stiffer field joint design of the ASRM versus the pinned joints of the RSRM yields the same factor of safety of 1.28. ASRM flight loads are favorably affected by both the larger diameter of the ASRM case and integrated electronics assembly box relocation.

While a factor of safety of 1.28 is considered adequate, radial biasing on the spherical bearings on the holddown posts is required to achieve it. In addition, there is a study underway to improve the strength of the skirt by adding an external bracket or groove in the skin. Due to the planned use of this skirt on the ASRM, the exceptionally low factor of safety at the skirt weld, and lack of a good understanding of the failure mechanism, NASA's safety organization should continue to monitor strain data from each launch to develop an adequate profile. This will establish a truly credible data base for the statistical justification of the low factor of safety.

Ref: Finding #23

It is important to review logistics planning activities early in a program such as the ASRM. Approximately 10 people currently are working on ASRM logistics representing all major contractors and NASA groups. Plans include maintenance, supply and support, transportation, and training. A line replaceable unit (LRU) list has been prepared for flight hardware, and a number of pieces of ground support equipment (GSE) have been identified. Training manual and related document needs have been identified, and transportation barge operations are evolving. A good start on the ASRM logistics has been made.

LAUNCH AND LANDING

Ref: Finding #24

During the past year, several Space Shuttle landings either experienced problems or off-nominal performance. Due to the planned increases in landings at KSC rather than Edwards Air Force Base (EAFB), with its relatively large margins for landing error, it is important to understand the reasons behind any landing problems and develop ways to prevent their recurrence.

The STS-37 landing was extremely short and slow. There were many reasons for the extremely low energy state of STS-37 including:

- The crew had never landed on runway 33 at EAFB and had not trained for its approach because it encroaches on Los Angeles International Airport airspace. EAFB runway 33 approach is not included in the simulators.
- The crew were not given the most precise wind-shear information because:
  - Ground controllers were in a high workload situation that was caused by carrying landing solutions for both KSC and EAFB.
  - Information from the Shuttle Training Aircraft (STA) was not passed along adequately; there is no direct communication between the STA pilot and the Space Shuttle crew.

- The crew's belief, which was reinforced by their training, was that they could make up their energy deficit during the post-heading alignment cone portions of TAEM or as part of approach and landing.

STS-39 experienced some tread loss on the right main gear and some nose wheel abrasion. This has been attributed to a faster than normal landing and drift near touchdown. The right gear crossed the crown in the KSC runway twice at high speed, which contributed to the tire wear. The safe limit of the tire (6 plies) was not reached as only three plies were damaged.

There were many lessons learned from analyzing the STS-37 and STS-39 landing anomalies. Some already have resulted in changes in procedures and training. Overall, a heightened awareness of possible landing problems seems to have emerged. A continued focus on communications and decision-making during landing as well as the process of energy management would seem to be warranted.

Ref: Findings #25 through #30

The task team concept that has been implemented at KSC is an approach to involving hands-on leadership at the task level. One of its benefits is that it keeps jobs moving without sacrificing quality, control, or safety. It also brings together all personnel needed to perform a particular job in conjunction with an identified leader and places responsibility at an operationally realistic level. Specific training on operating within a task team environment has been developed and used by the Shuttle Processing Contractor (SPC). Task team leaders are selected from the ranks of engineers and technicians as appropriate.

The task team leader concept has not yet been widely introduced formally into Vehicle Assembly Building operations. However, the operations concerned with solid rocket booster (SRB) stacking and external tank (ET) attachment have developed many similar characteristics. These include a stable workforce that has developed a team approach, authority to accept verbal deviations with subsequent documentation, and direct engineering support and involvement.

In addition to the introduction of task teams, a joint NASA/SPC Steering Committee has been established to oversee and improve launch processing. The Steering Committee developed its "Top Ten" agenda from 250 potential improvements that could be undertaken. As improvements are completed, new targets are to be added to the active list. The general revision of all Standard Practice Instructions (SPIs), underway for the past 6 months, has been a major source of recommended changes that the Steering Committee has pursued. The workforce has been directly involved in these revisions. The objective has been to achieve simplification of SPIs and streamlining of the processes.

Other targets of Steering Committee activity include signature reduction, reduction of witness inspections in favor of greater surveillance and verification, and avoiding steps that do not add value. Additionally, the concept of a designated verifier (where a certified technician hand stamps his/her work such as in airline maintenance/inspection) is being presented to Level I management for acceptance. A shop data collection system is now in place to identify the sources of delays in Space Shuttle processing. This system, originally planned for inclusion in the Shuttle Processing Data Management System II (SPDMS II), was developed as a stand-alone because of delays in SPDMS II development and implementation. It will be important to ensure that this subsystem as well as others like it that have sprung up to fill specific needs are adequately accounted for in the final SPDMS II design. This can best be accomplished by ensuring involvement of system users in the SPDMS II design and implementation process.

LOGISTICS AND SUPPORT

Ref: Findings #31 through #38

Although some problems persist, the Space Shuttle support programs are generally in very satisfactory condition.

The Integrated Logistics Panel (ILP) is an essential component of the overall logistics and support activities for the Space Shuttle. In 1991, there were three ILP meetings. At these meetings, presentations were made on subjects germane to the activities of the meeting host site. The wide-ranging issues that were covered in detail included trend management reporting; development of computer tracking systems; control, use, stocking, and disposal of hazardous waste; and interface problems among Centers and contractors. The meetings provide for good working-level integration and interchange on all aspects of the Space Shuttle logistics programs.

The Logistics Management Responsibility Transfer (LMRT) function was initiated to coordinate the transfer of management skills, equipment, and funding to the KSC vicinity to the maximum extent practical for greater overall launch efficiency. LMRT involves transfer of both NASA and contractor resources. It appears that the present atmosphere surrounding LMRT within the NASA Centers is one of cautious retrenchment, thus slowing the transfer of resources. For example, the memorandums of agreement (MOAs) for transfer of SRB, RSRM, and SSME flight and GSE hardware are all being reevaluated. Other activities, such as thermal protection system, are proceeding as planned. Other issues, such as the Fleet Leader Program to determine the best supportability and repair strategies for the orbital maneuvering system and reaction control system hardware, are being reviewed for transfer to KSC.

This year's work at the NASA Shuttle Logistics Depot (NSLD) concentrated upon meeting the goals for the number of certifications contemplated and on achieving much faster turnaround for component repair and overhaul. However, statistics on the number of certifications completed can be very misleading because some can be completed in 18 months whereas others, like the multiplexer/demultiplexer (MDM), may take as long as 2½ years to perfect using the advanced Automatic Test Equipment (ATE) installed at Cocoa Beach. The schedule calls for the acceptance of six MDM units in 1992 and seven other MDMs in 1993. Although the effort is expensive and time-consuming, there is good reason to believe that eventually an almost routine checkout can be achieved using the ATE.

On the matter of reducing component turnaround time for the combined NSLD and original equipment manufacturer activity, the latter months of 1991 have shown some illuminating data (Figure 5). The overall workload for repair at the NSLD is now increasing to the point that the backlog is becoming significant. An example of the savings in component repair turn-around time (RTAT) for the rate gyro assembly refurbishment on the SRB shows an average of 105 days versus 160 for the OEM and a cost of $7,936 versus $31,000. While not all of the components being repaired or refurbished by the NSLD have shown such spectacular gains, the important issue is that they are now under the control of NASA so that appropriate priorities may be assigned to meet launch supply needs.

Figure 6 shows the history of cannibalizations for recent flights. The controls over the problem have been noted in previous ASAP reports. Whereas about five cannibalizations per vehicle were reported after STS-26, the average number is now down to two. A few repeat items still are involved. For example, TACAN equipment and cables still were being swapped from OV-102 and OV-105 for OV-103 on its recent launch (STS-48). During the last 10 flights with three vehicles in the processing flow, there have only been nine vehicle repairable items, three government furnished equipment items, and eight secondary structural items provided by cannibalization. Overall, this is satisfactory performance for a limited fleet of complex vehicles.

Component RTAT performance is improving with an overall average RTAT through the NSLD of 45 days against a previous 180 days for OEM-handled components. The NSLD management appears to be working hard to further improve this encouraging performance. One of the problems is that of "streamlining" the paperwork. A typical instance showed a particular part being "logged in" no less than 17 times before reaching the workbench for actual hands-on repair work. Figure 7 shows the reparable line replaceable unit (LRU) fill rate up to STS-42. This parameter is judged to be highly satisfactory at the present time. The overall average fill rate of 92 percent is probably due mostly to improvements in repair cycles.

Finding #37 discusses the "zero balance" (or "none in stock") and those items for which the stock is below the established minimum safe levels. The chart shown in Figure 8 indicates a recent sharp rise probably due mostly to the introduction of OV-105. This problem has the attention of logistics management personnel.

The problem of out-of-production spares, or in NASA terminology "Pending loss of repair/spare capability," can only continue to worsen. In the majority of cases, the principal solution must lie in the extension of NSLD capabilities. Obviously, some components will defy the repair capability of even a well-funded NSLD. With total wear-out of these parts, the only recourse is to institute some redesign and modification action to keep the systems working. Lists of critical vendors and their components are being drawn up. Although this situation is receiving energetic middle management attention, further help may be required from the higher echelons.

The general situation of availability of spare SSMEs (which are supported directly by Rocketdyne out of their Canoga Park facilities) is satisfactory at the present time. The history of cannibalization within the SSME engine shop is shown in Figure 9; the spares requested versus those filled shows a very satisfactory performance. Use of expensive commercial air cargo or other airline charter flights for turbopumps virtually has been eliminated by the introduction of new shipping containers. Current issues including hydraulic actuators, bolt and seal surveillance due to stretched bolts, and nozzle insulation kits, are being handled in routine fashion.

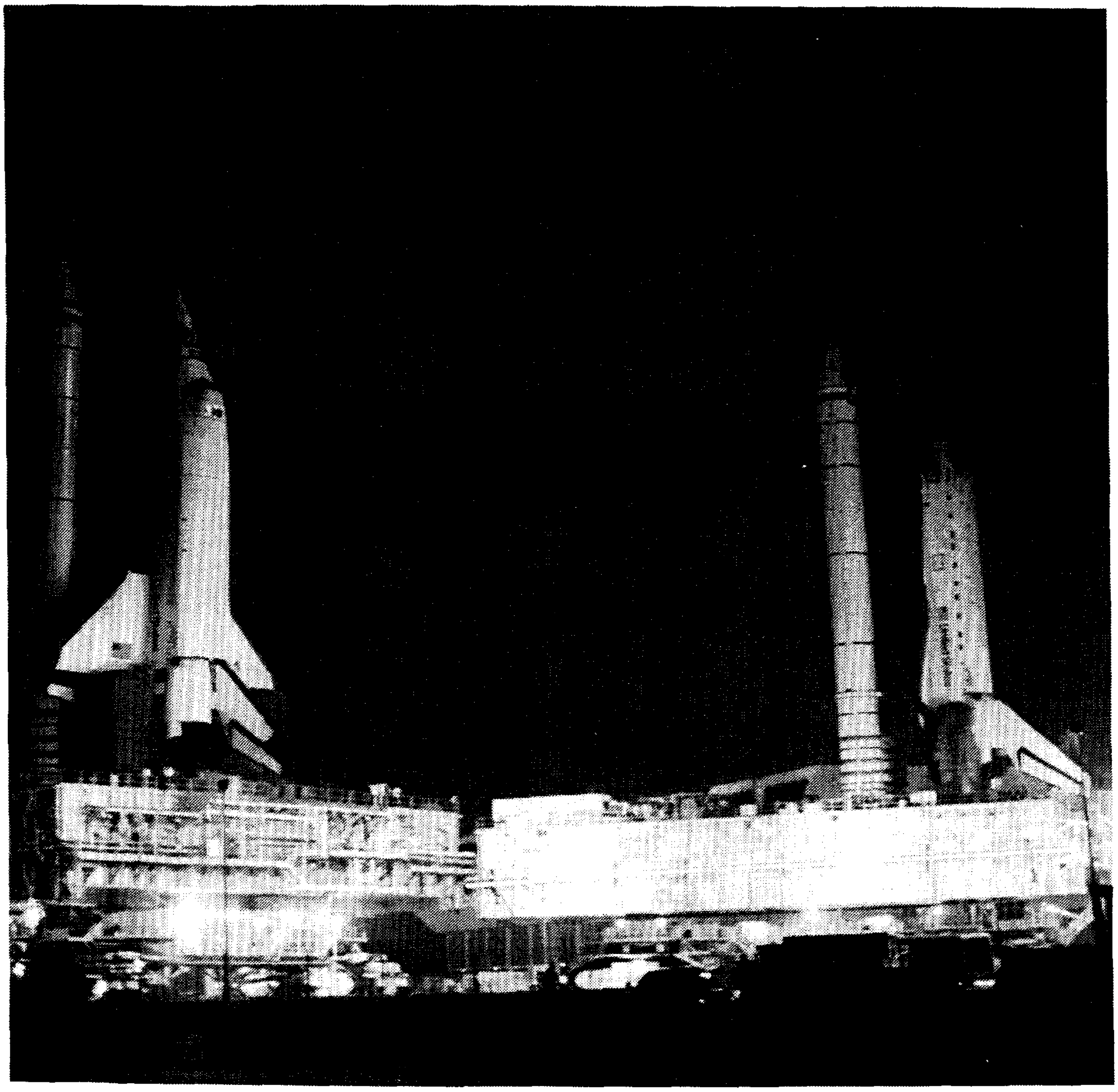
All logistics measurement parameters for the RSRM such as cannibalization, fill rates, zero/below minimum balance, RTAT, and pending loss of spare or repair capability were in the desired range. In addition, Thiokol has full support capabilities at its Brigham, Utah facility. There has been no cannibalization on the RSRM. All repairs of LRUs are done on a "real-time" replacement basis in the Thiokol Wasatch facility. Overall, inventory control accuracy presently is running at 95 percent with a target of 100 percent. This is a very impressive performance.

United Space Booster, Inc., (USBI) handles the SRBs at KSC and in their support facilities nearby. They report no cannibalizations. Fill rate and zero/below minimum balance issues do not arise because production assets are used. USBI can repair all on-site items except the lube oil accumulator; an agreement is being made with an alternative vendor for this item. Only six components have been selected for off-site repair; there are no concerns about support by these OEMs. RTAT for some elements of the thrust vector control system are lengthy. The paperwork is said to be taking longer than repair of the hardware. USBI is developing their own simple test set for checkout of some of the electrical and instrumentation components to eliminate some of the comprehensive test routines now being accomplished. Off-site repair and recertification is used in the cases of the hydraulic pumps, servo-actuators, and APUs.

A large number of logistics-related annual audits are now being conducted by various agencies such as NASA, the Air Force, and the Department of Defense (DoD). Transfer of selected elements of GSE and commercial consumables is being made from MSFC/USBI to KSC Lockheed Space Operations Co., under the aegis of the LMRT program. An in-production control system (IPCS) is employed by USBI to support the Space Shuttle by minimizing the inventory investment. The IPCS is based on a predetermined flight rate rather than an "initial lay-in" of spares. Considerable economic and control advantages are derived from the IPCS. A state-of-the-art integrated electronics assembly (IEA) test set is being developed at the USBI Slidell facility to perform intermediate and depot-level maintenance. The test procedures are being simplified in the light of experience. The general assessment is that the USBI/SRB logistics and maintenance work is evolving well and is being managed competently. The only concerns appear to be storage capacity and the status of some parts suppliers. A new facility is to be built and will be available in 1994.

ET production and supportability trends appear to be on a steady track with all parameters in the desired range. Fill rate, zero balance, and below minimum stock are under control. Some pending issues of repair/spare capability are being worked out. There have been no cannibalizations and LRU replacements are declining. RTAT issues present no problems for the ET because items are replaced within 24 to 28 hours from production assets. Overall, performance is very satisfactory.

LMRT activities for the ET are proceeding and the transfer MOA has been approved. Single-source vendor activities on four items are being pursued. An ET GSE plan to recertify every 10 years by analysis, repair, and replacement, currently is being reviewed. ET logistics have initiated state-of-the-art procedures through several dedicated teams including a lively Total Quality Management (TQM) approach.

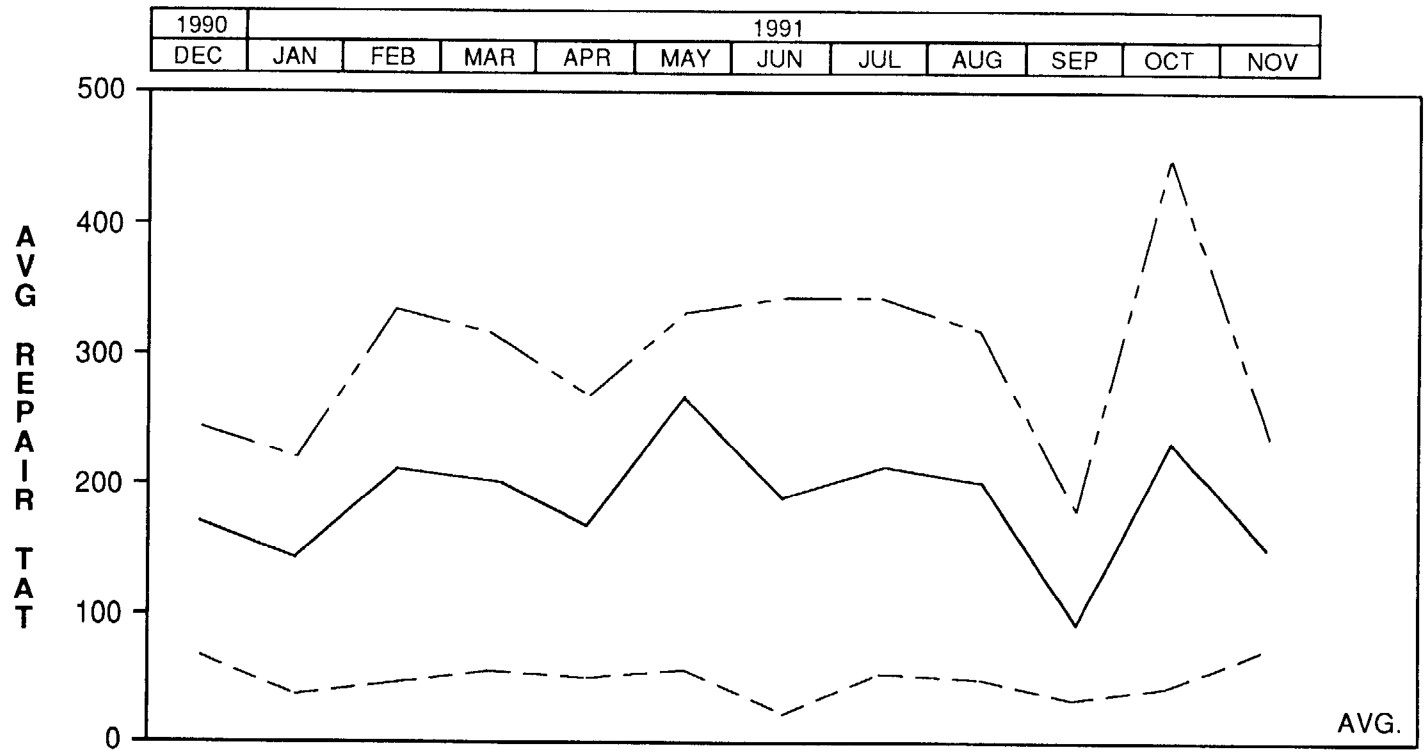


MAINTENANCE TREND ANALYSIS REPORT

ORBITER HARDWARE REPAIR PROCESSING

–OEM'S/NSLD REPAIR TURNAROUND TIME (RTAT)

OHRP-3



	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	AVG.
OEM'S RTAT ------	243	220	333	315	268	338	344	342	318	179	*464	233	300
NSLD RTAT ———	68	37	46	55	51	55	21	53	52	33	45	71	49
COMBINED RTAT — — —	170	142	208	204	167	272	188	212	201	93	233	146	186
PRR'S COMPLETED													
OEM'S PRR's:	35	64	84	78	53	46	62	61	61	36	60	43	57
NSLD PRR's:	25	48	65	58	46	14	58	50	48	52	74	50	49
TOTAL PRR's:	60	112	149	136	99	60	120	111	109	88	134	93	106

NOTE: 1. HISTORICAL FIGURES ADJUSTED PERIODICALLY TO REFLECT REPAIR DISPOSITION CHANGES.

2. * = RTAT SKEWED OCTOBER 1991 DUE TO EMPHASIS ON CLEARING REPAIRS BACKLOGGED > 12 MONTHS.

NOVEMBER 1991

DATA SOURCE: RIC KSC

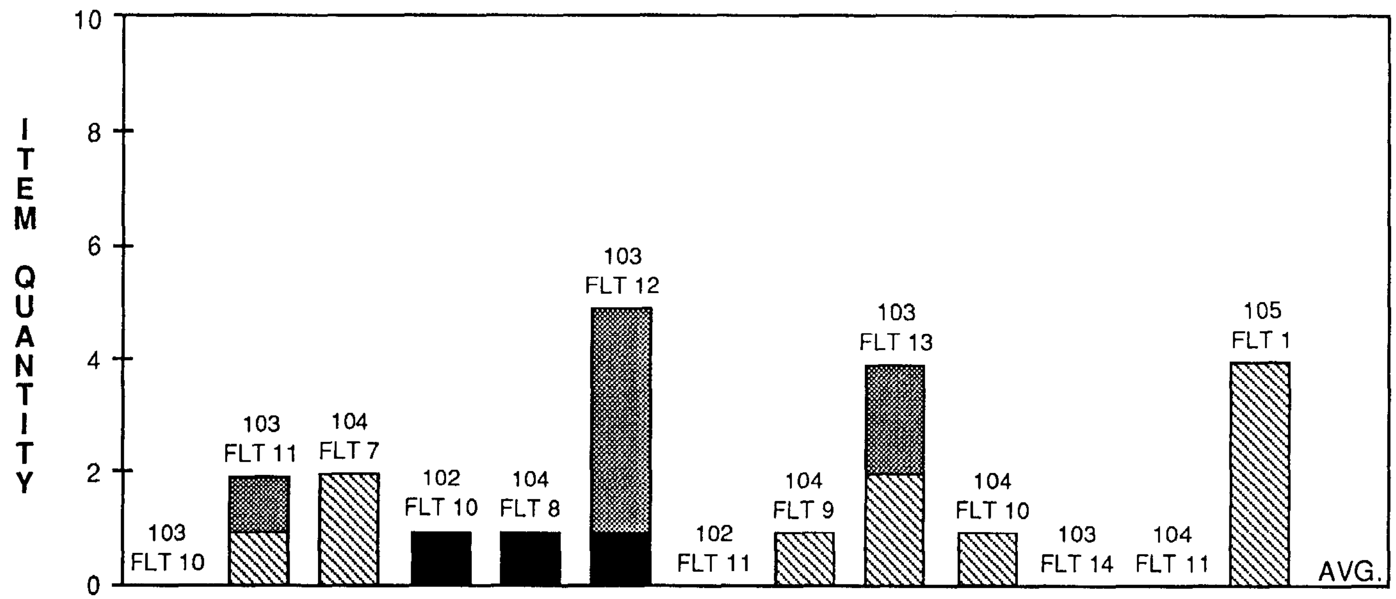
Figure 5. Orbiter Hardware Repair Processing

MAINTENANCE TREND ANALYSIS REPORT

ORBITER CANNIBALIZATIONS

VEHICLE & GFE/MISSION KIT CANNIBALIZATIONS

CN-1



	STS-31R	STS-41	STS-38	STS-35A	STS-37	STS-39	STS-40	STS-43	STS-48	STS-44	STS-42	STS-45	STS-49	AVG.
JSC GFE/MSN KIT ITEMS	0	0	0	1	1	1	0	0	0	0	*0	*0	*0	0.3
VEH REPARABLE ITEMS	0	1	2	0	0	0	0	1	2	1	*0	*0	*4	0.7
VEH NON-REP ITEMS	0	1	0	0	0	4	0	0	2	0	*0	*0	*0	0.7
TOTAL CANNS	0	2	2	1	1	5	0	1	4	1	*0	*0	*4	1.7

NOTE: * = INTERIM COUNT AS OF 12-3-91; NOT INCLUDED IN AVERAGE

NOVEMBER 1991

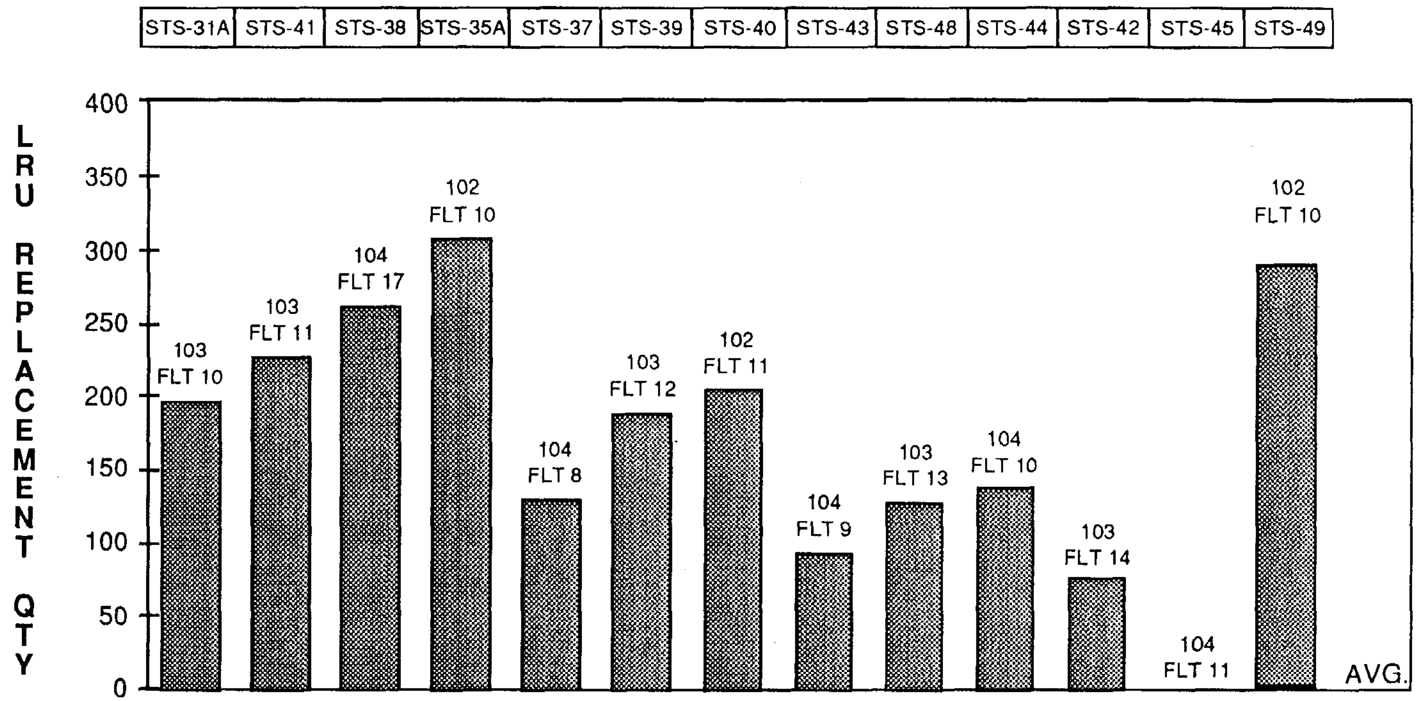
DATA SOURCE: LSOC LOG ENGRG

Figure 6. Orbiter Cannibalizations

MAINTENANCE TREND ANALYSIS REPORT

ORBITER REPARABLE LRU FILL RATE BY REPLACEMENT SOURCE

LR-2



LRU SOURCE	STS-31A	STS-41	STS-38	STS-35A	STS-37	STS-39	STS-40	STS-43	STS-48	STS-44	STS-42	STS-45	STS-49	AVG.
FROM CANNIBALIZATION	0	1	2	1	1	1	0	1	2	1	0	*TBD	*4	1
FROM STOCK/RECEIPTS	199	228	262	309	130	190	206	94	128	141	79	*TBD	*281	189
OPEN REQUISITIONS	0	0	0	0	0	0	0	0	0	0	0	*TBD	*2	0
TOTAL	199	229	264	310	131	191	206	95	130	142	79	*TBD	*287	190

% FROM STOCK/RECEIPTS	100	99.6	99.2	99.7	99.2	99.5	100	99.0	98.5	99.3	*100	*TBD	97.9	99.5

NOTE: 1. * = INTERIM FLOW COUNT (AS OF 12-3-91); NOT INCLUDED IN AVERAGE.
2. "FROM CANNIBALIZATION," QUANTITIES INCLUDE REPARABLE ITEMS FROM THE VEHICLE AND JSC GFE/MISSION KIT.

NOVEMBER 1991 DATA SOURCE: RIC LOG/LSOC LOG ENGRG

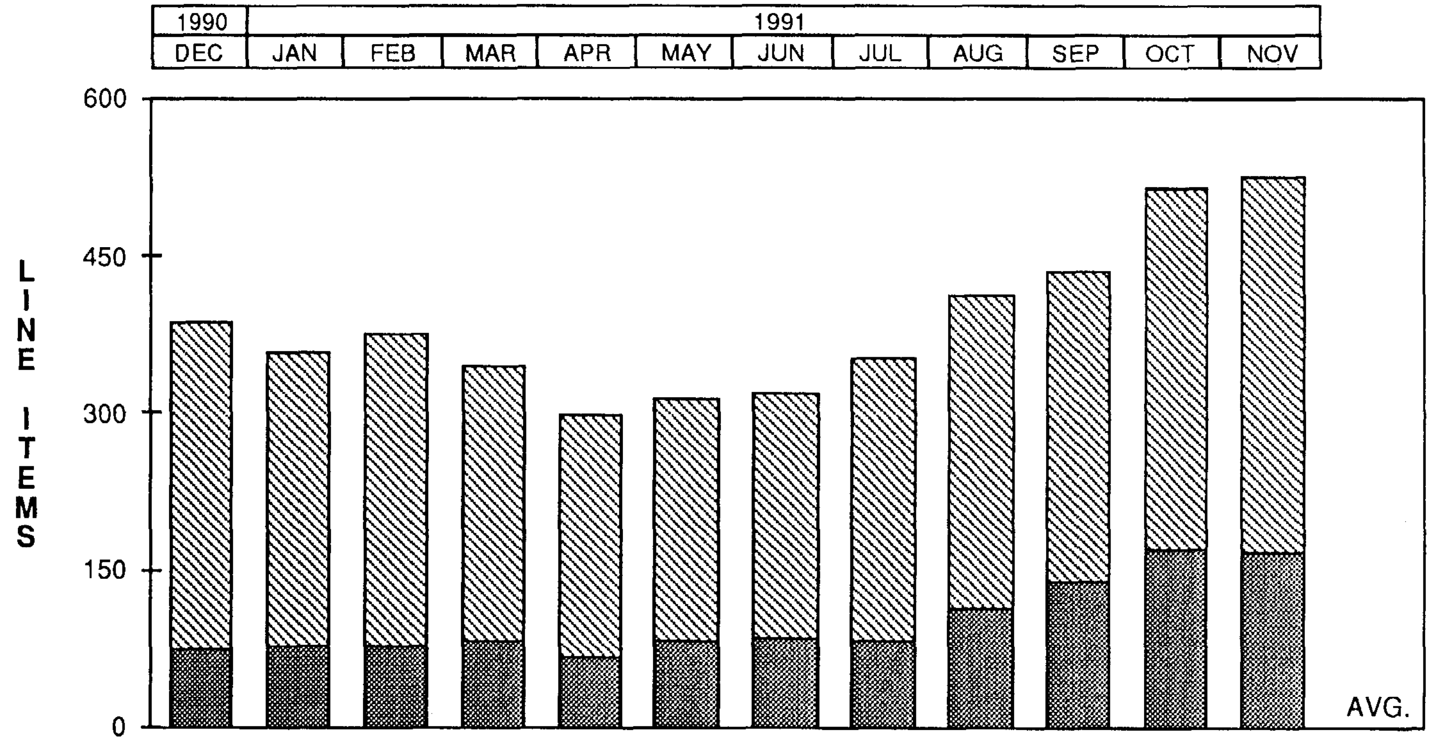
Figure 7. Orbiter Reparable LRU Fill Rate by Replacement Source

MAINTENANCE TREND ANALYSIS REPORT

ORBITER INVENTORY SITE SUPPORT

–INVENTORY BELOW ESTABLISHED LEVEL–

ORBINV-3



	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	AVG.
QTY 0 BALANCE	76	80	79	85	69	85	87	84	116	141	172	171	104
QTY BELOW MIN	315	284	301	264	235	235	238	273	301	298	347	357	287
TOTAL	391	364	380	349	304	320	325	357	417	439	519	528	391
Ø BAL ADDED	22	31	21	30	26	34	24	21	40	64	62	55	36
Ø BAL CLOSED	21	27	22	24	42	18	22	24	8	39	31	56	28

NOTE: EFFECTIVE OCTOBER 1991, FIGURES INCLUDE LINE ITEMS PREVIOUSLY MANAGED UNDER SCHEDULE B.

NOVEMBER 1991

DATA SOURCE: RIC LOGISTICS

Figure 8. Orbiter Inventory Site Support

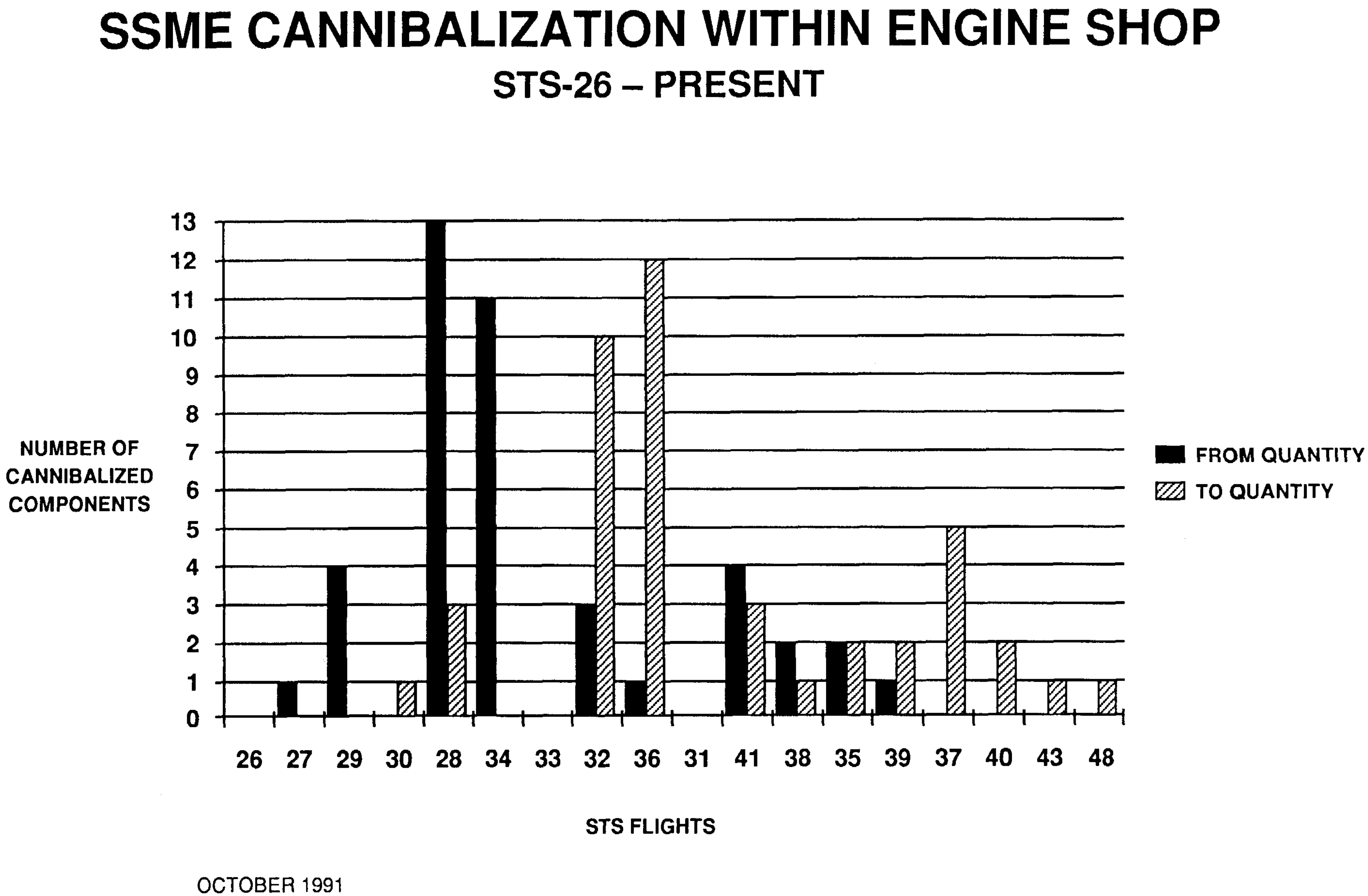


Figure 9. History of Cannibalization within the SSME Engine Shop

C. AERONAUTICS

Ref: Finding #39

On August 12, 1991, NASA Management Instruction (NMI) 7900.2 on aircraft operations management was signed. This NMI deals with critical functions needed to ensure safe administrative aircraft operations. It is understood that a companion delineation of aviation safety requirements in the basic safety manual is contemplated to complete the establishment of a proper aviation safety management organization and Agencywide statement of the philosophy of aviation safety. A Headquarters organization to coordinate flight policies throughout NASA is needed to obtain the maximum operational and safety value from these various policy statements.

Ref: Finding #40

In the current year, the ASAP only examined the aeronautical flight research programs at the Dryden Flight Research Facility (DFRF). Significant effort also is ongoing at the Langley and Ames Research Centers; the Panel has reviewed these in past years.

DFRF has established an impressive array of test vehicles, which include the X-29s, F-16XLs, SR-71s, F-18, F-15, F-104G, B-52B, T-38, and PA-30. The B-52G is programmed to replace the B-52B. The aircraft are a national asset, and should be maintained and programmed for flight research tests at a high utilization level.

The F-18 High-Angle-of-Attack Research Vehicle (HARV) program includes a massive thrust vectoring apparatus mounted on the tail section that (with ballast) weighs approximately 2120 pounds. It reduces the maximum Mach number of the F-18 from 2+ to 1.2. The flight control system modifications have been tested in the simulator, and one closed loop (pitch and yaw) flight has been completed. The system currently is cleared to a 20-degree angle-of-attack (AOA) with a potential to trim to a 70-degree AOA. A follow-on activity will incorporate forebody control blowing in the nose for yaw control experimentation.

The X-29 AOA program has completed 85 flights with very stable controllability up to 45 degrees. The vehicle has been flown to 70 degrees; however, loss of vertical tail effectiveness causes a reduction of yaw control above 40-degrees AOA. A strong forebody/wing vortex impinges on the vertical tail. This can cause a fatigue problem and needs to be monitored.

The F-15 Highly Integrated Digital Electronic Control (HIDEC) program has completed 36 flights. It has demonstrated excellent performance gains by implementation of its real-time, adaptive optimization of the flight control, engine, inlet, and engine nozzle. Of great importance is the propulsion-only flight control for landing with no or reduced control of the aerodynamic surfaces. This has application to both civil and military aircraft.

The SR-71B (two-seat) is to be flown for a year to assess and determine a set of research programs than can best be performed on this aircraft. NASA is fortunate to have been given a wealth of spare parts by the Air Force. Also, the SR-71B had completed its periodic depot maintenance check prior to being assigned to NASA. Two SR-71As have been acquired by NASA and are being placed in flyable storage pending the definition of suitable flight test activities.

The F-16XL aircraft currently is being flown to evaluate the ability to produce laminar flow in the surface of a highly swept (65 degrees on the leading edge) supersonic wing. A portion of the left wing has been fitted with a glove containing suction holes for removing the boundary layer. A turbo-compressor is mounted in the fuselage to produce the wing suction. Concerns were expressed over the potential for turbine wheel failure with potential ensuing damage to the aircraft. The flight tests were begun in March 1991.

The B-52 currently is being used as a launch vehicle for the Pegasus space vehicle. The first two of the planned six flights have been accomplished successfully. The gross weight of the Pegasus is approximately 42,000 pounds, which is well within the load carrying capability of the NASA B-52 pylon that previously was used to launch the X-15 aircraft.

Another interesting test program utilizes the Convair 990 aircraft for dynamic tests of the Shuttle landing gear. The Orbiter speeds and weights can be duplicated to evaluate tire wheel performance on various landing surfaces.

Overall, the assessment of the ASAP is that these programs are being managed with an acceptable emphasis on flight safety through a rigorous process of analyses and safety reviews.

D. OTHER

Ref: Finding #41

Reports from crew members on extended Space Shuttle missions that involved two shift operations indicated that they experienced some difficulty in achieving restful sleep. This phenomenon is not unusual when circadian rhythms must be shifted. These problems are similar to those experienced by aircraft flight crews in long-haul operations. A program of research and countermeasure development on crew rest cycles and circadian rhythm shifting to support both Space Shuttle and Space Station operations is needed to address this problem. This program could productively be modeled after the ongoing NASA aircrew research being conducted at the Ames Research Center (ARC).

Ref: Finding #42

In analyzing the causes of aircraft accidents and near accidents over the last decade or more, case investigators have come to rely increasingly on clues furnished by experts in human engineering. Individualistic behavioral patterns performed under stress, in some instances, have been identified as prime contributors to the accidents. Extensive worldwide military and civil aviation has provided a broad data base for such analyses. In contrast, the data base for manned spaceflight and associated ground operations is relatively small and of recent origin. As a consequence, little interest has been shown in harnessing this discipline to spaceflight programs. Nevertheless, as Space Shuttle flight duration is increased to 30 days or more, and SSF is activated, the potential for accidents attributable to human error will increase. For example, sleeplessness and boredom have been highlighted as the reason for several airplane accidents. Therefore, the time may be opportune to enlist the insights of human engineering to help prevent accidents in the manned space programs attributable to such situations.

NASA possesses competent in-house capabilities in human engineering, especially at ARC and JSC. ARC, in particular, has made frequent contributions affecting aviation safety whereas JSC's role principally has involved astronaut's experiences in spaceflight. Coordination and information exchange between these two Centers has not been as effective as it might be; this is partially due to the different programmatic responsibilities. However, with the beginning of operational planning for SSF, NASA should bring about a closer relationship between these programs and potentiate efforts to enlist human factors research as an agent to prevent human errors in space activities.

Ref: Finding #43

NASA has a hierarchy of reporting systems for mishaps and incidents. Formal documentation, including NMI 8621.1, which is currently in revision, defines the various levels of mishaps and investigation and reporting requirements. At the top level, NASA operates the NASA Safety Reporting System (NSRS). Although named and modeled after the Aviation Safety Reporting System

(ASRS), that NASA runs for the FAA, NSRS is not its analog. ASRS was designed to provide data on near-misses and human errors in the aviation system (pilots, controllers, and mechanics), which otherwise would have gone unreported because they did not result in property damage, injury, or a detected violation. It is a voluntary system of self-reports with the reporter being granted limited immunity in some cases.

NSRS was developed in the aftermath of the Challenger accident to provide a direct line to NASA top management so that people in the system at any level could surface a safety concern if they believed it to be of sufficient importance. It perhaps is unfortunate that NSRS was named after ASRS because their objectives are quite different.

Even though it is lightly used, NSRS provides a valuable service by providing a potential safety valve for reporting Challenger-like situations. However, NASA has no system analogous to ASRS that allows people to report their own errors or near-errors in an anonymous manner ***at the local level.*** The new task team approach emerging at KSC encourages some reporting of this type but appears neither to structure it nor to provide any expert analysis of the information collected.

NASA is lacking a mechanism for reporting those events in which an error happens and is recognized by the person involved or an observer but does not result in a defined accident, incident, close call, or reportable violation. For example, a technician working on a fuel cell might momentarily cap a vent line that is not to be capped but immediately realize his/her error and remove the cap before any damage occurs. Likewise, someone may start to turn a bolt the wrong way but realize the mistake before the action takes place. These types of situations do not get attention unless someone involved perceives a fix. In this case, a suggestion may be generated to management in the hope of receiving some recognition. Otherwise, the situation goes largely unreported.

Because the existing reporting systems go outside the local environment (e.g., to Safety or to Center or Headquarters management) it is likely that a "near-error" is perceived as too inconsequential to warrant a report. This is exactly the opposite of the ASRS situation in which pilots, controllers, etc., have been encouraged to make a report of any such event, no matter how insignificant it seems. Trained analysts then can look across events for patterns indicating an emerging problem or within a particular occurrence for possible remedies.

The clear benefits from collecting information on human errors does not imply that an additional, highly structured reporting system is required. Inclusion of a training module for task teams and quality working groups might be sufficient if a way were devised to amass and analyze the information over time. The major benefit of systems such as the ASRS is that they permit trained analysts to spot emerging safety problems and trends before they lead to accidents.

Ref: Finding #44

There were two indications of a quality control problem having to do with the Tethered Satellite System (TSS) program. The first occurred when a spare clutch to the vernier motor failed its acceptance test due to the failure of bonding between the rotor and the cork clutch material. The shelf life of the bonding had been exceeded. A question exists regarding the flight clutch because the bonding material shelf life is uncertain. Investigation revealed that neither the flight article nor the failed spare unit had an adequate build paper with quality assurance acceptance. There are two other flight clutch assemblies that do possess the proper documentation.

The primary control of the trajectory of the TSS is the rate of extension or retraction of the tether. Since an accurate analytical prediction of the system dynamics is directly related to the ability to control roll, all components of the system, including the clutch, should be without operational uncertainties.

The other problem involved a shipment of 15-5 stainless steel material that was marked incorrectly as not needing heat treatment. It was used erroneously to manufacture 18 parts in the mechanism that deploys the TSS. Therefore, these 18 parts have a lower hardness and strength than was intended -- assuming they had been heat treated. Initial investigation by NASA and Martin Marietta indicate the parts will not have a critical impact on the operation or safety of the TSS.

Ref: Findings #45 and #46

Current plans for long-term use of the Space Shuttle, and assembly and operation of the SSF suggest a continued and increasing need for extravehicular activities (EVAs). Although excellent efforts have been mounted and are ongoing to reduce the need for EVAs whenever possible, contingencies, design requirements, and economics each will dictate the need for some EVA activities. These EVAs must be supported by an appropriately designed extravehicular mobility unit (EMU) and associated space suit. For example, current projections for the on-orbit repair of the Hubble Space Telescope (HST) call for three separate EVAs, each lasting over 6 hours. This is a more ambitious EVA profile than previously has been attempted.

As the demand for both the number and duration of EVAs increases, the benefits possible from an improved EMU and suit to support them become clear. Existing suits and their associated portable life support system (PLSS) have several characteristics that limit their flexibility and utility. They operate at low pressure thereby requiring extensive prebreathing of pure oxygen to avoid problems associated with nitrogen bubbles in the blood ("the bends"). This could be severely limiting if an emergency EVA or an EVA evacuation is needed from the Space Station. Even if sufficient prebreath time is available, this activity places additional workload on the EVA crews, which might be more productively allocated to the EVA activity. This, in turn, could potentially reduce the number of EVAs required because crew members could work more productively and accomplish more on each EVA. In addition, the refurbishment and sizing of the existing suits is extremely time-consuming and labor intensive and can now only be fully accomplished on the ground.

NASA already has explored the technology needed to overcome these problems. Two programs, the AX-5 at the ARC and the Mark 3 at the JSC, have built and tested prototype suits that do much to overcome the problems inherent in the current design. Neither the AX-5 nor the Mark 3 are complete solutions to all of the problems inherent in having humans work in space. However, they successfully have demonstrated that a more flexible design capable of on-orbit maintenance and sizing and eliminating or reducing prebreathing requirements is possible. They have further demonstrated that there are no significant technological issues associated with producing these improvements.

Existing budgetary constraints have prompted the deletion of most funding for completing development of an advanced suit and EMU. Because the existing suits continue to perform satisfactorily on Space Shuttle missions, a decision to defer some or even most of the costs of developing a new suit is not unreasonable. However, it is clear that the ultimate implementation of SSF can be greatly enhanced by an improved suit design. Therefore, NASA should commit to specification and development of a new suit, and establish its implementation schedule consistent with budget availability. One possible pathway to upgrading the suit design would be to couple the existing PLSS with a new suit based on AX-5/Mark 3 technologies. The PLSS could be modified to operate at a higher pressure to reduce prebreathing time and take maximum advantage of the design qualities of the new suits. As funds and time permit, the PLSS could be replaced with an upgraded EMU that could be based, in part, on lessons learned from the already planned extended EVAs for HST repair and Space Station assembly. It also would seem wise for NASA to support the research necessary to characterize more fully the bends risk associated with micro-gravity EVA activities. Existing tables relating prebreathing time and atmospheric pressure are based on pressure chamber and deep sea diving experience. While these are good analogies, they ignore the influence of micro-gravity and the exertion levels expected of EVA astronauts. NASA has the research expertise and the data collection opportunities during on-ground simulations and Space Shuttle flights to collect the data necessary to clarify this issue. A potential side benefit of conducting this research would be a significant clarification of the need for and use of hyperbaric airlocks on the Space Station.

IV. APPENDICES

APPENDIX A
NASA AEROSPACE SAFETY ADVISORY PANEL MEMBERSHIP

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Aerospace Consultant
Former Vice President, Engineering
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MR. GEORGE A. RODNEY
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MR. ARTHUR V. PALMER
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MS. PATRICIA M. HARMAN
Staff Assistant

APPENDIX B
NASA RESPONSE TO MARCH 1991 ANNUAL REPORT

SUMMARY

In accordance with the Panel's letter of transmittal, NASA's response dated June 17, 1991, 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 Panel considers that the following 3 of the 34 original items noted in the June 17th response are "open" at this time:

Finding/Recommendation No. and Subject		Comments
#2	Space Shuttle Autoland System	The Panel will continue to follow the Autoland progress.
#4	Space Shuttle Software Verification and Validation	The Panel will revisit this system.
#10	Integration of ASRM/RSRM Plan	Schedule problems warrant Panel review.

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Office of the Administrator

JUN 17 1991

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

Dear Mr. Parmet: Norm

In accordance with your introductory letter to the March 1991 Aerospace Safety Advisory Panel (ASAP) Annual Report, I am enclosing NASA's detailed response to Section II, "Findings and Recommendations."

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

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

Sincerely,

Richard H. Truly
Administrator

Enclosure

FINDINGS AND RECOMMENDATIONS

A. SPACE SHUTTLE PROGRAM

SPACE SHUTTLE ELEMENTS

Orbiter

Finding #1: NASA has planned to implement the wing/fuselage modifications indicated by the results of the 6.0 load analysis. Modification work has been scheduled for OV-102, and plans are being developed for the remainder of the fleet.

Recommendation #1: The implementation of these modifications should be accomplished as soon as possible so that the restricted flight envelope (green squatcheloid) parameters can be safely upgraded.

NASA Response: Concur. Modifications are scheduled for each vehicle's Orbiter Maintenance Down Period (OMDP). The OMDP has been incorporated into the Space Shuttle Program to provide dedicated times for performing detailed vehicle structural inspections, subsystem inspections and internal functional checks as well as modifications. All vehicle modifications will be complete by mid-1993.

Finding #2: The uncertainties surrounding crew performance after extended stays in space suggest a need for an alternative to manual landings.

Recommendation #2: The Space Shuttle Program should complete the development of a reliable autoland system for the Orbiter as a backup.

NASA Response: Concur. The existing Shuttle autoland system is certified and is a reliable backup for 16-day Extended Duration Orbiter missions. A significant program to collect crew performance data is being undertaken by the Office of Space Science and Applications during flights involving incremental increases of on-orbit duration. Current plans involve flying four 10-day flights and three 13-day flights prior to the first 16-day flight. Crew performance data will be evaluated and must be judged acceptable prior to commitment to the next increment of extended duration.

Finding #3: With plans to extend Orbiter use well into the next century, it will be necessary to upgrade the Orbiter computer systems several times. The present, rather ad hoc, approach of treating each upgrade as an independent action will be unsatisfactory for the long term.

Recommendation #3: NASA should accept the need for an upgrade involving a complete software reverification approximately every 10 years. A study should be undertaken to plan a path of evolution for all future changes in avionics computer hardware and software for the life of the Space Shuttle Program. The study should involve independent assessment to ensure the broadest possible perspective.

NASA Response: Concur. NASA has just completed integrating the Improved General Purpose Computer (IGPC) into the fleet. This upgrading of the orbiter computers included an extensive reverification of the flight software. Integrated testing of the flight hardware and software was one of the milestones in the certification of the IGPC hardware and flight software. In addition, the Shuttle software is incrementally upgraded and released for flight approximately every eight months. These upgrades are validated, verified, and certified through an extensive and thorough process. Future computing capability beyond recent incorporation of the IGPC is under development in the Assured Shuttle Availability (ASA) Program in the Multifunction Electronics Display Subsystem (MEDS). The plan for the subsequent 10-15 years involves maintaining the existing system. Issues involving obsolescence and enhanced performance will continue to be reviewed.

Finding #4: The Space Shuttle flight software generation process is very complex. It includes numerous carefully designed safeguards intended to ensure that no faulty software is ever loaded. When errors have occurred, or when concerns have been raised about steps in the procedure, new safeguards have been added. The whole process is long, complicated, and involves a plethora of organizations and computers.

Recommendation #4: NASA should conduct an independent review of its entire software generation, verification, validation, object build, and machine loading process for the Space Shuttle. The goals should be to ascertain whether the process can be made less complex and more efficient.

NASA Response: Concur. An independent review has been completed of NASA's entire software generation, verification, validation, object code build, and machine loading process. As part of the post-51L activity, NASA contracted with Intermetrics Inc., as the independent verification and validation (IV&V) contractor. NASA is developing a policy to define the scope of our independent oversight activity. To assist in this task, NASA has requested the National Research Council to perform an independent review of the IV&V process to include software generation, object code build, and machine loading.

Space Shuttle Main Engine (SSME)

Finding #5: The SSME is now available in sufficient numbers to support all the Orbiters. A suitable number of spare engines are available at the launch site.

Recommendation #5: Keep up the good work while recognizing any demands imposed by changes in planned launch rates.

NASA Response: Thank you. We intend to maintain a good posture on spare engines.

Finding #6: The program to develop safety and reliability improvements to the current SSME is meeting with a large degree of success. However, some components, like the pump end of the High-Pressure Oxidizer Turbopump (HPOTP) and the two-duct power head have not been successful. The bearing housing at the pump end of the HPOTP has not met its objectives, and an operational solution has been devised to accommodate the resulting small *number of allowable reuses between overhauls. Premature combustion chamber cracking and injector erosion were experienced with the two-duct powerhead.*

Recommendation #6: Continue the development and certification of the safety improvements so that they may be incorporated at the earliest possible time.

NASA Response: Concur. The SSME Project is continuing certification of both the 10K pumps and development of the two-duct powerhead through hot-fire testing at SSC and detailed engineering reviews of the test results. This effort will continue to develop these safety improvements for incorporation at the earliest possible time.

Finding #7: The Alternate Turbopump Program has encountered a number of design problems during testing. Fixes are being incorporated and fed into development testing. Planning for completion of component-level testing and entering the engine-level test phase is very optimistic, especially in view of the difficulties experienced in completing test runs on the component test stand.

Recommendation #7: Schedule pressures can engender the temptation to truncate the component test plans and objectives. Do not compromise the objectives and thoroughness of the planned component test program to start engine-level testing at the time currently scheduled.

NASA Response: Concur. In recent weeks, component-level testing for the alternate turbopump development (ATD) program has provided improved testing results. Using SSC testing to supplement component testing will add to the fidelity of the component testing program. The ATD Test Program will not truncate or compromise the objectives and thoroughness of the planned component testing.

Redesigned Solid Rocket Motor (RSRM) and Advanced Solid Rocket Booster (ASRB)

Finding #8: NASA is planning to use the existing Solid Rocket Booster aft skirt on the Advanced Solid Rocket Booster. The requisite Factor of Safety is to be achieved by biasing the spherical bearings at the hold-down posts.

Recommendation #8: The aft skirt design for the Advanced Solid Rocket Booster should be inherently strong enough to achieve a Factor of Safety of 1.4.

NASA Response: A factor of safety of 1.4 is not necessary for the Redesigned Solid Rocket Booster Aft Skirt since the loading of this structure is well understood. The Space Shuttle Program has been operating the current Solid Rocket Booster (SRB) with an aft skirt factor of safety of 1.28. The current radial biasing of the Spherical Bearings assures that this 1.28 factor of safety is achieved. Additional radial biasing, improved loads definition, and possible structural modifications, are being studied for their potential to further increase the factor of safety for the ASRB.

Small inward biasing of the pedestal spherical bearings has been used successfully since STS-28 as a means of increasing structural factor of safety. The biasing imparts a compressive preload in the area of the critical aft skirt weld, thus helping to offset the tensile load induced there during SSME Thrust Build-up.

Efforts are also underway to improve even further the definition of Aft Skirt loads. Strain gauge instrumentation on skirts has provided an extensive data base since STS-26 and such data gathering will continue on the current SRB. An improved definition of ASRB Aft Skirt Loads will be available as the ASRB Structural Models are developed. Also, structural modifications are being studied that will enhance the load carrying capability of the skirts for the ASRB. With biasing and structural modifications, the aft skirt factor of safety will be maximized, but achieving a safety factor of 1.4 is not an absolute requirement.

Finding #9: The Redesigned Solid Rocket Motor manufacturer has made impressive strides in the quality of industrial operations. Incorporation of existing state-of-the-art automation for manufacturing and assembly processes is continuing.

Recommendation #9: Continue the industrial enhancements to achieve further reduction of requirements for hands-on labor and increased product quality.

NASA Response: Concur. NASA is incorporating enhancements in the Thiokol Redesigned Solid Rocket Motor manufacturing facilities and processes in the areas of propellant mixing, casting, and in final assembly operations. These enhancements involve new facilities for automated propellant premix, sample casting, a modified oxidizer facility, and new propellant analysis equipment. For final assembly, there will be a new six-bay segment processing building with vertical nozzle installation capability and other handling improvements.

Finding #10: The use of the Advanced Solid Rocket Motor and Redesigned Solid Rocket Motor during the same time frame will pose procedural and test challenges because of their different configurations and performance characteristics.

Recommendation #10: NASA and its contractors should develop a well integrated plan for such concurrent operations.

NASA Response: Concur. An integrated plan to govern program transition from SRB Operations to ASRB Operations is under development. This plan will show how Space Shuttle Program goals will be met within the technical constraints involved in integrating a new element into Shuttle operations. The development of the SRB-to-ASRB transition plan is scheduled to be completed by July 1991. Once complete, this transition plan will be incorporated into the System Integration Plan and controlled at Level II. This will ensure that any proposed changes to the transition plan will receive total program review.

Finding #11: The test program for the Advanced Solid Rocket Motor/Advanced Solid Rocket Booster has been well planned and uses the many lessons learned from the ongoing Redesigned Solid Rocket Motor project. There are, however, a number of uncertainties including characterizing the physical and manufacturing properties of the case material.

Recommendation #11: The project should provide an allowance for contingencies beyond those indicated in the current schedules and budgets to account for proper closure/resolution of expected test results.

NASA Response: The ASRM Program cost/schedule is under review as Congress considers the FY 92 Budget request. Our desire is to have a reasonable allowance for schedule reserve, but budget pressures will likely drive us to a somewhat success oriented schedule where further schedule margin will have to come from first flight date.

Finding #12: NASA has embarked upon an ambitious program of automation for manufacturing the Advanced Solid Rocket Motor. The new automation will be a significant step forward and an impressive accomplishment. However, there are concerns about the feasibility of completing automation of this scale in the time frame indicated. Therefore, there may be significant delays in the availability of the Advanced Solid Rocket Motor.

Recommendation #12: NASA should be prepared to extend use of the Redesigned Solid Rocket Motor beyond current plans.

NASA Response: Concur. A 1-year overlap of RSRM and ASRM is planned to cover contingencies. While the degree of automation planned for the ASRM manufacturing facilities is ambitious, the process development involves an acceptable degree of schedule risk. Since construction of facilities and development of the manufacturing processes precedes the design verification phase of the program, any schedule delays would occur at a time when adjustments to extend the use of the RSRM can be made.

Finding #13: It is planned to move the highly instrumented T-97 Solid Rocket Motor Dynamics Test Stand from Utah to the Stennis Space Center in Mississippi for use during the Advanced Solid Rocket Motor Program rather than constructing an equivalent new test stand. This will leave the current Redesigned Solid Rocket Motor Program without a dynamic test facility support.

Recommendation #13: Retain the current T-97 dynamic test stand at the Utah site to support the Redesigned Solid Rocket Motor Program. A new dynamic test stand should be constructed for the Advanced Solid Rocket Motor at Stennis Space Center.

NASA Response: Relocating the T-97 Test Stand Hardware to Stennis Space Center (SSC) is being considered as a cost-effective means of meeting the combined testing needs of the RSRM and ASRM Projects. It has been determined that neither the ASRM or RSRM test stands require dynamic (side load) test capability. This plan leaves the T-24 Test Stand at Thiokol for RSRM tests and moves the T-97 Test Stand (without dynamic capability) to SSC for ASRM.

External Tank (ET)

Finding #14: The external tank project is moving along very well.

Recommendation #14: Keep up the good work.

NASA Response: Thank you.

Finding #15: This past year, NASA management has postponed Space Shuttle launches when technical uncertainties existed, declared a hiatus during the Christmas season and interrupted launch operations until the cause of hydrogen leaks could be determined and resolved. This is clear evidence of NASA management's commitment to the principle of "safety first, schedule second."

Recommendation #15: NASA management should maintain this policy even as Shuttle launches become more frequent.

NASA Response: Strongly concur.

Launch And Landing Operations

Finding #16: Reports indicate that launch processing operations at the Kennedy Space Center (KSC) are being carried out with a declining rate of incidents. This is a trend in the right direction since the extreme sensitivity of Shuttle launch processing requires reducing errors to the lowest possible levels.

Recommendation #16: KSC, the Shuttle Processing Contractor, and associate contractors should continue to make all possible efforts to reduce incidents. However, care must be exercised to ensure that any observed decrease in incident reports is not merely an artifact of the reporting system. In particular, if management's response to incident reporting is perceived as punitive in nature, the net result may be a suppression of reporting with a resultant reduction in the information available to management on which to identify problems and design remedial actions. Total Quality Management (TQM) techniques can be of great assistance. Likewise, the inclusion of human factors professionals on incident investigation teams can be very beneficial. Therefore, KSC should consider both an enhanced TQM program and a broader use of human factors.

NASA Response: Concur. KSC and the Shuttle Processing Contractor (SPC) are continuing to try to reduce incidents, even beyond the success we have had to date. We are accomplishing this through a network of preplanning, communication, and coordination that encourages everyone to work together and understand that they are an essential part of the task at hand. Management takes no punitive action against any worker for incidents unless it is clearly shown that the worker had a preconceived negative intent or makes the mistake repetitively (more than twice). For repetitive errors, the worker is simply reassigned to other tasks and/or retrained. Any repetitive error is automatically evaluated from the human factors viewpoint. It should be noted that human factors concepts have been used throughout the creation and verification of all Orbiter Maintenance Instructions (OMIs) and the initial performances of all tasks involved in vehicle processing. With quality control checks at all levels from planning, engineering, OMI creation, and progressive steps of task team work, we are practicing TQM and reducing incidents. We will continue to use enhanced TQM and a broader use of human factors, as appropriate.

Finding #17: There is a perception among some workers at KSC that disciplinary actions for errors are overly severe.

Recommendation #17: NASA and its contractors should make every effort to communicate the facts and rationale for disciplinary actions to the work force and involve workers in incident reviews. TQM techniques can be of great assistance. There is simply no substitute for sincere communication between management and labor in dispelling negative perceptions.

NASA Response: Concur. NASA is very concerned about the potential that such a perception may exist. KSC and SPC have instituted a program of vertical and lateral communications that extends from the highest KSC management levels (both civil service and SPC) down through middle management, engineering, and the task team technical floor workers. Practices include weekly meetings at top management levels, daily reviews at middle management and throughout engineering, and per shift (or more) coordination sessions at the task team level. There are also horizontal channels for coordination from hands-on-workers, logistics/supply elements, and support operations. It is continually stressed throughout these channels that disciplinary action for errors will not be severe or punitive unless the errors or incidents result from clearly proven negative intent. All employees are advised of their obligation to come to work fit and able, and to perform the tasks carefully and successfully. Any error is discussed with the responsible employee and efforts made to help him or her understand how to avoid a repetition.

Finding #18: There are cases in which recurring waivers are sought and issued for the same subsystem or component on successive Space Shuttle flights. For example, waivers have had to be issued to fly with the tumble valve disabled on the external tank.

Recommendation #18: Continuing waivers for the same condition should not be permitted. If it is deemed acceptable to fly repeatedly with a configuration that varies from specifications, the specifications should be altered rather than risk diluting the significance of waivers by making them routine. For example, the underlying specification for the tumble valve could be changed to require its inclusion only on high inclination launches.

NASA Response: Concur in principle. The ASAP is correct in suggesting that there are continuing waivers where the specification can be changed; a good example is the tumble valve. Based on Flight Data for tanks with an active tumble system, the tumble systems were disabled on selected flights based on analysis of External Tank (ET) Rupture Altitude and the corresponding debris footprint. Flight and tracking data were used to determine the correlation between non-tumble system tank trajectories, ET motion, ET Rupture Altitude and the ET Debris Model. Based on these analyses and flight tests, the applicable specification was changed to preclude the necessity for continuing ET Tumble System Waivers. However, it should be pointed out that waiver disposition is never "routine." As outlined above, a request for waivers or to change a specification requires rigorous supporting data (many times flight data) presented through a series of at least three change control boards. Specifications have been, and will continue to be, changed where it is proved that the limits should be revised for all flights.

Mission Operations

Finding #19: The Mission Control computer support system is quite old, relatively slow, and has monochrome displays primarily of tabular data. The advantages of applying current technology to Mission Control are being explored with the Real-Time Data System at the Johnson Space Center (JSC).

Recommendation #19: NASA should embark upon a systematic process to replace the old Mission Control system with one based upon up-to-date computer and human interface system technology.

NASA Response: Concur. Since 1986, NASA has been in a phased process of upgrading the operational elements of the Mission Control Center (MCC) to incorporate advanced technology. This includes the replacement and upgrade of mainframe computers, and the placement over the last 2 years of current generation workstations in the MCC that are capable of using advanced techniques for analyzing and displaying data. These enhancements are part of a comprehensive multi-year plan developed to introduce new technology into the operating environment.

ASSURED SHUTTLE AVAILABILITY PROGRAM

Finding #20: The majority of the safety and reliability enhancements that the Panel suggested be included in the Assured Shuttle Availability Program have been undertaken by NASA. It now appears that under this same label, NASA is undertaking a program of Space Shuttle modifications whose primary objectives are life extension and the elimination of obsolescence. This could lead to confusion.

Recommendation #20: The Panel urges that the two sets of objectives be pursued through independent, separately titled, but coordinated programs.

NASA Response: The Space Shuttle Program considers safety changes to be the responsibility of the baseline program and funds are made available to implement these changes. A recent example is the modification of the Orbiter External Tank door fixture. This modification was not planned nor budgeted, but was immediately implemented.

The objective of the Assured Shuttle Availability (ASA) Program is to keep the Shuttles flying well into the 21st century. The program addresses supportability, maintainability, and safety margin issues. Previously ad hoc programs will be combined in the future into a structured program that will prioritize candidates and manage the programs with managers whose primary function will be development programs.

The current approved programs include the Multifunction Electronics Display Subsystem and the Hardware Interface Module. These programs are primarily obsolescence (supportability) programs. The other approved program, SSME Advanced Fabrication, replaces main engine obsolete manufacturing techniques by using castings versus weldments. The goal is to reduce cost and eliminate many Criticality 1 failures. The

Space Shuttle Program will continue to manage safety enhancements. The ASA Program primarily will provide program supportability, but also will increase safety margins, where applicable.

LOGISTICS AND SUPPORT PROGRAM

Finding #21: The Orbiter logistics and support systems are continuing to evolve satisfactorily. The expansion of component overhaul and repair facilities at the launch site and in the nearby areas is most impressive. Liaison between all NASA Centers and contractors appears to be excellent, and the control and communications networks are being further improved.

Recommendation #21: Continue with the philosophy of centralizing Orbiter spares support and overhaul/repair activity in the KSC area. Good work!

NASA Response: Concur. Thank you.

Finding #22: The total elapsed time for repair and turnaround of many repairable components is still too high. Delays in accomplishing failure analysis appears to be a major part of the problem.

Recommendation #22: Continue to take all steps necessary to reduce turnaround time.

NASA Response: Concur. Turnaround times continue to receive NASA management attention. KSC logistics personnel frequently review with the logistics contractor those items that have been in the repair process for longer than 180 days. These reviews provide an incentive for the logistics contractor to ensure that vendor repairs are not delayed for other than engineering concerns. In addition, the transition of repair capability from the original equipment manufacturers (OEMs) to the NSLD will continue to shorten overall turnaround time. The overall turnaround time for the last 3 calendar years has decreased significantly: 194 days in 1988, 174 days in 1989, and 155 days in 1990.

Finding #23: While the overall cannibalization problem appears to be under good control, there are still a few shortages of high-value items such as Auxiliary Power Units (APUs).

Recommendation #23: Review, once again, the critical supply issues in long-lead and high-value items to ensure an adequate spares level to avoid the safety problems associated with cannibalization.

NASA Response: Concur. There are still a few shortages of high-value and long-lead items. These shortages are being addressed either through modification/improvement programs (as for the APUs) or through additional procurement (as for the reaction control system thrusters).

Finding #24: Out-of-production, aging, and obsolescent parts are a growing problem.

__Recommendation #24:__ Increased emphasis should be given to ensuring the availability of sufficient quantity of up-to-date hardware.

__NASA Response:__ Concur. NASA recognizes the potential problem posed by obsolete parts. KSC has instituted a three-part program to minimize the impact that obsolescence could have on orbiter logistics supportability. The program includes identification of potentially obsolete parts; evaluation of available prevention options; and tracking of obsolescence data, including actions taken. These actions are taken in conjunction with the Assured Shuttle Availability Program. The increased emphasis on parts obsolescence should ensure the ability of KSC to provide up-to-date hardware for orbiter launch processing.

__Finding #25:__ There does not appear to be a comprehensive and realistic plan for scheduling and accomplishing major overhaul of the Orbiter fleet.

__Recommendation #25:__ To help ensure structural integrity of each vehicle, much greater effort must be devoted to these tasks. A comprehensive program should be developed for the orderly overhaul of Orbiters that are expected to operate into the 21st century.

__NASA Response:__ Concur. The Space Shuttle Program has developed and instituted a plan by which the orbiter vehicles are inspected and modified every 3 years. This plan involves the use of specific orbiter flow periods commonly referred to as Orbiter Maintenance Down Period (OMDP) to perform vehicle structural inspections and modifications. The orbiter structural inspection will verify the integrity of primary structural elements of the vertical tail, flight control surfaces, aft fuselage, mid-fuselage, landing gear, crew module and forward fuselage. Critical elements will be inspected for corrosion, fatigue, deformation and cracks, which would result in reduced structural integrity. Flow periods of 188 days have been allocated for an OMDP. OV-102 is the first vehicle to be scheduled for an OMDP and will begin in FY 91. OV-103 and OV-104 are currently scheduled to begin their modification/inspections periods in FY 92. The Space Shuttle Program will continue to use OMDP's to inspect and modify each orbiter throughout a vehicles operational lifetime to ensure each orbiter's structural integrity and upgrade the systems as required to ensure operations through 2020.

B. SPACE STATION FREEDOM PROGRAM

__Finding #26:__ The Space Station Freedom Program has been plagued by technical, managerial, and budgetary difficulties since its inception. The instability of this program coupled with extensive externally stipulated design constraints has made it extremely difficult to conduct this program in a sound and orderly manner. The program has suffered from the absence of a clearly defined primary purpose that has resulted in an incomplete specification. Also, there has been a lack of effective systems engineering and systems integration activity.

__Recommendation #26:__ The purpose and funding of the redefined Space Station Freedom Program must be firmly agreed upon by the Congress and NASA. Then, NASA should be permitted to organize and manage the program. Systems engineering, system integration, and risk management must be integral and vital parts of the revised program.

NASA Response: Concur. The restructured Space Station Freedom program plan successfully responds both to the guidance of the Congress on funding and function and to the recommendations of the Advisory Committee on the Future of the U.S. Space Program, the Augustine Panel. The restructured plan enjoys strong support from the Administration and from many elements of the Congress. This consensus should permit NASA to go forward with a stable program and a consistent interaction of engineering design and risk management.

C. AERONAUTICS

AIRCRAFT OPERATIONS

Finding #27: Past ASAP reports have cited concerns over the extent of Headquarters involvement in aircraft operations safety. During the past year, a reorganization and redelineation of Headquarters safety responsibilities has gotten underway.

Recommendation #27: NASA should follow through with the implementation of Headquarters policies regarding the safety of the operation of NASA's aircraft.

NASA Response: Concur. The responsibilities for aviation safety and aircraft operations have been clarified. New management instructions have been drafted to document the responsibilities. These instructions are in their final coordination phase. NASA ***will*** follow through with the implementation of these policies.

RESEARCH AND TECHNOLOGY

Finding #28: The joint Air Force/NASA high angle of attack program conducted at the Dryden Flight Research Facility has been a model of safe and efficient experimental flight testing.

Recommendation #28: NASA should document the experience of this flight test program in the tradition of the NASA/NACA flight test reporting.

NASA Response: Concur. Flight test results will be documented thoroughly, and findings and lessons learned will be disseminated NASAwide. Aeronautical Research Flight Test Programs in NASA will continue to be the model for safe and efficient experimental flight testing for the U.S. aviation community. Safety will continue to be the most important principle in our research and testing programs, and this philosophy will be clearly presented in all related documentation.

D. SAFETY AND RISK MANAGEMENT

MISSION SUPPORT

Finding #29: The use of Fault Tree Analysis and Failure Modes and Effects Analysis techniques proved to be valuable in solving the hydrogen leak problems on STS-35 and STS-38. Their use led to the identification of probable sources of the hydrogen leaks, the probable causes of these leaks, and the nature of the corrective actions needed.

Recommendation #29: Use of these techniques for problem resolution should be encouraged throughout NASA. Suitable training programs should be established to ensure proper implementation.

NASA Response: Concur. Fault-tree analysis (FTA) and Failure Modes and Effects Analysis (FMEA) are techniques fundamental to the NASA systems engineering disciplines. They are used throughout system development to enable early identification of problems, and assign hardware and software criticality. Critical Item Lists (CILs) are tabulated by criticality level and require review, resolution, or waiver before flight is approved. FTA is used by the safety organizations to provide top-down analyses of safety-critical problems, while the FMEA is a bottom-up approach that begins at the parts level. Both formal and informal on-the-job training in these techniques is provided.

TOTAL QUALITY MANAGEMENT (TQM)

Finding #30: NASA has a TQM program intended to improve quality and productivity within NASA and its contractors. The implementation of the TQM (or its equivalent) concept, however, has been quite variable across the NASA Centers and contractors.

Recommendation #30: The principles of TQM have merit when implemented by a dedicated and concerned management. NASA should implement a consistent TQM methodology that ensures adherence to those principles and participation of all levels of the work force.

NASA Response: Concur. NASA's ongoing emphasis on quality and productivity improvement (QPI) began in 1982, with an internal and external focus. In 1986, a special emphasis was placed on the external efforts in recognition that the majority of the NASA budget is allocated to contractors. In fact, Martin-Marietta/Michoud (which was referenced in the ASAP report) was evaluated under the NASA Excellence Award Program and won in 1987 for their quality achievements. In 1989-90, a renewed emphasis was placed on internal QPI programs, while still maintaining our external efforts. In February 1990, NASA formally launched an internal TQM initiative, and recently conducted a NASAwide TQM assessment. We are now planning an internal TQM evaluation initiative patterned after the George M. Low Trophy (NASA's Quality and Excellence Award program) using TQM criteria contained in the President's Award for Quality and Productivity Improvement. NASA top-level management is committed to successfully implementing the TQM program and will be directly involved in formulating strategies for achieving NASA TQM program goals. The TQM Steering Committee, consisting of NASA senior management, will report on the status and progress of TQM implementation at their Fall 1991 meeting.

SAFETY REPORTING SYSTEMS

Finding #31: NASA has a management instruction (NMI 8621.1E) that addresses "Mishap Reporting and Investigation." This NMI includes a specification of board composition. It does not, however, realistically address the need for human factors input in such investigations. It notes that if human factors are thought to be substantially involved, then human factor input is to be sought from a "NASA or resident NASA contractor physician" rather than a trained human factors expert. Also, this NMI does not require investigation of "close calls."

Recommendation #31: Inclusion of a member on the incident/accident investigation board with specific human factors expertise should be given much greater consideration. "Close-call" investigations should be more formalized.

NASA Response: Concur. NASA is investigating the human element in all NASA mishaps. Efforts are currently underway to refine and update NMI 8621.1E. Part of this effort will be the transition of NASA Mishap Investigation Board Membership requirements to the Basic Safety Manual, NHB 1700.1. Consideration will be given to incorporating a requirement to have a Human Factors Engineering professional assigned to a NASA Mishap Investigation Board during this transition. The NASA Headquarters Safety Division is sponsoring a Human Error Avoidance Project at KSC that includes funding for a full-time Human Factors Engineering professional. This individual will be available to participate in future mishap investigations at KSC. Formalization of the NASA close-call investigation process is also a NASA concern. The update to NMI 8621.1E will stipulate investigation of Type A, B, and C mishap-related close-calls as a requirement in the Basic Policy for NASA Mishap Reporting and Investigation. Under the current policy, all close-calls must be reported; close-call reports are evaluated at NASA Headquarters and, when necessary, an investigation board is established.

E. OTHER

NASA FACILITIES

Finding #32: NASA has undertaken a well organized, 5-year program for safety and operational renovation/revitalization of some of its major experimental research facilities.

Recommendation #32: NASA and the Congress should continue to keep in focus the importance of preserving and periodically updating the physical plants and research facilities at NASA Centers. The current program should be continued and extended to cover the facilities that were not included because of funding limitations.

NASA Response: Concur. There should be a continuing focus on the importance of preserving and periodically updating the physical plants and research facilities at the NASA Centers. NASA's current efforts emphasize the rehabilitation and modernization of their 40- to 50-year-old wind tunnel facilities.

EXTRAVEHICULAR MOBILITY UNITS/SPACE SUITS

Finding #33: NASA's current plans for Space Station and the Space Exploration Initiative will inevitably involve the need for both planned and contingency extravehicular activities (EVA's).

Recommendation #33: The planning and design for Space Station and other manned space exploration programs should make every attempt to minimize dependence on EVA. In addition, NASA should undertake the development of an improved Extravehicular Mobility Unit that eliminates or reduces the maintenance and operational problems inherent in the current suit designs.

NASA Response: Concur. The planning and design for the Space Station Freedom (SSF) and other manned programs should minimize extravehicular activity (EVA). Subsequent to the SSF External Maintenance Task Team (EMTT-Fisher-Price) study, the External Maintenance Solutions Team (EMST) was formed to evaluate EMTT findings/recommendations and provide further recommendations for mitigating EVA requirements. Many of the EMST recommended actions were incorporated by program management and additional actions were developed during the restructuring activity; other recommendations are still being evaluated. NASA concurs that development of an improved Extravehicular Mobility Unit (EMU)/Space Suit is desirable but budgetary constraints preclude pursuing that activity at this time. Two candidate designs for the EMU have been studied at the Johnson Space Center and Ames Research Center.

TETHERED SATELLITE SYSTEM (TSS)

Finding #34: The tethered satellite concept involves potentially operational activities that have never been attempted and that cannot be simulated on the ground before flight. Hazard studies and analyses have revealed the possibility of the Orbiter becoming adversely affected by the tether in the event of a malfunction during extension, while deployed, during retraction, or during stowage.

Recommendation #34: Program risk management should continue to focus on the results of the principal hazard analyses and their implication for Space Shuttle and satellite control.

NASA Response: Concur. The risk management process for the Tethered Satellite System (TSS) continues to focus on hazard analyses and their implications for the Space Shuttle Program. There is an operating strategy that assures all potential satellite control issues will not become hazardous to the Shuttle. A "Safety of Flight" operations envelope is being defined using performance gates that assure Orbiter maneuvers used to avoid contact (breakout techniques) remain viable during all TSS mission phases. The

"Mission Success" operations envelope is contained within the safety of flight envelope so that mission success will not conflict with safety. The performance gates will be reflected in the flight rules and console documentation. The hazard analysis and safety review process along with operations working groups are proceeding at greater levels of detail to continue to implement this strategy.

APPENDIX C
AEROSPACE SAFETY ADVISORY PANEL ACTIVITIES
FEBRUARY 1991 - JANUARY 1992

FEBRUARY

19-22	Aerospace Medicine Advisory Committee Meeting; NASA Headquarters
26	Space Station Work Package #4 Rocketdyne Briefing; Cleveland

MARCH

22	ASAP Annual Report to Administrator; NASA Headquarters

APRIL

30	Intercenter Aircraft Operations Panel Meeting; Cocoa Beach

MAY

1	Intercenter Aircraft Operations Panel Meeting; Cocoa Beach
2-3	Intercenter Aircraft Operations Panel; Washington, DC
9	Space Shuttle Orbiter Autoland; Johnson Space Center
21	Space Station Program; NASA Headquarters
22	Space Shuttle Program; NASA Headquarters
22	Office of Management and Budget; Washington, DC
28	NASA Safety Reporting Systems; NASA Headquarters

JUNE

17-19	Aerospace Medicine Advisory Committee Meeting; NASA Headquarters
19	Space Station Restructure and Space Shuttle Main Engine; Rocketdyne, Canoga Park
19	ASAP Management Meeting; NASA Headquarters
20	Space Shuttle Orbiter Autoland; Johnson Space Center

JUNE (Cont.)

25	National Research Council Panel on Advanced Solid Rocket Motor; Washington, DC

JULY

16-17	Space Shuttle Launch and Landing Processing; Kennedy Space Center

AUGUST

5	Advanced Solid Rocket Motor; Aerojet, Sacramento
6	Aeronautical Programs and Human Performance; Ames Research Center
6	Space Shuttle Performance; Rockwell, Downey
7	Flight Programs; Dryden Flight Research Facility
9	Space Station Freedom Program, Level I; NASA Headquarters
12-13	Space Station Freedom Program, Level II; Reston
20	Space Shuttle Processing/Operations; Kennedy Space Center
21	Space Shuttle/Space Station Logistics, Kennedy Space Center
21	Advanced Turbopump Development Program; Pratt & Whitney, West Palm Beach

SEPTEMBER

4-5	Redesigned Solid Rocket Motor/Advanced Solid Rocket Motor; Marshall Space Flight Center

OCTOBER

9	Space Station Work Package #4; Lewis Research Center
9-10	Space Shuttle Program Directors Management Review; Johnson Space Center
16-17	Manned Space Flight Activities; Johnson Space Center
18	Space Station Integration; Johnson Space Center

NOVEMBER

6-7	NASA/Contractors Conference; Houston
4-6	AIAA 4th Space Logistics Symposium; Cocoa Beach
6-8	Integrated Logistics Panel; Kennedy Space Center
7	STS-44 Flight Readiness Review; Kennedy Space Center
13	Space Station Freedom, Work Package 2; McDonnell Douglas Company; Huntington Beach
14	Human Factors, EVA; Ames Research Center

DECEMBER

4	Tethered Satellite System; NASA Headquarters
10-11	Intercenter Aircraft Operations Panel; San Diego

For Further Information
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NASA
National Aeronautics and
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