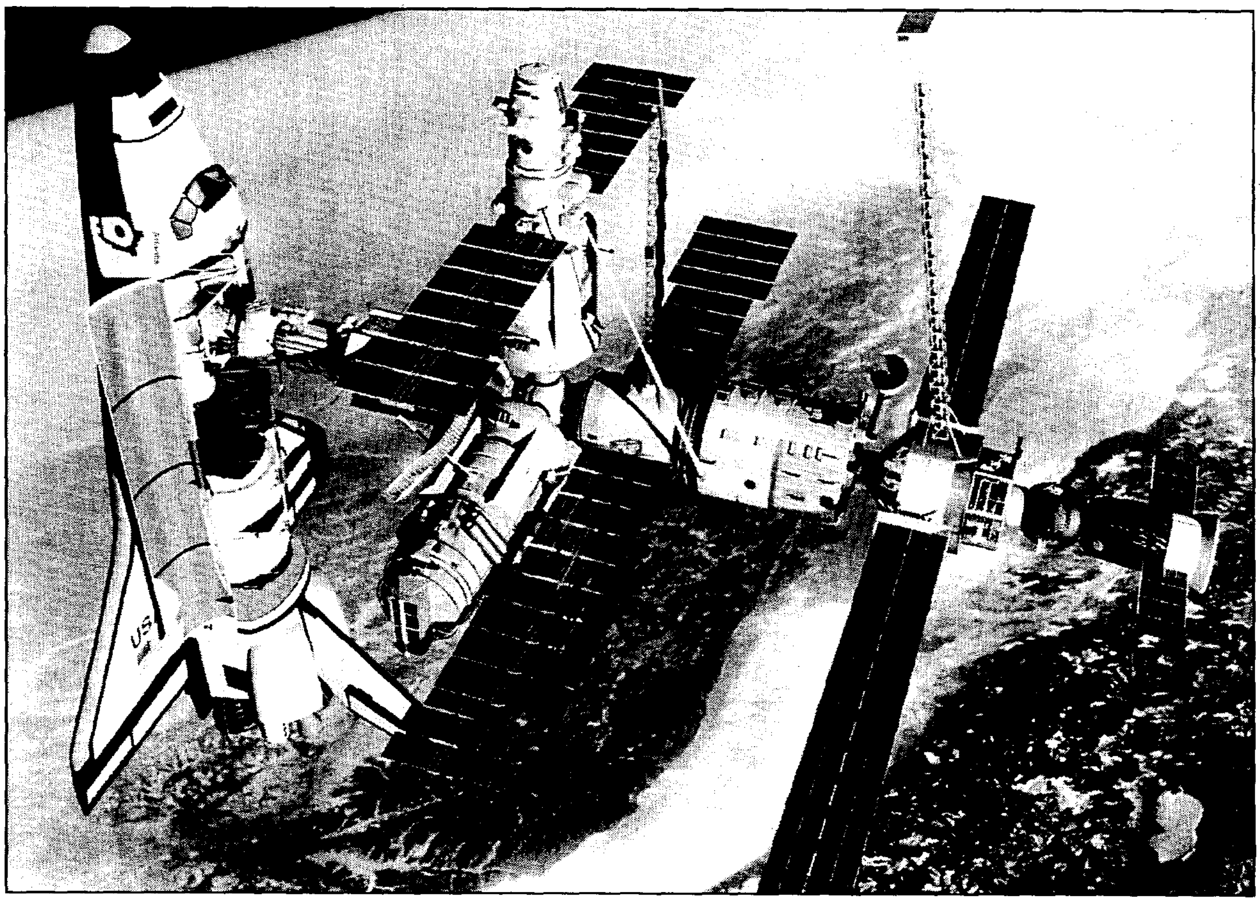
Protection of the ISS from debris must be considered as an overall system composed of understanding of the environment, external and internal shielding, a comprehensive avoidance system, and operational procedures to minimize the likelihood of impact as well as to react to penetration damage and possible depressurization. Such a design is being proposed, but it is still in the early stages of formulation, particularly with respect to the active avoidance system and operational procedures.

B. SHUTTLE/MIR (PHASE ONE) PROGRAM

Ref: Findings #7 and #8

The Androgynous Peripheral Docking System (APDS) joins the Space Shuttle and Mir using 12 active hooks on the Orbiter side that engage 12 passive hooks on the Mir side. It is not currently known how many latched hooks are required for safe docking security. The best that can be said is that the number is equal to or less than 12 but more than zero. The hooks operate in two sets of six each. One of the hooks in each set is activated directly by a motor which also drives a cable control assembly to actuate the other five hooks in the set. In order to release the orbiter from the Mir, the motors have to counter-rotate to disengage the active hooks. Any single failure in the system can result in one or more hooks not engaging or disengaging as commanded. The system design makes no provision to advise the flight crew or ground control of the status of each hook, and therefore a positive docking or undocking indication is absent. NASA should implement an indicator system as soon as possible to eliminate this risk.

The first backup separation system for the APDS is a set of pyro bolts which disengage the 12 active hooks on the Orbiter side if they fail to retract. Having to rely on the pyros as presently supplied by the Russian Space Agency poses risk because of lack of knowledge relating to the pyros' pedigree and certification. A second contingency demate procedure is available involving removal of 96 bolts at a different interface by Extravehicular Activity (EVA) if the pyros do not function. In the event that either the pyro or the EVA plan to separate Shuttle-Mir must be used, its implementation may leave the Mir port unusable for future dockings.



C. SPACE SHUTTLE PROGRAM

ORBITER

Ref: Finding #9

In order to assemble the Space Station at its 51.6 degree inclination, an additional 13,000-15,000 pounds of Space Shuttle payload capability will be required for most assembly flights. The additional capacity is to be provided by a combination of weight reductions and ascent performance enhancements.

NASA has begun to analyze the thermal and structural loads environments for the Orbiter after the defined enhancements are incorporated and expects to complete the analyses in August 1995. The situation is, of course, dynamic and highly interactive. The large number of simultaneous changes creates potential tracking and communication problems among system managers. Emphasis must therefore continue to be placed on the adequate integration of all of the changes into the total system.

Ref: Finding #10

The New Gas Generator Valve Module (NGGVM) development program for the Improved Auxiliary Power Unit (IAPU) is on target for commencing fleet retrofit towards the end of 1996. The NGGVM design effectively eliminates many of the design deficiencies and Criticality 1 failure modes associated with the Improved Gas Generator Valve Module (IGGVM) which is now flying. In particular, the NGGVM: eliminates many welds and those remaining are inspectable; is designed to eliminate seat cracking problems; and has eliminated thin wall hydrazine barriers. The NGGVM design employs a spring-loaded metal-to-metal seat/poppet configuration for the pulse control valve which will reduce the safety concerns associated with seat exposure to hydrazine.

The NGGVM Design Acceptance Review was successfully completed in late July 1994. Pre-qualification testing is scheduled to begin in the second quarter of 1995 and conclude with a Design Review in the fall of 1995. Long lead time items of qualification hardware will be started while pre-qualification is still underway (late 1995). Fabrication of qualification and production units will start in parallel at the beginning of 1996 to support commencing fleet retrofit late in that year.

The NGGVM test plan has been greatly truncated based on recommendations of an expert team. The reduction from the originally planned 375 hours of testing to only 98 hours will save cost and time. The rationale for this reduction appears sound and consistent with a safe level of operations.

The program has examined three alternative plans for introducing the NGGVM into the fleet. The first strives for the *earliest possible* incorporation. It would have all APUs upgraded to the NGGVM by roughly the end of 1997. The second plan is *attrition-based* and would only upgrade the valve in an APU when the unit was already scheduled for overhaul. This would delay complete fleet introduction until approximately the year 2000. The third plan, which is the present plan for introduction, is *opportunity-based.* The ground rule of this plan is to maintain a predetermined minimum Kennedy Space Center (KSC) stock level of spare IAPUs during the modification cycle to support any unplanned removals. Any removed IAPUs not needed to support the minimum stock level will be shipped to the manufacturer for the NGGVM upgrade. Under this plan, NASA indicates that the NGGVM modifications can be completed in late 1998 or early 1999.

The problem with the *earliest possible* incorporation plan is that it must appropriate flight assets from the KSC. The projected result, assuming no unplanned removals, is that there will be fewer than a shipset of spares on hand at KSC for virtually all of 1997 and one quarter of 1998. In fact, for two quarters of 1997 a position of zero spares is projected. The low spares count means that any unplanned removals could force cannibalization to keep the fleet flying. This is a highly undesirable situation which mitigates against adopting the *earliest possible* introduction plan. Including the IAPUs on whichever vehicle is undergoing its Orbiter Maintenance and Down Period (OMDP) at Palmdale in the spares count provides only minimal relief for this problem.

The *attrition-based* plan delays introduction and hence the availability of an important safety and logistics improvement. The *opportunity-based* plan, while a compromise, may still be associated with an unacceptably high chance of the need for cannibalizations to support flight.

There is a possible way to reduce or eliminate the potential for cannibalizations with the *earliest possible* or *opportunity-based* introduction plans at an additional cost. There are four baseline APUs in storage which were not upgraded to IAPUs with the balance of the units. The program assets include spare IAPU components sufficient to upgrade three of these baseline units to IAPUs, although this would significantly reduce the parts inventory. If a timely commitment for this conversion is made, the additional IAPUs would be available to support NGGVM introduction. Although this would not move up the completion date for either plan, it would ensure that at least a full shipset of spare IAPUs was available at all times.

Given the manufacturing problems with the IAPU which surfaced during 1994 and the extent of hands-on labor needed to keep them flying, NASA should carefully consider all of the facets of the adopted NGGVM introduction plan and give appropriate emphasis to the avoidance of possible cannibalizations or the need for unplanned IAPU removals from Orbiters during their OMDP.

Ref: Finding #11

A Multi-Function Electronic Display System (MEDS) with enhanced quality and functionality of displays has great potential to reduce workload, improve crew response time, reduce crew training requirements and provide the crew with better information for both normal and contingency operations. These capabilities could be extremely important for the safety of proximity operations with Mir or the Space Station. They will also be invaluable in the event of an abort situation.

The initial plan was to install the foundation for the MEDS during an OMDP and to complete the installation during normal flows at KSC. In addition, the displays on the initial MEDS implementation were to emulate the existing electro-mechanical devices in both format and information content. Both of these decisions delayed achieving the full safety and operational benefits of which the MEDS is capable. The Shuttle Training Aircraft and training simulators are also to be upgraded to a MEDS configuration.

The Space Shuttle Program has now decided to install the entire MEDS system during a single OMDP. Under this plan, an Orbiter will arrive in Palmdale with conventional instruments and leave with a full "glass cockpit" installation. This represents a significant improvement in the installation strategy and eliminates a myriad of problems associated with a two-step transition. It has also been decided to depart somewhat from a strict emulation of the old displays, although a fully developed MEDS format has been deferred until a later generation of the system.

NASA has committed to a future phase of Orbiter displays-and-controls update activities in order to achieve a state-of-the-art system. This effort should include both enhancements to the display formats themselves and the quantity and nature of information presented.

Display format improvements for the existing set of displayed information can be achieved within the programming of the MEDS itself. Changes in the type of information presented will require modifications to the General Purpose Computer software. An Advanced Orbiter Displays/System Working Group has been formed to plan for the next generation of MEDS formats. This group has a limited budget and no firm deadlines. Given the potential benefits from a fully-enhanced MEDS, it would seem best for NASA to plan a firm schedule for MEDS upgrades and to support the working group to the maximum extent possible.

Ref: Finding #12

The full Microwave Scanning Beam Landing System (MSBLS) installation on the Orbiter includes three receivers, although only two must be operating in order to launch. When one of the three receivers fails to provide a correct output, it is taken off-line. This first failure is easy to identify when all three are on-line since the failure logically takes place in the receiver with a signal that differs from the other two or, if a logic flag within the receiver identifies a fault in that unit.

With only two receivers on-line, certain failures may be identified by a flag or by the Orbiter's on-board computer logic, but the probability of any failure being detected is not very high. With the current Orbiter system installation the two remaining receiver outputs are averaged and this signal is used as a navigation input during the final approach, flare and landing. If one of the two receivers fails during this time, the averaged output will obviously change and the MSBLS output will be in error. Flying with only two MSBLS receivers would be adequate for mission success provided that the flying pilot can visually monitor the final approach and landing to determine if the remaining MSBLS receivers are providing accurate guidance information.

The Global Positioning System (GPS) could avoid the above deficiencies and thus enhance the operational performance and safety of the Orbiter. There are two distinct aspects of considering GPS as a replacement for MSBLS. First, MSBLS is not only obsolescent but also possibly could become a safety issue because of the great difficulty in maintaining very old electronic airborne units. Second, there is the considerable expense involved in maintaining a network of MSBLS ground stations at all landing and primary abort sites. The ability of the Orbiter to navigate independently for approach and landing using GPS could also significantly increase the number of contingency abort sites available.

The Federal Aviation Administration (FAA) has already announced that GPS may soon be used as the sole navigation source by the airlines. Non-precision approaches using only GPS have already been approved, and precision approaches will almost certainly follow soon.

The issue of MSBLS seems abundantly clear. The performance and safety enhancements that GPS can offer to Orbiter performance in ascent, aborts, on-orbit operations and approach and landing warrants its installation as soon as possible.

Ref: Finding #13

Throughout the history of the Space Shuttle program, there has been a continuing demand for upgrades to the functionality achieved with the on-board General Purpose Computer (GPC) system. This increase in functionality has been achieved through upgrades to the GPC software with the exception of a single GPC hardware upgrade which took over eight years to implement. Almost every flight sees some level of software change, and at somewhat larger intervals, major upgrades to the software take place. There has been a general tendency for the memory and processor requirements to grow during this continual software upgrade process.

As early as 1983, NASA recognized the need to upgrade the computational capabilities in the GPC hardware, and began a program to replace the original processors and memory. In 1991, NASA began use of the "new" GPC. However, the new GPC achieved considerably less additional memory usable for active flight control software than originally expected due, in part, to the non-modular arrangement of the Space Shuttle software.

Upgrades to the Space Shuttle software continue, but at a slower rate than before. There are concerns within NASA that important safety-related software upgrades are being postponed because of the complexity associated with changing the non-modular software. Moreover, at some point, the new GPC memory will be filled, making further upgrades much more difficult, or, perhaps, even impossible. Little analysis has been conducted on the long term impact of continuing demands for performance improvements and the ultimate limits of the current processors.

Attention to date on computer related functionality has been largely focussed on the GPCs and their memory. However, other avionics components, such as the MDMs, are also growing older, with an attendant concern over maintainability. Concerns have been expressed over how much longer they can be used.

While the situation with respect to the Space Shuttle computer and avionics systems has not become critical, there are at least two major concerns. First, the GPC is gradually approaching saturation. Second, the time required for any major upgrade in computer/avionics hardware or redevelopment of the basic flight software is very long, on the order of a decade. Therefore, NASA should begin a long range strategic hardware and software planning effort on ways to supply future computational needs of the Space Shuttle throughout its lifetime. Postponing this activity invites a critical situation in the future.

Ref: Finding #14
The ASAP has long advocated that more attention be paid to the existing autoland function on the Orbiter. At present, the capability exists and crews are aware of it. They do not, however, train for executing an autoland. They also do not engage in a formal process to examine topics related to autoland engagement and disengagement. These topics would include such things as conditions under which an autoland was the preferred mode and how and when a manual takeover should be accomplished if necessary during an automatic landing. The Panel is simply proposing that crews receive a reasonable level of training and system familiarity so that autoland becomes a true contingency possibility rather than a capability with a remote chance of being used even if needed. NASA should also improve the autoland equipment on the Orbiter; for example, replacing MSBLS and TACAN with GPS.

SPACE SHUTTLE MAIN ENGINE (SSME)

Ref: Findings #15 through #17
PHASE II ENGINE: The current SSME systems ("Phase II") have performed well in flight during the past year. However, a number of new and/or heightened concerns have arisen. Among them is an increased incidence and severity of "sheetmetal" cracks (or peeling) in the High Pressure Fuel Turbopump (HPFTP) turn-around and inlet ducts. This has resulted in the need for increased inspections to tighter limits as well as redesign of the sheetmetal of the inlet duct including a change in its manufacturing technique. It was also discovered that the turning vanes in the High Pressure Oxygen Turbopump (HPOTP) preburner volute diffuser had undersized (out of specification) fillet radii, a condition that enhances the probability of fatigue failure. This has resulted in a Deviation Approval Request (DAR) being issued limiting the number of turbopump starts and runs between removals

for refurbishing. All told, as a result of the accumulation of DARs, it is now necessary to remove and at least partially disassemble the engine and turbopumps after each flight. The continuing need for additional special inspections and service time limits confirms the validity of the decision to commit to the major engine improvements that have been undertaken—the Blocks I & II programs discussed later in this section.

There was a launch abort caused by a violation of the start limit for the HPOTP turbine exhaust temperature (1,560 degrees F) on an engine during the initial launch attempt for the STS-68 mission. The control system performed as designed during this abort and shut down all three SSMEs prior to solid rocket motor ignition. A thorough investigation of the incident led to the conclusion that there had been a concatenation of a number of factors, none of which individually would have caused the over-temperature, that led to the shutdown. These factors included, among others, a Main Combustion Chamber (MCC) that had above normal leakage and a flowmeter that exhibited a calibration shift during its first acceptance test but performed normally thereafter. The engine containing the pump that caused the shutdown was removed from the vehicle and sent to the Stennis Space Center for test firing. Care was taken to ensure that there were no changes in its configuration. The engine performed normally in the test. A review of the methodology used to set the start and flight redlines is continuing.

Sensor failures continue to be a problem. They are mitigated somewhat by the use of redundant instruments and controller logic. Some actions have been taken to improve the reliability of the current sensors. For example, new pressure sensor inspection techniques are being employed to help detect and eliminate particulate contamination. Flux contamination of the cryogenic temperature transducers is being eliminated by changes in manufacturing and inspection techniques and sequences. Hot gas temperature transducers using thermistors as the principal sensor will be replaced by a more rugged thermocouple-based sensor.

BLOCK I ENGINE: The Block I engine improvement program is proceeding very well. The Block I engine includes the new two-duct powerhead, the single tube heat exchanger and the Advanced Turbopump Program (ATP) HPOTP. The first two of these major changes have flawlessly completed certification tests. The first unit of the ATP HPOTP has completed initial certification testing accumulating 10,000 seconds of run time in 22 test runs and is into its second series. These tests included considerable time at 109% thrust as well as a margin demonstration at 111%. The unit was disassembled after these tests and only minor wear was observed. The turbine blades and the silicon-nitride ball bearings were in excellent condition and can be re-used. One roller in the roller bearing had slight wear indicating contact with the end rail of the bearing—a minor problem. There was some delamination of the honeycomb structures that serve as part of the labyrinth seals between stages of the turbine. No performance degradation was observed and the phenomenon poses no danger to the machine. This wear can be remedied by minor design changes. The second HPOTP unit had completed its first series of tests and has accumulated 10,000 seconds of run time without any problems as of the time of this writing.

As part of the HPOTP program it was necessary, for proper matching of the boost and main pumps in the oxygen system, to redesign the angle of the inducer blade of the Low Pressure Oxygen Turbopump (LPOTP) that feeds the HPOTP. This change is straightforward and was achieved without difficulty. While this was being done, the current (Phase II) LPOTP began to exhibit excessive ball wear in its thrust bearing. The solution adopted for the new LPOTP is to employ silicon-nitride balls in this bearing. Serendipitously, these balls are the same size as those employed in the HPOTP making the change simple to implement.

In total, the Block I engine development and certification is proceeding well and is on schedule for its planned introduction into the fleet in the first half of 1995.

BLOCK II ENGINE: This engine version comprising the Block I changes plus the Large Throat Main Combustion Chamber (LTMCC) and the ATP HPFTP is also proceeding well. Go-ahead for the re-start of the HPFTP and the start of the LTMCC development was given in the spring of 1994 thereby completing the scope of the program of major component re-design and development that had been recommended for over a decade. The LTMCC, which is considered by many to be the most significant safety improvement in the SSME, is ahead of its manufacturing plan, and a development unit has been shipped for test. A development unit of the HPFTP has also been assembled using parts that had been made before the activity was put on a stop-work status. At the time of this writing, a complete Block II development engine had been assembled and a full duration test run (including operation at 109%) had been completed. The preliminary data review from this test showed that the performance objectives predicted were achieved and that there were no systems integration problems evident. The first "final" configuration HPFTP is scheduled for delivery in the spring of 1995. The limiting factor in the delivery schedule is the time to develop and produce an improved fine-grain casting that should eliminate some cracking that had occurred in the earlier version. Other changes such as decreasing the turbine flow area by increasing the number of turbine nozzle vanes are to be delivered with adequate lead time. The increase in the number of turbine nozzle vanes also detunes the excitation of the first stage turbine blades and should preclude the cracking experienced at the trailing edge of the blade tip.

HEALTH MONITORING: As noted in last year's report, it would be advantageous to develop the engine controller and associated software and sensors into a true and more effective "health monitoring system." Such a system would ideally reduce both the probability of shutting down a healthy engine and the probability of failing to detect an engine malfunction in a timely manner. Improved health monitoring would reduce the risk involved in engine operation. To accomplish this requires not only development of suitable algorithms but also improvement of the reliability of sensors and increasing the computational capacity of the controller. The improvement of sensors was discussed earlier in this section. Regarding the controller, during the past year it was found that it was subject to "single event upsets" due to cosmic ray strikes either during flight or on the ground. This eventuality was believed so remote during controller design that "radiation hardened" solid state electronic devices were not selected. It would be advisable to substitute such hardened devices for existing hardware to reduce risk. While this is being accomplished, it appears possible simultaneously to increase computational speed by adding a co-processor. This would permit the controller to perform the added functions required for improved health monitoring without a major redesign and re-manufacture.

Studies have been conducted to define the algorithms that would be needed to enhance engine health monitoring. It was found, that with the current complement of sensors (i.e., pressure, temperature, valve position, and speed) and computational power it was not possible to effect any significant improvement in the health monitoring function effectiveness. It was determined that if engine vibration were added to the inputs to the system along with the previously mentioned co-processor, significant improvements could be made as parameters of this type can give early warning of severe malfunction. Accelerometers measuring these variables already exist on each engine in the Flight Accelerometer Safety Cut-Off System (FASCOS). The instruments themselves appear to have requisite reliability, but cables and connectors that transmit their signals do not. Their reliability is so low that the information transmitted cannot be trusted. Correcting these problems should be pursued and, when successful, the development of a modern health monitoring system (similar to those employed in jet aircraft) should be undertaken.

Ref: Finding #18

Space Shuttle operations planning includes provisions for a variety of aborted flight situations in the event of the failure of one or more SSMEs. The particular abort mode to be flown is dependent on the number and timing of SSME failures. Loss of a single SSME leads to one of a series of abort modes known as *intact* aborts. The first of these is the Return to Launch Site (RTLS) abort. It results from the early shutdown of an engine which yields a trajectory without sufficient energy to reach even a Transoceanic Abort Landing (TAL) site. RTLS is currently the only intact abort possible with a single engine failure in approximately the first 160-175 seconds of flight.

If a main engine is lost in the middle of powered flight (from approximately 175 seconds to 300 seconds), the Space Shuttle can fly to a TAL site at Ben Guerir, Morocco; Moron, Spain; or Banjul, The Gambia. The powered flight, external tank separation and entry profiles of the TAL more closely approximate the normal flight profile than do the unusual flight path and maneuvers of RTLS.

When sufficient energy is achieved, the Space Shuttle has the capability to abort by flying once around the earth and landing at Edwards Air Force Base, White Sands Space Harbor or the Shuttle Landing Facility (SLF) at KSC. This is known as an Abort-Once-Around (AOA).

The loss of SSME thrust late in the trajectory still permits the Space Shuttle to Abort-to-Orbit (ATO) at a minimum altitude of 105 nautical miles. The mission can then be continued or terminated "normally" with a deorbit burn and landing.

Loss of two SSMEs results in a *contingency* abort situation. This can require the Space Shuttle to land at a contingency landing site or necessitate a bail-out or ditching. The availability of suitable contingency landing sites is dependent on the inclination of the launch (intended flight path) and timing of the second engine failure. In general, if a second failure occurs while the Space Shuttle is already flying an RTLS maneuver, Bermuda, one of the preferred contingency landing sites, cannot be reached.

Any abort increases risk over normal flight. Therefore, although each of the intact abort types has been "certified" by analysis, avoiding abort situations, especially the more unusual aborts which do not approximate a normal flight profile, is desirable. Hence, ATO is clearly the preferred mode since it is really a quasi-normal operation. The STS 51-F mission executed an ATO when an engine was shut down prematurely late in flight due to a sensor failure. It continued uneventfully and achieved many of its objectives even though the intended orbit was not reached.

RTLS raises several particular concerns because of the unusual flight profile which must be flown. After the Solid Rocket Boosters (SRBs) are separated, the Space Shuttle must continue flying to dissipate propellants in the External Tank (ET). While dissipating propellants, a powered pitcharound must be performed so that the Orbiter is literally flying backwards with the thrust of the remaining SSMEs being used for braking. This is followed by a powered pitchdown before main engine cutoff and ET separation.

The Space Shuttle then executes a pullout and enters the region of Terminal Area Energy Management. The RTLS concludes with heading alignment and a landing at the SLF. The unusual RTLS maneuver leads to several concerns such as overheating from flying into the SSME plume and extremely complex flight mechanics.

Previous examinations have been made of what is required to eliminate or reduce exposure to RTLS by achieving TAL capability sooner in the ascent profile. In general, reducing or eliminating RTLS exposure requires changes in entry trajectory ("stretched entry") as well as an SSME ***abort*** throttle setting above the typical 104% level (at least 109%). For the present engine configuration, the use of 109%, even in an abort situation, was considered undesirable because of the inherent reductions in operating margins at the higher thrust. The upcoming Block II engines, however, are designed to operate at a 109% power setting with margins comparable to (or better than) the current SSMEs at 104%.

In light of the operating flexibility offered by the Block II engines, it would appear prudent to reexamine the entire issue of aborts in detail. Eliminating RTLS should be one objective of this review. The resulting risk reduction and improvement in launch probability would represent significant benefits to the Space Shuttle and ISS programs.

EXTERNAL TANK

Ref: Finding #19
The Super Lightweight Tank (SLWT) is being designed and built for the Space Shuttle to provide a large proportion of the weight savings needed to accommodate the increased payload requirements of the ISS. The liquid oxygen tank aft dome gore panel thickness of the SLWT has been reduced significantly from its initial design on the basis of analytic results. To stiffen the dome, a rib was added.

The current plan to verify the buckling strength of the aft dome involves a proof test only to limit load. This will permit the test hardware to be reused. The problem is that buckling phenomena cannot be extrapolated with confidence between limit and ultimate loads. Thus, the proof test will only demonstrate that the structure will withstand limit load without buckling. In order to provide a sufficient level of confidence, the SLWT aft dome should either be tested to ultimate loads or its strength should be increased to account for the uncertainties in extrapolation.

SOLID ROCKET BOOSTER (SRB)

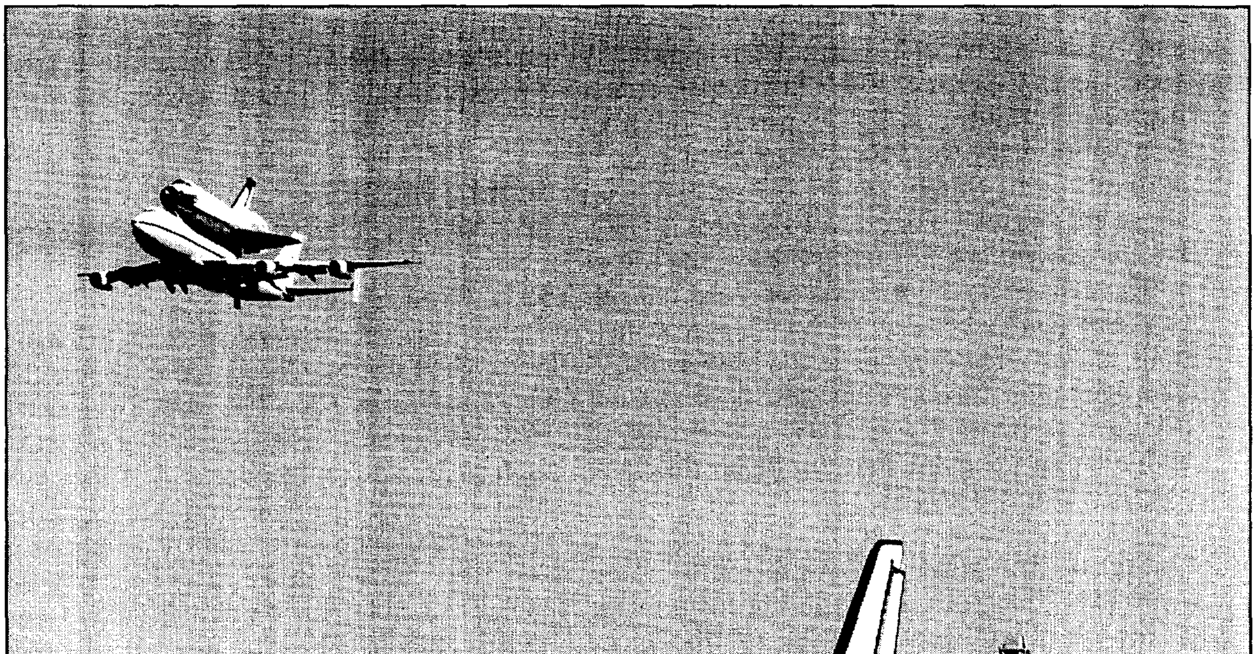
Ref: Finding #20
The addition of an external bracket to the aft skirt of the SRB has been proposed to restore the factor of safety to 1.4. The effectiveness of this modification was to be tested using segments cut from an aft skirt and loaded so that the boundary conditions of stress and strain duplicated those encountered in a previous full scale test of an aft skirt (the "STA-3" test). The first step was to duplicate the baseline conditions with an unmodified segment. This test did not successfully repeat the stresses and strains measured in the STA-3. This suggests that segment testing of the proposed bracket modification to improve the aft skirt's factor of safety may not be valid.

LOGISTICS AND SUPPORT

Ref: Findings #21 through #23
The principal logistics performance measurements such as cannibalization, shelf fill rates, zero/below minimum balance and repair turnaround time showed good to excellent results this year. Cannibalization has shown the expected response to the control being exercised, but is still not at zero and is therefore of concern. The reporting and control systems have reached a mature stage and appear to be very satisfactory for all Space Shuttle elements.

A major effort toward consolidation of logistics activities at KSC has recently been announced which should optimize spares levels, eliminate functional duplication and centralize control and administration. A group has been established to study and recommend final organizational and functional realignments.

The overall benefits of a comprehensive consolidation such as the reduction of unnecessary duplication at KSC are apparent. The decision to omit the Spacelab logistics from the new system appears wise as its requirements and structure are unique and the program is nearing completion.



D. AERONAUTICS

Ref: Finding #24
NASA has entered into an agreement with the Russian Tupolev Design Bureau to support a set of research flights on a TU-144 supersonic airplane. The TU-144 has a questionable safety record, and the particular airplane to be flown has been "mothballed" for years. The level of assurance available for this flight project may not be equivalent to that typically associated with NASA's flight research programs.

The TU-144 program has the potential for assisting in validating design codes used in the High Speed Civil Transport (HSCT) efforts and can thereby reduce the probability of making costly mistakes. However, this depends upon a well conceived program that correlates the data derived from the flight program with predictions. The currently planned experiments include boundary layer measurements, handling quality assessments, propulsion system thermal environment, sonic boom signatures, cabin noise and temperature prediction verifications.

Before the flight program is to be conducted, the aircraft will undergo significant modifications. In addition to being returned to flight status after a long period of storage, the plans include replacing the original engines with a different type adapted from the Blackjack bomber. This will require adapting new nacelles and a digital engine controller. In light of the changes and uncertainties involved in the TU-144 flights, NASA should assure that all design and safety data and operational characteristics of this vehicle have been fully explored.

Ref: Finding #25
Wind shear is created during an atmospheric phenomenon known as a "microburst." This consists of a powerful downdraft that cascades earthward creating rapidly shifting winds. An airplane flying into such a condition can suddenly encounter winds that can reduce airspeed to a hazardous level. Wind shear is a major safety concern even though it occurs infrequently. It has been a causal factor in at least 27 U.S. aircraft accidents between 1969 and 1985 and has been cited as the cause of over 50 percent of accident fatalities in the 1975 to 1985 period. Close calls continue to be reported; the risk still exists.

A National Integrated Wind Shear Program Plan was initiated by NASA and the FAA to develop methods for detecting this atmospheric phenomenon and providing timely information to aircraft in imminent danger of encountering this hazardous condition. The program consisted of three principal elements: (1) hazard characterization—wind shear physics, heavy rain aerodynamics, impact on flight behavior; (2) sensor technology—airborne doppler radar and other instrumentation; and (3) flight management systems—requirements, displays, pilot procedures.

In operational use, the system displays in the cockpit a ***predictive*** wind shear hazard index. The FAA has already published system requirements and certified certain technologies for implementing the system. All national and international carriers will be required to have such a wind shear detection system in the near future—as early as December 1995. The U.S. Air Force already requires this capability on all its transport and tanker aircraft.

The wind shear program is a good example of a productive cooperative research program. Although the work has already been transferred into operations, there is more to be done on the subject of wind shear. For example, radar frequencies other than the X-band which is currently employed might profitably be investigated. Therefore, continued support of research relating to wind shear and other aircraft-threatening phenomena, such as wake vortices, and the transfer of related technologies to industry appears warranted.

Ref: Finding #26

NASA has had a long history of research supporting industry's efforts in tire design and operation. Through the years, aircraft performance has continued to increase placing greater reliance on tire design for safe high speed operation, and for durability in service. Although significant progress has been made, much work remains. Supersonic aircraft, and in particular the future HSCT will require even higher performance from its tires. The Space Shuttle has tires that require replacement after each flight. Thus, there are continuing safety and economic reasons for additional research aimed at developing improved tire materials and designs.

NASA's tire program operates from the Langley Research Center using the Aircraft Landing Dynamics Facility and from the Dryden Flight Research Center (DFRC) using the Convair 990 Landing Systems Research Aircraft. The combination of a flying testbed and a ground-based facility provide researchers with excellent flexibility to study important tire issues.

Ref: Finding #27

The Dryden Flight Research Center has completed a demonstration of the concept of a Propulsion Controlled Aircraft (PCA) system using an F-15 aircraft flight test and an MD-11 simulator demonstration. The PCA system permits an aircraft to be guided to a landing in an emergency using only differential thrust for control. This might have prevented a crash such as the one experienced by the DC-10 at Sioux City, Iowa. With the successful landings in the F-15 and demonstrations with airline pilots in the simulator, the PCA program has clearly progressed beyond the proof of concept stage and identified the potential safety benefits from a full-scale development and deployment of this concept. Now that the concept has been proved and before it is tested in a commercial transport, it is appropriate to address the ***total*** system design of propulsion control. This should include a strong focus on defining and designing the optimum pilot control interface for the system. A basic concern is that an assumption appears to have been made that the standard Mode Control Panel is the appropriate interface. This may not be correct. For example, if a pilot must make any manual throttle inputs, using the Mode Control Panel at the same time could be awkward. For this and other reasons, other control approaches, particularly the use of the standard controls (yoke or sidestick) should be carefully considered. This would result in a control approach similar to the *Control Wheel Steering (CWS)* mode available on many current aircraft.

Ref: Finding #28

The Perseus Program involves Unmanned Aerial Vehicles (UAVs) for environmental research. Last year, the Panel recommended development of a range safety policy at DFRC to be applied to UAVs. Dryden did indeed develop such a policy in coordination with the Edwards Air Force Base (EAFB) test range. This policy had to be applied to a Perseus flight on November 21 when the vehicle diverged at 35,000 feet. The vehicle was lost, but range safety was not compromised. The vehicle crashed in the prescribed range safety area.

Dryden is responsible for operating Perseus flights. An investigation team has been appointed by the Center Director to review this incident. Since the intended use of these vehicles is to provide a research platform for studies in atmospheric science, the Perseus will ultimately have to fly outside of the EAFB protected area. In fact, UAVs such as Perseus may operate in both national and international airspace. Dryden cannot take responsibility alone for these flights. Other U.S. and international governmental authorities must be involved.