NATIONAL RECONNAISSANCE OFFICE ASSESSMENT OF THE FIRST STS ORBITAL TEST FLIGHT

OVERVIEW

The National Reconnaissance Office (NRO) has completed an independent assessment of the first flight of the Space Shuttle. The STS-1 mission was planned to last 54.5 hours with an orbital inclination of 40.3° in an initial 130 nm circular orbit and a 150 nm final orbital altitude. The primary objectives of the mission were to launch the Orbiter, operate it successfully on-orbit, and return safely. Overall, the mission was highly successful, accomplishing all the objectives. The success of STS-1 certainly increased overall confidence in the concept, design, and health of the shuttle program. However, while extremely encouraging, this single flight represents the maiden voyage of a complex vehicle under essentially benign conditions. Consequently, while our confidence has been greatly enhanced, prudence requires retention of maximum sensitivity to potentially undiscovered or undetected problems. As the STS program progresses and a wider range of operational capabilities are demonstrated, we can perhaps better afford to relinquish our ELV back-up capability.

The NRP posture at this time should, therefore, consist of an aggressive pursuit of shuttle transition and maximum practical utilization, while protecting critical national defense space programs with an adequate back-up ELV capability. This strategy will prevent unacceptable impacts to national collection capabilities while facilitating an orderly and timely NRP transition to the STS.

INTRODUCTION

This report assesses the DOD perspective of the STS Program based primarily on the data obtained from the successful STS-1 mission. STS-1 was the maiden voyage of the Columbia and the first in a series of four missions that comprise the STS Orbital Flight Test Program (OFT).

A total of 168 Flight Test Requirements (FTR) were identified for the OFT Program, of which 138 were assigned to STS-1. Since data from more than one flight are required to complete all of the orbiter FTR's, none have been completed.

No hard or quantifiable projections into the early STS operational phase can be drawn from the single STS-1 experience which was baselined to avoid exposure to the limits of flight conditions. However, limited inferences can be made and the conclusions about the STS Program based on STS-1 data must be considered in this context.

STS-1 MISSION PERFORMANCE SUMMARY

Overall, the prelaunch, launch, orbital, and landing phases of the STS-1 mission were excellent. All of the Flight Test Requirements (FTR's) for STS-1 were accomplished; however, due to a Development Flight Instrumentation (DFI) Recorder failure, segments of data were lost, affecting 22 of 138 FTR's. While the loss of some of this data is considered serious, adequate data was obtained to establish high confidence for all systems.

The Main Propulsion System (MPS) performed satisfactorily for 8 minutes 40 seconds with only minor anomalies observed. Overpressure after the ignition of the Solid Rocket Boosters (SRB's) was significantly larger than predicted. Measurements on the orbiter heat shield and on the upper surface of the body flap read 2.0 psi above ambient, 4 times the predicted value. SRB burn-out and separation at the end of the first stage was nominal. The left SRM thrust was approximately 1.7% above the predicted nominal and the right SRM was approximately 1.0% high.

The vehicle flew well within the 3-sigma flight path envelopes; however, several variances from nominal predictions were noted. A vehicle pitch attitude error (lofting) started at about 40 seconds after liftoff and peaked at about 5.2° at 70 seconds, diminishing gradually thereafter. Launch and ascent load levels were near the predicted values and well within design limits with the exception of Z-axis loads at SRB ignition; Z-axis loads were as high as twice the preflight predictiions and exceeded the specification levels. These Z-axis loads may be related to the high SRB overpressures at ignition.

The launch loads were fully demonstrated while the ascent loads, as typified by the maximum dynamic pressure, were approximately 80% of the envelope. The launch and ascent vibration and acoustic environment for STS-1 was almost completely demonstrated.

The acoustic levels in the payload bay were within specification. The External Tank (ET) separated from the orbiter as planned, but the ET tumble valve did not function; the ET appears to have broken up at a higher altitude than predicted, but the debris footprint remained completely within the broad ocean areas.

Significant debris was observed in the pad area at liftoff and during ascent; a small percentage caused damage to the orbiter Thermal Protection Subsystem (TPS) tiles, but the damage was minor and had little or no effect on the thermal performance of the vehicle.

All orbiter subsystems operated well on orbit with remarkably few anomalies; only four "hard" component failures occurred in flight - the Development Flight Instrumentation (DFI) Recorder, the Auxilary Power Units (APU) Heater, the Horizontal Situation Indicator (HSI) Compass Card, and the Orbital Maneuvering Subsystem (OMS) Fuel Gauge.

Ascent and reentry heating and loads were conservatively within specification; on-orbit thermal conditions were also kept well within the operation design envelope.

Entry guidance and terminal area energy management during automatic and control stick steering operations were normal. Most of the entry was flown in the automatic mode, as planned, with the crewman engaging control stick steering at the planned points. The Microwave Scanning Beam Landing System performed well, having locked on the vehicle at 19,200 feet.

Damage to the Thermal Protection System was less than expected. No critical tiles were lost in flight. Initial inspections of the orbiter showed it to be in very good condition. Several areas of localized heating were noted, but nothing to cause serious concern.

Post flight examinations of the payload bay indicated several types of contamination that, while of no serious consequence to the orbiter, might represent a significant problem to certain classes of payloads.

TURNAROUND PROCESSING FOR STS-2

The Columbia was ferried to KSC on 28 April and transferred to the Orbiter Processing Facility (OPF) on 29 April marking the official end of STS-1 and the beginning of the STS-2 processing flow. Both Orbital Maneuvering Subsystem (OMS) Pods and the forward Reaction Control Subsystem were removed and sent to the Hypergol Maintenance Facility. Both OMS Pods were modified to add stiffness in the areas that were exposed to higher than predicted localized temperatures.

All three main engine high pressure fuel turbo-pumps were removed, inspected, reinstalled, and the engines certified for the second flight. A total of only 1430 Thermal Protection Subsystem Tiles have been removed and more than half were removed for planned densification, inspections, or instrumentation. Tile damage resulting from the flight required very little repair. As TPS repair is manpower intensive and slow, the positive experience of STS-1 increases the confidence that extensive tile repairs will not endanger operational turnaround times. An assumption that must be made for this conclusion is that the higher dynamic pressures encountered during STS-2, 3, and 4 will not significantly affect the tiles.

Successful prelaunch and flight performance during STS-1 should permit reduction in prelaunch redundant test and checkout requirements, with greater use of flight data and off-line checkout during the OPF processing. Approximately five months were scheduled for the first turnaround. After three months of work, STS-2 processing has remained on schedule. Pod damage was less than expected and should present no problems to turnaround timelines.

The ground support equipment used for checkout and launch performed very well and indicates no major changes are required. Improvements in procedures and methods are apparent in the processing for the second flight. As an example, the SRB stacking took 23 days for STS-1, but only 9 days for STS-2. While this learning curve may appear dramatic between STS-1 and STS-2, continued improvements may be much less dramatic. The projections for operational turnaround times are very likely optimistic and most likely will not be achieved during the early operational era.

This should not necessarily impact DOD missions on the shuttle if the missions are given the appropriate priority. If turnaround times begin to disrupt the flight schedules, the manifest will have to be revised. As long as national defense missions are regarded as firm requirements, the shuttle should be able to support all scheduled missions. Only launch-on-demand missions or unplanned launch requirements by DOD would be impacted by longer turnaround times during the early operational era.

Overall, the STS-1 launch processing, flight operations, and turnaround processing to date went very well and represents the first concrete assurance that the STS will be available for operational support in late 1982. While the STS-1 mission was very encouraging and a significant first step, it still represents the most benign portion of the flight test program. STS-1 has certainly done more to allay concerns about STS transition than to increase them, but the remaining flights in the OFT program will provide more realistic data for evaluating critical elements such as the life of the reuseable Space Shuttle Main Engines (SSME's), durability of the Thermal Protection Subsystem (TPS), reliability of the many complex subsystems, and system turnaround time.

Other key factors that could adversely affect the utility of the STS for our programs should also be carefully evaluated during the next year. First is the ability of NASA and its contractors to hold STS costs down. Increased costs can translate into reduced flight rates and disrupt the logical progression of demonstrating the range of capabilities necessary for the STS to reach its full operational status. Also, final agreements should be formalized that assure that NASA fully appreciates the high priority of the DOD missions and accepts the fact that future perturbations to the manifest will have to be borne heavily by other users, primarily commercial customers. This will place NASA in a very difficult position with the other users. Finally, the performance aspects of the STS program are critical to DOD programs. The 109% SSME Certification Program should be carefully monitored; the orbiter operational weights, and numerous weight savings options also have a definite affect on overall lift capability. The lightweight tank, the lightweight SRB's, thrust augmentation, and other performance improvements must also be monitored.

The STS-1 issues still requiring resolution are:

1) the SRB overpressures,

2) the above-specification Z-Axis launch loads, and

3) continued evaluation of payload bay environment and cleanliness.

In conclusion, the experience gained from STS-1 is certainly encouraging and did not produce data that would emphasize any old concerns or uncover any new issues that should cause us to question the viability of the STS as a future option; it did not identify any new constraints that would impact our transition to the shuttle. Every effort should be made to transition our programs to the shuttle as planned, but data to date does not provide adequate justification for failing to protect those programs that are dual compatible by retaining a limited ELV inventory to hedge against future uncertainties.

REASSESSMENT OF STS RISKS AFTER STS-1

The STS development philosophy has always been based upon a progression of test flights that permitted the initial flights to be flown well within predicted capabilities considering the possible dispersions in predicting performance, and then provide, in later flights, an orderly buildup of testing data to complete verification of design capabilities. The number of tests have been reduced from six to four and test objectives scheduled during the OFT Program have been deferred due to the requirement to fly the first DOD payload on OFT-4. This was caused by delays that slipped the completion of the OFT Program into the planned operational period. The predetermined number of test flights and the desire to complete the development testing within approximately one year, represent an ambitious and success-oriented schedule. This same philosophy and phased approach apply to extending the shuttle performance and modifications/improvements to meet operational requirements. The risk will remain low as long as a logical sequence of verification is followed which progresses only as rapidly as safety and logic permit. As flight rates are reduced for any number of reasons (fiscal, technical, turnaround times, modifications, etc.), firm requirements may force a compression of this logical sequence of verification. This would increase the program risks or force delays in the availability of required capabilities in lieu of increased risks. This should be monitored and carefully considered.

SPECIFIC RELATED ISSUES:

POSSIBILITIES OF GROUNDING AND IMPACT ON LAUNCH SCHEDULES

"Groundings" may be grouped into 3 categories:

(1) generic system problems that affect the entire fleet,

(2) specific problems with a particular component or vehicle configuration that only affects that vehicle,

(3) lack of parts to support requirements due to failure or removal which may affect from one to several vehicles.

The STS-1 performance (good propulsion and TPS performance, with adequate margins, lower-than-expected temperatures, nominal performance of hydraulics, electrical and environmental systems, etc.) indicates that margins are available. While there are minor hardware fixes to be made before STS-2, there is no indication of significant problems that would appear likely to either delay completion of the Orbital Flight Test Program or cause specific concern about fleet-wide shuttle grounding during the operational phase.

Planning to accommodate limited orbiter "out-of-service" periods has been included by NASA in the development of the STS manifest. The reliability experienced through STS-1 would indicate that groundings for lack of parts may be less than might have been expected, and that support from the production line is practical.

A significant difference between ELV and STS grounding should be considered. Since the orbiters are reusable, any perturbation to the processing flow represents an in-line impact to the entire manifest until the delay can be overcome by slack time. With dedicated ELV's, the only serial impact is pad time. We have seen this problem with facilities such as SLC-4 that support several programs. In the case of the STS, the entire vehicle processing flow, as well as the facilities, can be affected.

The probability of grounding based solely on complexity and parts count should be higher for the STS than ELV's.

Again, this impact can be minimized if DOD launch requirements are treated as mandatory commitments. Consequently, if the fleet has been grounded for several months, it may become necessary to first support a DOD launch at the expense of the flights that were scheduled ahead of it, but were delayed due to the grounding.

IF ELV'S ARE PHASED OUT AS PLANNED, WHAT MIGHT BE RECOMMENDED FOR STS?

Orbiters do not currently appear to be the critical path to expanded STS utilization. External tank (ET) production paced the latest reduction in flight rates. However, the different sensitivities of the system elements to additional money could possibly change the critical path. A more systems-oriented perspective aimed toward augmenting known system deficiencies would seem prudent at this time. An unmanned, partially reusable shuttle derived vehicle (SDV) could be an attractive complement to the STS; perhaps a modular SDV that could be expanded to fulfill the initial role of a Heavy Lift Launch Vehicle (HLLV) could be developed. This could be used to provide large weight and volume to low earth orbit for construction in space or an effective means of placing and retrieving large weights in higher orbits than the STS can presently serve directly. Additional critical ground facilities could be augmented or backed up by redundant sites even if they included only minimal capability. Specifically, the KSC launch facilities, the VAFB facility as a backup for KSC, or the SCF as a backup for JSC. If a SDV were developed, perhaps it could utilize the USAF Titan facilities to provide a degree of redundance and protection.

NO UNMANNED CAPABILITY IN PERIODS OF HOSTILITIES OR HOSTILE ACTION.

The requirement for a scheduled DOD launch or the need to unexpectedly replace a failed or damaged DOD satellite would be greater in a period of tension or hostility. The fact that the Soviets have already indicated that they perceive the STS as a potential military threat could pose additional problems for DOD shuttle launches during such periods of tension. Also, the high public visibility of the STS would certainly increase the speculation in our news media and highlight the situation even further. The combination of these events might create a situation in which the Soviets demand that we refrain from launching the system on the grounds that it represents a hostile act in its own right and would force them to take retaliatory action. Reasonable pressure could be expected from elements of our own Government, the press, allies, and third world countries to reveal the mission of the payload to guarantee that its launch is, in fact, not provocative as the Soviets have claimed. The decision is then one of maintaining security and launching in the face of the Soviet demands and widespread public criticism or standing down and not launching. The third choice is to abandon security and identify the payload and its mission. To launch, whether the payload and its mission were revealed or not, might still provoke the Soviets to respond. If their response endangered the crew, intentionally or not, tensions would certainly be strained. An unmanned STS flight is certainly an expensive option and places an extremely expensive national resource in jeopardy. The absence of a crew would not lower the public profile, but heighten it; the absence of man would not necessarily reduce the Soviet fears of the STS's military capability and would only make their decision to interfere with it easier and somewhat less provocative. A low profile, unmanned ELV launch capability for military satellites is, at the very minimum, an extremely desirable capability during periods of increased tension or hostile action.

VULNERABILITY OF THE STS TO NATURAL DISASTER OR HOSTILE ACTION.

The STS is vulnerable to the same natural disasters as ELV's. KSC is subject to hurricanes and VAFB is subject to earthquakes. JSC is subject to hurricanes and flooding and AFSCF is subject to earthquakes. Both the STS and ELV's are vulnerable to the same hostile actions while on the ground. The high public visibility of the STS makes it more difficult to make launch preparations. The STS is fundamentally more vulnerable than an unmanned launch vehicle during ascent and orbital operations. The numerous crew related subsystems and the aerodynamic, reentry, and recovery subsystems increase the fragility of the orbiter over the limited boost and release mission of an unmanned ELV. Also, the extensive support required during the expanded timeline necessary for the orbiter to deploy payloads makes it a more vulnerable target.

COMPLEXITY OF THE STS MANNED SYSTEM AND UNMANNED ELV'S AND POSSIBLE IMPACT ON STS PRE-LAUNCH AND ON-ORBIT OPERATIONS.

The presence of man significantly increases the complexity of the STS launch, on-orbit and de-orbit operations. Furthermore, the man's biological needs create additional timeline constraints on these operations. A great deal of the orbiter complexity is the result of supporting man rather than supporting the payloads. Consequently, the probabilities are higher that the processing flow might be delayed or turnaround time impacted by a man-related subsystem whereas the processing of an ELV would be much simpler and, therefore, shorter. This would probably not be significant except in the case of a crisis reaction, launch-on-demand situation. This scenario can be better supported by ELV's, trading off system capability, flexibility and potential recoverability for expediency. A similar situation exists for on-orbit operations. The possibility exists that a failure in a non-payload related subsystem could force recovery after a successful launch before the payload could be deployed. This must be compared to a failure in the simpler ELV that prevents achieving orbit or precludes deployment in which case the payload is lost. With the STS, the mission is lost, but the payload is returned. The STS is probably equally as vulnerable to a catastrophic launch failure as is an ELV. The final consideration is that much of the STS complexity is the result of redundancy and man-rating that theoretically should offset the single failures and prevent them from adversely affecting mission performance.

WHAT CAN THE SHUTTLE DO THAT ELV'S CANNOT?

While ELV's offer certain military advantages in terms of response time, simplicity, and low public profile, they cannot be directly compared to the STS without considering the additional capabilities of the STS. ELV's simply boost a paylod into orbit and release it; the STS capability practically begins where the ELV's stop. The more significant STS capabilities that cannot currently be matched by ELV's can be summarized as follows:

- Return the orbiter and payload in the event of most launch failures (abort).
- Return the payload in the event of an on-orbit payload malfunction after launch.
- Retrieval and recovery of certain classes of payloads (within the range of the STS orbital capabilities).
- Service or repair certain payload functions on orbit.
- Carry a mix of payload on a single mission.
- Provide human element for:
    - Manned presence in space (political)
    - Contingencies/unexpected actions
    - Services
    - Information/observation
    - Investigation
- Provide a support base for:
    - Experiments/development
    - Assembly of large structures

While most DOD satellites currently require very little manned intervention for their operation, the presence of man and the capabilities offered by the STS certainly provide new options for packaging, redundancy, and complexity associated with initial deployment and checkout. In future designs, these advantages can conceivably be translated into increased mission capability, albeit at high cost. In the short-term, DOD missions will certainly benefit most from the first five STS capabilities listed than from the specific presence of men available to support the payloads.

Security Requirements. NRO programs must contend with one major additional consideration in transitioning to the STS - SECURITY. The STS is, by its very nature, highly visible and enjoys great public and media interest. Classified military programs on the STS can expect an increased level of interest, speculation, background reports, and idle conversation during the peak periods of launch and on-orbit operations. BYEMAN operational security considerations compound this general problem and there will undoubtedly be numerous problems regarding media coverage and public speculation.

While these considerations are being worked, they should nevertheless not be minimized. The need for a serious and concentrated effort should be re-emphasized to carefully plan, coordinate, and integrate BYEMAN security concerns and procedures into the daily routine of STS secure operations as they are developed. These types of concerns have been manifested in several areas. One of the more difficult issues still requiring resolution is an umbrella security policy for all DOD Shuttle launch operations. The umbrella concept, as it has become known, would require all DOD Shuttle launches to be classified SECRET, both in the scheduling cycle and in actual launch operations. Thus, all launches involving "DOD" (including NRO) payloads would appear similar in procedures, scheduling and physical security; NRO payloads could not be identified by any heightened security or unique procedures.

Continued delays in the coordinated acceptance of a practical set of security objectives and procedures severely jeopardize BYEMAN programs. Careful integration of BYEMAN security requirements with DOD security requirements is the key to protecting BYEMAN resources. This is particularly important as the first operational DOD payload is the BYEMAN [redacted]

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