National Aeronautics and
Space Administration

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JUL 24 1986

Reply to Attn of: DA01

TO: Distribution

FROM: DA01/T. J. Lee

SUBJECT: Lessons Learned Report

The STS 51-L Data and Design Analysis Task Force has produced a Lessons Learned Report, copy attached. This report represents various areas where problems exist or improvements are desirable, and is the culmination of effort of the Task Force Team and sub-teams.

This report is provided for your use and information. I believe it is essential that all existing programs and projects, and associated technical organizations, review the data contained in the report and make a dedicated effort to assure that, where applicable, its intent is presently satisfied, or positive action is initiated. Internal plans of action should be developed for the applicable items. Although the majority of the findings and lessons learned are directed to the Space Shuttle Program and its elements, many in fact are generic and should be considered and applied to non-Shuttle endeavors.

I further consider this report to be a valuable reference in the preparation and formulation of future Request for Proposals, contracts, and associated specifications and requirements documents.

It is recognized that implementation of certain of the recommendations contained in the report may require higher level authorization and may require additional resources. In this event, such authority and resources should be sought through the established formal channels.

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The STS 51-L incident was a national tragedy, yet it offers the agency an opportunity for improvement in its fulfillment of engineering and management responsibilities. This report is one such entity and therefore must be addressed and considered in total seriousness by all.

T. J. Lee
Acting Director

Enclosure

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NASA

JUN 17 1986

Reply to Attn of: DDATF-341

TO: NASA Headquarters
Attn: M/Chairman, STS 51-L Data and Design Analysis Task Force

FROM: DDATF/Vice Chairman, STS 51-L Data and Design Analysis Task Force

SUBJECT: Lessons Learned Report

The Lessons Learned Report prepared by the STS 51-L Data and Design Analysis Task Force is enclosed for your utilization. You will note that the report is structured by Lessons Learned and Collateral Findings.

Robert L. Crippen

Enclosure

NASA INTERNAL USE DOCUMENT

STS 51-L Data and Design Analysis Task Force

Lessons Learned Report

June 1986

SPACE SHUTTLE

National Aeronautics and
Space Administration

NASA

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

LESSONS LEARNED REPORT

SIGNATURE PAGE

James R. Thompson, Jr.,
Vice Chairman

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

LESSONS LEARNED REPORT

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STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

LESSONS LEARNED

INTRODUCTION

The Data & Design Analysis Task Force was organized to support the Presidential Commission appointed by President Ronald Reagan to investigate the loss of the Space Shuttle Challenger and its crew. The Commission established four separate subgroups, charged with specific investigations in the areas of Development and Production, Prelaunch Activities, Accident Analysis, and Mission Planning and Operations. The Task Force then established four teams specifically to support the Commission in these areas. A fifth Task Force Team, Photo & TV Support, was established to analyze the extensive photographic and television coverage of the launch and inflight failure. A sixth, Search, Recovery and Reconstruction, was assigned the task of finding the vehicle and crew, recovering those parts useful to the investigation, and laying them out in locations analogous to their positions in flight for detailed examination.

Several of the Task Force teams in turn organized a number of subteams to investigate and report on specific areas of interest. The six teams and their subteams performed extensive and detailed investigations and analyses of the orbiter, solid rocket boosters, and external tank, as well as checkout and launch operations, environmental conditions at launch, pad facilities, and many other relevant factors.

The extensive and detailed work of the Task Force teams and subteams indicate many areas where problems exist or improvements are possible and desirable. These have been collected in this document in the form of "Lessons Learned" and "Collateral Findings." Lessons Learned provide a means of recognizing problems of broad sweep and scope, with potential applications over a wide range of NASA activities. Collateral Findings are more specific in nature, usually addressing a problem that can be corrected without affecting other programs or systems. Recommendations to correct the problems noted follow each Lesson and Finding.

For convenience and clarity, this document is divided into six sections, one for each Task Force team. An introduction appropriate to the subject area precedes each section.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

DEVELOPMENT & PRODUCTION TEAM

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

DEVELOPMENT & PRODUCTION TEAM

INTRODUCTION

The Development and Production Team was organized to examine the processes by which the major Space Shuttle components were designed, built and tested. This included the solid rocket motors, external tanks, the orbiters, and the main engines. The areas reviewed included design requirements and control, production reviews and certifications, qualification and testing, transportation and handling, launch support services, and others. The Lessons Learned and Collateral Findings that follow emerged during the course of, or as a result of, these studies and investigations.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: D-1
Lesson Learned

TEAM: Development & Production
(Reference Section VI, Development & Production Team Report)

BACKGROUND: The SRB field joints, which are susceptible to environmental conditions, were not qualified to the full range of the contractually required environments. This led to a lack of complete understanding of the joint design limits.

In addition, the configuration of the qualification test article was not, in all cases, representative of the flight dynamic effects on the case joints, and the putty preparation differed from that used on flight hardware.

FINDING: All environmental specifications imposed on Morton Thiokol, Inc. (MTI) by NASA for the Solid Rocket Motor (SRM) were not adequately verified by test, analysis, or similarity.

In order to verify the adequacy of the flight hardware and the processes, it is essential that the configuration and processes be as similar as pratical. Deviations from standard practice can lead to a lack of understanding of the performance of the system.

LESSONS LEARNED/RECOMMENDATIONS: Qualification testing on all systems over the full range of possible environments shall be conducted in the future to the maximum extent feasible. Operational procedure documentation should be complete and should be checked for consistency with engineering and test data. Qualification testing and/or preflight integrated testing should include dynamic considerations and conditions of environment, functions, and time duplicating those to be encountered in mission operations to the maximum extent feasible.*

*This Lesson Learned was previously documented in NASA Engineering Experience Bulletin No. 1, released in the 1977 time frame.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: D-2
Lesson Learned

TEAM: Development & Production
(Reference Section VI, Development & Production Team Report)

BACKGROUND: The O-ring used in the case joint is critical to the sealing of the joint, yet is not designated as a critical process. The adequacy of O-ring process and quality control is questionable, even though a number of O-rings in bonded storage at MTI were thoroughly analyzed and tested as a part of 51-L failure analysis effort and found to be acceptable.

FINDING: The manufacturing process included delivery of the final O-ring rubber material from Parker to Hydrapak where the material is cut to the proper lengths and a scarf joint is made. The arbitrary establishment of a limit of five joints per O-ring and the fact that repairs of inclusions and voids in the rubber delivered from Parker are routinely made by Hydrapak to a proprietary process appear to be an area of potential problem.

LESSON LEARNED/RECOMMENDATION: An investigation shall be conducted into the manufacturing process, final delivery and material cutting of the O-rings. Similar investigations should be conducted on all critical systems.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: D-3
Collateral Finding

TEAM: Development & Production
(Reference Section VI, Development & Production Team Report)

FINDING: The full scale hot fire static testing of the development and qualification SRMs was performed with the motors in the horizontal position rather than in the flight attitude. A review of the considerations for the decision to fire the full scale motors in the horizontal position reveals the decision to be based more on programmatics since the horizontal test facility was in place and the concern of being able to determine with a high degree of accuracy the actual thrust produced by the motor.

RECOMMENDATION: Perform analysis to develop pros and cons of positions of SRMs during development testing; i.e., horizontal, vertical nozzle up and vertical nozzle down. Develop rationale for the preferred testing position.

NO.: D-4
Collateral Finding

TEAM: Development & Production
(Reference Section VI, Development & Production Team Report)

FINDING: Some applicable Level II requirements of JSC 07700, Volume X are not imposed directly, or verbatim, on the ET contract. The CEI Specification requirement statements are written to satisfy the intent of these requirements. A specific example of concern is analysis that indicates potential catastrophic loss of ET structural integrity with missing TPS as small as 2.5 inches in diameter.

RECOMMENDATION: Conduct an overall program assessment to assure compatibility of the Level II and Level III requirements. Special attention should be given to the Criticality 1 and 2 components and identified hazards. In addition, an assessment of the hazard that actually exists for loss of ET TPS should be made and appropriate corrective action taken, if required.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: D-5
Collateral Finding

TEAM: Development & Production
(Reference Section VI, Development & Production Team Report)

FINDING: The SSME hot fire ground demonstration of two engines that lead the operational fleet by a factor of two must be considered a significant contributor to the understanding of the engine operational life to date.

The full extent of the available margin of critical engine components, subsystems, or systems has not been demonstrated during development, certification, or operational test. Hardware availability and the potential of damage to hardware and facilities resulting from test malfunctions has constrained this type testing during the ground test program.

RECOMMENDATION: Vigorously pursue the continuous SSME ground hot fire test program with multiple engines that demonstrate operational time far in excess of the orbiter fleet leader in order to help meet future operational requirements.

Continue the SSME overtesting, limits testing, and malfunctions testing to demonstrate the full engine capability.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: D-6
Collateral Finding

TEAM: Development & Production
(Reference Section VI, Development & Production Team Report)

FINDING: Extremely complex and critical payloads are being manifested for NSTS missions which may require Orbiter modifications. These include upper stages and specific payloads such as Spacelab which was designed to be a parasite. For payloads such as commercial and other spacecraft, the normal documentation for payload integration including specified safety reviews and reports has proven to be adequate.

RECOMMENDATION: Action should be taken to insure that extremely complex and critical payloads and upper stages, such as Centaur, are treated as elements of the NSTS with all STS documentation and practices applicable, as has Spacelab. This is to ensure the proper level of dynamic integration with the program elements.

NO.: D-7
Collateral Finding

TEAM: Development & Production
(Reference Section VI, Development & Production Team Report)

FINDING: The ET and Orbiter contractors no longer have direct reponsibilities for the total processing activities at the launch sites. Their roles are now only supportive in nature. The separation of responsibilities between the design organization and the processing organization has created additional interfaces which has made coordination, communication, and responsiveness more complex. The processing contractor may not possess the necessary technical background gained during the design and development phase to adequately determine system degradation resulting from multiple missions or to recognize the criticality of the hardware being tested and processing.

RECOMMENDATION: Methods should be developed which assure more direct design cotractor involvement in the processing and testing effort at the launch sites.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

PRE-LAUNCH ACTIVITIES TEAM

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

PRELAUNCH ACTIVITIES TEAM

INTRODUCTION

The Prelaunch Activities Team of the STS 51-L Data & Design Analysis Task Force performed an extensive investigation into the entire sequence of activities that preceded the launch. Even temporary conditions, such as an unusual convergence of activities at KSC that created a situation during which people could be overworked, was examined. The Team did not identify any event or condition throughout the processing cycle that was specifically related to the flight failure. However, several areas were noted where inefficiencies existed, or where procedures and/or equipment could benefit from improvements or upgrades. Human errors were found, indicating a need for more training and tighter operational discipline. The following Lessons Learned and Collateral Findings summarize the relevant areas where this detailed examination indicated improvements should be implemented.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

No. P-1
Lesson Learned

TEAM: Prelaunch Activities
(Reference Section VIII, Prelaunch Activities Team Report)

BACKGROUND: The practice of cannibalization has almost become a standard procedure during orbiter processing, due to insufficient spare parts. This causes a significant increase in the overall processing effort. One activity -- the removal of a needed Line Replaceable Unit (LRU) from the orbiter being cannibalized -- is an added unplanned activity. A second activity -- installing the removed LRU in the receiving orbiter -- has usually been allowed for in the overall contingency planning, but the processing flow time is impacted because it takes longer to cannibalize a part than to retrieve one from storage. When a LRU is obtained and reinstalled in the cannibalized orbiter, it must be retested. Some or all of these tests may not have been required if the original unit had remained undisturbed. Both the replacement of the removed LRU and its retest are added work. Also, the accompanying increase in physical activity required for the unscheduled removal and later replacement of a unit from the orbiter being cannibalized always increases the potential for damage. The follow-on tests that are performed to verify that no damage occurred are still another unplanned addition to the workload.

FINDING: The orbiter logistics system and spares supporting the 51-L mission were inadequate, causing significant LRU cannibalization, primarily from Orbiter Discovery. Some 300 parts were required during the launch processing of Challenger for the 51-L mission. Of these, 45 were cannibalized from Discovery. Overall, cannibalization is a highly inefficient way to process an orbiter.

LESSON LEARNED/RECOMMENDATION: Any major program such as the National Space Transportation System must be supported by a spares program capable of providing whatever quantity of spares are needed for the planned flight rate. The initial spares list should be periodically updated, based on flight experience, and the indicated quantities of parts obtained and kept in storage in a ready-to-use condition. In future decisions on whether to use a spare LRU or cannibalize, the use of a spare, when available, must always be considered the first choice.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

No. P-2
Lesson Learned

TEAM: Prelaunch Activities
(Reference Section VIII, Prelaunch Activities Team Report)

BACKGROUND: The Flight Readiness Review (FRR) did not adequately address certain issues involving SRB flight safety which later proved to be critical. The FRR process is part of a total management system that includes many reviews, a system that began early in the development program. Overall, FRRs have been reduced in importance. Some presentations have been curtailed because of time constraints. Reviews or portions of reviews have been conducted by telecon, with the technical content reduced to what can be understood using voice-only and in some cases, closed loop video inputs. Attendance at the FRRs by some key people has been spotty.

FINDING: It is now apparent that the developed engineering knowledge base, and the interpretation of available engineering data, were inadequate to support the STS 51-L launch decision process. The management tools in place, including the Critical Items List, did not adequately protect against the possibility of a fatal mishap. FRRs as they are now being conducted no longer provide the necessary assurance of a successful mission.

LESSON LEARNED/RECOMMENDATION: It should be recognized that the Space Shuttle is too complex a vehicle ever to be considered operational in the same sense as a jetliner. The engineering data base on performance parameters must be accumulated on Shuttle systems that are fully stressed for only about eight minutes per mission. The NASA management system should be reviewed and changed to reflect a better understanding of these facts, and of the system's total relationship to the launch decision process. The FRR process should be reviewed and structured to ensure that it is accomplishing the desired assurance of readiness for flight, as follows:

(1) The FRR process should be a bottoms-up review that requires the definition of all critical processed flight products, hardware modifications, and trend monitoring requirements. The responsibility for establishing the readiness for flight should be placed at the level where the work is done.

(2) The FRR process should be recognized as a continuous flow that occurs throughout flight preparations.

(3) The formal FRR should be structured to provide positive oversight for each flight to ensure that:

(a) The established requirements for flight readiness certification have been executed.

(b) All significant problems and anomalies in that process have been reviewed, understood by all parties, and properly dispositioned.

(c) All previous flight anomalies have been reviewed, understood by all parties, and properly dispositioned.

(d) All trend data have been evaluated and understood, and appropriate actions taken.

(e) These processes encourage the dissemination and review of data between participating organizations.

Adequate mechanisms and staff to accomplish the above should be put in place. The formal FRR should be conducted in an environment that allows the proper participation of those responsible for FRR oversight, as well as of those technically responsible for certification of flight. FRRs should be attended in person by the key personnel required to accomplish these objectives. Teleconferenced FRRs should only be used to allow participation of the large technical support communities. Time constraints should be eased to allow the presentation of all important information.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

No. P-3
Lesson Learned

TEAM: Prelaunch Activities
(Reference Section VIII, Prelaunch Activities Team Report)

BACKGROUND: In the early morning hours before the launch, a KSC ice team performed an inspection of the Challenger and pad. Their specific aim was to check for the amount and type of ice, but they also had with them an infrared gun designed to measure surface temperatures. This instrument was focused on the external tank and both SRBs during the course of the survey. The infrared gun indicated temperatures on the right SRB of from seven to nine degrees Fahrenheit, compared to 23 to 25 degrees for the left SRB. This discrepancy was not reported up the ladder to launch team officials. The primary purpose of the team was to evaluate the ice hazard to launch, on which they did report.

FINDING: Later tests have indicated that the infrared gun was operating properly, but requires a minimum of 40 minutes to stabilize at the temperatures experienced at KSC on the morning of January 28, 1986. The gun was focused on the right SRB prior to the time it had stabilized; the readings taken then were not reliable.

LESSON LEARNED/RECOMMENDATION: Instruments such as the infrared gun should not be placed in service until their operation and function are thoroughly understood, and personnel have been carefully trained in their use. Ice team members should have reported the low readings on the right SRB to the appropriate launch team officials. All similar evaluation teams should be thoroughly trained in the use of any instruments they handle, and supplied with appropriate criteria by which results can be evaluated. All discrepancies and unusual observations noted must be reported to the proper launch team official.

No. P-4
Lesson Learned

TEAM: Prelaunch Activities
(Reference Section VIII, Prelaunch Activities Team Report)

BACKGROUND: Historically, one of the major strengths of the NASA flight readiness review process has been the upward flow of information/problems, and the downward flow of probing/penetration to assure the satisfactory disposition of reported anomalies. This system has been used extensively throughout all NASA manned flight programs, and has always been effective.

FINDING: Two significant ascent propulsion failures occurred during the first 25 Shuttle launches; an early SSME shutdown and the Challenger accident. Both failures were preceeded by several anomalies, or fingerprints, that indicated a potential problem developing. One failure was tragic, one fortunate in that it occurred late enough in flight that the problem it created had minimal mission impact.

LESSON LEARNED/RECOMMENDATION: The several communication problems identified during the 51-L Challenger accident investigation indicate the NASA treatment of flight anomalies requires increased emphasis on both reporting and disposition. Clearly, the surfacing of all flight anomalies and resulting corrective actions -- particularly those occurring on Category I and IR criticality items -- needs to be strongly focused to all levels of NASA management during the launch readiness review process. Simple statements on charts, viewgraphs of anomaly listings and status, etc., are completely inadequate. These anomalies must receive a real and in-depth assessment that includes: what happened; the corrective action taken; and, the impact/risk if the action taken proves to have been inadequate. These assessments of past flight critical item anomalies should be discussed by both NASA Level III and contractor management, with penetration as to the adequacy of the disposition by NASA Levels II and I. Any repeating anomaly should serve as a clear signal that a problem/fix is not understood, and should be treated as a potential cause for launch delay.

No. P-5
Collateral Finding

TEAM: Prelaunch Activities
(Reference Section VIII, Prelaunch Activities Team Report)

FINDING: A review of the KSC Work Control Documentation System disclosed a number of unacceptable deficiencies in the performance and recording of preflight activities. This system provides the key to vehicle configuration control, proper definition and authorization of the work to be performed, the assurance of adequate work having been performed after close-out, and traceability and accountability for actions taken. Contingency operations (i.e., cannibalization of parts from another orbiter) generate unplanned, non-standard operations and test requirements. Operational scheduling procedures do not assure that this work is accomplished in a well-planned fashion. Also, test team errors were found that had been caused by not following the steps required by the documentation. One such was the unplanned opening of the 17-inch external tank disconnect valve during the STS 51-L countdown, an incident which was not recorded. Another example of inadequate reporting occurred during the destacking operations on STS 51-E, when water was noted draining out of the field joints in the SRBs; the discovery was not brought to the attention of appropriate management. Some signatures and quality control stamps were missing on closed-out records; specifically, there were no stamps on the paperwork covering the 17-inch hydrogen disconnect, where a seal had been discovered improperly installed on the STS 51-E mission. Other inadequacies were uncovered in the form of poor annotation of the steps taken in performing authorized deviations, and a lack of traceability.

RECOMMENDATION: A system review of the KSC Work Control Documentation System has been initiated, with the aim of streamlining and simplifying the paperwork in all places where this can be accomplished without loss of accountability and control. Procedures which integrate the non-standard and contingency operations required on each processing flow will be implemented, in a manner that assures a well-planned overall activity schedule. A personnel training program should be conducted, with an emphasis on the importance of using the Work Control documentation properly. The potential seriousness of errors, and the need to report all problems and unusual or unexpected conditions, will be stressed. Paperwork must not be closed out with missing signatures and/or inspection stamps. If such exist, the assumption must be made that the work and/or inspection did not occur. Strict discipline must be enforced to assure complete compliance with the approved procedures.

No. P-6
Collateral Finding

TEAM: Prelaunch Activities
(Reference Section VIII, Prelaunch Activities Team Report)

FINDING: It had been anticipated that the first launch from Pad 39B would uncover minor problems, and some discrepancies between the Pad A and Pad B systems. One such expected problem was pad launch damage. Some 216 items which were damaged or loosened during the liftoff have been identified as candidates for additional pad "hardening." Other mechanical and electrical systems are being reviewed to identify minor operating differences between the two pads.

RECOMMENDATION: Launch Complex 39B requires additional modifications to correct minor operating problems, particularly where systems operate differently from those on 39A. Where differences exist, they should be assessed to ensure that the two pads operate alike where possible, and that Ground Support Equipment can be connected and used interchangeably on either pad.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

No. P-7
Collateral Finding

TEAM: Prelaunch Activities
(Reference Section VIII, Prelaunch Activities Team Report)

FINDING: An unusually high workload at the time of the STS 51-L ground processing caused manpower limitations, and some areas where particular skills were in short supply. The major cause was the necessity of processing four orbiters, while also completing the Launch Complex 39B activation. Original planning called for Orbiter Discovery to be shipped to Vandenberg AFB in September 1985. The shipment was delayed in order to fly Discovery on an additional flight from KSC. The need to delay the movement of Discovery, in turn, was caused by major work on Columbia that had traveled to KSC. This resulted in a long processing flow prior to the STS 61-C launch. Problems in processing both orbiters were further increased by a substantial reliance on part cannibalization to support the operations. This was compounded by the STS 61-C activity, which moved from a planned December 1985 launch date to January 12, 1986. This unplanned delay, along with several intermediate launch attempts, created a higher than anticipated demand upon manpower, resulting in schedule limitations. In some skills, such as test conductors and senior engineers, the higher than normal test activities created abnormal demands upon their availability.

RECOMMENDATION: Manpower limitations due to a high workload created scheduling difficulties and contributed to operational problems. The manpower/skill mixes for prelaunch operations should be reevaluated, to minimize the effects of repeated launch attempts on the processing operations.

No. P-8
Collateral Finding

TEAM: Prelaunch Activities
(Reference Section VIII, Prelaunch Activities Team Report)

FINDING: The effects of an adverse environmental condition -- specifically, unusually cold weather -- are not sufficiently well understood. The amount of ice formed by leaving valves open to prevent freezing inside water pipes was greater than expected. After the STS 51-L launch, photographic documentation revealed that ice released from the pad structures after SSME ignition translated further toward the vehicle than predicted. Some ice was seen to impact on the left-hand solid rocket booster, though none was observed to hit the external tank or orbiter. Even if this problem is resolved by pipe heaters and insulation, under worst-case conditions sleet or nearly freezing water can fall and be followed by a drop in temperature sufficient to form ice. Also, the performance of some other Complex 39B systems was marginal due to the cold. The number of cameras that failed to operate at the liftoff of 51-L was almost three times that of the historical average. The existing instrumentation and analytical models are not adequate to define the unusually cold operating environment in which the 51-L launch was conducted. Additionally, the effects of such temperatures on the components of a Space Shuttle standing on the pad have not been sufficiently determined.

RECOMMENDATION: The ability to assess the effects of adverse environmental conditions on pad systems must be improved, and appropriate launch constraints imposed. All vehicle and ground systems which can be affected by environmental conditions should be reassessed to determine the changes or improvements needed.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

ACCIDENT ANALYSIS TEAM

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

ACCIDENT ANALYSIS TEAM

INTRODUCTION

The Accident Analysis Team was established to examine all aspects of the STS 51-L Challenger mishap and determine the most likely cause or causes of the flight failure. Some 9 subteams reviewed all the major component parts of the Space Shuttle, including its payload. Based on the evidence in hand at the time, components were classified as "improbable," "probable," or "possible" causes of the failure. Several failure scenarios were examined in detail, resulting in the elimination of the less likely modes of failure and the selection of the most probable cause. Then various possible faults which could have led to the selected mode of failure were examined to determine if the cause or causes of failure could be isolated and identified. The following Lessons Learned and Collateral Findings were identified as worthy of follow-on remedial actions during the course of these studies and tests.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: A-1
Lesson Learned

TEAM: Accident Analysis
(Reference Solid Rocket Booster Working Group)

BACKGROUND: In the past, criteria for design, performance, Launch Commit, and other operations have used "ambient" as a reference or base. This term is not specific and, subsequently, results in misinterpretation.

FINDING: The term "ambient" should not be used. A specific set of conditions should be described as measured at specific locations and clarified as to the effects of time of day, wind velocity and direction, temperature, humidity, and other parameters.

LESSON LEARNED/RECOMMENDATION: All design and performance requirements and Launch Commit and other operational criteria should be re-evaluated and all designs should be verified as meeting these criteria. All Launch Commit Criteria should have direct measurements data available to confirm adherence to the criteria.

NO.: A-2
Lesson Learned

TEAM: Accident Analysis
(Reference Solid Rocket Motor Working Group)

BACKGROUND: With the Space Shuttle flight program still in the early years of demonstrating and establishing operational maturity and reliability, there is clear evidence that a previously aggressive parallel ground test program has been substantially curtailed. There is no question that the supporting ground test program can be throttled back, at some point and to some degree, and even in some areas stopped. In critical propulsion systems, the issue is threefold: (1) When should the ground testing be cut back; (2) how much testing is enough; and, (3) where should the testing be focused.

FINDING: Using the Space Shuttle Main Engine (SSME) Project as a suitable example, due to the criticality of the engines during ascent, a review of the ground test program status illustrates the point. This should suggest to NASA that a re-look at this important support phase of the flight program is in order.

Since 1981, the year of the first Space Shuttle launch, the number of development tests conducted on the main engines has been reduced by 50%. The operating time accumulated on the engines in ground tests has been reduced by 17%, at a time when the flight rate increased by a factor of 4.

The Space Shuttle Main Engine program is only an example. Clearly, the Solid Rocket Motor (SRM) program would have benefited from a more aggressive ground test program as anomalies became evident in the flight program. Component tests have been conducted as part of the 51-L failure investigation which have been extremely valuable, providing an understanding of the operation of a component or system of components that was not previously available. These include tests to define the pressure transmission and blow-through characteristics of the joint putty and joint dynamic simulation tests to determine the sealing characteristics of the O-rings. Sub-scale or full-scale component testing is necessary to achieve a complete understanding of systems which do not lend themselves to a pure analytical approach. This testing should be conducted for all critical systems.

A-2 Lesson Learned (Cont'd)
Accident Analysis Team

LESSON LEARNED/RECOMMENDATION: Program elements in select areas could provide a safer flight product by placing more emphasis on ground testing conducted in parallel with the flight program. The safest flight program requires an aggressive supporting ground test program, including, in some cases, taking the ground test article to failure. In critical systems -- and certainly ascent propulsion fits in this category -- an aggressive supporting ground test program should be a firm requirement and should be maintained through time in the flight program that all limits have been bounded, and periodic ground tests should be conducted thereafter. The ground testing should emphasize firmly established safe operating boundaries, or limits, so that the flight program can safely operate in the middle of the defined envelope, with known margins.

NO.: A-3
Lesson Learned

TEAM: Accident Analysis
(Reference D-7, Development & Production Team Report, Section VI and Solid Rocket Motor Working Group)

BACKGROUND: It was found in the review of STS 51-L inspection records that Government mandatory inspections (GMIs) had been improperly deleted on some Solid Rocket Motor hardware and that some GMIs required by the critical items list (CIL) for the External Tank were not performed because they were not incorporated into the shop planning paper.

Also, for a period of time, which included the processing of the 51-L O-rings, mandatory inspection points were eliminated from the O-ring acceptance criteria at MTI. The secondary O-ring for the suspect 51-L field joint was processed during the time these mandatory inspection points were not in effect.

FINDING: Although a well-organized CIL with accompanying hazard analysis currently exists, it does not appear that these CIL items were readily identified to the work force or that these items received special attention.

LESSON LEARNED/RECOMMENDATION: The CIL items should be identified in all work papers so that the work force and quality personnel know when they are working with such an item. Any special care in handling or testing should be identified.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: A-4
Collateral Finding

TEAM: Accident Analysis
(Reference Solid Rocket Motor Working Group)

FINDING: Solid Rocket Motor segments are shipped from the Morton Thiokol facility in Wasatch, Utah to KSC, FL horizontally on railroad cars. All segments are shipped with the 90° location (systems tunnel) at the top of the segment. During the assembly process at KSC, it has become necessary to reshape case segments to make them concentric with mating segments. This has resulted in assembly difficulties and eccentric loads on the joint O-rings. Assembly difficulties resulting from the lack of concentricity include the generation of case metal slivers produced by having to force pins into the joint pin holes. The pin-to-pin hole tolerances are such that the pin is difficult to install if the tang and clevis pin holes are not precisely aligned. If the tang and clevis are not concentric, the pin holes do not precisely align. Case segment ovality which apparently results from horizontal shipping on railcars, can cause tight tolerances in the area of the O-ring sealing surface. This can cause assembly difficulties and result in undesirable O-ring squeeze. Also, case pin hole distress can result in the generation of metal slivers when pins are forced into pin holes not properly aligned due to lack of concentricity.

RECOMMENDATION: A method of verifying roundness at the Morton Thiokol plant in Wasatch, Utah, prior to shipment to KSC, should be developed. The shape should be maintained during shipping or shaping equipment should be developed to aid assembly.

NO.: A-5
Collateral Finding

TEAM: Accident Analysis
(Reference Section IV, G5, External Tank Working Group)

FINDING: The failure of a Hardware Interface Module (HIM) supporting the MPS Ground Support Equipment propellant loading system caused a 2-hour, 20-minute delay while repairs were made, which resulted in the loss of all fire detection and hazardous gas measurements in the MPS Ground Support Equipment with propellant on board. This capability is required for loading to provide adequate visibility of propellant leaks and fire.

RECOMMENDATION: Consideration for a back-up system or module should be undertaken to preclude the inability to monitor these measurements during loading on the MPS Ground Support Equipment propellant loading system and also to preclude delaying propellant loading.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: A-6
Collateral Finding

TEAM: Accident Analysis
(Reference IUS and Systems Working Groups)

FINDING: The OI flight data are inadequate to totally reconstruct and verify SRB operation. This is more evident in the structures subsystem than in the other subsystems. Also, more payload bay environmental measurements should be included in Orbiter downlink. In addition, the SRM head pressure recorded by the Orbiter during SRM ignition does not have enough resolution for evaluation purposes. This problem has existed since the removal of the SRB onboard recorders. SRM ignition data were not available to evaluate STS 51-L.

RECOMMENDATION: Perform a NASA review of all operational instrumentation on the STS vehicle for adequacy, with emphasis on SRBs.

NO.: A-7
Collateral Finding

TEAM: Accident Analysis
(Reference Solid Rocket Motor Working Group)

FINDING: All inventory SRM case O-rings were reinspected during the 51-L investigation. When reinspected using original inspection equipment (mechanical micrometer), very few out-of-tolerance conditions were identified, but when reinspected with a laser micrometer with a 0.007-inch measuring beam, numerous small localized out-of-tolerance conditions were detected. Although test proved that these conditions were not detrimental to sealing capability, this does indicate a need for processing improvements and improved inspection techniques. All inventory O-rings were also x-rayed, indicating numerous O-ring inclusions. Again, these noted conditions did not affect the sealing capability, but they do indicate a potential problem and a need for this inspection method and improvement in processing.

It was learned during this investigation that the O-ring material manufacturer had changed material formulations and processing numerous times since starting to produce SRM O-ring material. While all these formulations resulted in O-ring material that was in compliance with MIL-R-83248, this lack of standardization could possibly result in application problems and is unacceptable for such a critical item.

RECOMMENDATION: Because of the critical nature of the material, O-ring processing and inspection requirements should be reviewed to assure they are compatible with the criticality 1 criteria. Of special interest is the loss of visibililty/control of lower level suppliers' compliance with specifications.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: A-8
Collateral Finding

TEAM: Accident Analysis
(Reference Solid Rocket Motor Working Group)

FINDING: Dimensions and functions critical for reused hardware performance should be established and periodically verified. SRM clevis and tang sealing surface diameters were assumed to be stable and were not remeasured during refurbishment. Subsequent testing revealed growth in these diameters after hydroproof (and possibly flight) which introduced an unrecognized variable into O-ring squeeze calculations.

RECOMMENDATION: All case segments currently in inventory should be remeasured to determine their acceptability for reuse and the requirement for retaking these measurements included in the refurbishment procedures. Testing should continue to provide full understanding of the mechanisms of case growth and to provide the basis for assuring dimensional stability in any case segment redesign.

All other reusable hardware should also be assessed.

NO.: A-9
Collateral Finding

TEAM: Accident Analysis
(Reference Solid Rocket Motor Working Group)

FINDING: The 51-L accident investigation has covered a number of areas where the design has not been reviewed in a number of years, even though new techniques have been developed for analysis, new material properties developed, or flight experience obtained.

RECOMMENDATION: A review of performance against the design requirements and implementation considering flight experience along with new technology and test methods should be instigated on a periodic basis.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: A-10
Collateral Finding

TEAM: Accident Analysis
(Reference Systems Working Group)

FINDING: Measurements and models used to perform preflight, flight and postflight predictions need to be reviewed and upgraded. The number of actual flight parameters that various trajectory groups (MSFC, JSC, and RI) tried to match on 51-L was far greater than on any previous mission. In the search for this universal parameter match, it became apparent there are additional forces that need to be modeled and some existing models that need to be modified. The accuracy we were seeking in our reconstruction activity was being masked by the uncertainty in the input data, much of which consisted of reconstruction data, as well as by the accuracy of postflight performance reconstruction, which depends directly on measurements that currently have large uncertainties associated with them.

RECOMMENDATION: A joint review of measurements and computer models shall be conducted with a goal of producing high fidelity preflight and postflight reconstructions.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: A-11
Collateral Finding

TEAM: Accident Analysis
(Reference Space Shuttle Systems Working Group)

FINDING: There was a lack of easily accessible certification and a flight experience data base. Data giving certification limits, as well as pertinent flight experience within these limits, are not readily available.

RECOMMENDATION: A computer program that provides current information on environmental certification of each element and subsystem should be developed. The data should include range of environments specified, how equipment was certified to these environments (test, analysis, or similarity), and flight exposure which is constantly updated. It should be possible to query for all or any limiting conditions including element or subsystem that is limiting any exceedances in flight, any waivers granted, and justification. These data should be readily available to designers, flight planners, and operational personnel in real time.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

MISSION PLANNING & OPERATIONS

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

MISSION PLANNING & OPERATIONS TEAM

INTRODUCTION

The Mission Planning and Operations Team was charged with performing a critical review and analysis of the National Space Transportation System, including flight schedules, mission planning, flight operations, mission safety, range operations, and all aspects of mission design and development. The pressures exerted by tight schedules, and their impacts on mission planning, were examined, as was the steady expansion of the flight envelope. A critical review of flight operations capabilities, preparedness, mission and range safety was conducted. Flight procedures were also evaluated for adequacy and maturity. The technician and engineer workload was examined, as was flight controller training, hardware and software testing program content changes, the effects of postponing repairs, modifications and software changes, and the adequacy of the time allotted to each mission for design and development.

The following Collateral Findings emerged from this detailed examination.

NO.: M-1
Collateral Finding

TEAM: Mission Planning & Operations
(Reference Section VI, Mission Planning & Operations Team Report)

FINDING: The 1985 Mission Operations were successful in spite of significant remanifesting and perturbations. However, all trends prior to the STS 51-L mishap indicated that the milestones required to support preparations for the 1986 flight schedule were not being met. The current program commitments preclude devoting adequate resources to developing a capability to support an increased flight rate.

RECOMMENDATION: The NSTS Program should develop a bottoms-up strategy for expanding the flight rate. As a start, rigid manifesting criteria need to be established and enforced.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: M-2
Collateral Finding

TEAM: Mission Planning & Operations
(Reference Section VI, Mission Planning & Operations Team Report)

FINDING: The Operations and Maintenance Plan (OMP) does not provide Level II with an adequate closed loop overview that the program element design requirements have been satisfied. Presently, the OMP is used for planning, and the subsystem engineers are responsible for verifying the compliance of the program element design requirements or that an exception or waiver was approved. The OMP lacks a comprehensive system for tracking and auditing of the compliance with the established OMRS requirements.

RECOMMENDATION: The Operations and Maintenance Plan (OMP) should be modified such that it becomes a closed loop system which verifies that the program element design requirements are satisfied and that positive feedback to Level II is implemented. Additionally, for those requirements not satisfied, an exception or waiver should be processed in a timely manner.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: M-3
Collateral Finding

TEAM: Mission Planning & Operations
(Reference Section VI, Mission Planning & Operations Team Report)

FINDING: The current landing and deceleration systems have not demonstrated an adequate margin for KSC and TAL abort operations.

RECOMMENDATION: The NSTS Program should focus attention on defining and providing an adequate margin in landing and deceleration systems for end-of-mission and intact abort landings. This includes both ground facilities and flight hardware.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: M-4
Collateral Finding

TEAM: Mission Planning & Operattions (Reference Section VI, Mission Planning & Operations Team Report)

FINDING: There was no action possible that could have resulted in survival of the STS 51-L crew. The Program had many considerations of crew escape, but because of technical complexity, limited application and severe weight penalties, no systems were implemented.

RECOMMENDATION: The NSTS Program should evaluate options to augment Orbiter abort modes. In lieu of an escape system, engineering and operations should rigidly adhere to the principle that we will not experience a catastrophic failure during powered flight. For example, this should include, but not be limited to the following:

- SRMs will not fail.
- SSMEs must have safe shutdown regardless of system failures.
- APUs must have safe shutdown.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: M-5
Collateral Finding

TEAM: Mission Planning & Operations
(Reference Section VI, Mission Planning & Operations Team Report)

FINDING: The Range Safety System (RSS) did not contribute to the STS 51-L mishap. The actions of the Range Safety Officer (RSO) were appropriate. However, a review of the Range Safety System is appropriate.

RECOMMENDATION: A joint NASA/DOD review of the Range Safety System should be conducted prior to the next Space Shuttle launch.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: M-6
Collateral Finding

TEAM: Mission Planning & Operations
(Reference Section VI, Mission Planning & Operations Team Report)

FINDING: Statistical weather and forecasting uncertainties have resulted in several weather wave-offs and dictate a need for multiple landing sites for end-of-mission.

RECOMMENDATION: The NSTS Program shall operate with at least two landing sites for end-of-mission.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

SEARCH, RECOVERY & RECONSTRUCTION TEAM

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

SEARCH, RECOVERY & RECONSTRUCTION TEAM

INTRODUCTION

The Search, Recovery, and Reconstruction Team was charged with the responsibility of locating and recovering the parts of the Space Shuttle off the floor of the Atlantic, and assembling the fragments in a manner that approximates the location each occupied as a part of the flight vehicle. Location and recovery operations involved a small fleet of ships, specialized recovery equipment, manned and unmanned submersibles, and divers. This effort was supported by the U.S. Air Force, U.S. Navy, U.S. Coast Guard, NASA, National Transportation Safety Board, and representatives from all major concerned Space Shuttle contractors. It is believed to be the largest such underwater locate and recovery effort ever undertaken.

The Collateral Findings that follow pertain to the efforts conducted by this team to find and recover the parts of the Space Shuttle Challenger lost on the STS 51-L mission. A separate report is being issued on the organization, history, and performance of the Recovery Team itself. The latter is an attempt to capture the specific actions undertaken, the results, and the resources used for this unprecedented effort. In some cases, the contents of that document overlap the findings presented here. But the intent of this document is to capture the valuable information generated by this particular search for and recovery of a Space Shuttle vehicle. The intent of the Recovery Team document is to capture knowledge generated by this huge effort that can be applied and used in recovery operations for any vehicle, under a variety of circumstances.

NO.: S-1
Collateral Finding

TEAM: Search, Recovery and Reconstruction (Reference NASA/KSC Biomedical Operations and Research; NASA/KSC Safety)

FINDING: Immediately after the accident, all telephone lines were "blocked out" for several reasons. The personnel in the LCC Firing room were unable to communicate by phone for a critical time after the loss of downlink from the Orbiter. For example, the Emergency Medical Support (EMS) on the console was unable to communicate with hospitals off-center to alert them for possible assistance to crew family members, nor were other consoles able to communicate with other locations.

RECOMMENDATION: Provide protected uninterruptible communications to essential positions. Areas to be addressed will include inter-center communications and KSC to local emergency services. Items to be included in the study:

- Requirements
- Technology Required
- Implementation Planning
- Schedule
- Budget
- Safety
- Ordnance
- Dock-side Personnel.

NO.: S-2
Collateral Finding

TEAM: Search, Recovery and Reconstruction
(Reference NASA/KSC Biomedical Operations and Research)

FINDING: An incident of this magnitude required the use of all of KSC's medical forces (NASA and contractor) just to take care of the families of the crewmembers. This indicates that in a disaster which causes astronaut, family, spectator, and employee victims, we would be severely short of adequate resources.

RECOMMENDATION: Review in-place emergency preparedness plans to determine needed updates for probable industrial accidents in light of experience gained from the 51-L accident.

<u>STS 51-L DATA & DESIGN ANALYSIS TASK FORCE</u>

NO.: S-3
Collateral Finding

<u>TEAM</u>: Search, Recovery and Reconstruction (Reference Initial inputs S-5, S-8, S-9, S-10, S-11, S-13, S-14, S-15, S-16, and S-17, submitted by KSC Safety (P. Ashburn), DDMS, and KSC Shuttle Engineering (D. Carlson).

<u>FINDING</u>: A number of deficiencies were noted in the KSC/ESMC contingency planning, salvage planning, safety and security manuals, and ordnance procedures.

<u>RECOMMENDATION</u>: Review all KSC, ESMC, DDMS, Navy, and Coast Guard documents relating to salvage oeprations, incorporating the STS 51-L incident experience. Address Memoranda of Understanding and contingency planning. Review dock procedures including ordnance handling instructions and other handling instructions for completeness based on the 51-L recovery effort.

Develop a viable Salvage Plan as appropriate, including notification procedures, activation procedures, and transportation procedures.

Prepare salvage procedures to include briefings to ships' captains on potential hazards.

Review existing agreements on data and physical evidence handling and impoundment. Update as required.

Establish an MOU with NTSB for future participation in investigations.

NO.: S-4
Collateral Finding

TEAM: Search, Recovery and Reconstruction
(Reference Discussions KSC Rescue)

FINDING: Rescue could not enter the area identified where falling debris was impacting the Atlantic Ocean due to the danger to aircraft from the continued falling of the debris. It was approximately one hour before the area was declared safe for entry.

RECOMMENDATION: Rescue crews cannot wait that length of time. To be effective and to recover the crew, the attempt must be made as soon as possible. Investigate the possibility of allowing properly outfitted rescue vehicles to have immediate access to the impact area.

NO.: S-5
Collateral Finding

TEAM: Search, Recovery and Reconstruction
(Reference NASA Public Affairs)

FINDING: Throughout the salvage effort, the presence of a Public Affairs person from the primary service involved was helpful in compiling information for clearance. The Navy or Coast Guard Public Affairs Officer was familiar with the ships being used, methods, and people involved in the recovery effort. This resulted in rapid assembly of data and status reports for submission to the Task Force in a timely manner.

The Navy and Coast Guard Public Affairs Officers were also looked on as experts by the media and took the pressure off the people actually conducting the operations to respond to the media. The presence of the service PAO also helped in assuring the service organization that they were receiving the recognition they deserved.

RECOMMENDATION: Whenever an operation involves other elements of Government, Public Affairs from that organization should be involved as a resource for the NASA Public Affairs Office.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

PHOTO & TV SUPPORT TEAM

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

PHOTO & TV SUPPORT TEAM

INTRODUCTION

The three concerned NASA Centers (JSC, KSC, and MSFC) independently began substantial efforts immediately after the STS 51-L mishap. Intercenter coordination on these activities at first was limited. A substantial improvement occurred after the Task Force was formed, and the Photo & Video Analysis Team was chartered and given responsibility for the analysis of imagery.

The internal organization of the three Centers created start-up problems which hampered the early efforts. No image analysis team was in place at JSC at the time of the mishap. An image enhancement activity existed at MSFC, but it was physically and organizationally separated from the group which did postflight analyses. The photographic functions at KSC were fragmented and scattered throughout the Center.

The Photo & TV Support Team established common goals and schedules, selected events of interest, and assigned roles. Common or compatible methods for analysis were established. Analysis products, including enhancements, were reviewed by the group as a whole. This minimized differences in the conclusions drawn. The following Collateral Findings were identified by the Photo and TV Support team.

NO.: PH-1
Collateral Finding

TEAM: Photo & TV Support
(Reference Section VI, Volume IV, Photo & TV Support Team Report)

FINDING: There was no contingency plan for imagery in existence at the time of the 51-L mishap.

RECOMMENDATION: Establish a contingency plan for imagery which calls out an intercenter organization with named chairmanship and membership and with a charter parallel to that of the other teams in the NASA contingency plan. Air Force participation would be helpful.

NO.: PH-2
Collateral Finding

TEAM: Photo & TV Support
(Reference Section VI, Volume IV, Photo & TV Support Team Report)

FINDING: An uncoordinated situation among the Centers existed at the time of the STS 51-L mishap as far as the use and analysis of the imagery that had been obtained was concerned.

RECOMMENDATION: Establish at the concerned Centers (JSC, KSC, MSFC) contingency photo teams which are parallel to those of the teams currently in Center Contingency Plans.

Additional follow-up action should also be considered in the following areas:

NASA should have a self-sufficiency objective for a total end-to-end photographic and TV products analysis capability. This includes from the initial acquisition of the product through a report writing conclusion capability. Utilization of other Government facilities should be for special project work only. Cost trade-offs can be performed to help draw the practicality line. This recommendation is intended to be for an agency program capability and is not intended to promote needless redundancy within the STS Program.

Procedures are required for film review and processing, dissemination of master copies, image analysis, and enhancement for use in failure investigation.

Common photographic cataloging, communication, and data transfer systems between Centers are required.

A controlled archival storage system for launch photographic and video original material is required at KSC.

Conduct a study through the intercenter organization and center teams of the future engineering data and analysis required and procedures to be followed for accident prevention purposes and contingency accident investigation at KSC and VAFB. Include review and selection of optics, cameras, film exposures, selective filtering including downrange haze penetration, removal of uncovered blind spots at launch, and coverage for orbit and landing phase.

PH-2 Collateral Finding (Cont'd)
Photo & TV Support Team

Improve the quality of documentation of closeout photographs by using experienced phtographers rather than hardware inspectors with limited photo training experience.

Include alphanumeric display of frame number and standardized timing on each frame of film and video.

A review of the state-of-the-art equipment should be made to implement the best capability for engineering analysis purposes.

Augment and maintain image analysis and enhancement efforts within the Agency to ensure adequate capabilities.

Establish a KSC engineering photographic analysis lab with state-of-the-art equipment.

A capability for making color reversal prints should be established at KSC.

There should be an improvement in lighting, especially at night of critical areas such as the holddown posts on the pad.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: PH-3
Collateral Finding

TEAM: Photo & TV Support
(Reference Section VI, Volume IV, Photo & TV Support Team Report)

FINDING: The KSC photographic support contract is mostly funded by NASA but is managed by the Air Force. Most of the photo facilities are located on Air Force installations making access and transport difficult, especially during contingency operations. The arrangement with the Air Force is archaic.

RECOMMENDATION: The entire arrangement with the Air Force should be reviewed with the objective of KSC being self-sufficient.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: PH-4
Collateral Finding

TEAM: Photo & TV Support
(Reference Section VI, Volume IV, Photo & TV Support Team Report)

FINDING: The imagery collected as a result of the clear day weather was very significant in the accident analysis efforts. Had it been a night launch or a launch with an overcast sky, the amount of time required to reach conclusions drawn would have been much greater and perhaps never as clearly understood.

RECOMMENDATION: Launch visibility for photographic reasons should be a primary mission rule until the hardware fixes resulting from this investigation are proved operational.

STS 51-L DATA & DESIGN ANALYSIS TASK FORCE

NO.: PH-5
Collateral Finding

TEAM: Photo & TV Support
(Reference Section VI, Volume IV, Photo & TV Support Team Report)

FINDING: The intercenter effort obtained by this compact cohesive photo and TV team was invaluable in reaching the conclusions drawn.

RECOMMENDATION: The STS Program should charter an intercenter photographic/TV working group to document the activities required to implement the findings and lessons learned of this report.

No. PH-6
Collateral Finding

TEAM: Prelaunch Activities
(Reference Section VIII, Prelaunch Activities Team Report)

FINDING: The SPC has responsibility for closeout photos. Not only do they not have the best photographers at KSC, but also it is questionable that there is not a built-in conflict of interest for their contract to perform this function.

RECOMMENDATION: Review the role of the SPC in closeout photos and determine the best overall location for the closeout photo documentation responsibility.