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OVERVIEW OF STS GROUND OPERATIONS/ORBITER TURNAROUND STS-1 THROUGH STS-7

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ABSTRACT

A review of STS-1 processing is presented as a reference for Shuttle processing time and the magnitude of the associated modifications, discrepancies, technical requirements, and ground systems activities. STS-1 processing provided the basis from which a plan to perform operational turnaround was established. Turnaround processing for Launch and Landing are treated separately to depict more clearly the progress made to reduce turnaround time and manhours expended.

Turnaround time was reduced from 187 days for STS-2 to 60 days for STS-7 and landing turnaround was reduced from 14 days to 5 days. Modifications were reduced from 114 to 51. Requirements changes for launch readiness verification were reduced from 536 to 107. Special tests or inspections were reduced from 292 to 52. Anomalies resolved concurrent with processing were reduced from 13,000 to 4,000.

While total turnaround time was reduced, the relative time spent in the Orbiter Processing Facility (OPF) continue to be one half of the turnaround. Integration in the Vehicle Assembly Building (VAB) is about 10 percent of the flow, and Launch Pad operations comprise 40 percent of the turnaround.

As turnaround operations matured, the volume of work and turnaround time steadily decreased. The work force has matured and has demonstrated the capability to perform planned and contingency operations. The turnaround program is fast approaching the goal of becoming operational. The challenge ahead is to transition from a development-dominated operation to a production oriented operation.

INTRODUCTION

In the last two decades many major technical projects have been designed concurrent with the planning of their operational phases. The Space Shuttle program exemplifies the challenge of concurrency, which is management of a project while significant factors are very dynamic. Ground operations for the Shuttle Orbiter flight test program were planned during the design and build phases of both the flight and ground systems. This planning of ground operations before the flight systems design certification and qualifications were completed later necessitated changes to insure compatibility. Facilities and support equipment were constructed before flight hardware had been completely defined, and later required changes as well.

Our progress toward achieving a repetitive operation with reduced turnaround time is easily traced. The approach was founded in the proven techniques of airline maintenance and aircraft fabrication. Maximum effort has been expended to establish a standard processing flow cycle that is repeated on each flight, while still dealing with the peculiar features of payloads or flight anomalies. To accomplish this, we have carefully evaluated requirements reductions, efficiency improvements, and design changes that could shorten the turnaround and reduce the cost per flight. Each of these improvements has been carefully analyzed to assure there is no degradation in safety and to assure mission success.

Requirements for ground processing are prepared by the design centers and levied on the operational center by the Operations and Maintenance Requirements Specification Document (OMRSD). These requirements have been carefully analyzed for reductions by the design and operational centers starting with STS-1.

Important among these reductions has been the retention of hypergolic propellants on the vehicle. Implemented only after a careful review by safety system engineers, hypergolic retention has saved significant time in the processing flow. No significant safety issue has occurred due to this operational improvement.

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Excellent progress has been made in firming processing procedures, and this has provided greater ground crew proficiency and efficiency. Procedures have been subjected to post-test critiques with both engineering and operations personnel. These critiques have improved operational sequences and eliminated unncessary steps.

Improvements have also been made in simplifying the work documents from which the technician must work, allowing him to spend more time on the job and less time obtaining related instructions. Another improvement is the provision of parts and tools to the work areas on a planned schedule.

These improvements, enhanced by the constant attention to bettering the operational turnaround, have resulted in a great reduction in the expended manhours per flight. Figure 1 shows the reduction in turnaround days and Figure 2 the reduction in manhours per flow. Continued application of these techniques and improvements will allow the Shuttle program to achieve and exceed its cost per flight objectives.

STS-1 PROCESSING

One of the major challenges of the Design, Development, Test and Engineering phase of the Space Shuttle Program was to develop the basic ground operations techniques which will be the cornerstones for the operational era ground processing methods. Two major criteria must be satisfied: fulfillment of the technical requirements of this highly complex spacecraft to certify its flightworthiness and accomplishment of major processing milestones that had been scheduled some months in advance. Ground operations are conducted to support a traffic model of 24 to 30 annual launches from the Kennedy Space Center and 6 to 10 launches from Vandenberg Air Force Base, California by 1990. These criteria must be met while still maintaining a high degree of flight safety and systematically reducing the cost per flight.

The ground operations effort for STS-1 cannot be assessed as a measure of Orbiter turnaround since these activities focused almost entirely on certifying Orbiter 102 for its maiden flight. Orbiter 102 arrived at KSC on March 25, 1979 and launched on April 12, 1981 - 744 days after its arrival. During this two-year period, 340 modifications were made to the Orbiter. In addition to these modifications, approximately 24,000 thermal protection system tiles (over-thirds of the total number of tiles which comprise the outer mold line of the Orbiter) were removed, densified, and reinstalled. This period also saw a tremendous effort in the development, evaluation, and changing of Operations and Maintenance Requirements Specifications and the development of Operations and Maintenance Instructions (OMI's) to implement the requirements. One thousand four hundred thirty-three (1,433) OMI's were developed to process STS-1. These procedures contained almost 250,000 pages of detailed processing instructions, special instructions such as operational and safety notations, data sheets, and emergency procedures. Formal approval of 2,373 Requirement Change Notices (RCN's), as well as numerous operational and safety requirements, resulted in virtually all of the OMI's for STS-1 being revised prior to or during their use. The STS-1 task was further complicated by the parallel efforts of modification of Apollo program facilities and ground support equipment, and new design, construction, and activation to support the STS-1 flow. As an indication of this effort, 9,273 design/modification packages were released to support the initial ground processing of the Space Shuttle vehicle.

Operational concepts on how to process a reusable spacecraft were developed, tested, and modified, and eventually resulted in vastly improved ground operations. New and modified processing and launch facilities were evaluated. A vast majority of the written processing procedures were developed and improved to support future Space Shuttle missions. Basic methods of doing business were developed into plans and detailed into implementing instructions implemented, and modified, as required, to streamline operations. The major benefit derived from this flow was the invaluable training the processing team gained in this first processing effort. The actual "hands-on" experience is resulting today in continuing processing improvements and lower cost per flight of operational Shuttle vehicles.

This massive effort culminated on April 12, 1981, at 0700:03.9834 EST when the Columbia, with Astronauts John Young and Bob Crippen aboard, lifted off from Launch Complex 39A and inaugurated a new era in manned space flight. During its planned mission of 54.5 hours, the Columbia completed 36 orbits of the Earth and landed at the Dryden Flight Research Facility at Edwards Air Force Base, California at 1022 PST on April 14, 1981. After the flight crew egressed, the Orbiter was towed to the mate/demate device for safing of systems, reconfiguring for transportation, and mating of the Orbiter to the Shuttle Carrier Aircraft (SCA). Ferry operations began on April 27 with SCA takeoff occurring at 1016 PDT. After an overnight SCA refueling stop, the Orbiter returned to KSC on April 28; just 16 days after launch. This successful landing and ferry operation completed the last phase of the STS-1 ground operations.

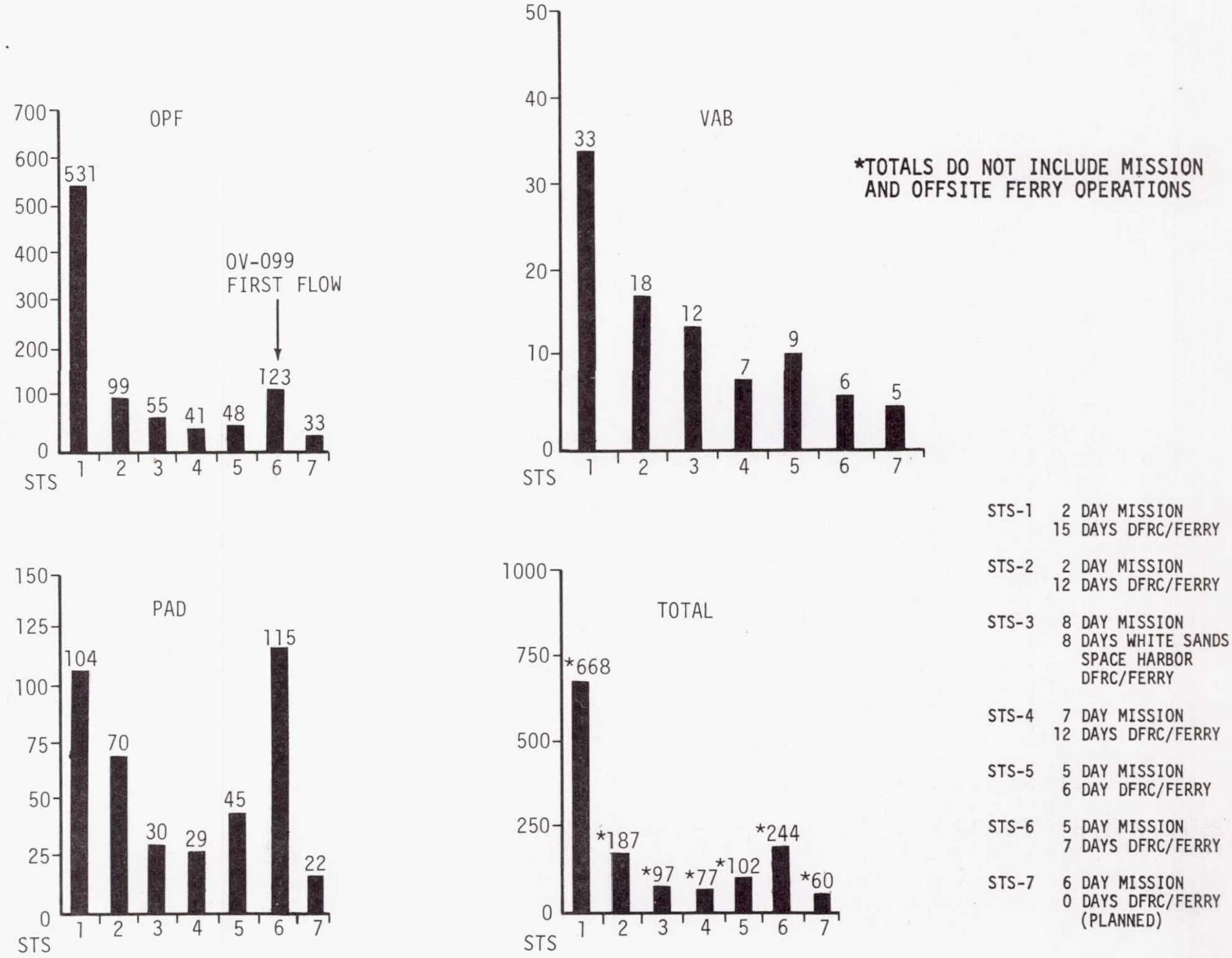


Figure 1.- STS Processing Times (Working Days).

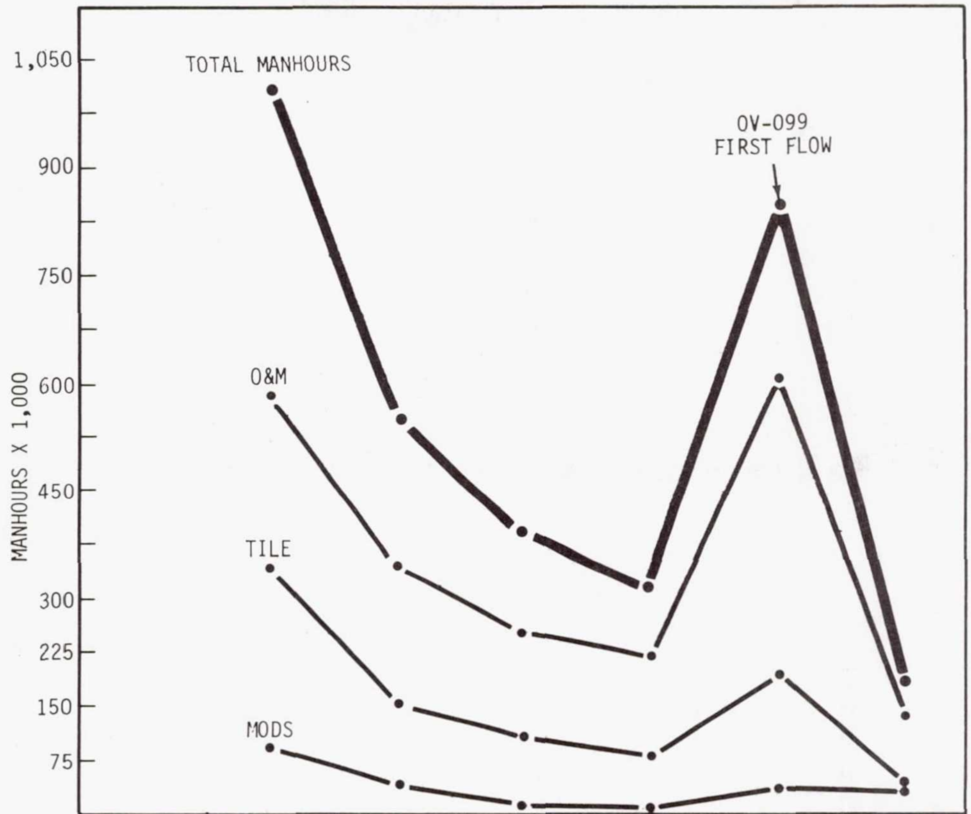
MATURATION OF SHUTTLE PROCESSING

The ground operations for STS-2 constituted the first Orbiter turnaround processing. It is from this processing flow that we have developed the data parameters to measure our performance toward our goal of processing Orbiters more efficiently at reduced cost.

The best measure of turnaround time is the actual number of working days required to process each flow. In examining the number of work days to process each STS flow, it is obvious that the data trend indicates a continuous improvement in each succeeding turnaround (Figure 3). The apparent exceptions to this trend is the number of days required to process STS-5 and STS-6. On these flows, the Orbiter spent more time in ground processing than for STS-3 and STS-4. On STS-5 this was due mainly to the first cargo installation with the vehicle on the launch pad. STS-6, of course, was the first flight of OV-099.

The trend in the reduction of turnaround time is continuing on subsequent operational flights. The total processing time for STS-7 was only 60 working days, with the processing time for STS-8 projected to be approximately 50 working days.

The continuing decrease in processing time can be attributed to the maturing of the flight hardware, decrease in the number of requirements and procedure changes, and an increased proficiency of the processing team. For turnaround flows for STS-2 through STS-7, the data indicate a continuing decrease in the number of Revision Change Notices, Master Change Records, Engineering Orders, and Work Volume Indicators worked for each flow. The total number of Work Volume Indicators includes Discrep-



FLOWS	2	3	4	5	6	7
TOTAL	1,014,017	537,756	400,236	308,757	849,351	182,350

Figure 2.- Total Manhours per Flow.

ancy Reports, Problem Reports, Interim Problem Reports, Operations and Maintenance Instructions, and Test Preparation Sheets. A massive reduction in the total number of work items performed is shown. Figure 3 illustrates these trends.

Some of the major requirement reductions and procedure changes that contributed to reduced turnaround time are: retention of residual OMS/RCS hypergolic propellants on-board the Orbiter; parallel loading of OMS, RCS, Orbiter APU and SRB APU propellants; reduced flight control system testing; deletion of dynamic integrated tests in the OPF and VAB; deletion of wet countdown demonstration tests; and improved propulsion system leak check methods.

In addition, a major contributor to the reduction in Work Volume Indicators and in processing time is the drastic reduction in tile work. The data indicate a progressive trend in decreasing tile repair with the exception of Flow 5 (Figure 4). A slight upturn of the trend is due mostly to a large number of tiles suffering minor damage in a hail storm just prior to the launch of STS-4, with this damage being repaired during the STS-5 flow.

An important indicator of the relative processing cost of each flow is the total manhours worked per flow. Figure 2 shows the total number of manhours charged against each flow, with each flow being less than the preceding flow. Also indicated is the consistent decrease in the percentage of total manhours devoted to modifications and tile work along with the corresponding manhours spent in Operations and Maintenance effort. This favorable trend is the key to accurate cost estimates for each flight in the operational era.

Recovery and ferry operations to return the Orbiter from the landing site to KSC have continuously shown the same favorable data trend as the KSC turnaround (Figure 5). The data show an upturn in manhours to recover STS-3, but it must be remembered that the STS-3 landing was moved from DFRF to White Sands Space Harbor, New Mexico, neccessitating transporting ground support equipment and personnel from California to New Mexico in a relatively short time.

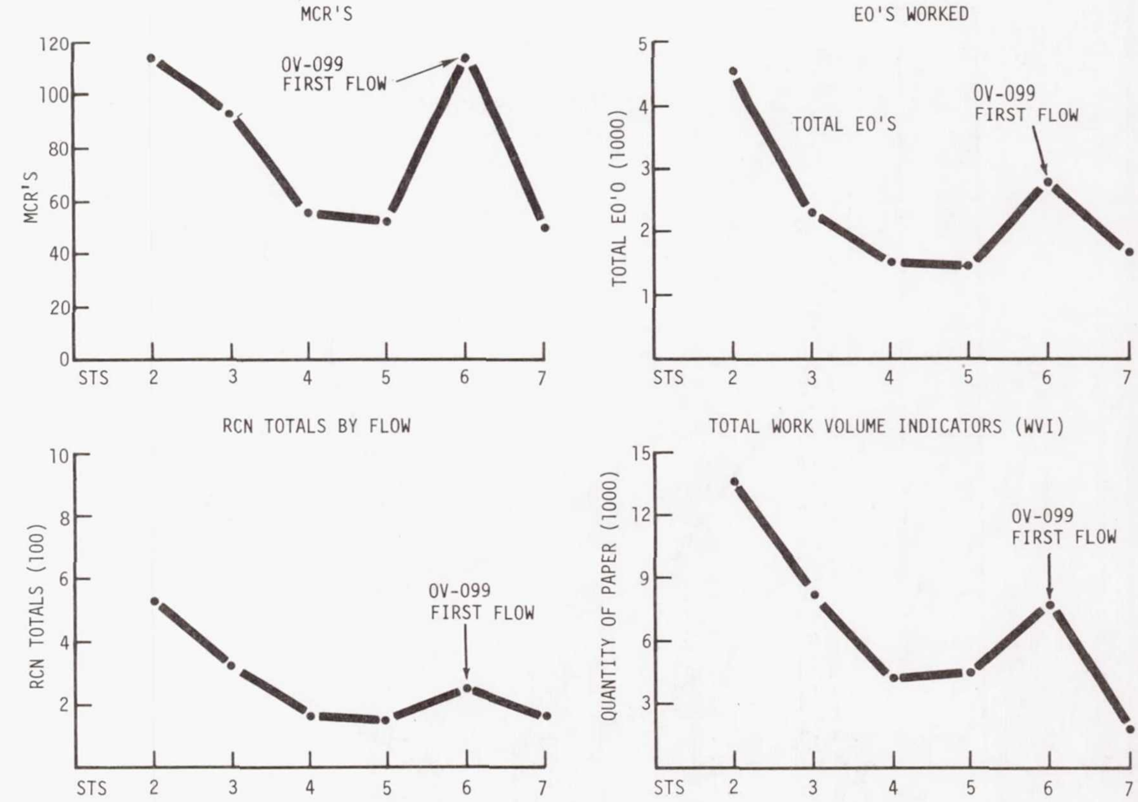
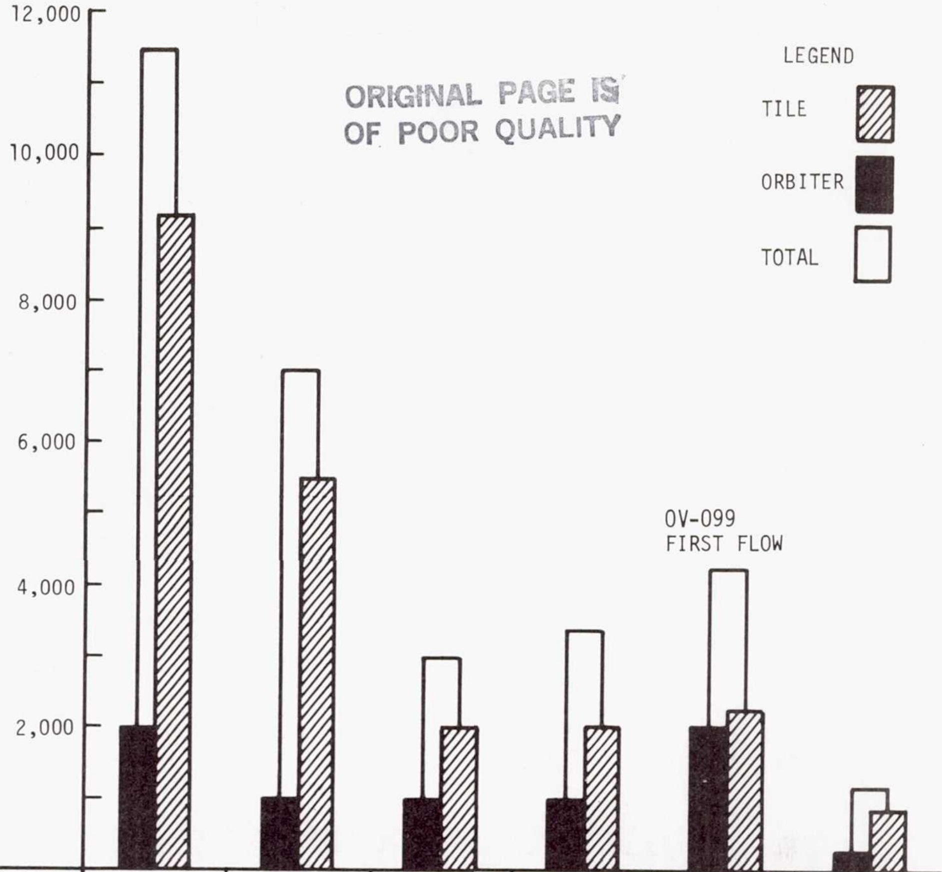


Figure 3.- Total Requirement Trends.

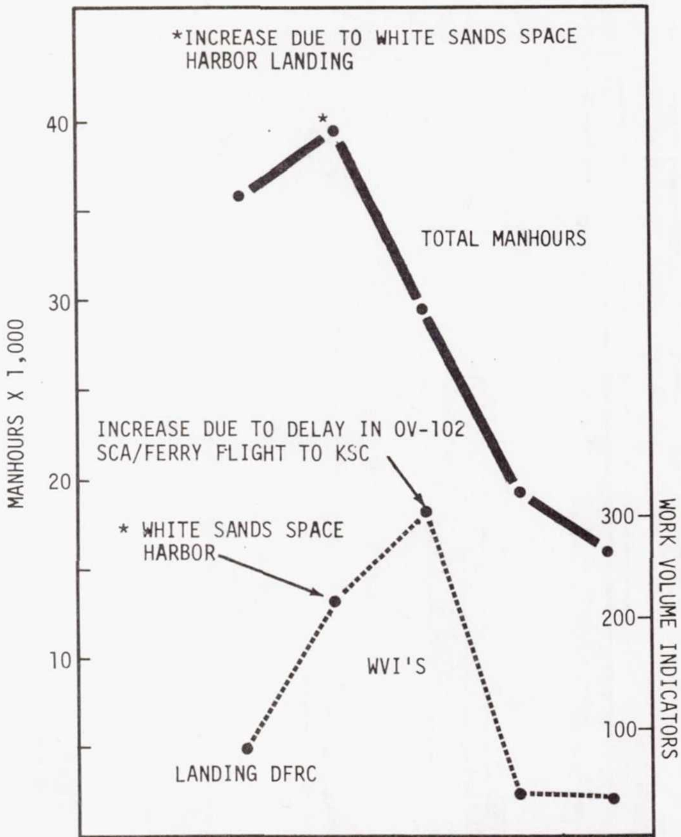
Flight safety has been outstanding, as indicated by the fact that of the six flights completed as of this writing, only STS-2 did not complete its intended mission duration. The anomaly on that mission, a malfunctioning fuel cell, was not related to ground operations, and did not jeopardize the safety of the crew or the vehicle.

In summary, the overall trend has been to perform each ground turnaround flow in fewer working days and with significantly fewer manhours expended during each successive flow. This overall reduction in time and cost has also been accompanied by a consistently decreasing number of in-flight anomalies (Figure 6). The increase shown in flight 6 anomalies is due to the fact that the flight was the first of OV-099. This indicator is indicative of flight hardware maturity, higher quality of workmanship, and increased understanding of the operation of the flight hardware.



TOTAL	11,369	6,827	2,769	2,913	4,124	1,025
FLIGHT	STS-2	STS-3	STS-4	STS-5	STS-6	STS-7

Figure 4.- Vehicle Problem Reports by Flight.



FLOWS	2	3	4	5	6
MANHOURS	36,054	39,087	29,581	19,712	16,295
WVI'S	79	*226	305	39	35

Figure 5.- Orbiter Off-Site Recovery Data.

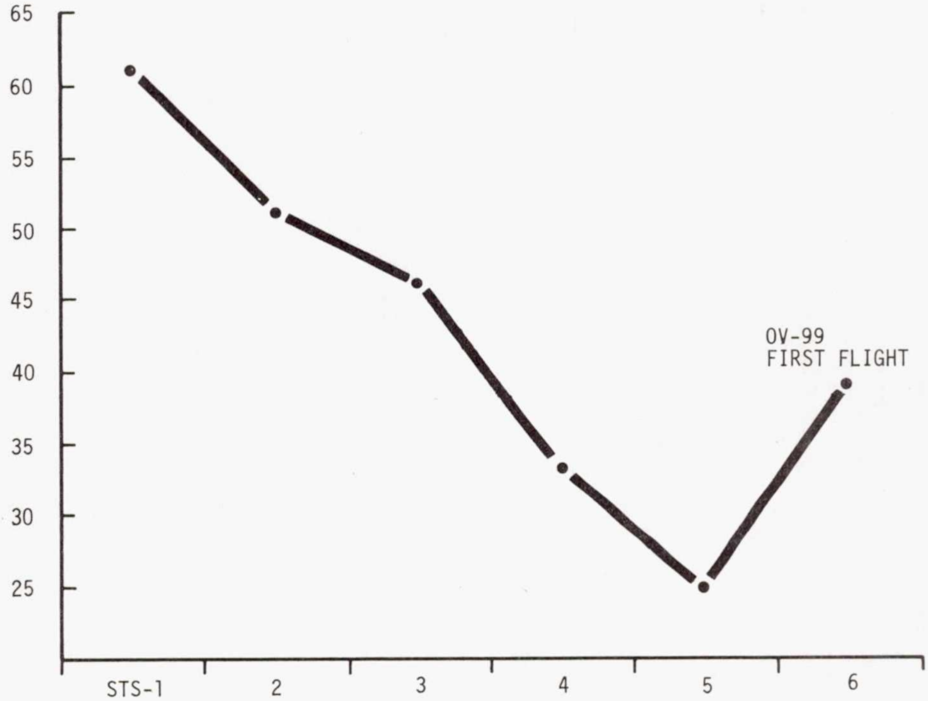


Figure 6.- In Flight Anomalies.