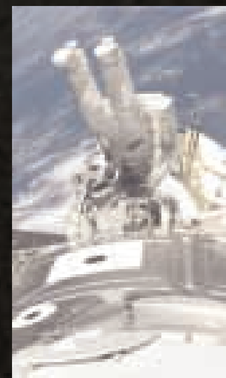
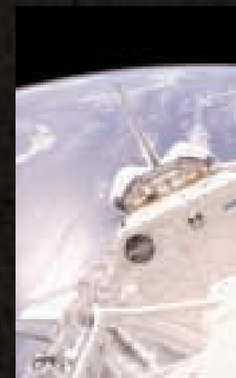
SPACE SHUTTLE PROGRAM 1999 ANNUAL REPORT

Fly Safely

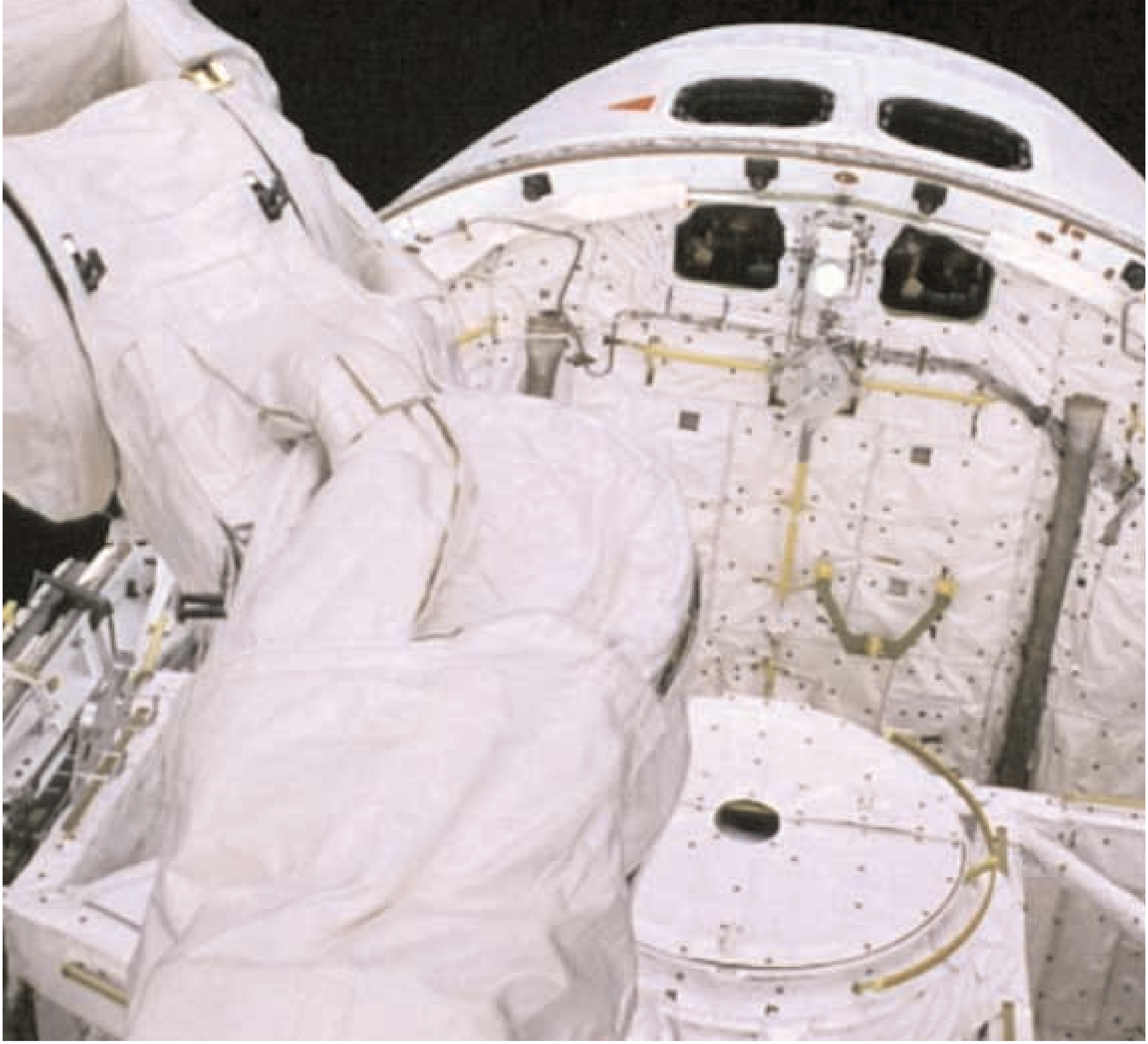
Meet the Manifest



Improve Mission Supportability



Improve the System



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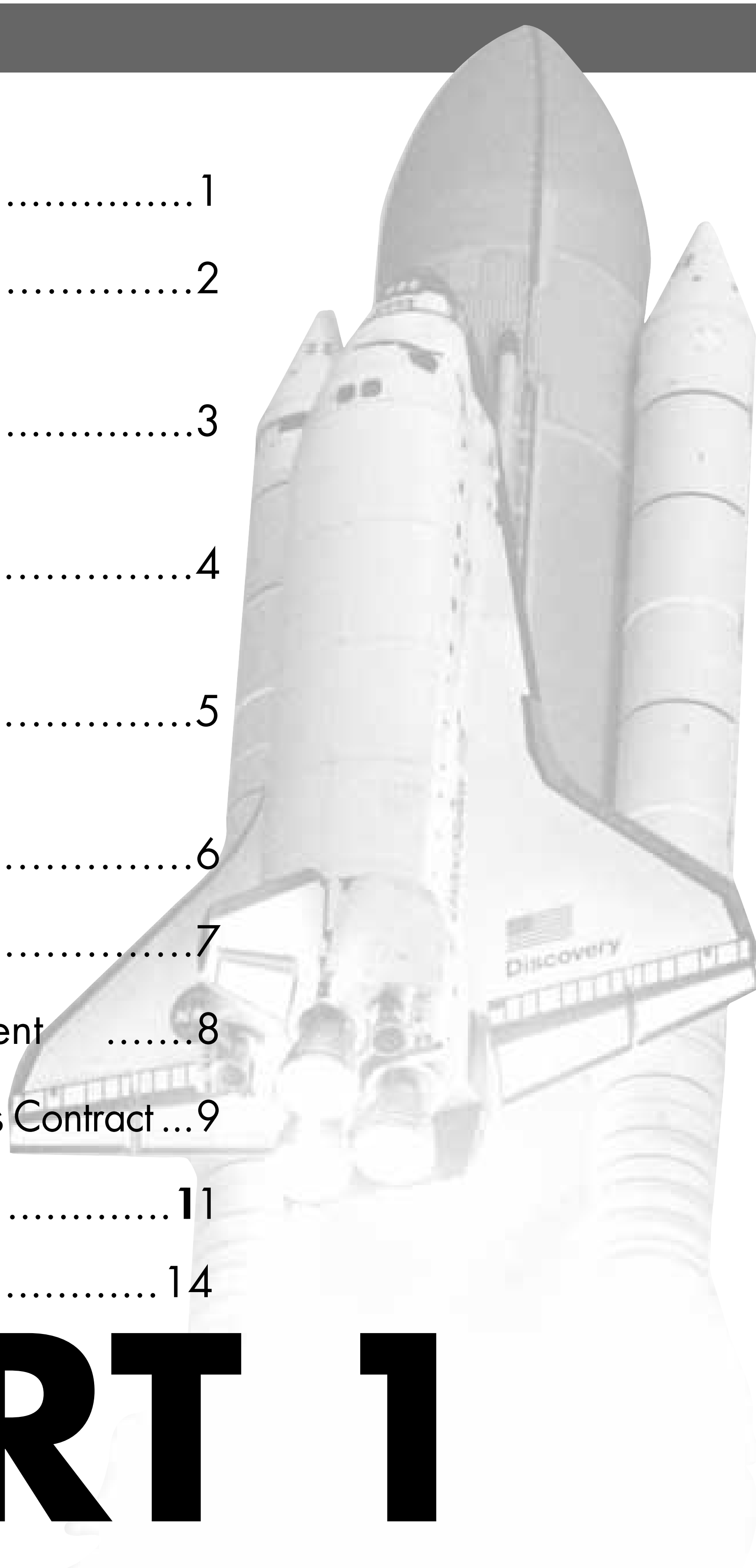


PART 1

General Information

Message from the Program Manager:

1999 was a productive and challenging year for the Space Shuttle Program (SSP). We have continued to strive to meet our Program goals to fly safely, to meet the manifest, to improve mission supportability, and to improve the system. We accomplished four safe and successful missions. On STS-95, a research flight, we returned John Glenn to space and obtained key scientific data on the similarities between the effects of microgravity and the aging process. We successfully launched the first and second flights of the International Space Station (ISS), beginning a new era in space exploration. We deployed the Chandra Observatory, the world's most powerful X-ray telescope, on a mission led by the first female Shuttle commander.

We delivered the 100th External Tank (ET); had the 100th flight of the solid rocket booster (SRB); and look forward to the 100th Space Shuttle flight in mid 2000. Our most experienced Orbiter, the Space Shuttle *Columbia*, completed its 26th spaceflight and has been ferried to Palmdale, California, for major modifications, while Space Shuttle *Atlantis* completed its major modification in 1999, outfitted with a newly designed glass cockpit.

The SSP will always maintain the highest vigilance toward safety of flight. Therefore, improving the safety and reliability of our flight systems is the highest priority. To accomplish this, we are exploring: the use of Electric Auxiliary Power Units (EAPUs) to eliminate the hazards associated with existing hydrazine APUs; the use of a Space Shuttle Main Engine (SSME) Advanced Health Monitoring System to enable real-time vibrational and optical plume monitoring; and more durable thermal protection to reduce damage in critical areas. We are continuing to aggressively identify improvements in the propulsion systems that result in increased reliability and safety.

We continue to look to a bright future. During this past year we continued to identify and implement upgrades to the Shuttle systems that will enable us to continue to safely fly the Shuttle well into the next millennium. Up-to-date ground support facilities are key to this plan. We supported plans to develop a next-generation spacecraft, and continue to look at new ways of developing hardware to shorten the development cycle without compromising safety.

The SSP continues to make great strides in improving safety for all of our employees. We have seen a decrease in safety incidents in our ground facilities and an increase in the overall safety awareness across the Program.

Reinvention is a key activity as we continue to improve the system, implementing efficiencies that not only make the Program better but result in lower operating costs. We have embarked on a path to further reduce the flight preparation template, allowing greater flexibility to future Space Shuttle customers. Efficiencies in processing and vehicle turnaround will continue to be aggressively pursued.

A Space Shuttle Program Council has been established, composed of senior level project and element managers, to address critical programmatic issues, develop strategy, and plan for the future. Additionally, a Chief Engineer's Council was formed to increase our focus on manufacturing, production, and process control. We conducted two program manager's reviews where the entire NASA and contractor team focused on safety and on process control.

Our personnel continued to remain involved in community education and outreach activities by participating in Open House, Inspection Day, Space Camp Exhibits, Engineering Week, and student mentoring.

Throughout the SSP it is evident that the key to success lies in our people. It is the talent and dedication of the Space Shuttle Team that has enabled us to be so successful in the past, and will serve us well into the future. The accomplishments described in this report are their accomplishments, and it is because of their commitment to excellence that we can proudly say, "We're ready to launch into the 21st century." ❖

The Program goals are derived from both the mission of NASA and the Human Exploration and Development of Space (HEDS) Enterprise. The SSP's four goals provide the foundation for operating the Program.

FLY SAFELY is the SSP's number one goal! Flying safely is paramount above anything else that is accomplished. This is attained through a combination of reliable hardware and an excellent team, and by finding problems before they occur. The commitment to achieve this goal is tied directly to the unique, human factor of our mission. Safety aspects include safety of the public, the flight crews, the workers, and the assets.

MEET THE MANIFEST encompasses the challenge to fly on schedule, achieve 100 percent mission success, and provide the flexibility and responsiveness to manifest and mission problems.

IMPROVE MISSION SUPPORTABILITY focuses on manifest flexibility and responsibilities, customer satisfaction and responsiveness, and hardware availability.

IMPROVE THE SYSTEM emphasizes reinvention, exploration, and quantum leaps. Making the system better will, in turn, reduce costs. This goal includes improving the support and the flight system.

NASA Mission:
To explore, use, and enable the development of space for human enterprise

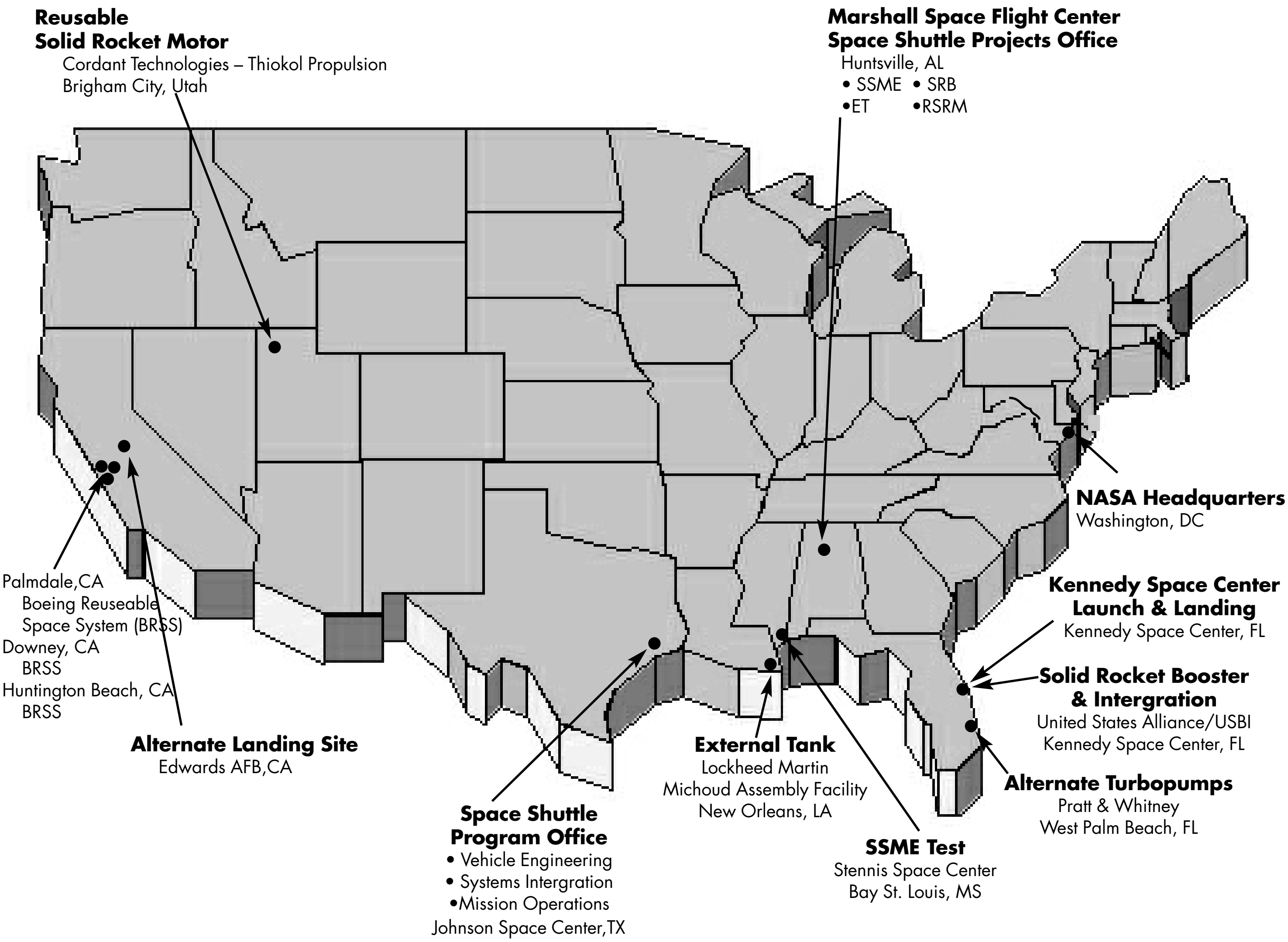
HEDS Goal:
To enable humans to live and work permanently in space

HEDS Objectives:
Provide safe, affordable, and improved assess to space

SSP GOALS
- FLY SAFELY
- MEET THE MANIFEST
- IMPROVE MISSION SUPPORTABILITY
- IMPROVE THE SYSTEM

THE STRENGTH OF THE SPACE SHUTTLE PROGRAM IS THE TEAM.
IT IS ESSENTIAL FOR THE SUCCESS OF THE PROGRAM THAT THE TEAM FOCUSES ON THE SAME GOALS.

Space Shuttle Program Major Sites



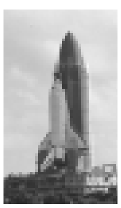
95 Total Flights
70 Since Return to Flight

Legend

Flt. No.	STS-XX No.	Launch – Landing Date Date

After 51-L (white)
Before 51-L (Flight-25) (gray)

Number of Flights

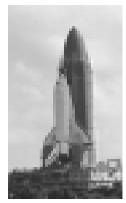


Challenger OV-099

25	51-L	1/28/86
22	61-A	10/30/85–11/06/85
19	51-F	7/29/85 – 8/06/85
17	51-B	4/29/85 – 5/06/85
13	41-G	10/05/84 – 10/13/84
11	41-C	4/06/84 – 4/13/84
10	41-B	2/03/84 – 2/11/84
8	8	8/30/83 – 9/05/83
7	7	6/18/83 – 6/24/83
6	6	4/04/83 – 4/09/83

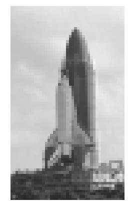
Columbia OV-102

95	93	7/23/99 – 7/27/99
90	90	4/17/98 – 5/03/98
88	87	11/19/97 – 12/05/97
85	94	7/01/97 – 7/17/97
83	83	4/04/97 – 4/08/97
80	80	11/19/96 – 12/07/96
78	78	6/20/96 – 7/07/96
75	75	2/22/96 – 3/09/96
72	73	10/20/95 –11/05/95
63	65	7/08/94 –7/23/94
61	62	3/04/94 – 3/18/94
58	58	10/18/93 – 11/01/93
55	55	4/26/93 – 5/06/ 93
51	52	10/22/92 – 11/01/92
48	50	6/25/92 – 7/09/92
41	40	6/05/91 – 6/14/91
38	35	12/02/90 – 12/10/90
33	32	1/09/90 – 1/20/90
30	28	8/08/89 – 8/13/89
24	61-C	1/12/86 – 1/18/86
9	41-C	1/28/83 – 12/08/83
5	5	11/11/82 – 11/16/82
4	4	6/27/82 – 7/04/82
3	3	3/22/82 – 3/30/82
2	2	11/12/81 – 11/14/81
1	1	4/12/81 – 4/14/81



Discovery OV-103

94	96	5/27/99 – 6/06/99
92	95	10/29/98 – 11/07/98
91	91	6/02/97 – 6/12/97
86	85	8/07/97 – 8/19/97
82	82	2/11/97 – 2/21/97
70	70	7/13/95 – 7/22/95
67	63	2/03/95 – 2/11/96
64	64	9/09/94 – 9/20/94
60	60	2/03/94 – 2/11/94
57	51	9/12/93 – 9/22/93
54	56	4/08/93 – 4/17/93
52	53	12/02/92 – 12/09/92
45	42	1/22/92 – 1/30/92
43	48	9/12/91 – 9/18/91
40	39	4/28/91 – 5/06/91
36	41	10/06/90 – 10/10/90
35	31	4/24/90 – 4/29/90
32	33	11/22/89 – 11/27/89
28	29	3/13/89 – 3/18/89
26	26	9/29/88 – 10/03/88
20	51-I	8/27/85 – 9/03/85
18	51-G	6/17/85– 6/24/85
16	51-D	4/12/85 – 4/18/85
15	51-C	1/24/85 – 1/27/85
14	51-A	11/07/84 – 11/15/84
12	41-D	8/30/84 – 9/04/84

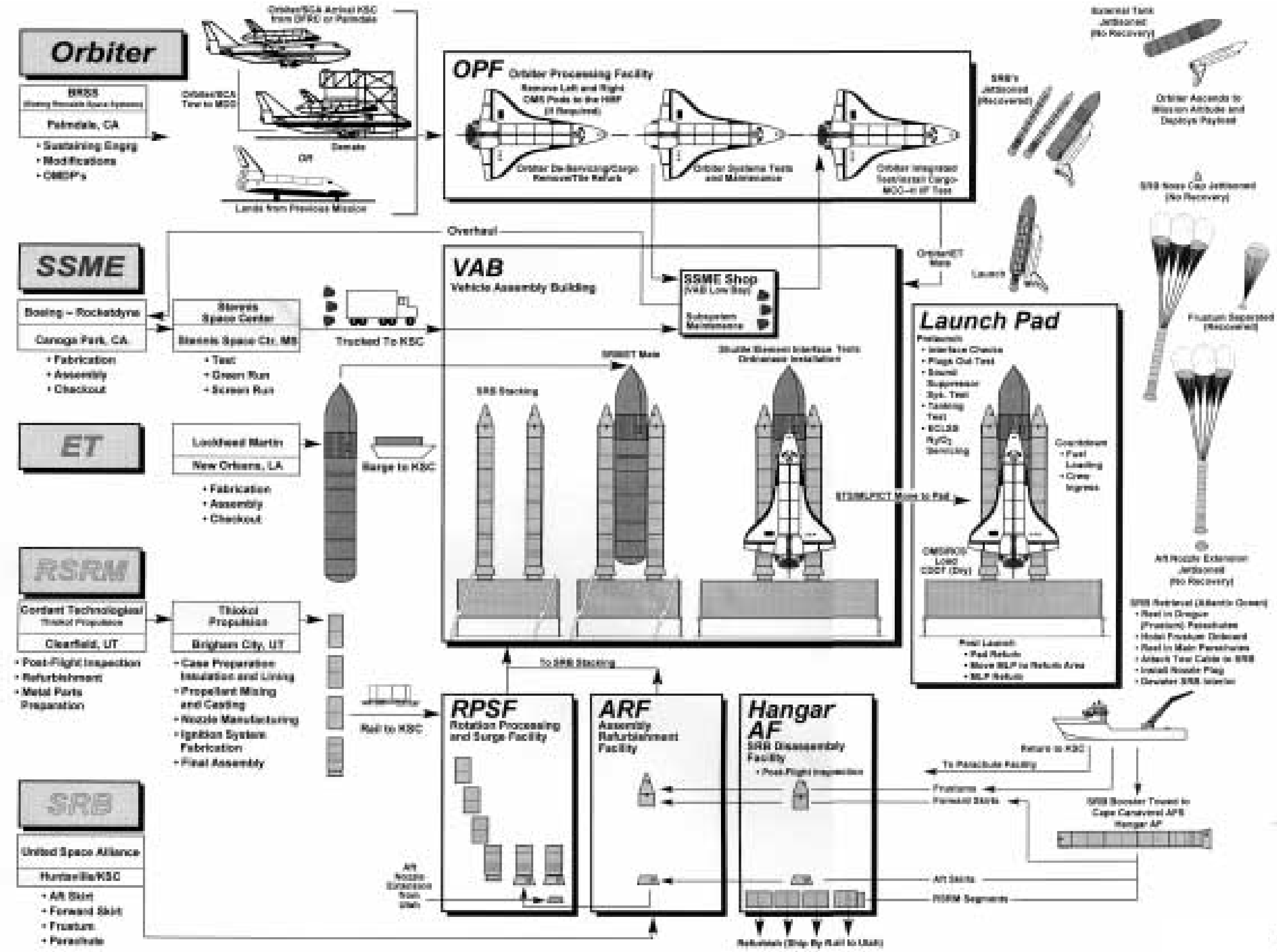


Atlantis OV-104

87	86	9/25/97 – 10/06/97
84	84	5/15/97 – 5/24/97
81	81	1/12/97 – 1/22/97
79	79	9/16/96 – 9/26/96
76	76	3/22/96 – 3/31/96
73	74	11/12/95 – 11/20/95
69	71	6/27/95 – 7/07/95
66	66	11/03/94 – 11/24/94
49	46	7/31/92 – 8/08/92
46	45	3/24/92 – 4/02/92
44	44	11/24/91 – 12/02/91
42	43	8/02/91 – 8/11/91
39	37	4/05/91 – 4/11/91
37	38	11/15/90 – 11/20/90
34	36	2/28/90 – 3/04/90
31	34	10/18/89 – 10/23/89
29	30	5/04/89 – 5/08/89
27	27	12/02/88 – 12/06/88
23	61-B	11/26/85 – 12/03/85
44	51-J	10/03/85 – 10/07/85

Endeavour OV-105

93	88	12/04/98 –12/15/98
89	89	1/22/98 – 1/31/98
77	77	5/19/96 – 5/29/96
74	72	1/11/96 – 1/20/96
71	69	9/07/95 – 9/18/95
68	67	3/02/95 – 3/18/95
65	68	9/30/94 – 10/11/94
62	59	4/09/94 – 4/20/94
59	61	12/02/93 – 12/13/93
56	57	6/21/93 – 7/01/93
53	54	1/13/93 – 1/19/93
50	47	9/12/92 – 9/20/92
47	49	5/07/92 – 5/16/92


Orbiter
Palmdale, CA
OPF
Orbiter Processing Facility
SSME
Boeing – Rocketdyne
Canoga Park, CA
Stennis Space Center
Trucked To KSC
VAB
Vehicle Assembly Building
SSME Shop
Launch Pad
ET
Lockheed Martin
New Orleans, LA
Barge to KSC
RSRM
Thiokol Propulsion
Brigham City, UT
Clearfield, UT
Rail to KSC
SRB
United Space Alliance
Huntsville/KSC
RPSF
Rotation Processing and Surge Facility
ARF
Assembly Refurbishment Facility
Hangar AF
SRB Disassembly Facility
Overhaul
Launch

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Space Shuttle Program
Development

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Space Shuttle SR & QA
Office

J. C. Boykin, Assistant Manager
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Customer and Flight
Integration Office

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Space Shuttle
Vehicle Engineering Office

D. A. Schaller, Manager
Space Shuttle
Administrative Office

R. H. Heselmeyer, Manager
Space Shuttle
Management Integration Office

J. B. Costello, Manager
Space Shuttle
Business Office

R. L. Segert, Manager
Space Shuttle KSC
Integration Office

A. A. McCool, Manager
Space Shuttle
Projects Office (MSFC)

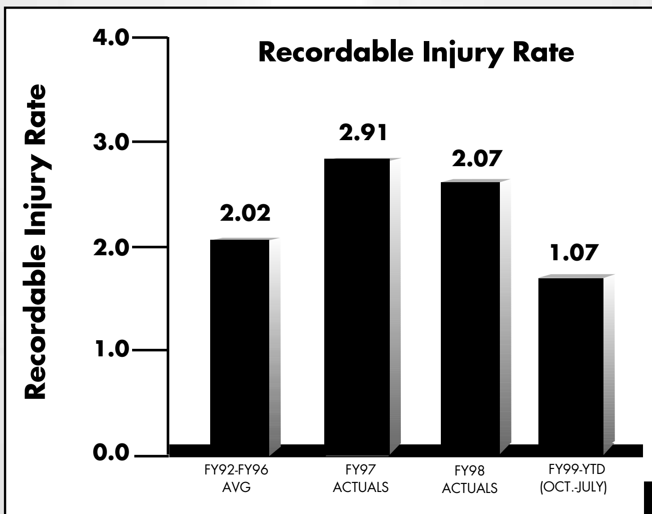
Flight Managers Payload integration

Space Shuttle Headquarters Office

Safety continues to be the TOP priority for the Space Shuttle Team. Numerous initiatives have been implemented to increase awareness, management accountability, hazard identification and prevention, and employee involvement. With an emphasis on public, crew, employee, and asset protection, dramatic improvements in safety have been realized. Some examples include United States Alliance (USA), who has realized a 54% reduction in OSHA recordable cases, 80% reduction in lost work-days, and 57% reduction in lost time cases compared to the same time last year. Lockheed ET Operations hasn't had a day away from work injury since January 8, 1993 and also has not experienced a cost impact incident since July 1998. All SSP elements continue to demonstrate similar improvements.

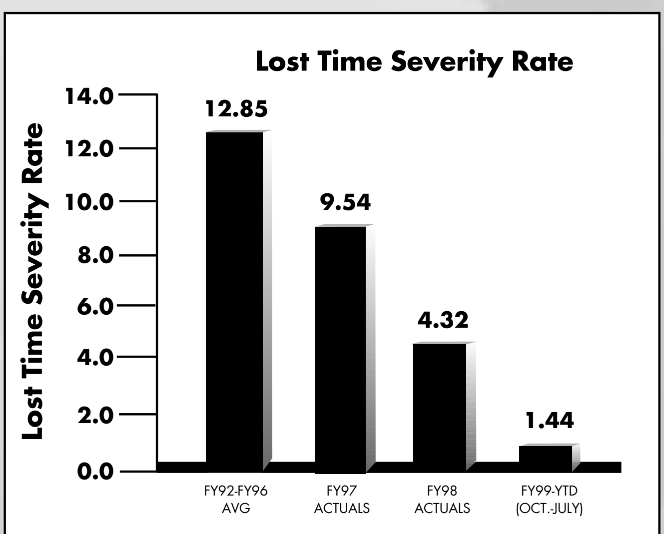
Management emphasis on safety has led to a number of education and awareness activities involving the total work-force. Organizations such as the Johnson Space Center (JSC) and USA have pursued and achieved STAR recognition under OSHA's Voluntary Protection Program. The Feb99 Program Management Review focused on safety and provided a forum for each NASA and contractor element to discuss a subject or project that supports and improves safety in the SSP. Various management, facility, and operational safety committees have been implemented to involve employees and supervisors in identifying and addressing safety throughout the workforce. USA has expanded its Training Academy to include safety, quality, and risk management training. DuPont Safety Program training, Safety and Total Health Day, and the use of computer based training are a few examples of the safety awareness activities utilized across the Space Shuttle Team.

Technology application has played an important role is improving SSP safety and mission success. It has improved the ability to provide safety analysis and access to safety data through use of interweb applications. As an example, before the Payload Safety Electronic Data Package Distribution Project, an average of 47,000 Safety Data Package (SDP) pages per week were prepared for reproduction (approx. $47,000/yr) and distributed to approximately 60 members of the PSRP with a distribution time of 5-8 working days. Now the process takes a half-day and eliminates the hard-copy reproduction. Additionally, the hardcopy archive is reduced or eliminated, as the information is stored electronically. Another example is the Electronic Failure Modes and Effects Analysis/Critical Items List (FMEA/CIL) utilized by the SSME Project. The new EFMEA also incorporates the SSME Integrated Hazard Analysis, providing comprehensive and detailed descriptions of all credible engine failure modes to the fingertips of NASA and contractor team members. ❖

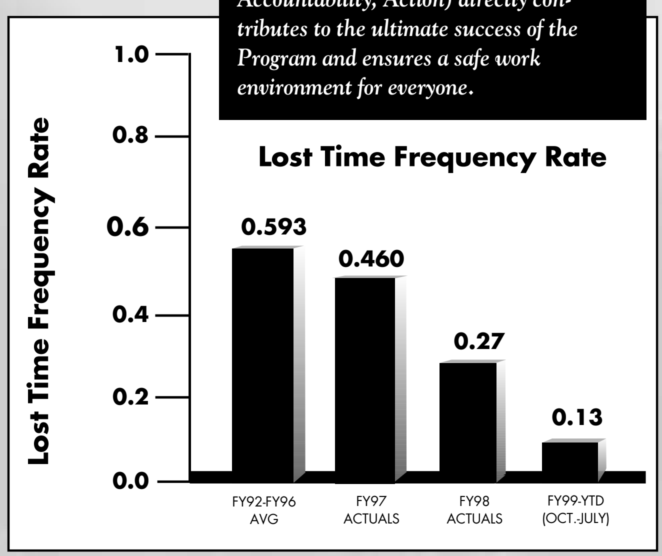


54% Reduction in OSHA recordable cases

Recognizing the need to stay focused on safety in the future and applying the Triple A's of safety (Attitude, Accountability, Action) directly contributes to the ultimate success of the Program and ensures a safe work environment for everyone.



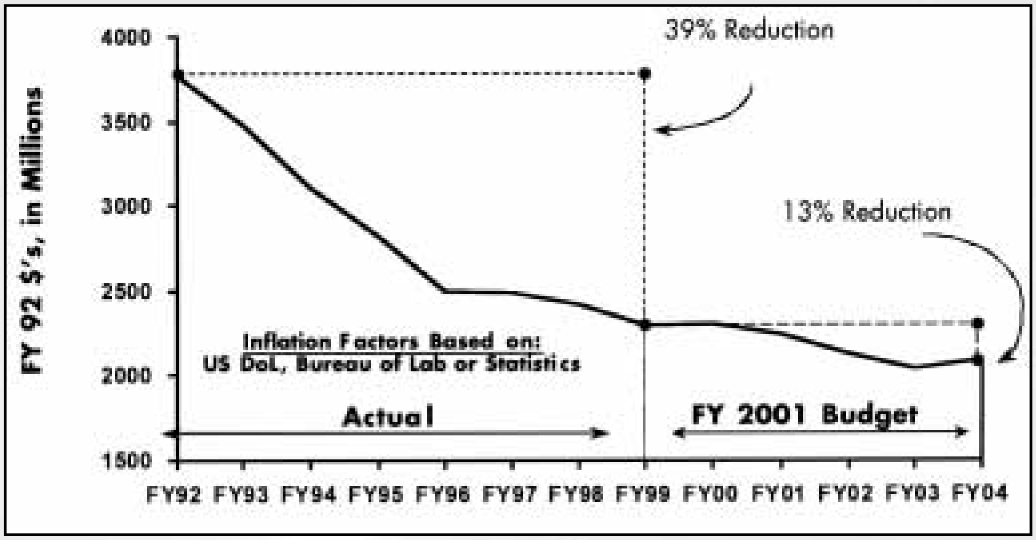
80% Reduction in Lost Work Days



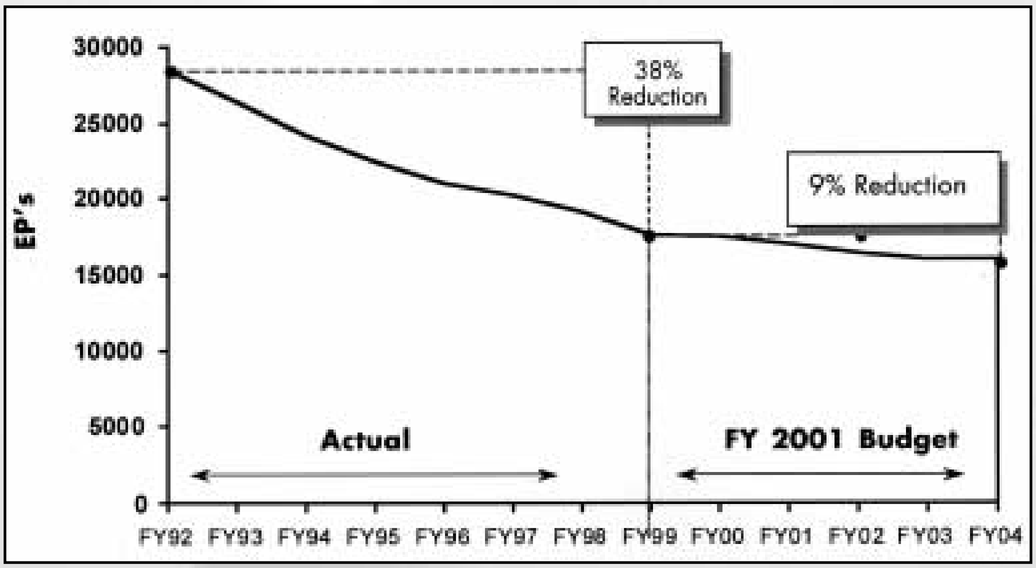
57% Reduction in Lost Time cases

The SSP achieved significant cost reductions since 1992. Costs are almost 40% lower relative to the buying power of a dollar in 1992. Program efficiencies and consolidations have allowed 38% reduction of the contractor workforce. Civil service workforce has been reduced 50% since 1992. The figures graphically depict these substantial reductions. While saving the taxpayers billions of dollars, the Space Shuttle Program has maintained an enviable record of safe and on time launches. The Space Shuttle Program costs were below the budget again in FY 1999; the first year that the Program has spent under $3 billion since early development days. ❖

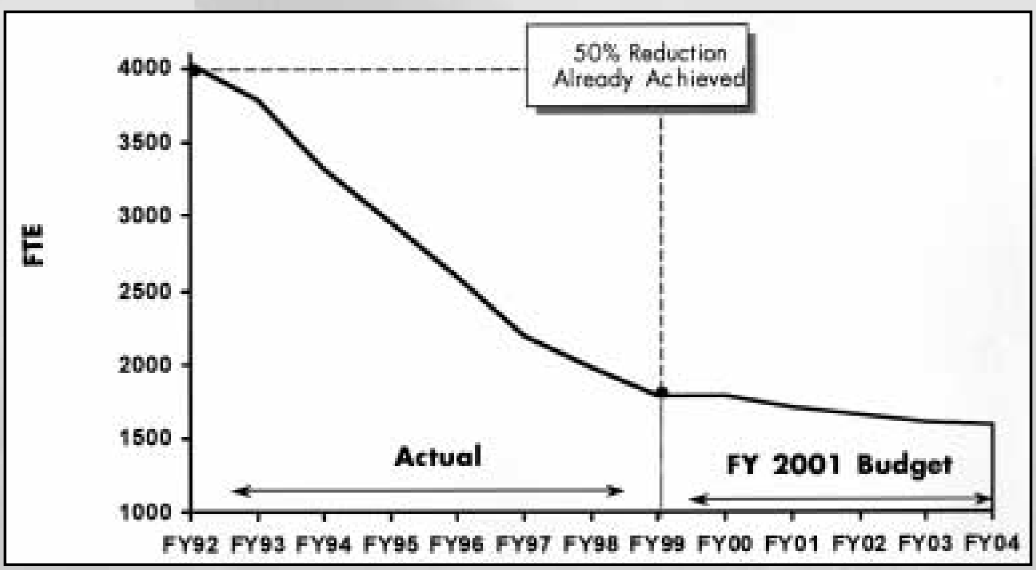
Total Budget FY92 $'s



Total Program Contractor Workforce



Total Program Civil Service Workforce



Basic Period of Performance: 10/1/96 to 9/30/02
Original Contract Value: $ 6.949 Billion
Current Contract Value: $8.4+ Billion

Background

The Space Flight Operations Contract (SFOC) is completing its third year of successful performance since being awarded to USA under a sole source determination by the NASA Administrator. As a joint venture of Lockheed-Martin and Boeing, SFOC was initially formed through the consolidation of 12 contracts previously performed by one of these parent companies. The SFOC is a completion-form, performance-based, cost-plus incentive fee/award fee contract. Included in the implementation of this consolidation of contracts is the transition of additional responsibilities and levels of accountability for the contractor as NASA strives to reduce the oversight of routine operations and moves towards a role of insight. Fifteen other contracts were targeted for transition as the successof SFOC was demonstrated, and several of these were transitioned in this last year. Overall, and as evidenced in the other portions of this annual report where the functional areas are described, USA has done a good job of consolidating the numerous contracts and continuing the high levels of performance as had been experienced under the previous individual contracts.

Successful Performance of the Contract Requirements

SFOC technical requirements emphasize insight by NASA rather than oversight in the performance of the day-to-day, routine operations and production. Over this last year, USA has continued to define and stabilize its management structure and its goals and objectives, and continued increases in its award fee evaluations demonstrate a very good level of satisfaction by NASA management with its progress. Horizontal integration, in areas like business systems and functional areas like logistics, continues to evolve and represents the real value of the consolidation of the contracts. While the Shuttle manifest for this past year was limited by events outside the control of SFOC, preparations and real time mission execution by USA was excellent for those missions we were able to execute. Re-planning efforts to best accommodate the ISS assembly manifest and the addition of an expedited Hubble Space Telescope (HST) repair mission have demonstrated both commitment and flexibility on USA's part, and continue to be a major task for both NASA and the contractor.

Phase II

Contract modifications this year have expanded the original scope to include the significant additions of the SRB, Primary Flight Software, and the Flight Equipment Processing contracts. These contracts were all incorporated into SFOC in July 1998, and the transitions were handled very smoothly, with high capture rates of the incumbent employees, and no measurable functional disruption of the work in any of these areas. A decision to delay the transition of the ET Project into SFOC in October of this year was made to take into account the expendable launch vehicle broad area review and potential impacts on SSP processes and procedures. The revised transition is projected for July of FY 2000. Further transitions (the SSME and Reusable Solid Rocket Motor (RSRM), or efforts) have also been delayed for additional assessment, with July 2001 being targeted at this time.

Contract Administration Changes

The level-of-effort portion of SFOC, originally used to accommodate the dynamic support requirements for the ISS Program Office, has been recently converted to completion-form content in a mix of program provisioning and incentive requirements. The result of this conversion is that the complete SFOC scope is now in completion-form format.

A value engineering change proposal clause was recently developed and added to the contract. This clause provides additional incentives for USA to implement cost improvements and efficiencies that reflect cost payback beyond the current contract end date of September 2002. Previously, the limited opportunity for realizing a return on the implementation costs of such actions could have resulted in USA business decisions to not implement such improvements. This contract change will better enable USA to continue developing initiatives that provide benefits to the Program past the current contract period of performance.

A NASA and USA Change Process Improvement Team activity was completed this year with the development and implementation of improved processes for the acquisition and contract change management needs of SFOC. The team developed an approach based upon multidisciplined partnering whereby joint NASA and contractor experts develop program requirements and determine the necessary resources to support those requirements. This new process reduced the number of approvals and concurrences required for processing a change and has resulted in significant improvements in the contract management metrics for SFOC. The average time to define a change on SFOC has been reduced by one third (from over 180 days to only 111 days) and continues to decrease. This reduces the change backlog and eliminates many potential proposal and re-proposal requirements which historically add costs and tie up manpower associated with such actions.

Performance Metrics

During FY99, USA has successfully received all of the performance fee in conjunction with the four Shuttle flights. The metrics were established as an objective measurement against specific criteria for each flight.

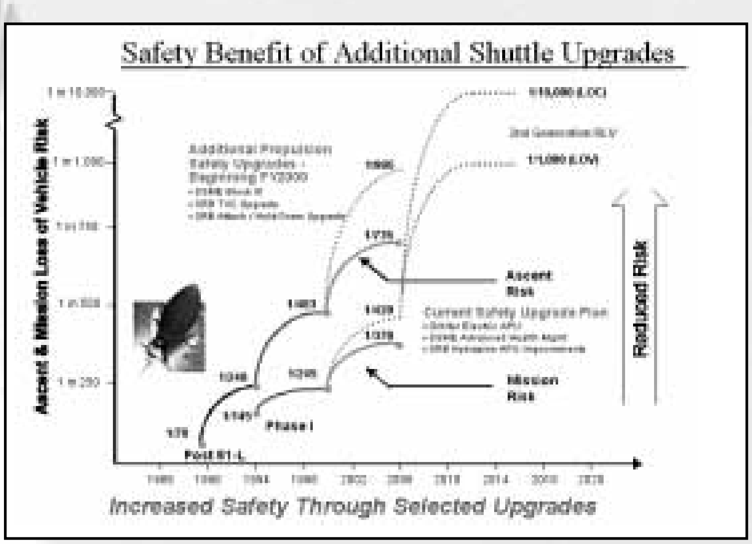
Space Shuttle Upgrade, Strategic Plan

The Space Shuttle Orbiter was designed for a service life of 100 missions. Even with anticipated increases to the flight rate of today, the service life of the Space Shuttle will extend well into the next century. To ensure its continued viability, system upgrades will be needed to improve safety, avoid obsolescence problems, meet the manifest, improve supportability, and improve the overall system. The Space Shuttle Program Development Office (SSPDO) is currently developing a strategic and proactive Upgrade Program that will keep the Shuttle flying safely and efficiently to 2012 and beyond,to meet agency commitments and goals for human access to space.

The Upgrade Program's primary goal is to improve crew flight safety and situational awareness, protect people both during flight and on the ground, and increase the overall reliability of the Shuttle system. To accomplish this, a multi-Center, multi-contractor team carried out an in-depth assessment of safety-related upgrade candidates submitted by each SSP element. The upgrade portfolio was presented to the NASA Administrator and the Office of Budget Management to secure funding for the safety upgrades.

The portfolio of safety upgrades presented to the Administrator includes: an EAPU which will eliminate hazards due to hydrazine leakage or fires; an SSME Advanced Heath Monitoring System which will be capable of real-time vibration monitoring and optical plume monitoring; avionics and cockpit upgrades which will improve crew situational awareness during routine operations and contingency modes; and more durable thermal protection which will reduce damage in critical areas. In addition to the flight hardware upgrades, several studies were also proposed. These studies include evaluating crew escape options, evaluating changes to the Main Landing Gear tires, and evaluating methods to improve safety and efficiency of the Self-Contained Atmospheric Protection Ensemble suits used during hazardous ground operations.

The candidate safety upgrades were evaluated and prioritized using a set of metrics established by the multi-Center, multi-contractor team. To determine the effect of each upgrade on the overall loss of vehicle and loss of crew risk of the Shuttle, a probabilistic risk assessment was performed for each upgrade candidate. The following chart illustrates the loss of vehicle risk for the ascent phase of the mission.



After implementing the Phase I upgrades, the ascent loss of vehicle risk decreased from 1 in 248 to 1 in 483. The Phase I upgrades included the new Block II SSME large throat main combustion chamber and high-pressure turbo pumps, the Super Lightweight ET (SLWT), and the Orbiter Multifunction Electronic Display Subsystem (MEDS) cockpit upgrade. Implementing the current safety upgrade portfolio would further decrease the loss of vehicle risk to 1 in 735.

In parallel to developing a safety upgrades portfolio, SSPDO is also evaluating upgrades that will significantly reduce supportability problems and combat obsolescence. A multi-Center, multi-contractor team is currently assessing and refining the SSP's supportability and obsolescence forecasts for flight hardware and ground infrastructure. The team's major focus will be on determining near-term vulnerabilities and hazards, with a minor focus on strategic long-term investments. A plan outlining the high-priority supportability and obsolescence issues and the funding requirements necessary to mitigate substantial supportability threats to the manifest through 2012 will be presented to the NASA Administrator in FY2000.

The primary goal of the SSPDO is to ensure that the Shuttle be the safest and most capable human-rated spacecraft possible. Upgrades that support this goal and the goals and objectives of the Shuttle Program will be the cornerstone of that achievement.

Space Shuttle Development Conference

The first Space Shuttle Development Conference, a national conference sponsored by USA and hosted by NASA, was held in July 1999. Over 700 people from NASA, industry, academia, and the media attended the conference which was held in the enormous blimp hangar at Moffett Field and the surrounding facilities at the Ames Research Center. The conference provided the opportunity for industry, academia, and government research and design facilities to present emerging technologies and system concepts as candidates for future upgrades to the Space Shuttle.

The conference featured new technology demonstrations, technical sessions, and panel presentations. Technical papers were presented in the areas of space vehicle processing, flight operations, propulsion, avionics, advanced shuttle first stage, cockpit, power systems, thermal protection systems, and information technology. NASA management and industry executives participated in panel discussions on the Space Shuttle of the 21st Century and space commercialization. The Space Shuttle Development Conference offered an excellent opportunity for the SSP to interface with academia, industry, and other government agencies to discuss new and often revolutionary ideas for future upgrades that would improve safety, reliability, and performance while reducing operating costs for the Shuttle. The Conference was an overwhelming success in creating an awareness of the on-going Shuttle Upgrades activities and encouraging industry and academia to get involved in the Upgrades Program.

Space Shuttle Upgrades

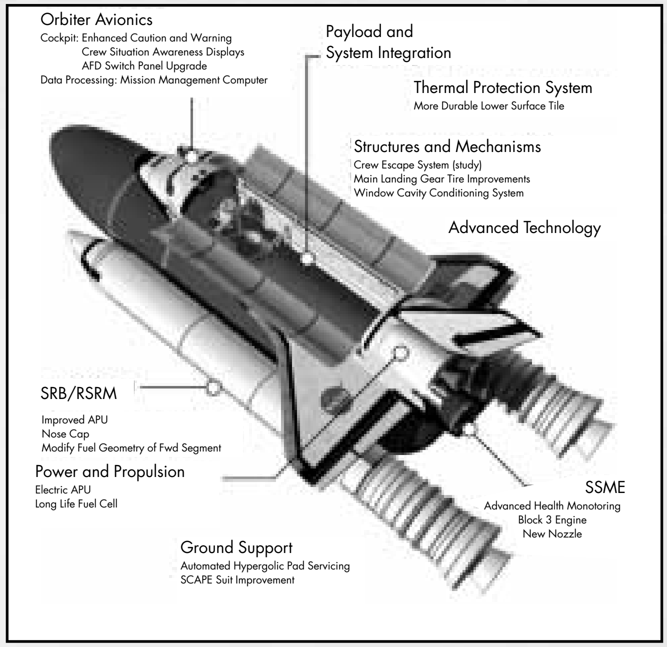
The SSPDOapproved approximately $95 million for Shuttle upgrade activities in FY99. Of the $95 million, over $18 million was approved for new flight hardware upgrade projects. The SRB Altitude Switch Assembly, Display Driver Unit, and Mass Memory Unit projects were approved to resolve obsolescence problems encountered due to aging hardware. The old hardware, which was becoming increasingly difficult to maintain and repair, will be replaced with new hardware that will improve maintainability by incorporating new state-of-the-art technology into the designs. An SSME Advanced Health Monitoring system will provide real-time monitoring of vibrations within the SSMEs and will increase safety by approximately 6%. The current fuel cells, which must be removed and overhauled after 2400 hours of operation, will be upgraded to a new long life alkaline fuel cell which will have an operational life of 5000 hours. Finally, a battery powered EAPU prototype is under development, and if successful, may replace the current hydrazine driven APUs. By eliminating the hydrazine and high speed, gas-driven turbines, the electric APU could increase the safety of the Shuttle by approximately 18%.

Approximately $65 million of the total SSPDO budget was approved for continuation of the following flight and ground hardware upgrade projects: SRB Composite Nose Cap, RSRM Nozzle to Case J-Joint Insulation Redesign, Radiator and Wing Leading Edge MMOD, SIGI, SSME Plume Prediction, Integration Structures Verfication Loads Analysis (VLA) Process Improvement, Chechout and Launch Control System (CLCS), and System Engineering Simulator (SES) Image Generator (IG) Enhancement. An additional $10 million was approved for HEDS Technology Demonstrator (HTD) projects, advanced technology studies and prototype demonstrations, and support activities.

Integrated Vehicle Health Management (IVHM) HTD-1, flown on STS-95, and HTD-2, flown on STS-96, demonstrated the capability of integrating competing modern, off-the-shelf sensing technologies and operating them in a space environment. The experience and data captured from the IVHM HTDs will assist in making informed design decisions for incorporation of an IVHM system on the Shuttle. In addition to the IVHM HTDs, a fiber optic HTD was flown on STS-95 and a (NanoMEMS) mid-deck test bed HTD was flown on STS-93. The Fiber Optic Flight Experiment captured telemetry data using a fiber optic communication pathway. The fiber optic data were then compared to telemetry data captured from the HST Orbital Systems (HOST) Test Platform via standard Shuttle avionics. Postflight comparison of the two sources of data was used to assess the viability of using fiber optic communication pathways onboard the Orbiter. No issues were identified that would preclude using fiber optic systems on the Orbiter. The Nano-Micro-Electrical Mechanical System HTD utilized low weight, low volume, low power, and highly reliable submicron and submillimeter- scale sensors to measure acceleration, temperature, and pressure in the crew module environment. Data collected by the NanoMEMS sensors matched data currently collected by other Orbiter systems.

Two HTDs, the Laser Dynamic Range Imager (LDRI) and Wireless Sensor, have been approved and will be manifested on future Shuttle missions. The LDI HTD, which is manifested for STS-97, will measure loads during critical ISS assembly tasks and will be an integral part of the Space Vision System(SVS). The Wireless Sensor HTD will install several wireless temperature sensors in the Orbiter crew module and docking module. Transmitters attached to the sensors will transmit data to a receiver connected to the Portable General Support Computer (PGSC). The Wireless Sensor HTD will demonstrate the ability to use wireless sensors in a space environment. Wireless sensors could eliminate the need for long wire runs, which are susceptible to wear and tear damage.

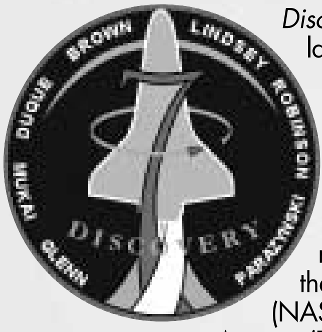
In addition to the HED's TD projects, SSPDO has also funded several advanced technology development projects. These projects typically have a low technology readiness level and need further development to support the Shuttle and next-generation launch vehicles. The advance technology projects include the Proton Exchange Membrane Fuel Cell, NonToxic Orbital Maneuvering Subsystem/Reactive Control Subsystem (OMS/RCS), and various flight and ground operations projects.



Shuttle Upgrades Technical Content Summary
(highlighting safety-specific improvements)

The SSPDO will continuously evaluate potential upgrade projects. As upgrades are approved and implemented, the Shuttle will become a safer and more reliable vehicle capable of fulfilling the goals and objectives of the SSP and the Agency. ❖

STS-95



Discovery was successfully launched from Kennedy Space Center (KSC) at 1:19 p.m. CST on October 29, 1998. *Discovery* carried nearly 3 dozen life sciences, microgravity sciences, and advanced technology experiments sponsored by NASA, the Japanese Space Agency (NASDA), the European Space Agency (ESA) and commercial entities. The crew completed all planned mission operations.

The primary objectives included conducting a variety of science experiments in the pressurized SpaceHab module, the deployment and retrieval of the SPARTAN free-flyer payload, and operations with the HOST and the International Extreme Ultraviolet Hitchhiker (IEH) payloads carried in the payload bay.

For STS-95, a single-module SpaceHab was located in the forward portion of *Discovery's* payload bay. A variety of experiments sponsored by NASA, NASDA and ESA focused on life sciences, microgravity sciences, and advanced technology during the flight.

The Spartan 201 free-flyer designed to investigate physical conditions and processes of the hot outer layers of the Sun's atmosphere, or solar corona, was deployed and retrieved using the Shuttle's mechanical arm. Information collected during this mission will lead to a much better understanding of the solar winds that directly influence television and phone communications, orbiting satellites, and weather conditions on Earth. SPARTAN downlinked over 500 solar coronal images from the Goddard Space Flight Center (GSFC) White Light Coronograph (WLC). An additional 600 WLC images and 300 Smithsonian Astrophysical Observatory Ultraviolet Coronal Spectrometer spectra were stored on the onboard recorders and retrieved after the flight. The mission was an outstanding scientific success.

The HOST platform carried experiments to validate components planned for installation during the third HST servicing mission and to evaluate new technologies in an earth orbiting environment. There were four experiments on the HOST platform:

(1) The NICMOS Cooling System, a zero-g verifica tion of a Reverse Turbo Brayton Cycle Cooler designed to replace the current dewar system

(2) The HST 486 computer, designed to identify any radiation-susceptible parts in the DF-224 replacement and demonstrate hardware and software responses to single event upsets (SEU's)

(3) Solid State Recorder, designed to compare on-orbit operation of the flight spare solid state recorder with the current HST unit

(4) Fiber Optic Line Test, designed to capture the same 4 kbps data stream that is sent to the Orbiter's Payload Data Interrogator via a fiber optic system routed to a laptop computer for postflight comparison. The HOST Platform experiments were highly successful.

The IEH payload involved six different experiments mounted on a support structure carried in *Discovery's* payload bay. The IEH-3 payload was the third in a series of five flights dedicated to the investigation of the absolute solar extreme ultraviolet (EUV) and far ultraviolet (FUV) flux emitted by the plasma torus system around Jupiter and stellar objects. The payloads also studied the Earth's thermosphere, ionosphere, and mesosphere.

The IEH-3 payload consisted of five prime experiments plus two get-away special (GAS) canisters containing educational experiments:

(1) Solar Extreme Ultraviolet Hitchhiker (SEH), managed by University of Southern California, that obtained EUV and FUV fluxes required when studying the Earth's upper atmosphere

(2) Ultraviolet Spectrograph Telescope for Astronomical Research (UVSTAR), managed by University of Arizona, designed to measure EUV fluxes which can be used to form images of extended plasma sources (Jupiter, hot stars, etc.)

(3) Space Telescope for Astronomical Research managed by the University of Arizona, which made observations of extended and diffused astrophysical targets

(4) Solar Constant Experiment (SOLCON), managed by the Royal Meteorological Institute of Belgium, dual-channeled radiometer viewed the Sun during 11dedicated solar periods and during 7 non-dedicated solar periods, acquiring over 17 hours of data

(5) Petite Amateur Navy Satellite (PANSAT), managed by the Department of Defense Space Test Program and involving a small deployable satellite that stored and transmitted digital communications to PANSAT ground stations

(6) Two GAS payloads:
(a) GAS G-238, sponsored by the American Institute of Aeronautics and Astronautics National Capital Section and managed by DuVal High School, Prince George County, Maryland contained two biological experiments
(b) GAS payload G-764, sponsored by the University of Bremen, Germany, and ZARM (Zentrum fur Ange wandte Raumfahrttechnologie und Mikrogravitation), whose objective was to simulate dust aggregation and the dynamics of dust clouds of the early solar system

The IEH-3 mission was by far the most successful flight of the IEH initiative, as evidenced by the unprecedented achievements of the UVSTAR, SEH and SOLCON experiments.

Two additional GAS payloads were aboard the STS-95 mission. The purpose of the G-467 GAS payload was to demonstrate in space the working principle and performance of a two-phase capillary pumped loop with two advanced evaporators, a two-phase vapor quality sensor with two condensers in parallel, and a control reservoir. The G-467 GAS payload was sponsored by the ESA, Paris, France. G-779, or Hearts in Space, was developed by researchers at Bellarmine College in Louisville, Kentucky. The purpose of the payload is to examine the role of gravitational-dependent hydrostatic pressure effects on the adaptation of the cardiovascular system to the microgravity environment of spaceflight. The payload consists of a fluid circuit simulator of the heart and mock circulation system, the instrumentation to automatically conduct the experiment protocol and record data, and batteries to power the experiment.

Cryogenic Thermal Storage Unit (CRYOTSU) was fifth in a series of cryogenic test bed flights. The CRYOTSU payload and avionics were attached to an adapter beam mounted on the sidewall of the Orbiter. The CRYOTSU payload was a compilation of four cryogenic experiments: A 60K Thermal Storage Unit (TSU); a Cryogenic Capillary Pumped Loop (CCPL); a Cryogenic Thermal Switch (CTSW); and a Phase Change Upper End Plate (PCUEP). The 60K TSU, CCPL, and CTSW benefit future integrated cryogenic bus systems. The PCUEP will benefit future cryogenic test bed missions and spacecraft requiring load-leveling for power-dissipating components.

CRYOTSU completed approximately 90 hours of operation that included 23 full melt cycles and 18 partial melt cycles at various heat loads. The unit performed as expected and correlated very well to tests conducted on the ground. CRYOTSU successfully achieved more than 200% of the minimum mission objectives, and over 100% of its nominal mission science objectives.

The Biological Research in Canisters (BRIC) investigation was contained in 3 canisters with a passive cooler in one mid-deck locker in the crew compartment. This payload, managed by KSC, contributed to researchers' understanding of how the weightlessness of space affects the development of plants. The implications are important for the crews of future long-duration spaceflights because they will depend on plants grown in space for food, water, and oxygen.

Electronic Nose (ENOSE) was located in a mid-deck locker and the objective was to flight test an environmental monitoring instrument that would detect and identify a wide range of organic and inorganic molecules down to the parts per million level. The instrument was designed to monitor changes in the atmosphere to which it is exposed and consists of an array of thin film polymer sensors dispersed with carbon. All ENOSE operations were nominal and all daily objectives were met.

The Protein Crystal Growth-Single Locker Thermal Enclosure System (PCG-STES) payload was designed to conduct experiments which supply information on the scientific methods and dynamics of growing large high-quality protein crystals in microgravity. The PCG-STES was installed and operated in the Orbiter mid-deck.

Since the aging process and a spaceflight experience share a number of similar physiological responses, a series of experiments sponsored by NASA and the National Institute on Aging were conducted during the STS-95 mission. The investigations gathered information that may provide a model system to help scientists interested in understanding aging. Some of these similarities included bone and muscle loss, balance disorders and sleep disturbances. All experiments were performed and the data downloaded for postflight analysis. ❖

STS-88

The launch of *Endeavour*, with five Americans and one Russian onboard, from KSC at 2:36 a.m. CST on December 4, 1998, began the largest cooperative space construction project in history; the building of the ISS.

After rendezvous and berthing of the Russian-built Zarya control module (FGB) to Node 1 (Unity), three space walks were successful in connecting electrical and communication lines between the Unity and Zarya. During the two days of open hatch operations, assembly and checkout of the early S-band communications system were completed and approximately 1200 lbs. of hardware was transferred to and 335 lbs. from, Unity/Zarya (Stage 2 of the ISS). After undocking from the ISS and successfully deploying two small satellites, the crew of six landed at KSC.

In addition to accomplishing all 23 of the ISS flight objectives, 3 Zarya repair/maintenance tasks were completed. The tasks were the replacement of a battery charging unit inside Zarya, the deploying of two TORO antennas that failed to deploy after Zarya reached orbit, and the configuring of the Komplast experiment located outside of Zarya.

On Flight Day 11, the crew successfully deployed the SAC-A satellite, a small non-recoverable satellite built by the Argentinean National Commission of Space Activities. This marked the first deployment of an Argentinean satellite. The ejection altitude showed a predicted lifetime of 6-9 months. During this time, SAC-A will test various new technologies including a differential global positioning System, a charge-coupled Device camera, silicon solar cells, a whale tracker, and a magnetometer.

On Flight Day 12, the crew successfully deployed the MightySat-01 satellite. The MightySat-01 team will demonstrate four advanced technologies during the life of the satellite: composite structure, advanced solar cells, advanced electronics, and a shock device.

Approximately 67% of the IMAX Cargo Bay Camera objectives planned for the flight were successfully accomplished. The camera accomplished execution of all scenes during Node grapple and installation.

Gas payload G-093R, the Vortex Ring Transit Experiment, successfully operated for approximately 9.5 hours. The objective of this experiment was to investigate the propagation of a vortex ring through a liquid-gas interface in microgravity. The G-093R GAS is sponsored by the University of Michigan.

The Space Experiment Module (SEM-07) flight project is one of a number of educational initiatives being pursued by the NASA Shuttle Small Payloads Project to increase educational access to space by means of Space Shuttle small payloads and associated activities. The SEM-07 on STS-88 utilized an existing 5 cubic-foot GAS canister with a GSFC-provided internal support structure. The canister housed various passive experiments from schools ranging from the kindergarten to the university level. Seven modules were provided by teachers and their schools participating in the NEWMAST – NASA Educational Workshop for Mathematics, Science and Technology Teachers.

The Shuttle Ionospheric Modification with Pulsed Local Exhaust (SIMPLEX) experiment is sponsored by the United States Air Force Space and Missile Center for the Naval Research Laboratory. The purpose of the experiment was to determine the source of the very-high-frequency radar echoes caused by the Orbiter and its OMS engine firings. ❖

STS-96

The STS-96 (ISS-2A.1 Logistics) mission on *Discovery*, with five Americans, one Russian, and one Canadian on board, was initiated with an on-time KSC liftoff on May 27, 1999 at 5:49:42 a.m. CDT, and began the second U.S. mission to the ISS. Following rendezvous and the first direct docking with the ISS Pressurized Motoring Adapter-2, one space walk was completed to transfer the U.S. Orbital Replacement Unit Transfer Device and Russian Strela cranes as well as the transfer of extravehicular activity (EVA) pre-positioning hardware to be used for subsequent ISS assembly tasks. This mission also highlighted the maiden voyage of the SpaceHab Integrated Cargo Carrier, which consists of an Unpressurized Cargo Pallet mounted on a Keel Assembly and was used for the mounting of external transfer items.

During the Flight Day 5 to Flight Day 9 docked operations all preflight-planned on-orbit task priorities were completed as well as over 4000 lb. of EVA and intravehicular activity (IVA) transfers. Additionally, seven more on-orbit inspection tasks were requested and completed.

Other payloads on STS-96 were the Student Tracked Atmospheric Research Satellite for Heuristic International Networking Equipment (STARSHINE), the Shuttle Vibration Forces Experiment (SVF) and the IVHM HTD.

The STARSHINE was a Rocky Mountain NASA Space Grant Consortium/Utah State University-sponsored ejectable satellite. The purpose of the mission was to train international student volunteer observers to visually track this optically reflective spacecraft during morning and evening twilight intervals for several months, calculate its orbit from shared observations, and derive atmospheric density from drag-induced changes in its orbit over time. Following undocking from the ISS, the crew successfully deployed the STARSHINE satellite at an altitude of 205 n.mi.

STS-96 was the second flight of the SVF experiment. The SVF experiment activated automatically by the Orbiter lift-off vibration and operated for approximately 240 seconds. This was accomplished by using commercially available triaxial force tranducers and three wide-band stand-alone acceleration measurement devices that were built by JSC and funded by the Jet Propulsion Laboratory for this application. This experiment provided flight measurements of the vibratory forces acting between an aerospace payload and its mounting structure.

The HTD-1402 and the IVHM was activated approximately one hour daily during pre-sleep to capture data during power reactant storage and distribution valve cycling. The IVHM is an evolution of a traditional vehicle instrumentation system that consisted of sensor, wiring, signal conditioning devices, multiplexing devices, and recording devices. IVHM also provids the capability to process the data versus merely recording the data. The purpose of this HEDS experiment was to demonstrate competing modern, off-the-shelf technologies in an operational environment to determine its use for future Orbiter upgrades. ❖

STS-93

Columbia was successfully launched from KSC at 12:31 a.m. EDT on July 23,1999, carrying the Chandra X-ray Astrophysics Facility to orbit to join the HST and the Compton Gamma Ray Observatory as the next in NASA's series of "Great Observatories."

The Chandra X-ray Astrophysics Facility is designed to observe x rays from high-energy regions of the Universe, such as hot gas in the remnants of exploded stars. The Observatory has three major parts:

1) The X-ray telescope whose mirrors will focus x rays from celestial objects
(2) The science instruments which record the x rays
(3) The spacecraft, which provides the environment necessary for the telescope and the instruments to work

Three payloads–the Lightweight Flexible Solar Array Hinge (LFSAH), the Midcourse Space Experiment (MSX), and the SIMPLEX sponsored by the Department of Defense Test Program at JSC flew on STS-93.

The LFSAH payload consisted of six hinges fabricated from shape memory alloys. The LFSAH on STS-93 provided a way to test this technology in a weightless environment before being applied to future spacecraft design. Good deploys were reported by the crew on all six hinges and no anomalies were reported during the flight.

Orbiter thruster firing and S-band radio transmissions were used as a sensor calibration and evaluation target for the space-based, ultraviolet, visible and S-band sensors on the MSX satellite. The MSX satellite is in a 99-degree inclination orbit and approximately 485 n. mi. altitude. There was no MSX hardware on the Orbiter. The MSX satellite gathered data from the Orbiter's RCS and OMS engine firings that were used as part of the effort to achieve the MSX objectives. During STS-93 three MSX burns were scheduled and accomplished.

The SIMPLEX experiment monitored the effects of the Space Shuttle exhaust in the ionosphere using ground-based radars located in Massachusetts, Puerto Rico, Peru, Australia, and the Marshall Islands. Six SIMPLEX burns were scheduled and accomplished during the mission. All SIMPLEX objectives for the STS-93 mission were accomplished as planned for a 100% success rate. STS-93 was the 25th and final mission of Shuttle Amateur Radio Experiment-II. The crew successfully completed five school and five personal contacts. The crew also completed contact opportunities with *Mir* and with a station in Colorado.

The Southwest Ultraviolet Imaging System (SWUIS) mid-deck experiment made its second flight on STS-93, with observations being made on three flight days. The sponsor is Southwest Research Institute, Boulder, Colorado. The SWUIS was used to perform ultraviolet astronomy, planetary, and cometary imaging, terrestrial airglow and atmospheric background imaging, auroral imaging, and studies of Shuttle glow and vehicle plume evaluations and orbital debris. Observations were made of Venus, the Vulcanoid search fields, the Moon, the Jupiter system, comet Lee, and two calibration targets. The Space Shuttle provided all of the planned astronomical observations and pointing, and also accomplished the highly desired test of SWUIS's camera science mode.

The BRIC-11 and BRIC-12 payloads were flown in the mid-deck. The payloads were designed to investigate the effects of spaceflight on small arthropod animals and plant specimens. KSC Payload Projects Management Office is the sponsor of these payloads.

The United States Air Force Space and Missile Systems Center sponsored the Cell Culture Module payload and the Space Tissue Loss-B payload. The objectives of the payload were to

(1) Validate models for muscle, bone, and endothelial cell biochemical and functional loss induced by microgravity stress.
(2) Evaluate cytoskeleton, metabolism, membrane integrity, and protease activity in target cells.
(3) Test tissue loss pharmaceuticals for efficacy. All pre-planned objectives were accomplished

The focus of Space Tissue Loss - B was direct video observation of cells in culture through the use of a video microscope imaging system with the objective of demonstrating near real-time interactive operations to detect and induce cellular responses.

Bioserve Space Technologies sponsored the Commercial Generic Bioprocessing Apparatus payload on STS-93, a self-contained incubation and refrigeration module unit used to stow and process several types of

experiments in microgravity. The three experiments flown on this mission were:

(1) NIH-B Drosophila neural development
(2) STARS-1 Research Facility (predator/prey relationship and chrysalid formulation and hatching in microgravity)
(3) Cell adhesion space experiment.

The gelation of Sols: Applied Microgravity Research payload was a middeck experiment for investigating the effects of microgravity on the microstructures of gels obtained by sol-gel processing. The crew activated the experiment with a switch throw on flight-day 2. All pre-planned objectives were accomplished.

The MEMS payload examined the performance, under launch,microgravity, and reentry conditions, of a suite of MEMS devices. These devices included accelerometers, gyros, and environmental and chemical sensors. The MEMS payload was self-contained in a mid-deck locker and required activation and deactivation only. The principal investigators for this experiment reported that they accomplished 100% of the planned mission objectives. ❖

CONTENTS

PART 2

Detailed Technical Activities and Accomplishments

Super Lightweight External Tank Performance

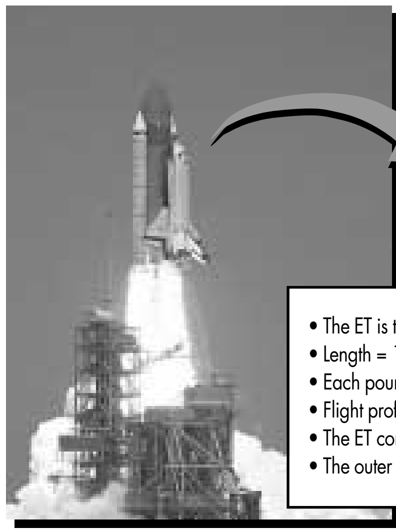
The ET Project was challenged to redesign the Lightweight External Tank (LWT) to support the ISS launch requirements, and through design changes and the use of a new aluminum alloy, aluminum lithium (AL) 2195, a weight reduction of approximately 7500 lb. was achieved. In just under three years, the NASA ET Project took a new material, AL 2195, from a development state to a fully qualified metal. The new SLWT remained dimensionally the same as the LWT, and retained the same or better structural safety and reliability margins.

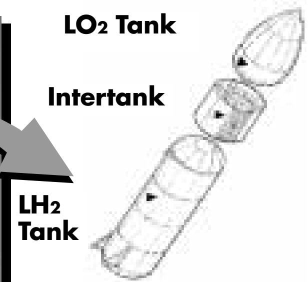
Due to the lack of industry experience with AL 2195, there was no established experience base for the properties of the material or for the welding techniques required during tank manufacturing. New techniques were successfully developed and the first SLWT was successfully built, tested, and then launched on STS-91 June 2, 1998.

Since the STS-91 flight, four additional SLWTs have flown: STS-95 launched October 29, 1998; STS-88 flew on December 4, 1998; STS-96 was launched on May 20, 1999; and STS-93 flew July 22, 1999. All the SLWTs have performed as expected. Currently, there are six SLWT tanks at KSC in various stages of launch processing.

The SLWT has fully supported the Space Shuttle launches. The 7500 lb. of weight reduction for the SLWT contributed to the Shuttle System meeting its required performance commitments to the ISS Program and other customers. The ET Project is continuing to investigate improvements in design and production that will help ensure continued support of the Space Shuttle manifest with increased safety and minimum cost through the year 2012. ❖

External Tank Overview



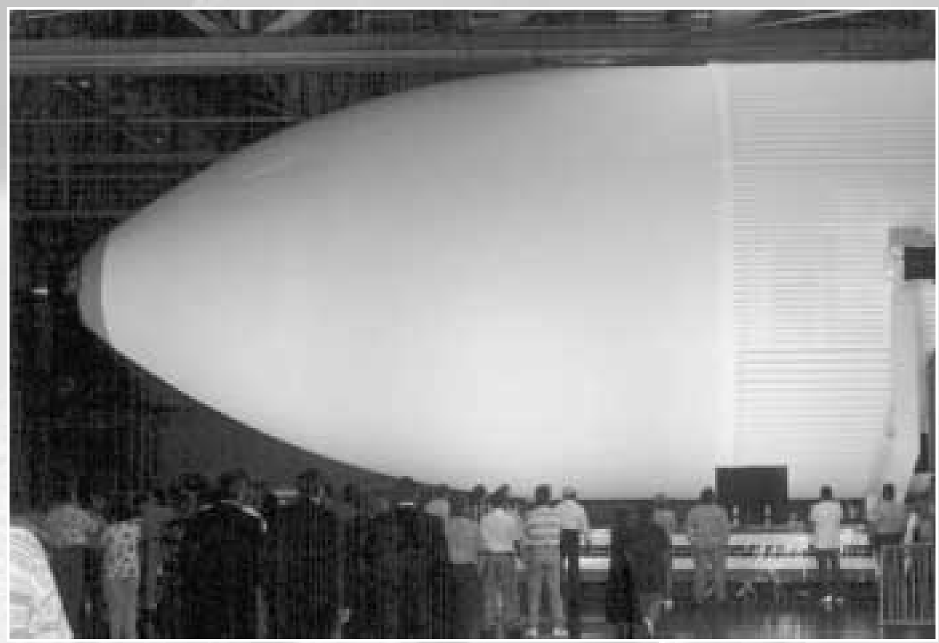


- The ET is the structural backbone of the Space Shuttle System.
- Length = 153.8 ft., Diameter = 27.6 ft., Empty Weight = 58,470 lb.
- Each pound of ET weight savings = 1 pound of payload to orbit.
- Flight profile includes space assent and reentry requirements.
- The ET contains cryogenic liquid fuels (-423°)
- The outer mode line surface is subjected to aerodynamic heating.


NASA

Delivery of the 100th External Tank

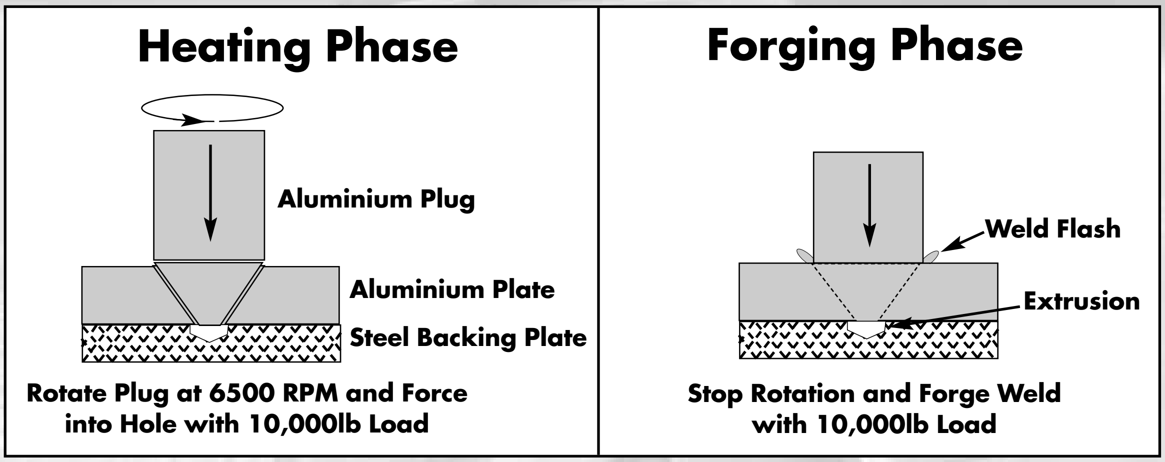
A general assembly celebrating the Space Shuttle 100th ET rollout was held at Marshall Space Flight Center's (MSFC) Michoud Assembly Facility in New Orleans, Louisiana on Friday, August 20, 1999. Approximately 600 Lockheed Martin employees gathered with the NASA and Defense Contract Management Command personnel inside the 43-acre manufacturing building for the celebration. The ceremony concluded with the 100th ET being rolled out. ❖



Rollout of 100th Tank

Progress on Enhancing Weld Processes for Aluminum Lithium

During welding, unlike AL 2219, the new alloy (AL 2195) is very sensitive to contamination. This presented several significant challenges. The immediate solution to the contamination issue was resolved using a traveling purge box, which provided an inert atmosphere during welding. Subsequently, an ingenious solution to the problem was developed. Instead of using a traveling purge box, a static purge chamber was developed that provides an inert atmosphere throughout the entire length. This eliminated all the moving parts that were jamming and provided a more consistent delivery of the purge gas.



Weld repairs have become a significant challenge for production of SLWTs. To resolve this challenge the ET project has developed a new weld repair technique. The new procedure is an industry first and and vastly simplifies weld repairs. The new process called friction plug repair, works very similarly to a forging process, where the metal is not melted, and thus the tensile properties are not adversely affected.

Another new technology is being developed to address the initial welds,known as friction stir welding. This technique overcomes many of the current process challenges such as torch control, heat sink, and purge gas. Additionally this new method changes the welding of aluminum into a machining process, which is less labor intensive, less technically complex and easier to control, and provides superior-strength welds.

The welding technologies being implemented and those being investigated will allow the ET Project to provide the SSP a more reliable ET that is less expensive to build. ❖

Friction Plug Welding Repair

RSRM Project Performance Highlights

RSRM thrust performance was right on the predicted target for each of the four Space Shuttle launches in GFY99. No significant anomalies were identified either during ascent or during subsequent postflight disassembly and inspection of the recovered motors.

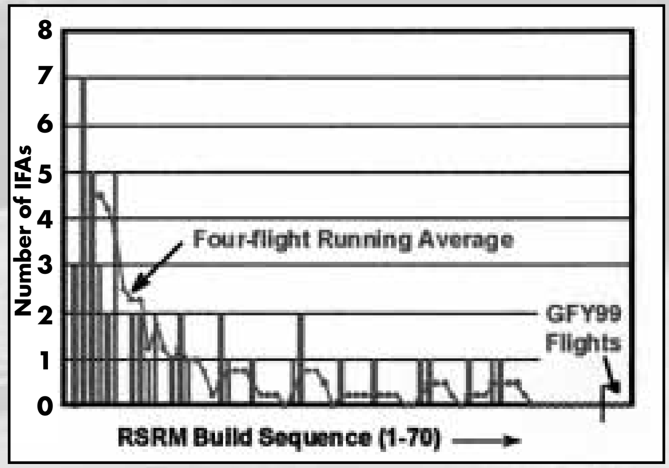
All RSRM segments for GFY99 were delivered on schedule, making this the ninth consecutive year of on-schedule RSRM deliveries to KSC.Safety continues to be a principal focus in the manufacture of the RSRM and is reflected in the job-related accident frequency rates at Thiokol Propulsion, which have been well below the rates for similar industries as published by the Bureau of Labor Statistics.

Because of its low accident rates, Thiokol Propulsion received the following recognition this past year:

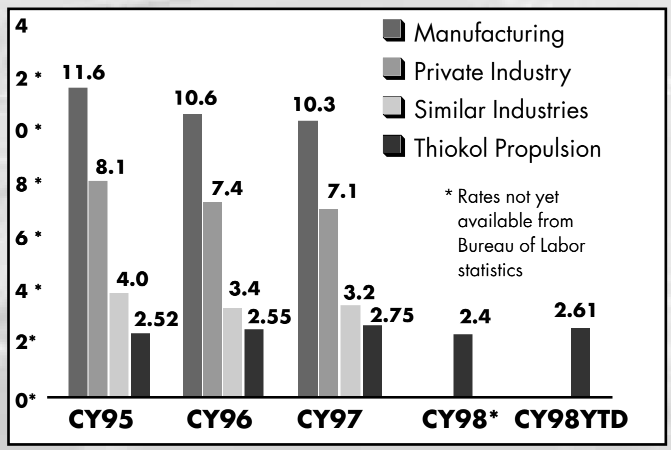
- National Safety Council Perfect Record Award for operating 1,965,694 hours without an occupational injury or illness involving days away from work (May-September 1999)
- Labor Commission of Utah Award for safety excellence in the manufacturing sector based on low workers' compensation costs
- National Safety Council Safe Driver Awards presented to designated company vehicle operators

The RSRM project continued to expand employee safety awareness, developing several safety initiatives throughout the year:

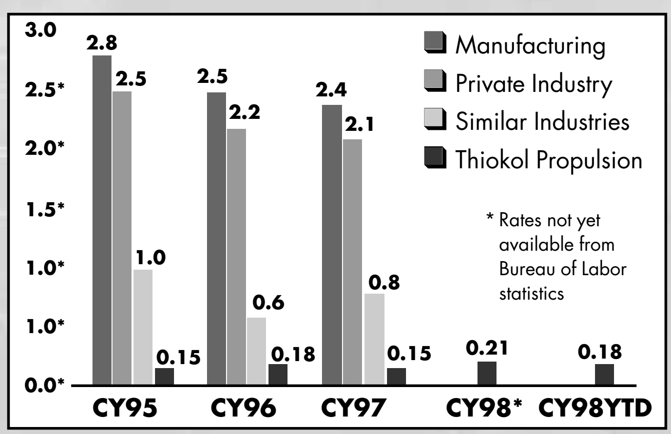
- Instituted "Safety Start-up Day" after returning from holiday shutdowns (special safety inspections and meetings were conducted by employees throughout the plant)
- Designated June as "Safety Month," with special safety activities that included several energetic material demonstrations shown to employees to promote explosive handling safety awareness
- Implemented a new "Safety Website" that provides employees with real-time access to the General Safety and Health Manual, safety video listings (e.g. Dupont's "Take Two" program), recent developments in safety/ performance goals, and Safety and Environmental Board safety communiqués



In-flight Anomaly Summary



RSRM OSHA Recordable Case Incidence Rate (PER 200,000 HOURS WORKED)



RSRM Lost Time Cases Incidence Rate (PER 200,000 HOURS WORKED)

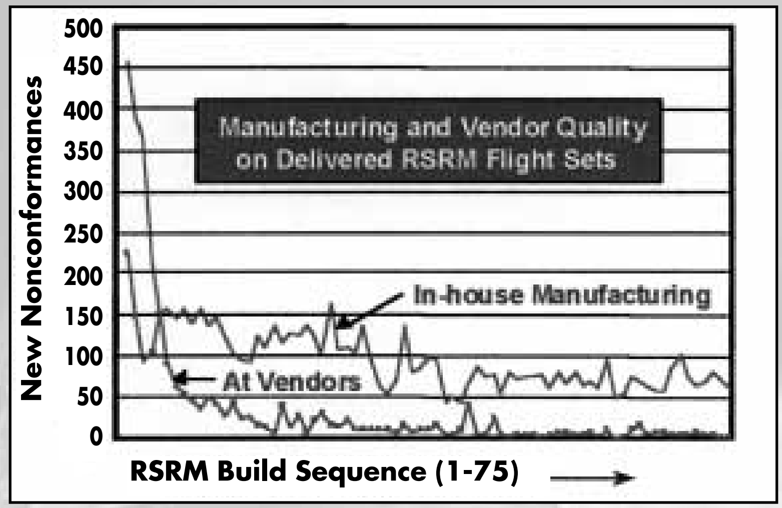
- Implemented a new Hazard Communication Website to provide employees easier access to hazardous materials information.

The RSRM program has progressively improved productivity and quality over the last decade. Quality conformance for each motor exceeds 99.999 %. RSRM manufacturing nonconformances have leveled off at a low rate. A new discrepancy reduction focus was recently initiated across all areas of the RSRM program, including suppliers.

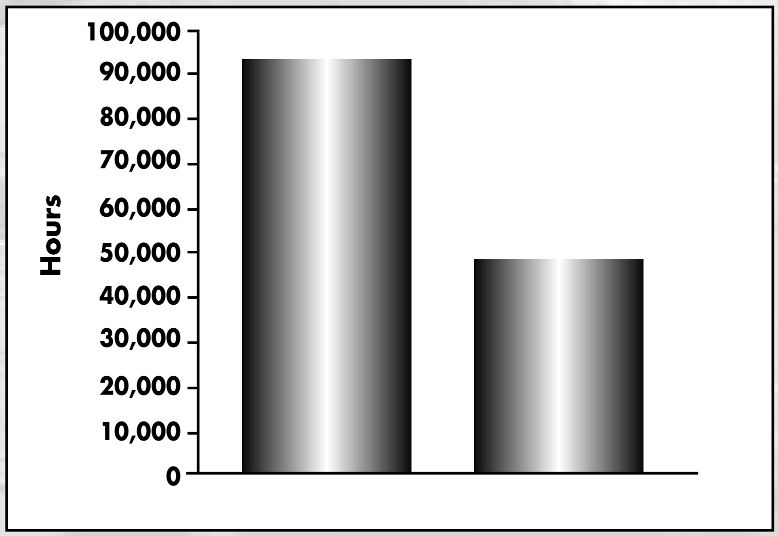
Manufacturing touch labor hours required to produce a motor have been cut in half over the last decade while in the same period the cost of production scrap, rework, and repair per motor has been reduced a dramatic 90 %.

In May 1999, Thiokol Propulsion cast the 1,000th solid propellant motor segment for the SSP. This brought the total to 277 million lb of propellant cast in support of the SSP.

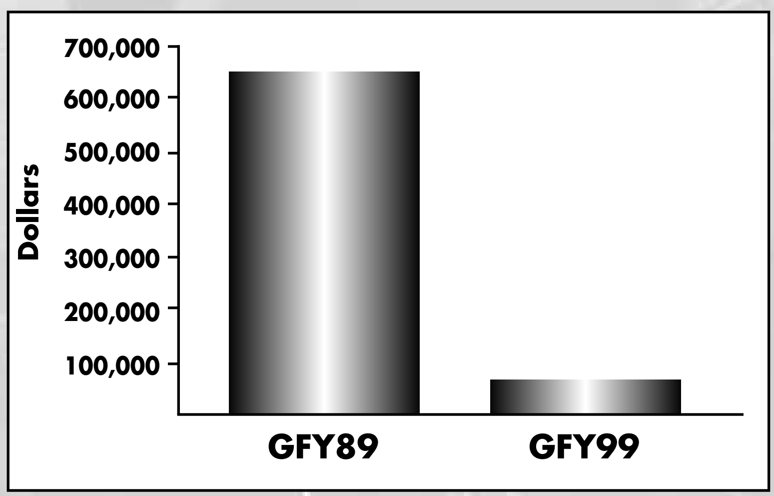
In recognition of its commitment to excellence, Thiokol Propulsion was awarded the 1999 MSFC Contractor of the Year Award and the 1999 George M. Low Award for Quality and Excellence. ❖



RSRM Nonconformances by Flight Set



Manufacturing Touch Labor Hours per RSRM



Scrap, Rework, Repair Costs per RSRM

RSRM Test Accomplishments
Flight Support Motor (FSM)

Full-scale RSRM static test motors are periodically tested to confirm the performance and safety of RSRM systems, components, materials, and processes. FSMs also provide the opportunity to evaluate, demonstrate, and/or certify design, process, and material changes. Health monitoring of RSRM hardware is enhanced through the utilization of specialized instrumentation. The capability to meet the program goal to static test every change was greatly enhanced by the recent program decision to fund annual full-scale static tests (versus 18-month intervals prior). The next FSM test firing (FSM-8) is scheduled for January 2000. The manufacture of FSM-8 has been largely completed during this government fiscal year and includes the following significant test objectives (and many other less significant objectives):

- ❖ Certify the performance of the nozzle throat fabricated using a new 120-in. phenolic tape-wrapper
- ❖ Certify the performance of replacement nozzle structural adhesives
- ❖ Certify the performance of a replacement operational pressure transducer (OPT)
- ❖ Obtain performance data on asbestos-free internal insulation
- ❖ Obtain forward-facing inhibitor erosion data
- ❖ Obtain field joint insulation temperature and motion data
- ❖ Obtain nozzle Joint 2 strain, pressure, and temperature data
- ❖ Obtain nozzle boot cavity (Joint 5) temperature data
- ❖ Obtain performance data on components cleaned with Ozone -depleting chemical free cleaners
- ❖ Obtain performance data on aluminum cell plating repair technique for sealing surfaces ❖

RSRM Flight Support Motor Firing

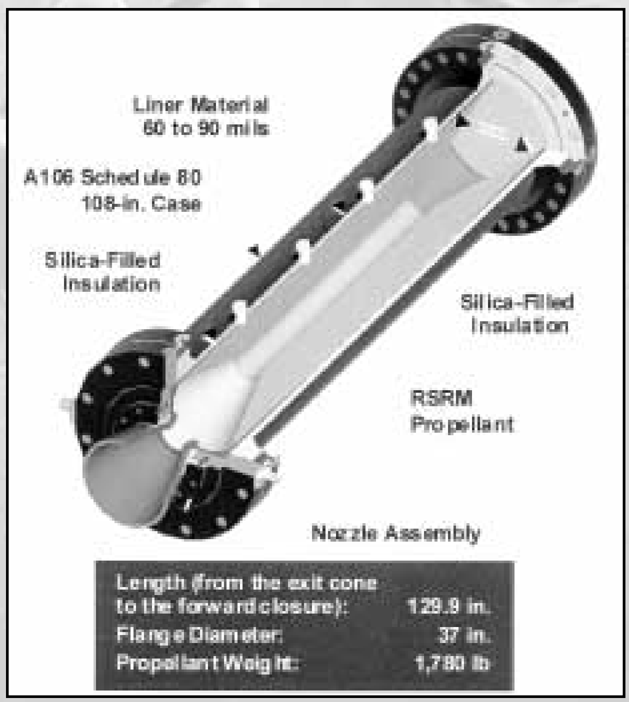
MNASA Motor

During GFY99, two MNASA motors were successfully tested. These large test motors provide a ballistic environment similar to the full-scale RSRM, with test components that are approximately one-fifth scale. MNASA motors burn approximately 10,000 pounds of propellant over a period of 28 seconds and are utilized primarily as test beds for evaluating case insulation and nozzle phenolic changes. MNASA-9 was tested at Thiokol February 1999. This was the first MNASA test in Utah and established the capability for testing at either Thiokol or MSFC. MNASA-10 was tested at MSFC August 1999. ❖

NASA Firing at Thiokol

24-inch Solid Rocket Test Motor (SRTM)

RSRM is developing a new 24-in. diameter SRTM test bed for RSRM nozzle and insulation materials. This will fufill an important roll between the large MNASA test motor and smaller subscale test motors. This will provide a relatively low-cost, fast turn-around representation of the RSRM internal environment. The 24-in. SRTM has two configurations: a one-segment test motor primarily for testing nozzle components (as shown) and a two-segment version for testing insulation. Both configurations use the same forward closure and loaded (with propellant) case. A successful 24-in. SRTM critical design review (CDR) was conducted May 1999. The first test firing of the 24-in. SRTM (nozzle configuration) is scheduled for November 1999 in a test stand at the U.S. Army's Redstone Arsenal. ❖

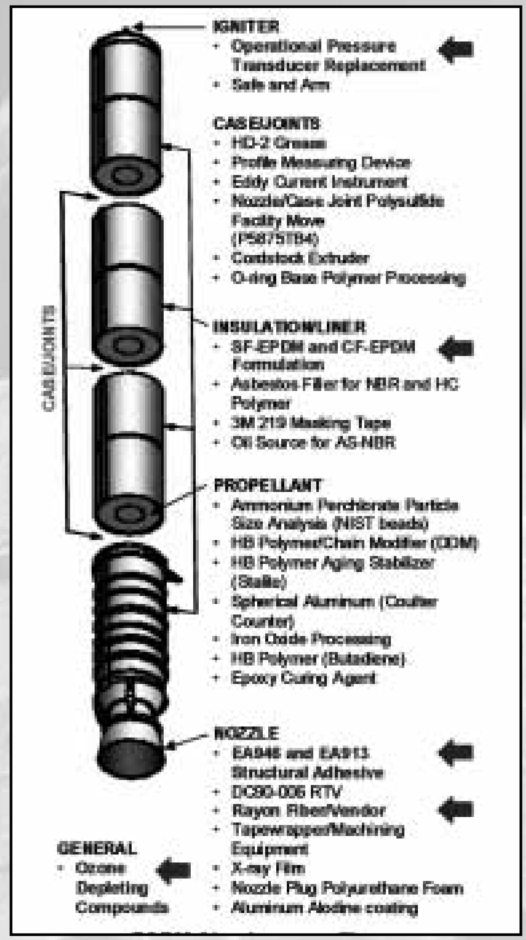


24 inch Solid Rocket Test Motor

RSRM Obsolescence Mitigation

The uninterrupted supply of unchanged components and materials is often challenged by factors such as state and federal regulation changes (including environmental, health, and safety), continued supplier and subtier supplier availability, supplier and subtier supplier process enhancements, and equipment and facilities aging/replacement. The RSRM program has made early identification and resolution of obsolescence threats part of its daily culture. All identified threats, however minor, are formally tracked and communicated in a bi-monthly obsolescence status report that identifies program protection steps (like stockpiling) to ensure continued RSRM production while resolution and verification plans are being worked. The following figure identifies all open RSRM obsolescence threats as of September 1999.

This chart provides status on key items (identified on the “RSRM obsolescence threats” chart by an arrow).



RSRM Obsolescence Threats

Operational Pressure Transducer

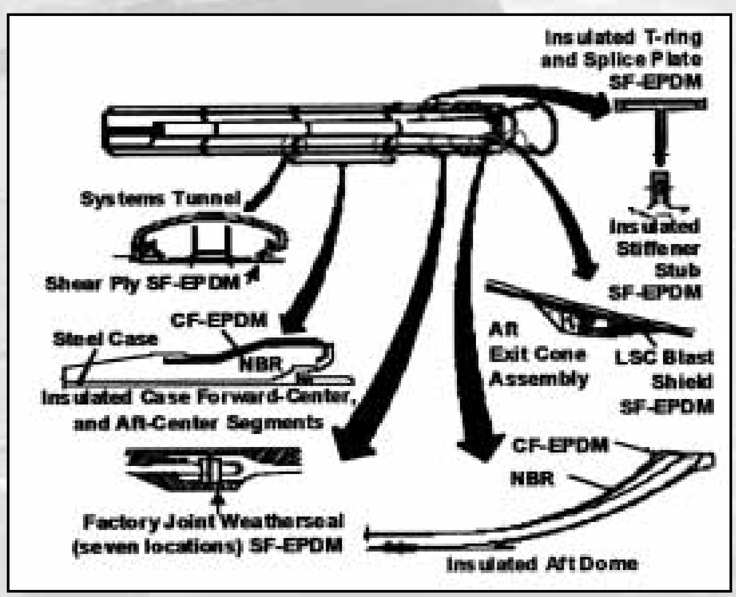
The RSRM program is evaluating and qualifying a new flight motor OPT. The current pressure transducer (used to monitor in-flight ballistics performance and to provide booster separation information to the Space Shuttle Orbiter) is no longer manufactured. Following the evaluation of numerous replacement designs and suppliers, a Stellar Technologies bonded strain gage pressure transducer was selected for final verification. A CDR was successfully held in August 1999. These replacement OPTs will be included on the FSM-8 full-scale static test motor in January 2000, with flight implementation projected for fall 2000. OPTs are refurbished and reused, and a sufficient quantity of the current OPT exists to support the SSP well beyond 2000. ❖

Replacement RSRM Operational Pressure Transducer

EPDM Insulation Reformulation

Silica-filled ethylene propylene diene monomer (SF-EPDM) and carbon-fiber-filled ethylene propylene diene monomer (CF-EPDM) are two principal insulation materials used on the RSRM. The SF-EPDM is used for external thermal protection applications such as the factory joints and the systems tunnel. The CF-EPDM is the primary internal insulation in the aft dome region and is the only elastomeric material known that withstands the RSRM aft dome environment with acceptable ablation and erosion rates. CF-EPDM is also used on the center segments under the split flaps.

In 1998, a subtier supplier of two of the constituents used in SF-EPDM and CF-EPDM formulations announced a discontinuation due to declining market demand. Stockpiling of quantities of the current constituents sufficient to last beyond 2005 was completed this government fiscal year before the subtier supplier's production shutdown. Extensive laboratory re-formulation effort in GFY99, including numerous subscale test motor firings, produced several promising candidate EPDM formulations. Three of these formulations were tested on an MNASA motor in August 1999 (MNASA-10), and three more have been selected for the next MNASA firing in early GFY2000. Culmination of the EPDM reformulation program is planned in 2003 following three full-scale static test firings. ❖

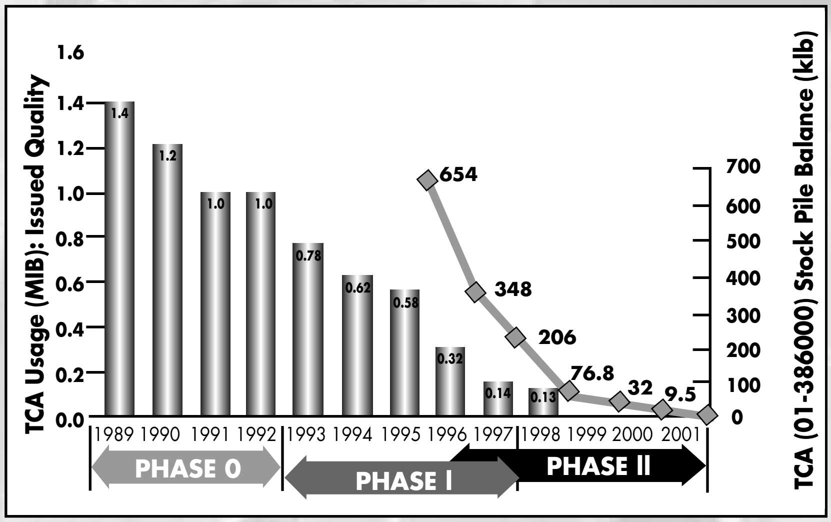


RSRM EPDM Insulation

Ozone Depleting Chemical Elimination

Methyl chloroform (TCA) production has been banned for emissive uses, such as those employed to manufacture the RSRM. Aggressive testing and investment in leading-edge technology has enabled the RSRM program to redirect the manufacturing process and reduce the use of TCA by over 1.1 million lb. per year.

The RSRM program is currently in the final phase of its ODC elimination program. The current effort is dedicated to eliminating the remaining 10 % of TCA usage involved in the hand cleaning of surfaces for bonding and assembly, as well as rubber activation. Extensive GFY99 laboratory testing led to the down-selection of five cleaner candidates (August 1999) that perform equal to or better than TCA in cleaning performance and bond properties. Full-scale process simulation articles have been initiated that will lead to the selection of a cleaner for a full-scale static test on FSM-9. ❖

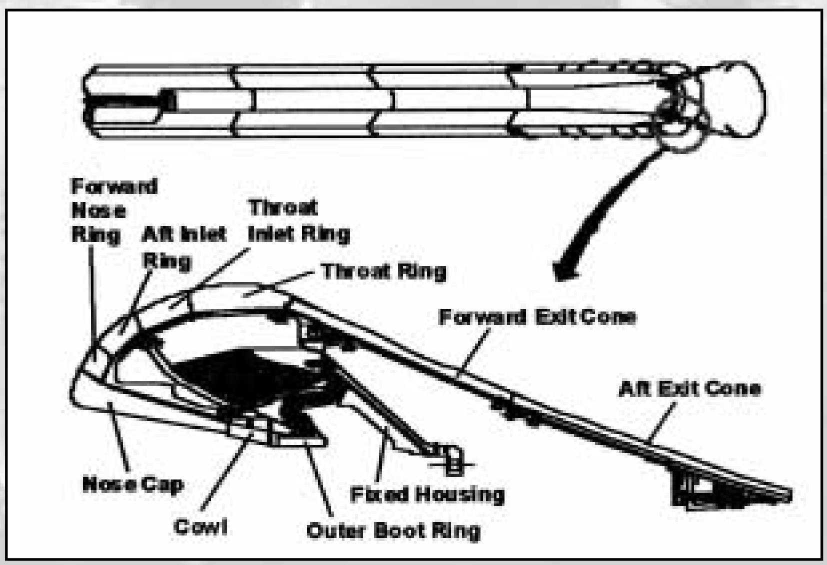


RSRM ODC Elimination Program
TCA Usage and Stockpile Balance

Nozzle Rayon Replacement

The RSRM program is developing a replacement for rayon yarn, a precursor material in the manufacture of carbon cloth phenolic (CCP) ablatives for the RSRM nozzle (see figure). The previous rayon yarn supplier discontinued production in September 1997. Prior to the shutdown, the RSRM program procured a stockpile that will support RSRM production through 2005.

Replacement fiber candidate screening activities began in February 1999. Each candidate was evaluated on the ease of transformation from a cellulose fiber into resin-impregnated carbon cloth, the mechanical performance of the phenolic composite manufactured from the carbon cloth, and the performance of the phenolic composite in an operational rocket motor environment. Fourteen of 22 fiber candidates have completed the screening tests, with the remaining eight candidates to complete testing in November 1999. Six candidates were also tested on MNASA-9 and -10: all six demonstrated ablative characteristics comparable to the current rayon-based carbon cloth phenolic ablative. Ultimately, the best fiber candidate will be selected in early 2002 and tested in three full-scale static test motors before use in a production RSRM nozzle. The first production nozzle made with the replacement fiber candidate is targeted for the spring of 2005. ❖



RSRM Nozzle

Nozzle Structural Adhesive Replacement

Adhesives used in the RSRM nozzle to bond the phenolic insulation liners to the metal shells are no longer produced due to various safety and environmental concerns. An extensive effort to select a replacement adhesive was initiated January 1997. Stockpiles of the current adhesive ingredients were procured and stored to support ongoing production. The adhesive replacement program entailed a three-phase effort for material screening, material characterization, and verification activities. Over 500 adhesive manufacturers were surveyed and 154 adhesive candidates evaluated in the screening phase. Successful materials had to meet or exceed all critical process, performance, and safety requirements. Four candidates were selected for detailed material and process characterization. Down-selection to a primary replacement candidate and a backup was completed November 1998. GFY99 verification activities included detailed material characterization tests to establish statistically based mechanical properties (A-basis), fabrication of a full-scale adhesive verification nozzle, and fabrication of a full-scale static test nozzle (FSM-8, which will be tested January 2000). Flight production implementation is planned for August 2000.

Results to date have shown that the replacement adhesive will be a significant improvement over the current RSRM nozzle bondline adhesives. Of particular note is the adhesive's ability to carry load over long periods of time, which will make the nozzle bondlines much more robust in regard to bondline residual stresses. ❖

RSRM Knowledge Enhancement/Technical Initiatives

In pursuit of safely flying the RSRM and the Space Shuttle for the next 12 to 30 years, the most significant enhancement from an RSRM perspective is developing increased understanding of RSRM materials, processes, and design and eliminating high technical maintenance areas of the design and process. The following paragraphs provide the status on several of these initiatives. ❖

RSRM Enhanced Sustaining Engineering Project

This project is a 5-year plan designed to enhance RSRM safety and reliability by advancing knowledge about the RSRM's design, performance, materials, and processes. It is a comprehensive solid rocket motor technology program directed specifically at the RSRM. The nine tasks currently in the project and some of their significant accomplishments are described below.

Analytical Models and Material Properties Upgrades: This task's objective is to upgrade critical analytical models through software updates, model refinements, and material model upgrades. The latter includes laboratory and subscale testing to obtain more refined material descriptions. GFY99 accomplishments include expanded propellant mechanical properties data, new dynamics models of the RSRM, upgraded field and factory joint parametric structural models, new subscale motor fluid dynamics models, and a significantly improved capability to model thermal effects in nozzle joints.

Material Fingerprinting: Chemical signatures are being established for key RSRM materials using a wide variety of analytical chemistry instruments/techniques. Subsets of these analytical chemistry instruments and techniques are then used to fingerprint materials as they are received. The fingerprints are compared to the historical norms cataloged in a computer database, which allows identification of changes in manufacturing process and ingredients at any level of the vendor chain. The data system and laboratory infrastructure, including software development, was completed in GFY99. Four pathfinder materials completed their signature development stage and are now being fingerprinted as part of receiving inspections. Four additional materials have started into signature development.

Process Validation and Sensitivity Studies: This task examines the sensitivity of key manufacturing processes to changes in process control parameters by deliberately varying operating parameters in a controlled manner to understand process robustness, or how close existing controls are to thresholds that would produce undesirable results. Three studies were completed in GFY99 (propellant materials standardization, ammonium perchlorate grinding, and specific aspects of nozzle tape-wrap), all of which demonstrated insensitivity to process variation outside the normal processing limits. A liner viscosity study resulted in the initiation of additional asbestos floats storage control to reduce moisture exposure. Studies initiated in GFY99 include nozzle aft inlet ring tape-wrap, aft inlet ring-to-forward nose ring dryfit and bonding, and case segment sling lining.

Nozzle Internal Joint Improved Thermal Barrier System: The objective of the improved thermal barrier system is to increase our understanding of Joint 2's mechanical behavior and develop enhancements to the current thermal barrier system in order to reduce the high level of technical maintenance associated with Nozzle Joint 2. This requires new material models and full-scale dynamic tests of the joint. Material testing is under way, and a full-scale nozzle dynamic test apparatus is under construction with testing anticipated to start late in this calendar year.

Nozzle Material Integrity: STS-79 and STS-80 experienced anomalous erosion (pocketing) in the nozzle throat phenolics. Although extensive investigations firmly established the condition was not a risk to flight safety, it is undesirable. These investigations established that the phenomenon resulted from the combination of two independent conditions: a material propensity to pocket and a localized distortion of the material plies. Processing controls eliminated the distortions and thus eliminated any reasonable probability of future pocketing events. This task seeks to find the reason that some phenolic materials have a higher propensity to pocket and to then define supplier process controls to exclude that condition. GFY99 results to date indicate the cause is likely related to temperature variation across the zones of the woven fabric carbonization furnace.

Statistical Process Control (SPC)/Trending at Key Suppliers: This task is focused on initiating and/or expanding SPC/trending programs at selected suppliers. GFY99 activities focused on four suppliers, ranging from semi-annual reviews of one supplier's established program to database development and statistical analysis at two other suppliers, and preliminary discussions with the fourth supplier.

Metal Component Nondestructive Evaluation Enhancement: The majority of metal parts on the RSRM are reused, requiring many hours of nondestructive evaluation such as magnetic particle and eddy current to revalidate the hardware for another flight. This task seeks to develop automated techniques for performing these or equivalent inspections. After extensive evaluation of various techniques, systems, and vendors during GFY99, automated eddy current inspection was selected. The RSRM program is in the process of selecting a vendor for system design and development.

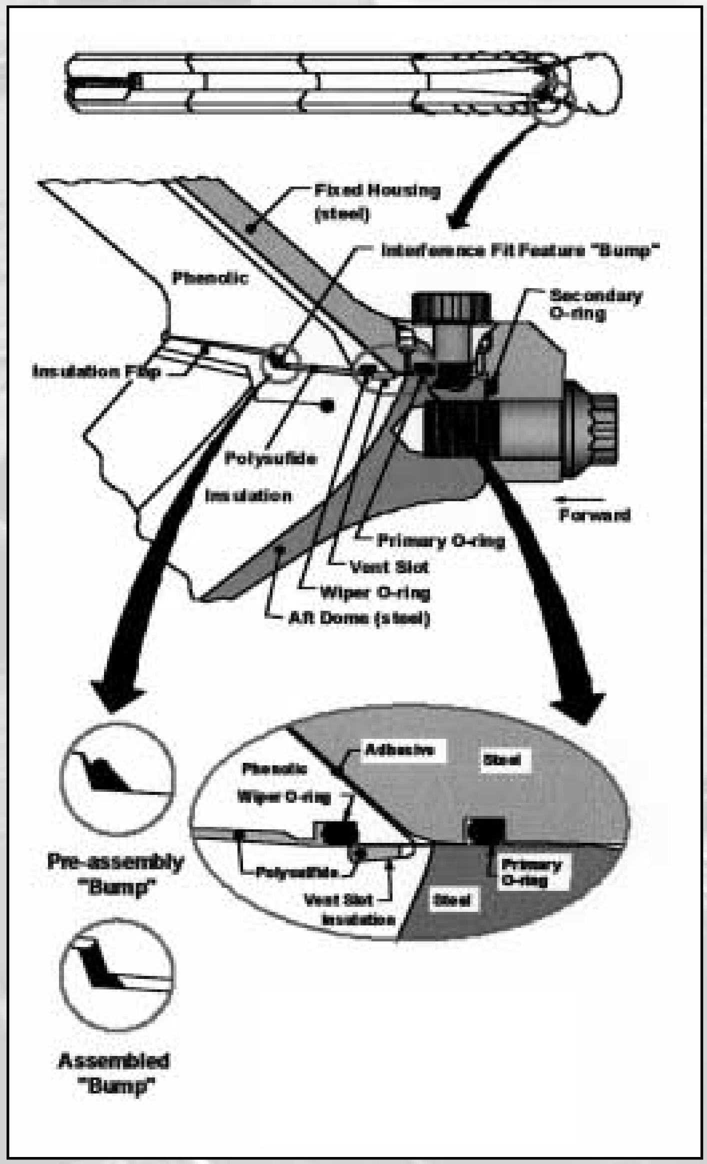
MNASA Motor Testing: The MNASA motor is a large (10,000 lb of propellant) subscale motor. This program provides the test bed for knowledge enhancement testing and evaluating changes to the RSRM. Two MNASA motor tests (MNASA-9 and -10) were conducted in GFY99.

Propellant-to-Liner-to-Insulation (PLI) Bondline Integrity: The objective of this task is to enhance analysis of the RSRM PLI bondline through exploration of new analysis techniques and material property evaluation and testing techniques. GFY99 efforts have been successful in developing nonlinear, viscoelastic material models for the propellant and linear viscoelastic models for the liner and insulation. ❖

RSRM Nozzle-to-Case (N/C) Joint Process Enhancements ("bump")

The RSRM N/C joint is assembled with a polysulfide adhesive that functions as part of the joint thermal barrier system. Historically, the N/C joint assembly process has resulted in a small percentage of assemblies with one of two mutually exclusive polysulfide issues. Either gas paths are created through the polysulfide due to entrapped air (13 out of 140 joint assemblies), allowing hot gas to reach the wiper ring, or polysulfide is extruded aft to the point of contacting the primary O-ring seal (2 out of 140 joint assemblies). While neither of these observed conditions are a flight safety issue, they are undesirable. A process improvement team developed process and assembly configuration enhancements, which, in extensive full-scale testing, have proven successful in significantly reducing both the potential for gas path formation and the potential for extrusion of polysulfide toward the primary O-ring.

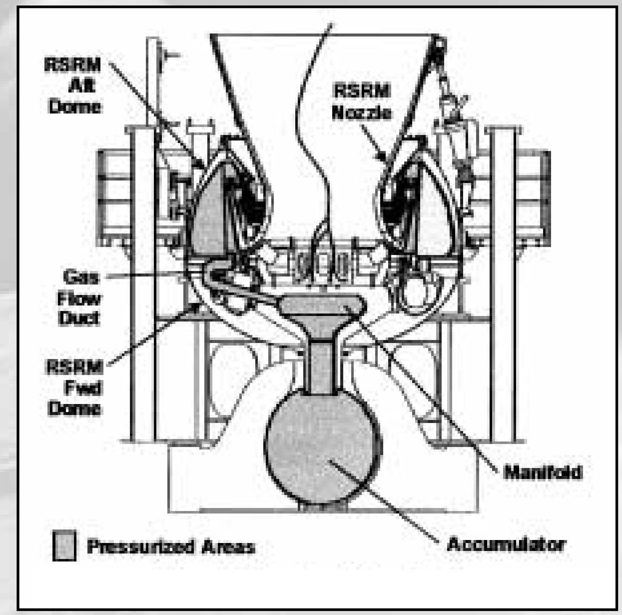
Although there are numerous process step refinements, the primary feature is the incorporation of a pre-cured polysulfide bead (bump). The bump is applied near the insulation step and provides full circumference interference between the nozzle and aft dome insulation during the final stage of assembly. The bump has demonstrated its capability to "nip" off the formation of gas paths in a full-scale assembly test setup that reliably produced gas paths using the current assembly process. These process enhancements, including the pre-cured bump, successfully completed full-scale assembly and disassembly verification testing in GFY99 and were incorporated into flight production beginning with RSRM-80 (June 1999), which is currently assigned to STS-105. ❖



Nozzle-to-Case Joint "Bump Configuration"

Nozzle Structural Test Bed (NSTB)

To date, the only test bed to evaluate the mechanical behavior of nozzle internal joints has been a full-scale RSRM static test motor. The NSTB was conceived to evaluate the mechanical behavior of a full-scale RSRM nozzle in a laboratory-type setting. The NSTB is designed to simulate the RSRM pressure rise at motor ignition. It also possesses nozzle vectoring capability. The arrangement allows for extensive instrumentation to measure nozzle structural response, including the bolted joint regions. Design and fabrication were completed in GFY99, with assembly of the NSTB planned for late CY99. ❖

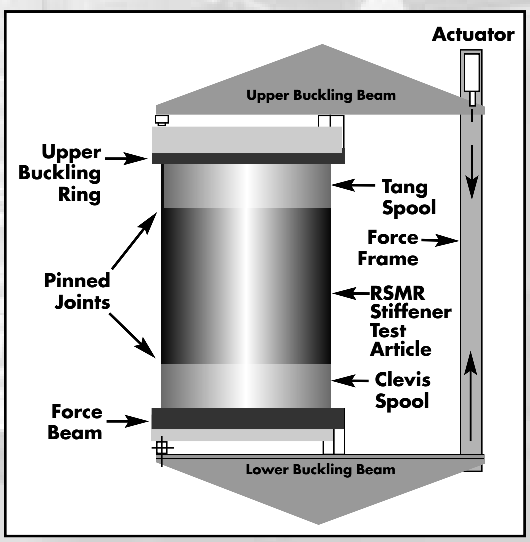


Nozzle Structural Test Bed

RSRM Case Buckling Capability

Each Space Shuttle launch is subject to hundreds of constraints designed to ensure flight safety. Wind speed is one constraint critical to the RSRM, as it affects the structural loads on the RSRM cases. The RSRM cases support the entire vehicle on the launch pad. As the orbiter's main engines start, the Space Shuttle vehicle bends over approximately three feet at the top of the ET. Wind loading can obviously add to this bending, especially southerly winds. The RSRM cases must resist this bending (called buckling capability) before the vehicle springs back to vertical and the RSRMs are ignited for launch. Buckling is analogous to the force on a soda can that can cause it to crumple. It is a principal design consideration in the aft segment stiffener cylinders. RSRM analyses currently include a large knockdown factor to account for uncertainties in loading and environmental conditions, manufacturing and inspection processes, modeling, etc. This analytical approach results in relatively low allowable wind speeds (15 knots from the south). Such wind speeds have the potential to delay a launch.

A full-scale RSRM case buckling test program was conducted to validate the buckling analysis with full-scale test data and determine how much conservatism could be removed and still guarantee the margins of safety at higher wind speeds. The test was conducted by selecting full-scale stiffener cylinders and characterizing their configuration: wall thickness, imperfections in straightness, etc. A specific analysis was performed to predict each cylinder's buckling capability. The stiffener was installed in a special tooling arrangement (see figure) designed to represent flight prelaunch loading conditions and capable of applying 4.3 million lb. of load to the cylinder. Each stiffener was heavily instrumented to measure strain during testing. Force was applied to each stiffener until buckling occurred. Ten tests were conducted, all in GFY98.



RSRM Case Buckling Test

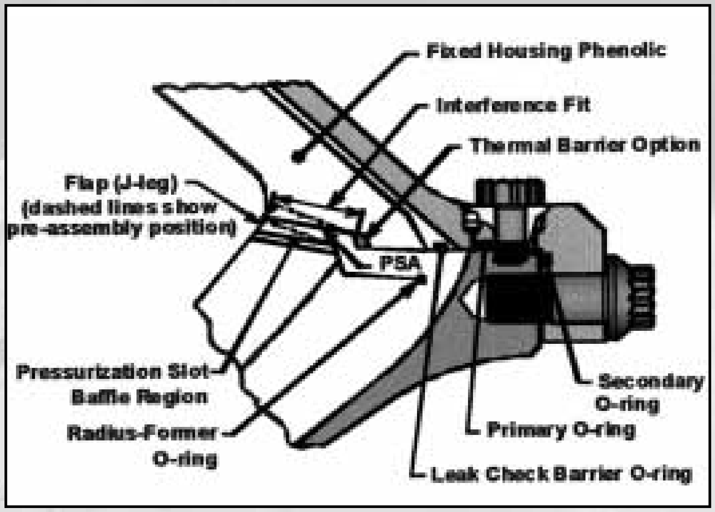
Test data-to-analytical model correlations were completed in GFY99. Analytical predictions were within 5 % of actual buckling loads, an impressive feat given the uncertainty normally associated with buckling analysis. Analysis to determine the influence of critical RSRM hardware parameters on buckling capability is 90 % complete. Based on a better characterization of these parameters, previous over-conservatism can be reduced, allowing higher day-of-launch wind speeds (values yet to be determined). This will result in increased probability of launching the Space Shuttle on any given day. ❖

RSRM Process Enhancements Nozzle-to-Case Joint J-Leg Configuration

As previously described, the current RSRM N/C joint employs polysulfide adhesive as a thermal barrier to protect the O-ring sealing system. In an effort to reduce or eliminate the occurrence of gas paths through the polysulfide, several design and/or process changes have been evaluated including the aforementioned bump process enhancement. A longer-range approach attacks the root cause of the polysulfide gas paths by eliminating the polysulfide adhesive entirely and also greatly simplifies the assembly processing. The design concept incorporates a pressure-actuated insulation flap (J-leg) based on the highly successful field joint insulation design.

The N/C joint J-leg insulation configuration has been molded in subscale and full-scale test articles to evaluate the dimensional characteristics of the joint and to allow evaluation of its assembly and disassembly characteristics. These test articles have shown consistent dimensional characteristics, and have shown that the assembled joint provides good joint bondline contact. GFY99 accomplishments include two MNASA one-fifth scale hot-fire motor tests. MNASA–9 demonstrated the ability of the J-leg configuration to seal and ensure no gases reach the O-ring system. MNASA–10 included an intentional flaw through the J-leg bond region, which demonstrated the spreading of gas at a carbon rope thermal barrier. Extensive laboratory and subscale motor testing of carbon rope thermal barrier material demonstrated exciting promise from this material in its ability to diffuse hot-gas flow and significantly reduce gas temperatures. The bulk of the hardware and tooling for the first full-scale hot-fire test (Nozzle Joint Environment Simulator No. 4A, November 1999) was also fabricated during this period.

This design enhancement will be tested on a full-scale static test motor (FSM-9) in early 2001. ❖



Nozzle-to-Case J-leg

Mix Room Modernization

An extensive 1999 process FMEA identified benefits from the modernization of the RSRM mix room facilities used for adhesives and liners. Scales and manual data recordings have been replaced with digital scales. Weigh-up data are now electronically transferred directly into the PC-based computer system (shown in photo). Bar code technology was used to ensure the accuracy of the data and the control of materials. The coded information is automatically re-verified via the Electronic Shop Instructions immediately before the actual mixing operation with other pre-weighed materials.

Following an extensive process flow analysis, storage locations, computers, and equipment in the mix room were relocated to streamline the process. Raw materials and support items were organized in convenient locations near the workstation where they are used. Streamlining the processes (in conjunction with new scales, bar codes, and computer equipment) represents significant ergonomic and process reliability improvements that are ultimately translated into hardware reliability. ❖

Cell Plating

RSRM Mix Room Electronic Weighting and Data Handling

The RSRM program, with the help of the Rocketdyne Division of Boeing, has applied cell-plating technology to repair small defects of seal surfaces on RSRM reusable aluminum nozzle housings.

Following splashdown, the RSRM boosters are towed back to Hangar AF and lifted out of the salt water. The nozzles are removed from the boosters at Hangar AF and shipped to Clearfield, Utah, for complete disassembly. By the time the nozzles are disassembled (approximately three weeks after flight), metal surfaces exposed to the seawater have had plenty of opportunity to corrode. If the corrosion is severe enough, it can render a nozzle metal housing unfit for further use. Although small corrosion pits do not cause structural concerns on the robust 0.5-in.-thick housings, they can have a detrimental affect on seal surfaces. Instead of selling housings with unacceptable seal surface defects to the local scrap yard at pennies on the dollar, NASA and Thiokol Propulsion teamed with Rocketdyne to apply cell-plating technology to the repairing of these defects. Rocketdyne has used the technique to repair similar defects on SSME components.

The technique involves fabricating a local plating cell around a defect. The surface is first cleaned to remove any contamination. The area is then electroplated with copper and nickel. The defect is overfilled and then machined level with the surrounding material. The plating blends smoothly into the surrounding surfaces until the surface finishes are identical.

The cell-plating process for RSRM aluminum nozzle housings completed its laboratory verification in GFY99. A corrosion-related defect in an RSRM nose inlet housing (0.018 in. deep) has been repaired. The housing is scheduled for full-scale static testing on FSM-8 in January 2000. Flight implementation will follow a successful post-static test assessment. ❖

NASA Takes Delivery of 100th Set of Shuttle Solid Rocket Booster Flight Hardware

NASA's Space Shuttle SRB program has marked the flight of its 100th set of booster hardware with this year's flight of the STS-96 mission.

The mission flew with the 100th assembly built of reusable booster hardware. The 100th Shuttle mission won't lift off until next year. But when the Shuttle program needed a cylindrical forward skirt modified to carry video equipment for filming the ET during launch, the next available hardware was the right forward booster section originally assigned to the 100th mission. The MSFC manages Space Shuttle main propulsion, including the boosters, liquid fuel main engines, and ET. USA manufactures the SRBs at NASA KSC facilities.

The Shuttle boosters designed to be reused are the largest solid propellant rockets flown on a piloted spacecraft and the largest objects ever to be recovered by parachute. ❖

SRB Develops ET Observation Camera

Viewers who were watching the on-orbit activities of the STS-95 flight on NASA TV during the afternoon of Saturday, October 31, 1998 were treated to a recorded view of the Space Shuttle during its ascent to orbit that had never been seen before. A close-up vista of the heat-discolored insulation on the side of the Shuttle's ET was quickly followed by a broader panorama of SRB separation. The ET and Orbiter rapidly moved out of the field of view as a SRB appeared by itself, twisting, turning, and spraying out hot embers as it disappeared into the distance against the blackness of space. The view then slowly changed to random scenes of white specks of cloud covering the broad expanse of the Atlantic Ocean far below. These clouds appeared ever closer and soon the scenes of space were replaced by close-up views of splashing water and parachute lines. The viewer had just experienced a "booster's eye view" of SRB separation, coast to altitude, atmospheric reentry, and splashdown.

How were these unique views of the Shuttle captured and for what purpose? Following the Orbiter *Columbia's* landing at NASA's KSC at the conclusion of STS-87, significant superficial damage was discovered on the protective heat shield tiles. Exhaustive analytical modeling and experimental testing by NASA's MSFC and JSC indicated that the most likely cause of the tile damage was high-speed impact of small particles of the ET's spray-on foam thermal insulation. Although the damage did not pose a safety of flight concern, it was imperative to quickly pinpoint and understand exactly how this ET Thermal Protection System material was breaking loose. A high-fidelity ascent videotape of the suspect area of the ET would provide exactly the needed data.

Time was of the essence! The SSP Office challenged Marshall's ET and SRB Projects to design, develop, qualify and implement an ET observation camera as quickly as possible. They allotted a maximum of 12 months for completion of the task. Preliminary assessments by the SRB Team indicated it would be feasible to mount a miniature video camera into a purpose-built aluminum canister with a heat-resistant window. This canister could be positioned to look out the side of the SRB Forward Skirt (through an unused connector cover) where it would have the ideal vantage point to view the suspect ET insulation.

To expedite the development process, the SRB Team elected to adapt an existing video recording system which had been flown in the forward skirt for several years. This existing system consisted of a miniature video cassette recorder (VCR) and a camera that looked straight up out of the top of the SRB forward skirt to film the deployment of the booster parachutes. For the ET Observation Camera System, the existing VCR was left in place and re-wired to connect to the new side-looking camera. The system would be activated by a built-in "G switch" that senses the motion of the Shuttle as it lifts off the launch pad.

Design, development, and qualification testing of the new portions of this camera system proceeded at a fever pitch. In addition to doing all the design work, USBI Company also built all the interconnecting cables. The camera canister was fabricated by Benton Machine, a small fabrication shop in Jacksonville, Florida, and the special window was built by the Corning Glass Works in New York. Vibration and electrical testing was performed at MSFC. Final flight certification was completed in early October 1999 and the first flight of the new system occurred on STS-95 on October 29,1999... start to finish in half the allotted time.

The camera system has now flown on 3 flights and will fly on at least 2 more. Although several of these have been night launches, the system has provided excellent video with the ET illuminated only by ambient light from the rocket exhaust plumes.

The close-up ascent imagery of the External Tank that this camera system continues to provide has proven critical to identifying and understanding the causes of Thermal Protection System loss. Actions intended to correct the insulation problem are currently being implemented by the ET Project. ❖

Photo from ET Observation Camera

High-Pressure Fuel Turbopump Development/Certification Status

The certification of the alternate HPFTP was initiated in July 1998. Testing was suspended in October 1998 due to an assembly problem. During this period turbine housing cracks were identified in previously tested development units. Investigation identified hydrogen embrittlement of the IN 100 material as the cause of the cracking, and design of modifications to eliminate cracking were completed. The first unit tested with all the changes exhibited an out-of-family mode of vibration. An investigation determined that some of the modifications to the housing joint were the most likely cause of the high vibration, and the configuration was changed to eliminate these, while leaving a barrier-coating to the housing for protection against the hydrogen effects. These modifications have been installed, and certification testing will resume in October 1999. Certification is scheduled for completion in May 2000 with first flight capability in August 2000. ❖

Final Production Build of Pratt & Whitney High-Pressure Oxidizer Turbopump/ Alternate Turbopump (HPOTP/AT)

The last production build HPOTP/AT, unit 8031, was successfully acceptance tested on 5/27/99. This milestone marks the 20th successfully delivered HPOTP/AT into the SSME Program. HPOTP/AT unit 8031 is scheduled to be flown on STS-103 in December 1999 in support of the Hubble Space Telescope Maintenance mission. The HPOTP/AT incorporated numerous flight safety enhancements and a 10-flight interval between rebuilds. Over 20,000 seconds of flight time have already been accumulated by the HPOTP/AT. ❖

Space Shuttle Main Engine Processing Facility (SSMEPF)

Funding for the new SSMEPFwas approved in 1994, and construction began in 1996 and was completed on June 26, 1998. This facility is a 34,600 square foot addition to Orbiter Processing Facility (OPF) No. 3. The SSME processing activity was moved from Vertical Assembly Building (VAB) in July 1998. The first engines processed through this facility powered Endeavour on the first assembly flight for the International Space Station, STS-88, December 4, 1998.

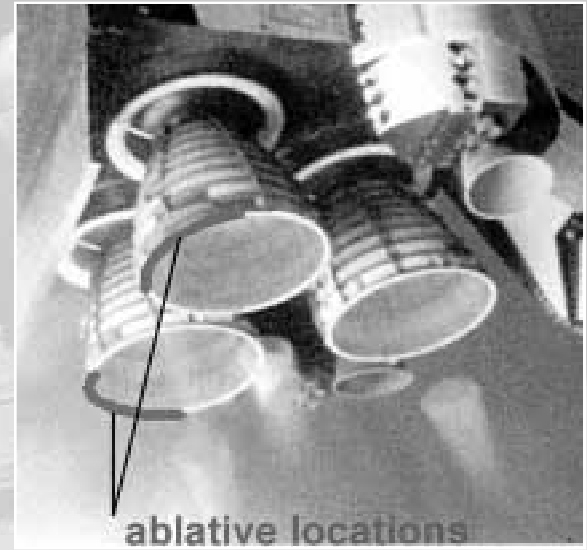
This facility addition provides space to increase the capacity and efficiency of SSME Operations. Within the SSMEPF there is a low bay with 6 vertical engine stands, a 10-ton crane and full capability of fluids, pneumatics and avionics to test and check out the SSMEs. It also has a high bay with a 15-ton crane, drying cells, pump room, ground support equipment (GSE) storage and workshop.

The three SSMEs generate approximately 375,000 lb. of thrust each during liftoff of the Space Shuttle, providing about 20 % of the power needed to boost the space vehicle into low Earth orbit. They are the only reusable liquid-fueled rocket engines in existence and undergo prelaunch preparation in the Main Engine shop before their installation into the Shuttle Orbiters in the OPF. ❖

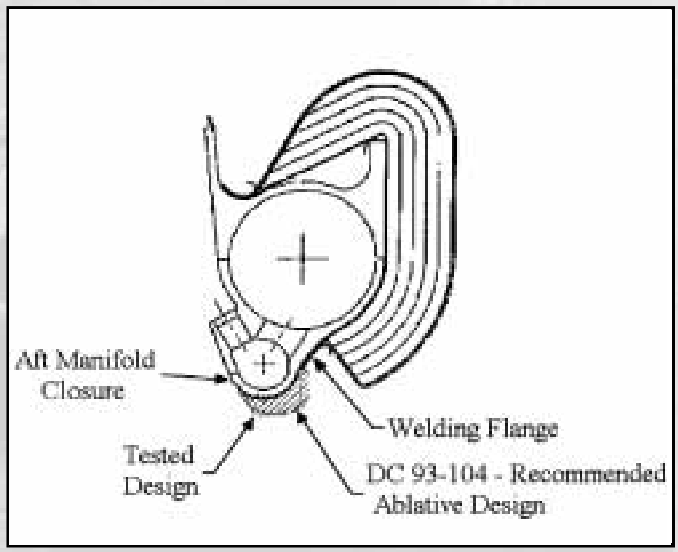
Processing Facility

SMEE Aft Manifold Ablative Insulation

The SSME nozzle aft manifold closure is exposed to high aeroheating during the reentry phase of flight. Aft manifold discoloration observed in postflight inspections following STS-33R, 36, and twelve subsequent Shuttle flights indicated exposure to thermal environments severe enough to potentially degrade the alloy 718 material properties. Microhardness measurements taken on discolored manifolds indicated that property degradation had not yet occurred, however, more severe areothermal environments predicted for future higher inclination flights increased the risk of overheating the aft manifold. The SSP established an ambitious design and development schedule leading to implementation within one year. The development required evaluation of various materials under extensive test conditions, including hot fire demonstrations. A major challenge was the design of tooling to match the exact contour of the aft manifold closure. The project was completed in seven months and successfully flown on STS-95 in October 1998. ❖



Manifold Ablative



Manifold Ablative Chart

Study and Strategy for Advanced Health Monitoring System

Since the early 90's, the SSME Project has been aggressively pursuing advanced health monitoring strategies and technologies with the goal of dramatically improving overall Shuttle safety and reliability. The project has evaluated and assessed numerous proposed strategies, algorithms, data mining and synthesis techniques in addition to conducting formal bench-marking reviews of both next generation space launch systems as well as advanced jet engine programs. This activity has culminated in the current SSME Advance Health anagement Program which has recently been presented to the Shuttle Upgrades Board and is expected to improve overall engine catastrophic reliabilitiy by 25%-35%.

The proposed system includes three primary features. The first is the real-time vibration monitoring system (RTVMS), which utilizes parallel digital signal processing for real-time extraction of discrete turbopump vibration frequencies. Unlike previous SSME vibration monitoring systems which look at composite vibration amplitudes, RTVMS examines the frequency spectra and locates the synchronous frequency. It then uses logic to qualify the accelerometer signals and reliably determine the health of the turbomachinery. A second technology to be demonstrated is the on-engine examination of plume constituents using spectroscopy for the purposes of determining engine wear, erosion, and/or breakage. The third technology to be demonstrated is onboard, real-time SSME performance modeling as a diagnostic, and in the future, a prognostic tool.

An integrated product team was formed in 1997 to develop the architecture and implementation approach for the system. Given the current high reliability and projected life of the Block II controller and the desire to provide flexibility for future advancements in health monitoring in a cost-effective manner, the team recommended a two-phased approach and distributing the functions.

The first phase involves a one-time upgrade of the current controller to incorporate the synchronous redline monitoring portion of the RTVMS and a high- speed interface to allow external communication. Additionally, us advanced technology, to design, develop, and certify a low-cost, upgradeable health management computer that would contain an advanced RTVMS, an engine plume analysis capability, and a real-time engine modeling capability. This approach provides the flexibility to evaluate and utilize advanced algorithms, instrumentation and monitoring systems with-out requiring expensive on-engine ground test certification of the avionics. ❖

Manufacturing Process Control Improvements

Rocketdyne has several ongoing initiatives that focus on improving the process control of the fabrication and assembly of its products. Data collection on the various machining processes and material types is being conducted using Quantum so that the process capability can be quantified and shared with the design community. Upper and lower control limits are being established for each of these processes and the data is monitored by the work centers on run charts so that process drift and out-of-family data points can be identified and corrected as part of the normal operations.

Integrated process management has been adopted as the methodology for process improvement at Rocketdyne. It consists of a series of 21 steps that begin with flow-charting the process and understanding the key characteristics of the process. Once the process has been defined, the subsequent steps help identify areas for improvement and provide a tool box containing various process improvement tools. At the completion of these steps, the process will undergo a validation review, where the revised process is locked in place.

To facilitate the use of the IPM approach, a steering committee, working-level advisory team, and facilitators have been established.

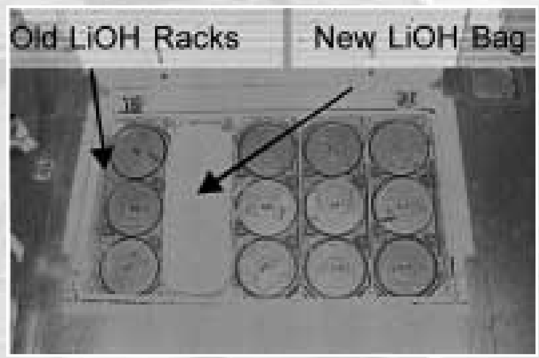
Another critical area for process control is hardware cleanliness and the elimination of potential sources of FOD and contamination. Rocketdyne has continued its commitment to a FOD-free work environment with the completion of the stack and braze (Whiteroom) work center upgrade. In addition, the SSME pump room is undergoing a complete facelift, with new flooring, ceiling, a mezzanine for larger tool storage, new work stations, and new cabinets with all tools and hardware nested. A renewed focus on production support material control will further improve our process control in the area of hardware cleanliness. A new web-based system has been developed to provide visibility to the production support materials (PSMS) that have been tested and approved for use on our hardware. All PSMs will be labeled to identify that it has been tested and any restrictions will be clearly stated on the label, as well as in the new web-based system. Centralized distribution and ordering of PSMs will further enhance the control over these materials. ❖

Orbiter Modifications

The Orbiter performs hundreds of modifications throughout the year related to design changes to improve reliability, supportability, or meet new Program requirements. These changes are a result of hardware failures or design enhancements identified through ground checkouts or inflight. Additional Orbiter modifications are approved as the ISS development advances and risk mitigation options are identified and implemented. The modifications are implemented either during a standard Orbiter processing flow at KSC in Florida or during an Orbiter maintenance down period at Palmdale, California.

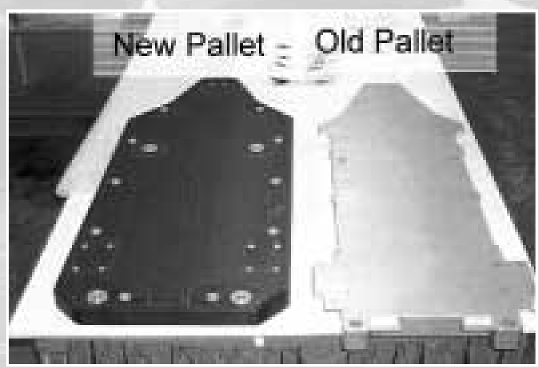
Parts Description	Old Weight	New Weight	Weight Reduction
Lithium hydroxide rack assembly	97	27	70
Ceiling Pallet	30	13	17
Floor Pallet	27	14	13
External airlock pallet	47	26	21
Pallet assembly EMU adapter	36	22	14
Locker trays (shipset)	164	75	89
Mid-deck lockers (shipset)	495	295	200
Middeck Accommodations Rack (MAR)	220	100	120
Tool Stowage Assembly	150	75	75

To increase the Space Shuttle weight to orbit performance in support of ISS flights, the SSP implemented a variety of Orbiter weight reduction modifications. The project consisted of converting a variety of Orbiter storage hardware from aluminum to composite or fabric structure. The components that were redesigned are in the table with their associated weight savings.



Lithium Hydroxide Rack Assembly

The approximate total per vehicle weight reduction is 600 to 700 lb pending the number of pallets flown. All of the above-mentioned hardware has been delivered and has supported missions with the exception of the second and third shipset of lockers, which will be delivered in early CY2000.

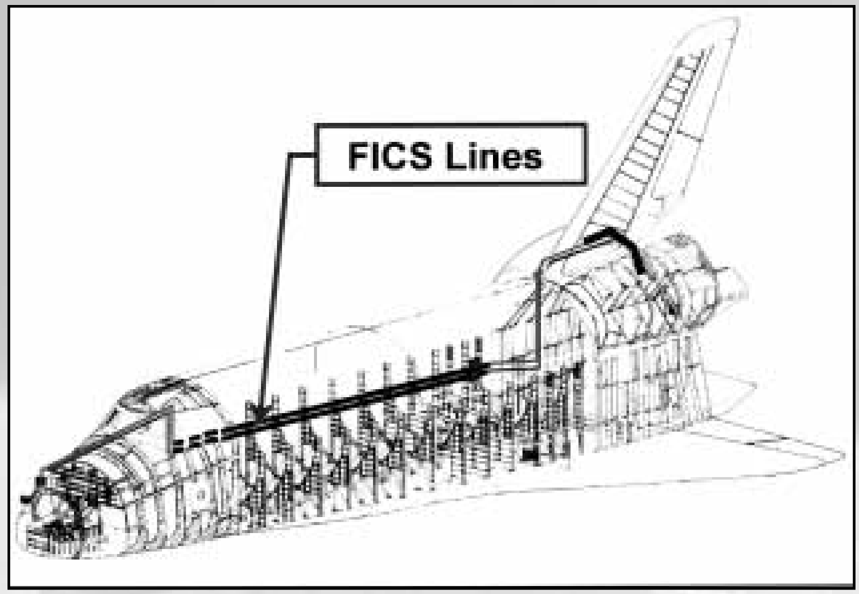


Pallet

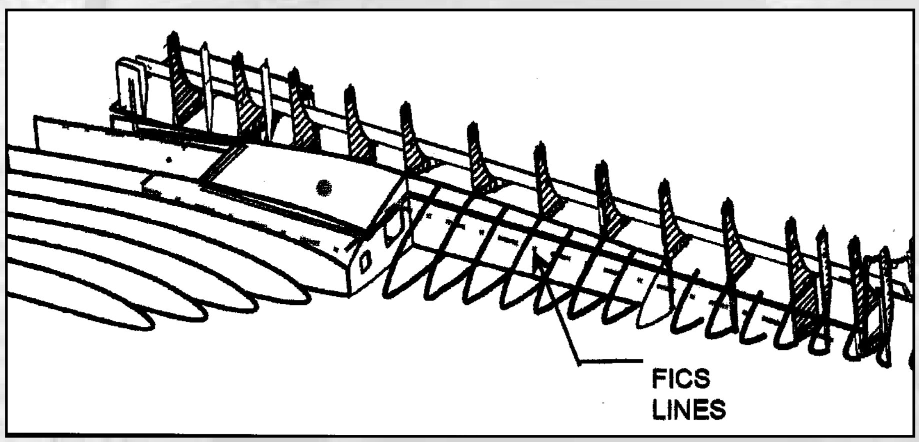
Another risk mitigation activity for the ISS derives from an existing payload requirement to provide more flexibility for boosting the ISS to higher orbit. Orbiter reboost can be utilized to help maintain the ISS within its required operational altitude range when the primary boosting functions are not available. During the initial ISS build phases, the aft Orbiter thrusters (where most of the available propellant is stored) can be utilized to reboost ISS. But during ISS assembly, a point is reached where the forward thrusters have to be used (very limited reboost capability) to reboost the ISS to minimize assembly stresses. To allow maximum reboost flexibility, the SSP is implementing a project called the forward interconnect system (FICS) which interconnects the forward propellant tanks with the aft propellant tanks where most of the available propellants are stored. The propellant and oxidizer for this operation will be based on fuels reserved for contingencies and margins during the ascent mission phase. FICS has successfully completed its requirements definition phase, which included a SRR. The program is moving towards a preliminary design review in November of 1999. This modification will be performed during maintenance down period starting with Orbiter Vehicle (OV-) -103 (*Discovery*). This system will be a key element in supporting the propellant resupply of the United States Propulsion Module (USPM).

The ISS is currently developing a USPM to enhance the reboost capabilities of the Space Station. The USPM will be used to supplement the reboost capability from the Russian-provided service module. The USPM reboost engines will use the same propellants as the Orbiter and will be resupplied by Orbiter through the Orbiter propellant transfer system (OPTS) that interconnects with FICS. This program is currently in the requirement definition phase with a preliminary design review currently scheduled for January 2000. Anticipated implementation is to support the USPM delivery in 2002.

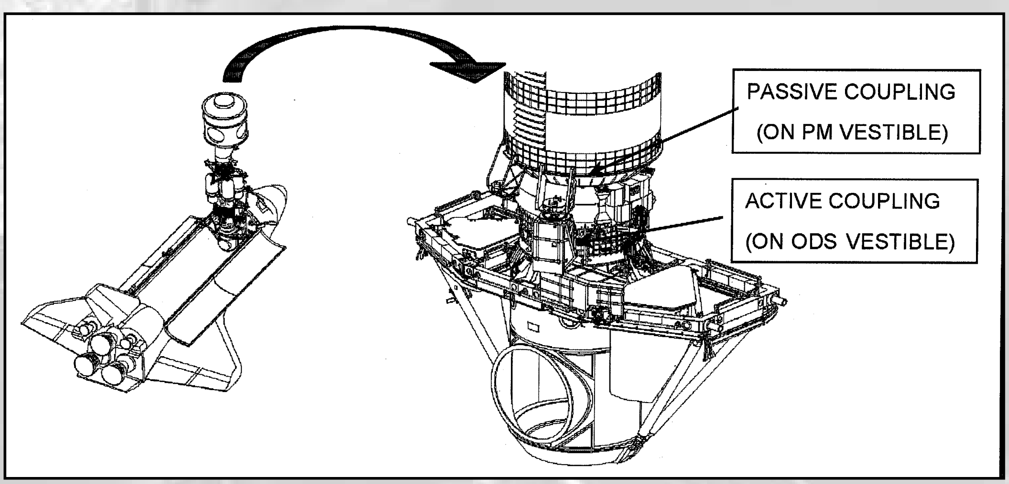
Other miscellaneous modifications completed throughout the year include the delivery of 322 redesigned remote power controllers (RPC) to replace the existing obsolete RPCs, 100 -mission certification of the 17-in. ET and Orbiter disconnect, delivery of the redesigned extravehicular mobility unit battery chargers, and the delivery of 13 shipsets of ET disconnects. ❖



FICS Overview

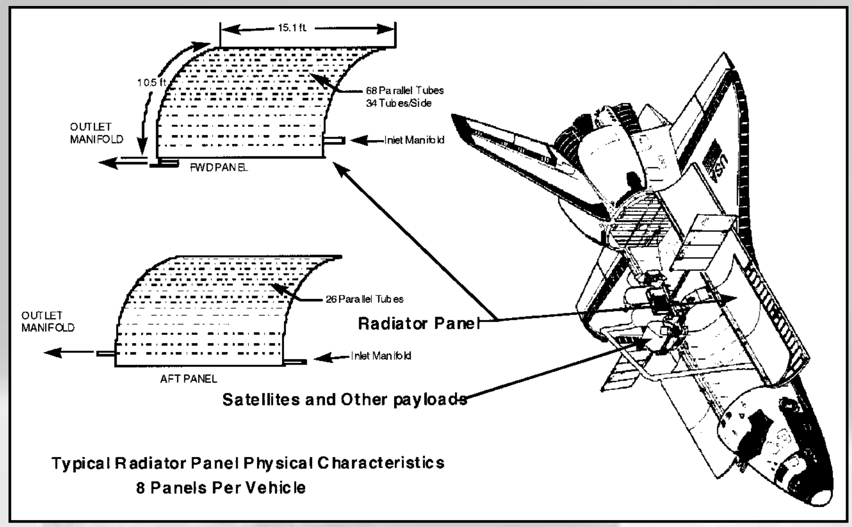


Wing Routing



OPTS Mounting to the Docking System

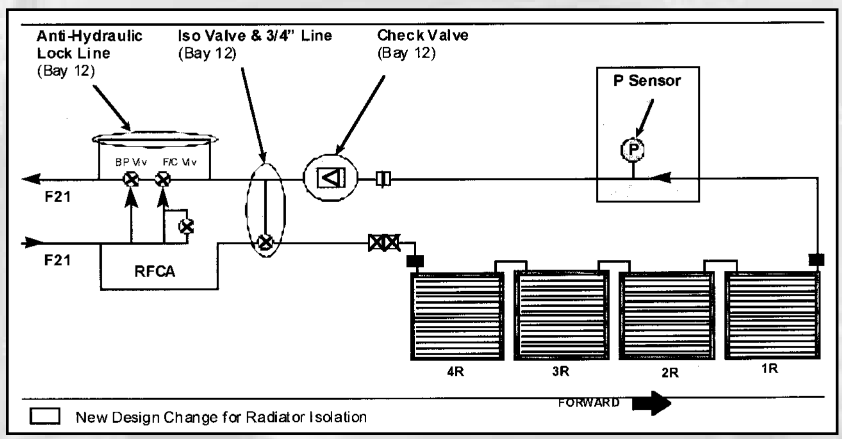
Orbiter Upgrades



Typical Radiator Panel Physical Characteristics
8 Panels per Vehicle

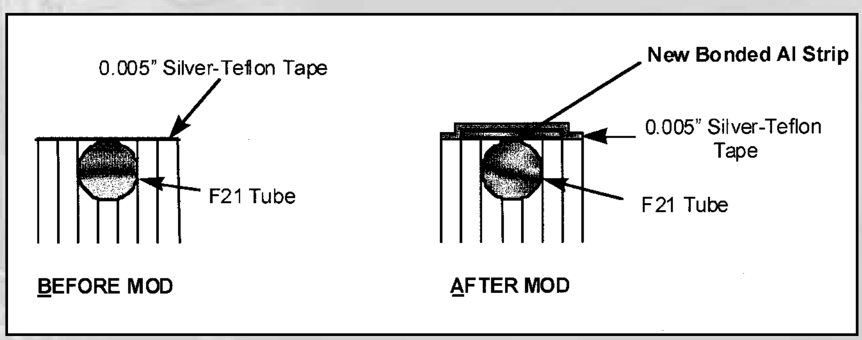
Eight radiator panels located inside the payload bay doors perform the Space Shuttle Orbiter on-orbit heat rejection. Each panel is approximately 15.1ft. by 10.5ft. constructed of 0.011-in. 2024-T81 aluminum face-sheets and 3.1-lb/ft ^{3} 5056-H39 aluminum honeycomb core. The tubes are 6061-T6 aluminum and the panel surfaces are coated with silver-Teflon tape.

System upgrades have been implemented to minimize the chance of an impact causing damage to a cooling tube and potentially impacting mission success. This upgrade consisted of redesigning the radiators to include radiator cooling tube shielding, aluminum strips bonded on the radiator directly over the cooling tubes, thereby increasing the resistance of the radiators to impacts. To allow the Orbiter to have a radiatorpuncture, but limited loss of cooling capability, radiator panel isolation was evaluated and implemented. In the event of a puncture, isolation valves and check valves have been added to allow the crew to isolate the leaking radiator from the rest of the cooling loop. This allows continued operation of that cooling loop for the other heat rejection systems the Orbiter has for on-orbit operation and entry. A leak is annunciated when a drop in the cooling loop accumulator quantity sensor is detected and the crew closes the bay 12 check valve that isolates the downstream cooling loop from the leak.



Radiator Shielding Modification

The radiator isolation and shielding modifications are complete on OV-104, will be complete in early CY2000 on OV-105, and will be implemented during the next maintenance down periods for OV-102 and OV-103.



Radiator Isolation Modification

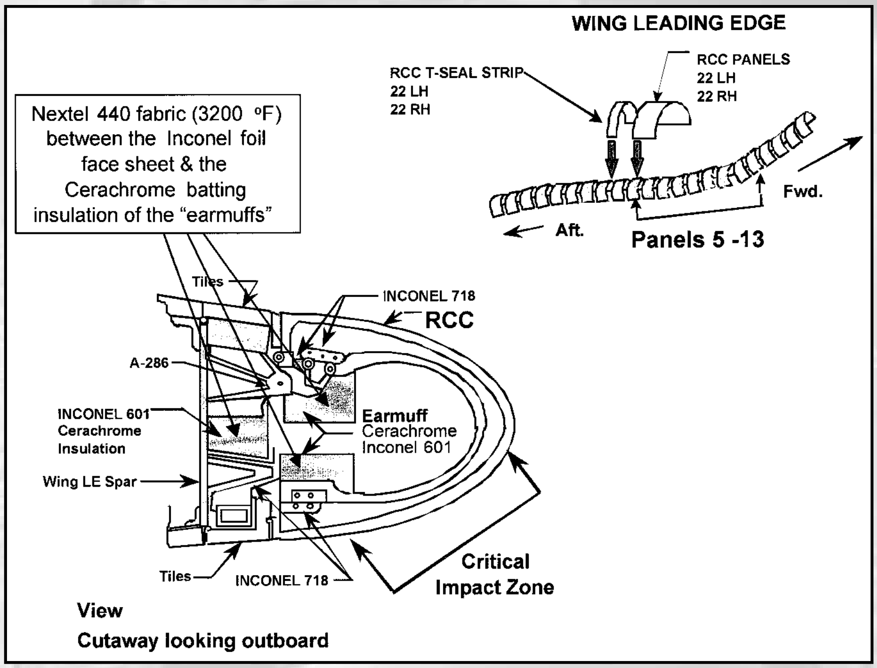
Another safety improvement the SSP implemented was additional thermal wing leading edge protection to prevent wing structure over temperature/failure and potential loss of vehicle due to a hole in the wing leading edge. Current wing leading edge capabilities permit a 1in. hole on the upper surface of any panel. But on the lower surface, no penetrations are allowed on the lower surface of panels 5-13. In these locations, a hole generated by orbital debris would allow heat from the plasma flow during entry to quickly erode the 0.004-in. thick Inconel foil of the "Incoflex"insulators. This will cause a loss of insulating properties and exposing the leading edge attach fittings and wing front spar to direct "blast" from the hot plasma. The upgrade to include additional insulation would allow single entry with a penetration of up to 0.25 in. diameter in the lower surface of reinforced carbon-carbon panels 9 through 12 and up to one inch on panels 5 through 8 and panel 13.

The design team evaluated requirements for meeting the 0.25 in. requirement. A variety of design requirements also considered during the evaluation including minimum weight with no additional post-flight inspections. The implemented design solution after analysis and testing were complete was to add high-temperature Nextel 440 fabric to the Incoflex insulators with one layer for panels 5 through 7 and 11 through 13 and two fabric layers for panels 8, 9 and10 (highest heating environments). Overall weight increase to the orbiter was 53 lb. This hardware is currently implemented on OV-103, OV-104 and OV-105 and OV-102 during the maintenance down period.

The IVHM HTD-2 was successfully developed and flown on STS-95 and STS-96. The purpose of these flight demonstrations was the advancing of the development of selected IVHM technologies in a flight environment and to demonstrate the potential for reusable vehicle ground processing savings.

The focus of the experiment is real-time system health determination of selected Orbiter systems including the Orbiter's main propulsion system, SSME and the Orbiter's power reactants storage and distribution system. The technologies to be demonstrated included the Fiber Bragg-grating photonic sensors for hydrogen, strain, and temperature sensing; smart sensors for hydrogen, oxygen, and pressure sensing; distributed data acquisition using X-33 remote health nodes, fiber data distributed interface (FDDI) communication; real-time information processing of SSME pump vibration; solid state storage,, and ground-based advanced control room equipment and applications.

This flight demonstration successfully demonstrated the ability to perform real-time vibration monitoring of SSME turbopumps, skin temperature measurements as a potential replacement for intrusive gaseous oxygen probes, use of fiber optic sensing for the detection of hydrogen, strain and temperature, use of solid state hydrogen detection, and the use of galvanic cell oxygen detection in a flight environment. STS-96 was also the first successful flight use of X-33 remote health nodes, and the FDDI interface for Space Shuttle applications.



Wing Leading Edge

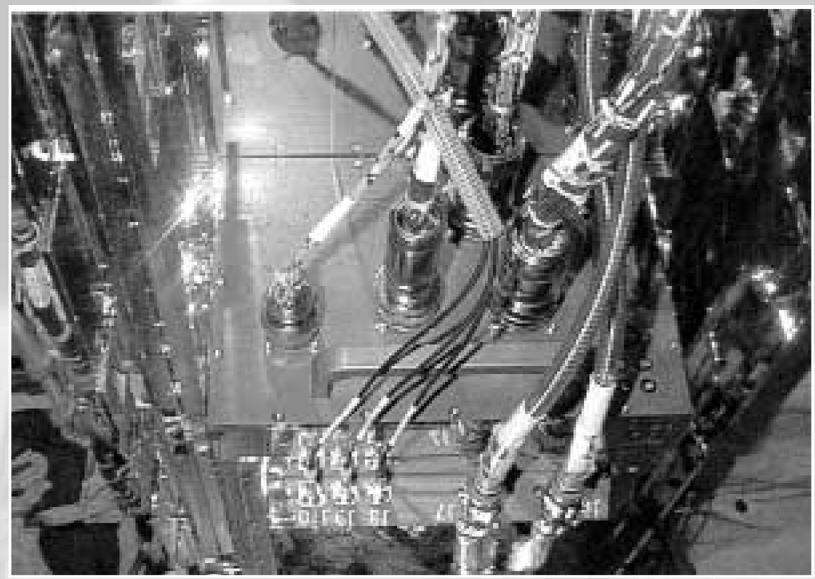
Additional information on this experiment as well as continuing work is available at:
http://www.ksc.nasa.gov/shuttle/upgrades/ksc/ivhm/data_depot/ivhmhome.htm

Another area of concern for the SSP is the increased supportability issue with the tape-driven data storage devices. A project called the modular memory unit (MMU), was initiated to replace the functions of the existing space shuttle mass memory units, operational (Ops) recorders, and payload recorders and integrate these three functions into a single unit. In addition, an option will be made available to replace the modular auxiliary data system recorder function.

The MMU will provide data storage and retrieval capability for flight-critical software, which includes the primary avionics system software and backup flight system; operational data and main engine data (previous Ops Recorder function), and payload data (previous payload recorder function).

The goals for this new development are to increase performance; eliminate mechanical moving parts to increase reliability; reduce unit count, weight, and power consumption; utilize off-the-shelf systems and open systems standards as applicable, and create a modular design to allow ease of repair and future upgrade.

This upgrade program is a pilot program for future consideration of an open architecture avionics design. The MMU is a Versa Module Eurocard-based open architecture system with standard modular building blocks, and growth capacity for future avionics upgrades. These building blocks will be considered for use in future avionics upgrades. ❖



IVHM HTD Chassis

IVHM RHN

IVHM Sensor

Orbiter Remote Manipulator Subsystem (RMS)

There are four RMSs in service and all have now been upgraded with digital SPAs. Three RMSs were flown in FY1999 with new digital SPAs: STS-95 for the deployment and retrieval of SPARTAN, STS-88/2A for the assembly of the first ISS elements, Zarya and Unity, and on STS-96/2A.1 for EVA support.

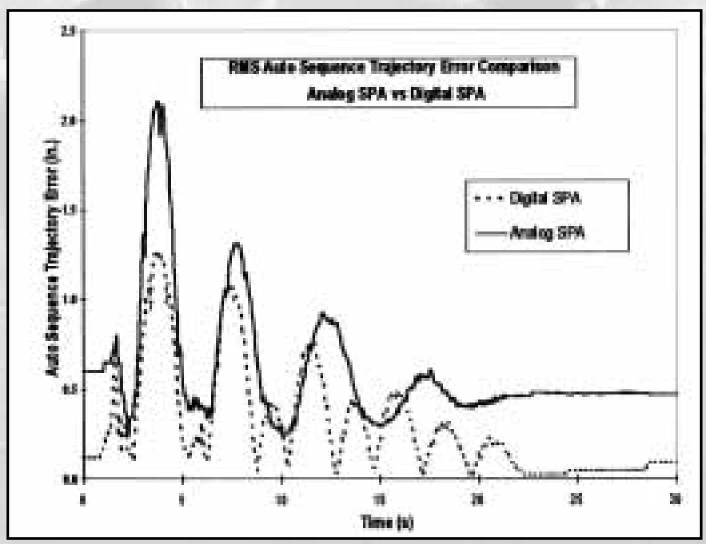
The new digital SPA is a microprocessor-based design. The digital SPA upgrade addressed improvements in safety by eliminating all 21 Criticality 1/1 items (loss of life or vehicle) associated with the old analog SPAs. This was accomplished by incorporating extensive self-checking features known as built-in test equipment. Additionally, selectable control loop gain parameters were added to improve RMS controllability of large mass payloads under low-speed conditions. The new design provides increased joint/motor torque at low commanded speeds for improved operator command authority. This stabilizes the motor control for operations with heavy Space Station-sized payloads and allows RMSs with new digital SPAs to handle payloads up to 586,000 lb (ISS size) as compared to the analog SPA maximum payload limit of 65,000 lb.

The RMS checkout performed during each RMS mission provides a good benchmark for comparing RMS performance from mission to mission. The best indication of the overall RMS tracking improvements can be seen in a comparison of analog versus digital SPA line tracking during a standard automatic sequence checkout (where coordinated tracking of all six joints is required). Note the improvements in performance, as is seen in the figure.

With the deployment and retrieval of SPARTAN, STS-95 provided a good basis for assessing the impact of the digital SPA upgrades on RMS handling performance with small payloads. As this was a re-flight of STS-87, which flew with analog SPAs, it offers a good comparison of analog versus digital SPA RMS performance. During SPARTAN unberth (2945 lb) from the cargo bay, a 70% reduction in the positional payload tracking error with respect to the operator commands was observed with the digital SPAs. Position errors reached 1in. on STS-87 with the analog SPAs and only 0.3 in. on STS-95 with the digital SPAs.

STS-88 used the RMS to assemble the first two elements of the ISS, Unity and Zarya and presented a good demonstration of the upgraded RMSs ability to handle medium and large-sized payloads. At 25,475 lb. the Unity module represented a medium sized payload with a large payload center of mass offset. During the Unity unberth there was approximately 1in. of clearance from structure. Review of RMS data from flight indicates that the RMS tracked very accurately with respect to operator commands throughout Unity unberth with tracking errors less than 0.3 in. and attitude errors less than 0.1 degrees.

At 42,637 lb. Zarya is the heaviest payload ever handled by the RMS, also with the largest center of mass offset. Flight data shows that the RMS tracked very accurately with respect to operator commands throughout the FGB capture to pre-install maneuver with tracking errors less than 0.7 in. and attitude errors less than 0.2 degrees. ❖



Orbiter Space Vision System (SVS)

The SVS has seen significant development activity this past year. The beginning of the fiscal year saw a tremendous effort to prepare SVS to support STS-88/2A. Post STS-88/2A, a number of new concepts have been investigated and are being implemented in the software to address system deficiencies in the areas of operability, robustness, and accuracy. Because of the short time before operational need on STS-92/3A and subsequent assembly flights, the decision was made not to change cameras or SVS hardware, but to work to fully understand the existing hardware and to mitigate hardware deficiencies with software.

The important features of the development work include:

1) Completing the SVS downlink capability, developing real-time SVS data logging and video frame grabbing.

2) Understanding the hardware, from the cameras used as sensors to the inner workings of the SVS box itself, including development of engineering tools for troubleshooting and analysis.

3) Implementing an efficient engineering software process.

4) Improving system performance and robustness.

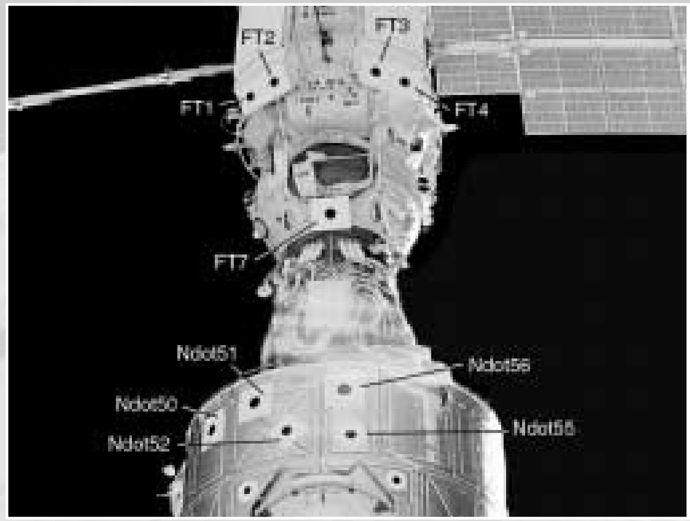
5) Radically simplifying the user operations concept by using the specifics of each operation to automate the procedures.

6) Using the accuracy of the SVS to calibrate the position of the RMS, then using the high precision of the RMS to continue operations through periods of adverse lighting when SVS may not be able to generate an accurate solution.

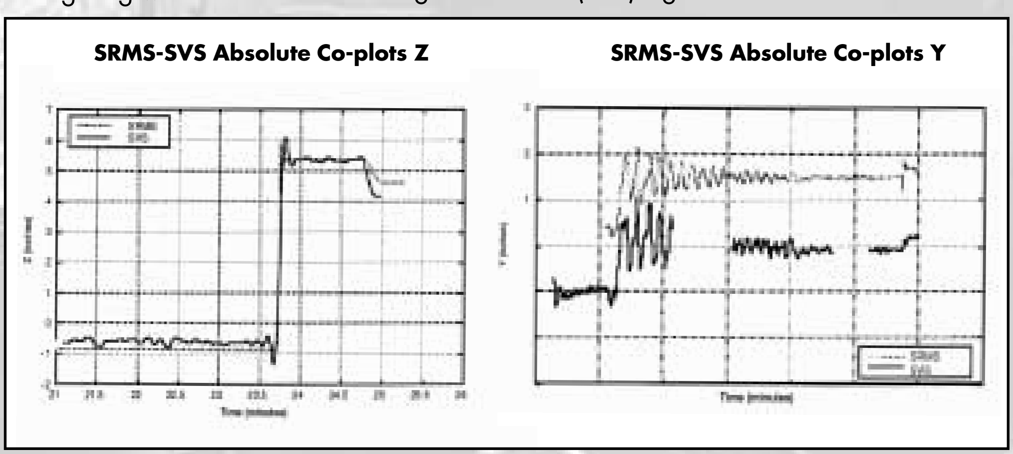
The SVS team supported three flights in FY1999. STS-95 was the final detailed test objective (DTO) flight prior to STS-88/2A and SVS was run during the SPARTAN unberthing and berthing. As shown in the photo, SVS was used operationally on STS-88/2A in support of the FGB installation. On STS-96/2A.1, camcorder views out the overhead window similar to those required for STS-92/3A were recorded and evaluated postflight.

FY1999 included preparations for two additional flights, STS-103 (HST) and STS-101/2A.2, to verify SVS performance in a number of development areas. Mission planning and crew training began for ISS Flights 3A, 4A, 5A, and 5A.1. In addition, training support has been provided to ISS increment crews.

Three flight loads of SVS software were released in FY99. Version 4.1.1, flown on STS-88/2A, and Versions 4.2 and 5.0. Since STS-88/2A, there have been engineering releases 5A through 5G. 5G was produced to verify the data logging and SEU capabilities of SVS during the STS-103 (HST) flight and will be run in an



SVS Targets used to dock the FGB to the Node on STS-88



unattended mode. The next flight load, Version 10, is expected to support STS-92/3A.

The last four of the Orbiter SVS hardware units were delivered. An additional SVS unit was delivered to the ISS. A program to upgrade all vision units is nearing completion. This upgrade included modifications to the video-input card to correct accuracy problems identified during ground certification testing.

The graphs above show the performance of the SVS during STS-88/2A, as analyzed postflight using flight parameters with flight video. The dropouts in SVS solutions seen in the graphs are directly attributable to poor lighting. A concept of calibrating the RMS digital position using SVS information has been developed utilizing the measured offset between the RMS and SVS. ❖

Flight Crew Equipment Upgrades

The SSP is investigating the integration of commercial, off-the-shelf digital television technology into the Orbiter to support a NASA initiative to convert NASA operational vehicles to digital television in the near future. The SSVEO has procured digital camcorders from several vendors of whom one was selected and flown on STS-93 and supported a live downlink from the Orbiter to ground stations. Further evaluations and flight demonstrations will be performed before full implementation into the Orbiter.

A high-definition camcorder, supporting high-definition television, flew as a demonstration on STS-93. The camcorder recorded mission highlights and was used for public affair events and crew interviews. This video stream is compressed to a bandwidth that the Orbiter can downlink to the ground. On the ground, the video stream is expanded to the original format for storage or distribution. This hardware is currently in development and will be ready in FY2000. ❖

High Definition Camcorder

Avionics and Software

General-purpose computer (GPS) software upgrades during the last year have supported numerous SSP requirements and operational improvements. Operational Increments (OI)-26B and OI-27 were developed to support the programís integration of the Global Positioning System (GPS) as a Shuttle navigation aid to relieve the dependency on the TACAN system. Both OI's were flown this year and supported detailed test objectives and other GPS/Shuttle systems engineering and integration activities. STS-96, which was flown with OI-27 software, demonstrated that the GPC software could support a single-string GPS operational capability. OI-27 software is designed to support three-string GPS capability when the GPS system is certified.

The OI-28 software system was developed and verified this year. The system is being configured to support first usage in June 2000, on STS-102. Upgrades in OI-28 also support numerous SSP requirements including safety, operational improvements, manifesting flexibility, contingency abort upgrades, and support of ISS Program requirements. The following items are included in OI-28:

ISS Reboost: Adds capabilities to perform either VRCS or PRCS reboost in auto closed-loop mode. Maximizes reboost within load/timing constraints and maintains attitude control without crew interaction.

Center of gravity (CG) relief during glide return to landing system (GRTLS): Provides up to 3 in. CG relief during GRTLS to allow payload manifesting flexibility, reduce landing weights, and use OMS propellant ballast rather than lead ballast.

Contingency Abort Upgrades: Automates complex guidance procedures for the entry portion of East Coast abort landings which will decrease vehicle loadings and increase capability/probability of reaching landing sites. Also modifies the flight control system to prevent rolloff during loss of second engine while in high Q portion of RTLS flyback cases where there is sufficient energy to reach a runway if control is retained. The loss of control scenarios were exacerbated by the addition of the SLWT to the program. Also added was the ability to uplink additional landing sites and navaid information during OPS 1,3, and 6 to support abort scenarios.

Uplink of Mass-Related I-Loads: Provides capability to uplink mass-related I-Loads to support late manifesting flexibility in terms of CG adjustments and maximizing performance without rebuilding software mass memories or generating and applying patches late in the flows.

On-Orbit Upgrades: Automates -X RCS maneuvers to reduce ground and crew workload. Provides for single forward jet for -X translation to minimize plume on ISS arrays and add redundancy to system. Provides capability to execute RCS maneuvers in target track to reduce propellant usage and decrease dispersions during rendezvous.

Expanded TDRSS Usage Capability: Increases capability to use up to 4 TDRSS vectors instead of 2 to allow more continuous coverage for ISS operations and support.

Variable Throttle for Aborts: Allows remaining at nominal throttle levels in abort regions that do not benefit from increased thrust levels. Improves thermal conditions and improves abort boundaries for TAL and ATO.

Orbiter Window Protection: Protects forward and middle window panes against hazing which results from booster separation motor exhaust plumes during SRB separation by firing forward up-firing RCS jets during separation.

Ascent Flight Control Upgrades: Expands flight control envelope for heavy, forward payloads in combination with the SLWT. Reduces flight to flight analysis activity.

RMS Precision Improvement: Allows independent calibration of the RMS point of resolution(POR) with the SVS by increasing the precision of the POR specification.

Requirements for OI-29 were baselined this year. Significant items included in OI-29 are support of the flight operations reinvention activity, support of the FICS that is a part of the Orbiter Propellant Transfer System (OPTS) being developed, upgrades to the On-Orbit Flight Control System to support automatic ISS reboost through station assembly complete, and modifying the interface between the GPCs and the MEDS system to allow the MEDS system to have access to more data in support of cockpit upgrade activities. OI-29 is expected to support launches starting in September of 2001.

Planning for OI-30 also began this year. Software to support the OPTS is being assessed at this time. The avionics upgrade and cockpit council team activities are being supported to ensure appropriate software support is provided.

The MEDS provides the human-machine interface between the crew and the Orbiter Data Processing System via 11 graphical displays. MEDS is a state-of-the-art integrated glass cockpit system, which utilizes large color flat panel, Liquid Crystal Display (LCD) multifunction displays.

The MEDS is an upgrade to the existing Orbiter Cockpit displays, that consist of electromechanical flight instruments, servo-driven tape meters, and monochrome CRT display units together with their interface electronics. The MEDS greatly enhances operational capabilities of the Space Shuttle and improves overall system reliability. MEDS provides the Program the ability to change the crew display interface to enhance safety and increase mission capability and effectiveness.

The MEDS software has performed very well over the past year in the Shuttle Avionics Integration Laboratory (SAIL), the Shuttle Training Aircraft, and the fixed-based training simulator. Installation into the motion-based training simulator was completed at the end of this year.

During this period, a special version of the IDP software was developed and verified to support crew-requested changes for the first flight of MEDS on OV-104. These changes improved the crew's interface for DPS display and keyboard operations and improved the display of MACH and equivalent airspeed during ascent and entry. This software version was developed, verified, and released for use in the facilities in less than four months, demonstrating the ability to develop MEDS software releases in a short amount of time.

The PGSC provides a low-cost crew situational awareness tool for the Shuttle as well as noncritical payload commanding/control and data gathering. The PGSC is a commercial laptop/notebook computer. The current SSP laptop is a Pentium-based laptop computer. The new laptop was purchased in August 1997 and supported STS-95 (October 1998) and subsequent flights. This new laptop is equipped with a computer card expansion tray that allows for a desktop computer card to interface between the laptop and the vehicle and/or payloads. The Shuttle laptops are noted as an inexpensive, quick, efficient, accessible, and upgradeable computing solution for onboard use.

The PGSC project has also implemented an onboard PGSC Ethernet network system. This system originally supported STS-81 and subsequent flights. This system provides file sharing, resource sharing, email accessing, and reduced cabling for the STS crew members. The onboard PGSC network system can also interface with the Orbiter communications adapter system. This integrated onboard PGSC network system and adapter system allow PGSC payload customers to monitor near-real-time data from ground, file sharing for crew members, and ground-to-crew video teleconferencing, and allow in-flight maintenance procedure reviews. All of these added features improve the quality of the mission and customer satisfaction.

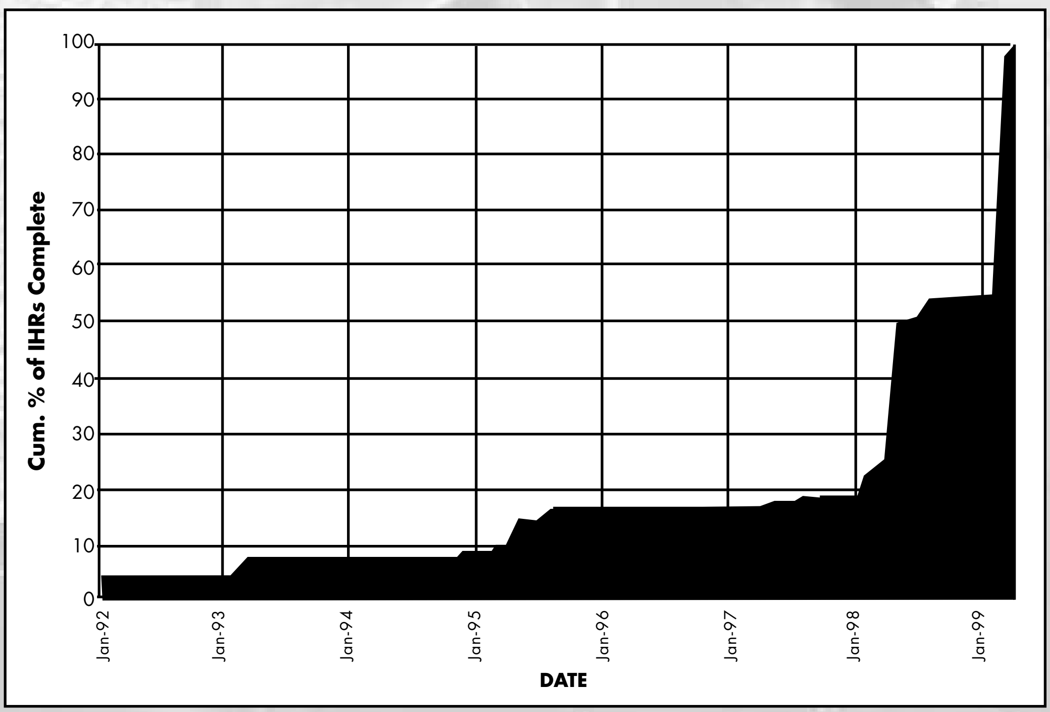
The PGSC Project also recently added a Portable In-flight Landing Operations Trainer. This system uses a PGSC laptop computer with a rotational hand controller used onorbit by crewmembers to maintain landing task proficiency. ❖

Flight Preparation Template Reduction

The SSP is striving to reduce the flight preparation time from flight baseline to launch for standard type missions to 12-months or less. Currently, the flight preparation activities for the STS-99, STS-102, STS-104, and STS-107 missions are being executed on a schedule consistent with a 12-month Template. To date, SSP organizational elements have been able to maintain their respective schedules supporting these missions. Further potential reduction in the SSP preparation template is possible. Organizational agreements and process changes necessary to execute mission preparation activities within an 11-month template is known and understood. However, at this time the SSP has chosen to further demonstrate its ability to successfully execute the 12-month template. This will better ensure process maturity and stability before additional schedule reductions are attempted. A further mitigating factor toward successful demonstration of the 12-month template has been a shift in launch dates resulting from external factors. There have been limited opportunities for the SSP to execute our preparation templates without some external factor changing a launch date, thus extending the preparation template. Template reduction is an ongoing activity and will continue when appropriate. ❖

Systems Safety Update of Integration Hazard Reports

In 1998, USA undertook an initiative to update all Integration Hazard Reports (IHRs) to meet the current Program requirements of NSTS 22254, "Methodology for Conduct of Space Shuttle Program Hazard Analyses." These requirements were revised in 1991 and 1993, requiring that all 78 IHRs be revised to be compliant. However, budgetary restrictions imposed on the Program at that time necessitated the updating of the IHRs on an opportunity-only basis, such that IHR updates were only performed as other Program changes required. The result of this policy was that only 19% of the IHRs were updated to NSTS 22254 compliance over a 6-year period. (See Figure at right.)



Integration Hazard Report Update History

Within 5 months of the beginning of the USA initiative, 24 additional IHRs were updated to the current requirements, bringing the compliance rate to 50 %. An additional 4 IHRs were updated in the next 3 months, for 55 % compliance. The remaining 35 IHRs were completed within 8 months, bringing all 78 IHRs into compliance with NSTS 22254 by April 1999. The contents of the updated IHRs were also thoroughly revised to enhance the level of technical detail provided, and to capture the Program hardware, software, or operational changes that had occurred since return-to-flight, such as the Performance Enhancements. The performance of this effort was on a non-interference basis with all other Safety related tasks. These updated IHRs contribute to a greatly improved Program safety risk baseline, enabling USA to more quickly assess safety risk for future changes in the Space Shuttle configuration and operation. ❖

Vehicle Standardization

The PRCB approved a short-term strategy to standardize the payload interfaces on ISS assembly flight vehicles, OV-103, OV-104 and OV-105. By constraining modifications, secondary payloads (including DTOs, and vehicle changes that impact reconfiguration engineering products, swapping of the ISS assembly flights can be decoupled from the engineering products and not result in launch delays or additional costs.

This eliminates the need to produce new engineering and hardware that incorporates vehicle differences, and the generation of new KSC work authorizing documents. Benefits resulting from a standardized aft flight deck and payload bay configurations include manifest flexibility, simplified training, predictable ground processing, and vehicle swap cost reduction. Drawbacks include constraints to some orbiter modifications that impact to reconfiguration products, a diminished manifesting flexibility for DTOs, DSOs and secondary payloads that are incompatible with Orbiter standard services and a diminished flexibility in weight and C.G. "get well" capability. ❖

Reductions in Thermal and Structural Cargo Verification Analysis Cycles

As part of the continuing efforts of implementing SSP initiatives, several improvements and enhancements have been realized in the thermal and structural analytical verification processes. These enhancements along with the many other improvements in work by other Program elements are evidence of the SSPs commitment to continuous improvements to better serve Shuttle customers and NASA. In the thermal analysis area, a number of improvements in the analysis process have been developed and implemented to enable the analysis cycle time to be reduced from a 12-month template to a 9-month template, effective October 1999. One improvement has been the implementation of more formalized coordination between the SSP and all the payload customers through the pre-verification thermal analysis review. This early meeting in the thermal analysis cycle establishes clear lines of communication and ensures understanding of what is expected of all parties and the schedules and milestones for all subsequent activities. Additional process improvements have included the acquisition of latest workstation hardware which provides a factor of approximately 7 reduction in the execution time for the important analysis tool, the Thermal Synthesizer System and its routines. In addition, the latest version of the SINDA thermal analyzer has been installed and reviewed for compatibility with the local host hardware. In this process, inefficiencies were identified and corrected, resulting in improved compilation and execution times.

Numerous efficiencies have been developed and introduced in the area of software tools. Many aspects of thermal analysis were formerly extremely manpower intensive. Software has been developed to automate tasks such as preparing graphical representations of the very detailed math models for inclusion in model documentation, screening large volumes of prediction data against the known payload system thermal limits and flagging the limit violations, and organizing analysis output directly into the formats needed for the verification documentation. Perhaps the most important parameter and variable in mission verification thermal analysis is the on-orbit attitude sequence. Software has also been developed to use the electronic versions of on-orbit attitude timelines to make timeline comparisons and to automatically create the input data to drive the TRASYS models (the math models used to generate the transient heating rates for the thermal models). Each of these recently automated tasks was previously very tedious and time-consuming for the thermal analyst, which contributed significantly to the length of the thermal analysis template. An added benefit of these efficiencies is the improvement in the quality and usefulness of the analysis product.

Other improvements in the thermal analysis process are ongoing, with the objective of further reducing the verification analysis template from 9 months to 7 months, effective October 2000. In view of the number of joint Shuttle/Station missions in the near future and the complexity of the hardware elements and operational scenarios involved in those missions, achieving compatible thermal analysis methods and products is an important goal for improving overall efficiency for NASA.

Several structures process/product improvements were implemented in FY99 which provided a structural analysis cycle time reduction and provided increased manifest flexibility. The most notable process improvement was the incorporation of the Manifest Uncertainty Factor (MUF) into the VLA. This process applies a small uncertainty factor to all VLA first cycle results which the Orbiter, payload integration hardware, and cargo elements analysts must verify to. Should a second VLA analysis be required, as a result of a manifest or payload change, a comparison table is developed that compares the second cycle results to the first cycle results which includes the MUF. The table is provided to each cargo element analyst and only the items which increased are required to be further analyzed. This significantly reduces analysis time for all parties. This approach was successfully implemented for STS-95, STS-96 and STS-101. With the similarity between the STS-96 and STS-101 cargo bay manifests, a variation of the above-described two-cycle VLA process is being used. The final STS-96 VLA results will be used in place of the normal first-cycle STS-101 results. This permits a single VLA cycle to be performed for STS-101 starting at L-4.5.

Other notable items include the increased staff experience with the ADVANS automation tool. Key ADVANS-related enhancements included rehost of the Quasi-Static Deflection program to a local workstation; creating a library of modular inputs for ADVANS job development; and the ADVANS/MFCP program now automates the Performance Enhancement Orbiter capability assessments, eliminating a hand-off for detailed stress analysis. Shuttle math model development was improved by developing a standard approach for main engine and ballast weight incorporation.

Bridge/Latch/GAS Beam stress analysis automation has been implemented that now creates output that is directly insertable into the VLA report. In addition, the VLA report is now in technical memorandum format, reducing the report preparation time. The VLA data dump procedure was improved by placing the data on a public server, rather than individual transmittals. Sidewall payload model generation was improved from days to hours by development of an automated coupling program.

The above enhancements and improvement have allowed a further reduction in the VLA cycle time to be implemented this year. The L-10 cargo element math model delivery date has now been changed to L-8.5 for the generic VLA template. This represents a 19% cycle time reduction in the 8 months of the generic template that is directly attributable to the structural analysis requirement.

As with the process improvements already adopted and currently being incorporated, a major objective of future improvements will be the maintenance or improvement in the quality of the SSP thermal and loads analysis products as a contribution to continued SSP success. ❖

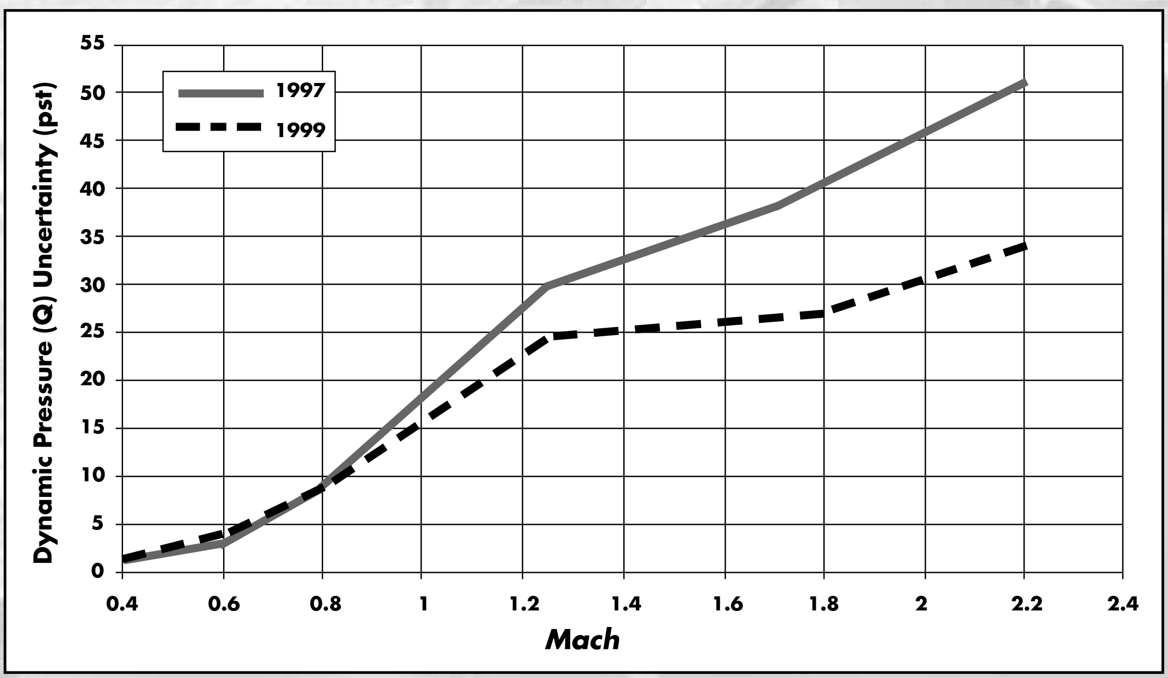
SES Scene Generation Upgrades

The SSP has upgraded its visual scene image generating capability for crew training and engineering studies to better support ISS assembly requirements. In March 1999, the SSP agreed to the concept of hardware standardization to support common software compatibility, and training commonality and continuity within the major engineering and crew training simulation facilities. The SSP is replacing its aging IGs that have a 3K-polygon capability with Silicon Graphics Inc. (SGI) IGs that have a 50K-polygon capability. The added polygon capability allows very detailed real world visual scenes to be displayed during crew training simulations and engineering studies. The SSP and USA have committed to upgrading the IGs in the SES, the Shuttle Mission Simulator (SMS), and the SAIL. The upgraded IGs allow the SSP to take further advantage of the software capability in the Virtual Reality Laboratory (VRL). Over the past three years, the VRL has developed the rendering software and modeling tool software that support very detailed on-orbit visual models that are required to support Space Shuttle and ISS on-orbit EVAs. The VRL rendering software and modeling tool software will be installed in each new SGI IG, that will allow visual scene loads to be shared between the VRL, the SES, the SMS, and SAIL, and used in desktop simulation trainers. The SES Dome IG upgrade was completed in September 1999. The SAIL IG upgrade will be completed in October 1999. The SMS Aft Guidance and Navigation Simulator IG upgrade will be completed in December 1999, in time to support the STS-92 (ISS-3A) crew training activities. The SMS IG upgrade to the Aft Fixed-Base Simulator will be completed in the third quarter of FY2000. In addition, the IG upgrade in the SMS will permit EVA simulations from either the VRL or the Neutral Buoyancy Laboratory to be added to joint integrated simulations. The SSP also presented this upgrade to the ISS Program, and since the SMS and Space Station Training Facility perform combined training, the ISS Program initiated activities this year to also upgrade their Space Station Training Facility IG to an SGI to maintain system compatibility with the SMS and the SSP. The SSP has made a significant upgrade that greatly improves crew training for ISS assembly missions, ensures safer Shuttle missions, and improves mission success capability. ❖

Ascent Postflight Reconstruction and Flight-Derived Dispersion Update

Flight-derived dispersions were updated for the Space Shuttle during 1999. This postflight reconstruction product updates uncertainties used in performance calculations for Shuttle missions. Updates were made to trajectory parameters such as angle of attack and dynamic pressure. The 1999 flight-derived dispersion updates were based on 68 Shuttle missions.

Flight-derived dispersions are typically less than the specification dispersions that were originally used in Shuttle performance calculations. As a result, flight performance reserve (FPR) has reduced 1200 lb. This change is equivalent to approximately 1200 lb improvement in payload to orbit. A significant reduction in dynamic pressure dispersion during ascent supersonic flight, shown in the attached figure, has been baselined, resulting in enhanced launch probability under day-of-launch conditions. ❖



1999 Flight-Derived Dispersion Update Reduces Q Uncertainty

Ascent Performance Enhancements Flight Summary

The primary objective of performance enhancement upgrades was to provide 13,000 lb of additional payload capability for ISS missions. This objective was driven by the need to provide the ISS Program with a total of 35,000 lb of payload capability for Space Station missions at a 51.6-degree inclination. To achieve this goal, the entire SSP embarked on performance enhancement upgrades to the Shuttle System. Following appropriate studies, Program reviews resulted in approval of enhancements consisting of hardware modifications, software changes, flight design updates, and consumables budget optimizations. Altogether the performance enhancements provide in excess of 17,000 lb of additional payload capability for the Orbiter. Exceeding the original performance goal set forth in 1994 has allowed the SSP to increase its commitment to the ISS Program from 35,000 lb to 36,200 lb. ❖

	Normal Performance Increase* (lb)	**STS-95**	**STS-88**	**STS-96**	**STS-93**
Date		29-Oct-98	4-Dec-98	27-May-99	23-July-99
Orbiter		103	105	103	102
Inclination/Altitude					
HARDWARE/CONFIGURATION CHANGES					
SLWT	7500	98	97	100	99
SSMEs: Phase 2	–				E1,2,3
Block 1A	–		E3		
Block IIA (104.5%)	500	E1,2,3	E1,2	E 1,2,3	
FLIGHT DESIGN					
FCS Filters	–	X	X	X	X
SRB Sep Yaw Gain/Constant Pitch	50	X	X	X	X
Onboard DEL PSI	500		X	X	
1st & 2nd Stage Gimbal Change	395	X	X	X	X
Roll-to-Heads-up	–	X	X	X	X
SRB Sep Timer Optimization	60	X	X	X	X
MECO alt-52 nm	740		X	X	
OMS Assist	250		X	X	
High-Q Mission	800-1300	X	X	X	

* 17,000 pound commitment (PRCB 4/7/98) also includes enhancements to Orbiter, crew & cargo equipment, and consumables budgeting.

Ascent Performance Enhancements Flight Summary

Flight Operations Reinvention

A major new initiative by the Mission Operations Directorate and USA was initiated in September 1998. This initiative, called Flight Operations Reinvention, is intended to restructure and streamline the flight preparation, flight crew training, and flight execution processes. This restructure effort will transform our current legacy processes into modern production-oriented processes. The primary benefits will be more effective and efficient operations, at reduced costs, and significantly reduced manifest template lengths. This restructure effort will provide the SSP increased flexibility in making manifesting decisions significantly later than the current manifest template. In addition, this effort will enable flight operations to be more flexible in responding to Program manifest changes.

Flight Operations Reinvention will enable opportunities to shorten the SSP flight preparation template from 12-months to approximately 7-months. Additional changes will facilitate more effective crew training and flight controller certification capabilities. In addition, the capability to conduct mission operations support activities from locations remote from the Mission Control Center will be demonstrated. These increased process efficiencies will reduce the required infrastructure necessary to sustain the capability for flight operations to plan missions, and train flight crews.

The implementation of Flight Operations Reinvention is dependent upon several key enablers and projects. Three major reinvention themes define the primary reinvention initiatives. The themes are a major restructuring of how payloads are supported in the flight preparation processes and in the onboard computer systems, a quicker and more flexible flight design capability, and new crew training processes that rely less on detailed mission specific training and more on generic distributed training.

The primary enabler for Reinvention is the elimination of payload software and payload data processing from the current onboard systems management GPC. Reinvention will implement an independent cargo computer (Cargo PC) which provides payload data display and payload command control capability to the crew. This system will allow a quicker preflight reconfiguration process and minimize the impact of payload changes to the critical GPCs. A new Payload Operations Support Team (POST) will be responsible for interfacing with the payload customer and support the development of the Cargo PC products required to support flight production, crew training, and actual mission execution. This POST activity will be critical to meeting the 7-month template goal.

Just-in-time flight design implements changes in the flight preparation processes that will enable the flight-specific design to be generated late in the production process. This will ensure that only one mission design cycle will be required per flight. Just-in-time flight design will have increased day of launch uplink capability and will relying more on standard mission designs for repeat missions such as the ISS missions.

Training for Shuttle missions will be streamlined by the utilization of generic flight software builds, the implementation of the Cargo PC system, the delivery of payload models for training by the customer via the POST team, and through generic ascent/entry training.

A detailed program-wide system requirements review was conducted in September 1999 to formally review the integrated operations concept and the system integration plan. This review was supported by all the various Program elements and stakeholders. Completion of the SRR review provided the technical baseline required for formal authority to proceed with full-scale implementation of the Flight Operations Reinvention initiative. Mission baselines utilizing the reduced template and reinvention processes are projected for July 2002. ❖

Mission Control Center Command Servers

The Mission Control Center's new Shuttle Command Server became fully operational in FY99. The new Shuttle Command Server utilizes a distributed computer system with a client-server type of architecture. It has replaced the old system, hosted on the Mission Operations Computer (MOC), which functioned in a mainframe type of architecture. The MOC architecture for commanding has been essentially the same since the initiation of the Mission Control Center in the Gemini/Apollo Programs. The new distributed system allows many of the functions done only by the MOC to be off-loaded to user workstations, thus taking advantage of modern computer technology and commercial-of-the-shelf software.

The new Shuttle Command Server was operationally used for the first time in October 1998 in support of the STS-95 mission. The new command server was utilized only for the orbit and entry phases of the mission. The first mission performance of the command Server was nearly flawless throughout the 9-day mission. The Shuttle Command Server continued to support orbit/entry phases for the next two Shuttle missions (STS-88 in December 1998 and STS-96 in May 1999).

In July 1999, the Shuttle Command Server was used for all phases of the STS-93 mission, including the critical phases of ascent and entry. Throughout FY99, the problem report trends for the Shuttle Command Server were low and indicated that the server has evolved into a very stable system. Since first operations use in September 1998, problem reporting against the system has been well within the error identification prediction models. User confidence in the new Shuttle Command Server is very high, and the Command Server has demonstrated that critical commanding can be accomplished in a distributed architecture system. A similar stand-alone command server system is in place to support the ISS Program, and this system has successfully supported early Space Station operations. ❖

Mission Control Center Command Services

Checkout and Launch Control System Progress

One of the primary Shuttle upgrades and major KSC projects supporting the SSP is the CLCS. CLCS is currently under development at KSC to replace the Launch Processing System, which has been used for Space Shuttle checkout and launch support since the 1970s. CLCS will essentially replace all the control room computers and software with state-of-the-art hardware and software. Five other sets will also be replaced, including one at the SAIL at JSC, the set used for OMS pod checkout at KSC, a payload processing set at KSC, a monitor-only set at Dryden, and a set used for main engine processing at KSC.

The CLCS will feature several major improvements over the Launch Processing System, including the capability to monitor more than one Orbiter from the same control room. A single engineer will be able to monitor multiple vehicle subsystems from one console. The engineer on console will have electronic access to a variety of data and tools, which will enhance the engineer's capability to perform a job, including drawings, advisory tools, problem reports, trending data, and work control information. The system will also provide the capability for an engineer to issue commands to the Orbiter remotely rather than only from the control room.

Benefits of the CLCS include reduction in amount of hardware and software that must be maintained, reduction in the facility space required, increased reliability of the hardware, and more efficient use of operations and process engineering personnel.

Environmental Improvements

Orbiter Ground Cooling Systems

R114, a chlorofluorocarbon (CFC)-type refrigerant used to provide Orbiter ground cooling at all Orbiter ground processing sites, has become a target for environmental improvement. The ozone layer of the stratosphere is very thin and susceptible to damage from chlorine atoms. R114 contains chlorine, fluorine, and carbon, which combine to become a very stable molecule that cannot break down without exposure to very high ultraviolet radiation found in the stratosphere and, therefore, has high ozone depletion potential. It is no longer legal to produce R114, and phasing it out of use began on January 1, 1996.

USA Ground Operations CFC Reduction Plan had dramatically reduced the consumption of CFCs since 1994, and it was planned to replace CFCs with a non-CFC refrigerant (R124) by 2001. However, existing reserves of R114 would not last through the current year, and procurement of additional R114 was cost prohibitive. Through the efforts of a team of NASA and USA engineers, the replacement project was completed 2 years ahead of schedule in 1999. The team replaced 24,000 lb of refrigerant at 12 sites, in 32 end items, during available windows of opportunity, while continuing to support routine operations and maintenance tasks. Additionally, steps were initiated for the resale of the recovered R114, which has resulted in a $60,000 credit, to date, toward the future procurement of R124. As a result of this project, CFCs have been eliminated from all ground cooling processing operations at KSC.

Orbiter Onboard Cooling Systems

KSC is also exploring replacements for the onboard Freon-21 (a CFC) and R22 (a hydrochlorofluorocarbon, which are used in our ground cooling and purge unit chillers. The replacements will be hydrofluorocarbons, which do not contain chlorine atoms.

Facilities

Space Shuttle Main Engine Processing Facility :

The 34,600-square-foot SSMEPF became fully operational in FY99. This new facility, built adjacent to the OPF 3, is contributing to improved efficiency of engine operations as well as significantly reducing safety risk by moving main engine processing out of the VAB. This state-of-the-art facility provides substantially increased capability along with safety and operational improvements for the SSP, including the following:

- Upgrades the Facility and GSE Systems to support Block II engines.
- Reduces distance traveled by SSME between engine/Orbiter removal and installation (OPF to VAB).

- Provides six vertical engine stands to enhance parallel processing and eliminate OSHA concerns.
- Provides major SSME maintenance off line.
- Provides engine drying area with oxygen monitors and installs all controls in a separate control/monitoring room.
- Equips each vertical stand with upgraded GSE to decrease system pressure losses and incorpo rates safety lockout devices on valves.
- Provides separate engine lower-head leak test area with heating, ventilating, and air conditioning system that reduces GSE background during encapsulation testing.

Launch Complex 39A

During the 8-month period from December 14, 1998, through August 3, 1999, Pad A underwent a down period to implement many significant upgrades and improvements.

The hypergolic oxidizer lines THAT support the orbiter OMS/RCS systems were replaced. These are 4-in., stainless steel lines that carry oxidizer from the oxidizer storage facility up to the Pad Fixed Service Structure and Rotating Service Structure to service the vehicle. The old lines first had to be decontaminated, then cut apart. New lines were pressure tested, then cleaned and decontaminated. The system was flushed with nitric acid to remove any free iron, then drained and dried. The final demonstration of system integrity and readiness was accomplished through a "hot flow" in which oxidizer was actually flowed through the newly installed lines.

The 9099 interface tower walls were replaced. The 9099 interface provides the electrical connections to the Mobile Launch Platform (MLP) when it is located at the Pad. All four walls of the 9099 interface tower were replaced because of corrosion issues with the old walls. The new walls are composed of prestressed concrete. The steel structure of the 9099 tower was also rebuilt, repaired, and repainted.

The Pad surface underwent major repairs. The more than 100 panels that make up the Crawler Transporter path on the Pad surface were removed, stripped, and repainted. This was an extraordinary effort since each panel weighs approximately 16 tons. The area under the panels was rehabbed with a new, flowable fill, and numerous small cracks in the supporting substructure were filled with a pressure-applied epoxy grout.

Fixed Service Structure elevators were replaced. This included rebuilding and replacing the cableway and shaft, as well as installing new cars (cabs) and the elevator controls.

The Payload Changeout Room (PCR) walls were repaired, and the PCR ceiling was modified into an open plenum to support the heating, ventilating, and air conditioning system. Three new pressure-sealing doors were added to facilitate access to the HEPA filters that help purify the air as it enters the PCR.

Safe Haven

The Safe Haven project maximizes the protection of Shuttle flight hardware by providing short-term storage capability for a partially or fully stacked vehicle in High Bay 2 of the VAB. This effort will also increase operational and manifest flexibility, especially during the hurricane season, by giving KSC managers the option of rolling a fully stacked Space Shuttle vehicle into the VAB High Bay 2. Historically, High Bay 2 has been used only for ET checkout and storage and offered no access to the Crawler Transporter/MLP.

The Safe Haven project will enable vertical flight hardware processing operations to simultaneously proceed on all three MLPs at any given time. Currently during hurricane season, vertical processing is significantly restricted to only allowing two full stacks to be completed. The third stacking operation is restricted to only the two aft segments.

Implementation of the internal VAB and external Crawlerway components of this project is being performed under two separate contracts. Construction for the external Crawlerway effort began in August 1999, and construction for the internal VAB work is expected to begin in October. Work under both contracts and an operational checkout of VAB High Bays 2 and 4 are expected to be completed before the beginning of the year 2000 hurricane season. ❖

Y2K Compliance and Certification Test

The Space Shuttle Program (SSP) formed a Year 2000 (Y2K) Working Group (WG) in August 1998 to bring a program focus to the myriad of activities necessary to ensure Y2K compliance for all flight and supporting systems. Over twenty-five team members from Shuttle projects, elements, and major support contractors from across the Agency as well as personnel from Station and SOMO participated in weekly teleconferences to share status information and coordinate Program-related Y2K activities. These activities included providing a complete inventory, categorization, and certification of all systems to NASA Headquarters and Office of Management and Budget. The thousands of individual software, hardware and firmware items which support the SSP were documented, assessed, and run through rigorous Y2K certification tests. These lower level subsystems were rolled up into higher-level inventory items for reporting certificationof compliance by the various project and element management levels by March 31, 1999. Y2K contingency plans and zero day strategies for the Y2K rollover have also been developed and reviewed by SSPY2KWG members. Follow-on activities include continuing to ensure that new systems introduced into the infrastructure meet Y2K compliance requirements and that "new finds" are reported and appropriate actions are taken to bring these systems into compliance.

On October 20, 1999, the SSP Manager requested a fully integrated end-to-end (ETE) testing of pre-flight, real-time, and post-flight support systems and networks in order to verify integrated Y2K compatible operation. The SSPY2KWG members and other technical systems experts have actively participated in defining the scope and participating systems for the post-certification Y2K integrated ETE simulations. The culmination of these tests is an integrated Launch Day simulation with an orbiter on the pad. A Test Readiness Review will be scheduled one week prior to the implementation of the test. This test is currently integrated into the STS-99 pad flow. If OV 105 does not arrive at the pad in time for testing prior to the end of the year, the Y2K ETE test will be run with the first mission Terminal Countdown Demonstration Test in the year 2000.

The extensive amount of Y2K testing and the focus on configuration management and controls are helping to ensure that the SSP and all its supporting projects and elements are flight ready for the Year 2000. ❖