National Aeronautics and Space Administration

Space Shuttle

Transition and Retirement (T&R) Knowledge Capture

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PREFACE

The authors acknowledge the support of Dennis Davidson, Jonathan Krezel, Sue Leibert, Larry Shaw, and Steve Newman for their support in preparing this monograph and assisting in the synthesis of lessons learned. In addition, the authors recognize Erin Mahoney for editorial assistance. The monograph is dedicated to the men and women, civil servants, and contractors who invested some portion of their lives in creating, supporting, and/or implementing the Space Shuttle Program.

SIGNATURE PAGE

The undersigned participated in conducting interviews with Space Shuttle transition and retirement participants, developing the content, and identifying opportunities to consider for improving the closeout of major programs.

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EXECUTIVE SUMMARY

The NASA Human Exploration and Operations Mission Directorate (HEOMD) is committed to capturing and transferring knowledge and lessons learned based on HEO program and project implementation. This monograph addresses lessons learned derived from the Space Shuttle Program (SSP) Transition and Retirement (T&R) effort. The document addresses important issue areas, including: overall management, planning, human capital, real property, personal property, environmental management, historical preservation, document management, and contract closeout. The report also chronicles unique lessons associated with decommissioning Space Shuttle Orbiters and transporting them to museums around the country. The SSP T&R activity involved 34 structured audio interviews, typically 60 to 75 minutes in length, with key participants. The interviews, along with relevant program documents, provided the basis for this monograph.

A companion web module provides video interviews with eight key individuals in management of the SSP T&R. The web module provides access to this document as well as a library of other key documents related to the T&R activity. This web module is available at:
https://nsckn.nasa.gov/Database/166/KBRs/Navigation.html.

The impressive scope and magnitude of this highly complex program, with its overwhelming volume of tasks and activities, spanned multiple years at locations across the country. The dedication, innovation, project management skills, and technical excellence of the T&R team led to the successful identification, planning, accounting, and disposition of more than $12B (billion) in Space Shuttle Program assets. The team transitioned more than 300 Government facilities, terminating operations, decommissioning equipment, packaging and shipping hardware, safely disposing of hazards, and vacating many of the buildings. The team identified, inventoried, deliberated, planned, and executed the disposition of more than one million Government property items, including the transfer of more than $1.4B in assets to new NASA programs. These include the Space Launch System (SLS), the Orion Multi-Purpose Crew Vehicle (MPCV), and the Technical Operations Support Contract (TOSC) in support of ground operations at the Kennedy Space Center (KSC). The team led the complex closeout of fifty-six detailed subcontracts with vendors and suppliers, seventy-nine Informational Technology (IT) plans, and many thousands of records accumulated over the life of the program.

In addition, the team worked closely with representatives of the public display sites at the National Air and Space Museum; Intrepid Sea, Air, and Space Museum; California Science Center; and the KSC Visitor Complex to prepare and transport *Discovery*, *Enterprise*, *Endeavour*, and *Atlantis*. The significantly complex processing, preparation, and delivery of the Space Shuttle vehicles to the designated public sites involved the work of hundreds of team members, was professionally executed, and captured the attention of millions of people across the country as the vehicles arrived at their final destinations.

Many of the people working the Space Shuttle Program transition and closeout activity were imminently scheduled for layoff following completion of their specific tasks. Yet, throughout the program, everyone was focused on high-quality results and successful mission performance. In fact, the workforce demonstrated the same professionalism and dedication after the final mission as they had during the flight campaign. It was a magnificent effort and a tribute to all involved.

INTRODUCTION

This monograph provides broadly applicable engineering, programmatic, and logistics management lessons learned derived from the Space Shuttle Program (SSP) Transition and Retirement (T&R) Program. While the SSP T&R is unique in many respects (e.g., closing-out a program that spanned 30 years), the lessons learned are in most cases largely transferrable to programs, projects, or organizations in change—any kind of transition, merger, fly-out, program cancellation, or end-of-program scenario. At a minimum, the SSP T&R experience (and this monograph) will assist organizations by providing a framework to successfully plan and implement change. An important feature of the SSP T&R story is the interaction between Space Shuttle Program culture and NASA institutional or functional management cultures and domains of expertise. The monograph chronicles the interactions, dependencies, challenges, and evolution of success between the SSP, Agency functional managers, and external stakeholders.

Knowledge Capture & Transfer Approach

This report is part of the Human Exploration and Operations Mission Directorate (HEOMD) commitment to capture and transfer knowledge and lessons learned based on HEO program and project implementation. This SSP T&R knowledge capture activity spanned 3 months and involved 34 structured audio interviews, typically 60 to 75 minutes in length, with key participants. The interviews were recorded and the transcripts were used in development of this document, as were related historical program documents.

In addition to this monograph, a companion web module provides video interviews with eight key individuals in management of the SSP T&R. This web module is available at: *https://nsckn.nasa.gov/Database/166/KBRs/Navigation.html*.

LESSONS LEARNED

Transition Management and Planning

Transition management lessons are separated into two categories: strategic and tactical. Strategic planning should be initiated several years prior to the anticipated change event and should include program personnel and all potential stakeholders—in the case of SSP T&R, this represented Agency institutional and functional managers. An integrated transition management team should include subject matter experts in human capital, real property management, personal property management, records management, environmental management, public affairs, historical preservation, legislative affairs, business management, and legal.

During the strategic phase, key activities should include engaging external Agency stakeholders to review, refresh, and refine NASA understanding of applicable laws, regulations, requirements, and executive orders. A second major activity is benchmarking. Every participant interviewed noted the importance and value of conducting benchmarking with other organizations that faced similar change events. The third key activity—now informed by 1) inclusion of Agency experts, 2) review of requirements, 3) engagement of external agencies, and 4) benchmarking—is development of preliminary cost estimates. The fourth activity in early planning (and important throughout T&R) is establishment of a communication plan. Every participant identified continuous communication as an essential success factor. A fifth activity is development of a systems engineering approach to T&R with decomposition of requirements and development of a preliminary work breakdown structure (WBS) within each functional area.

During the tactical portion of the T&R activity, one builds on the strategic planning activity in a flexible manner, updating cost estimates, refining functional area WBS, developing and updating schedules, developing necessary process documentation, monitoring progress, employing metrics, and continuously communicating with stakeholders.

<u>Early Planning Success Factors</u>

- Plan strategically early, but be flexible as things get better defined.
- Benchmark.
- Bring in institutional subject matter experts at the beginning.
- Employ small teams initially.
- Understand requirements.
- Understand derived requirements.
- Strive for cost realism in planning cost estimates.

Implementation Planning Success Factors

- Plan tactically as implementation approaches.
- Employ a systems engineering management approach (WBS), integrated master schedule, and budget management processes.
- Consolidate large quantities of small things to simplify the disposition process.
- Ensure a mutual understanding of processes.
- Employ disciplined processes.
- Communicate continuously in all directions—what you know, what you do not know.
- Establish focused working groups for specific discipline areas as called out below (e.g., business management, real property, records, management, etc.).

Transition Business Management

Participants in every functional area, including business management, emphasized the need to be included in early planning activities. An important benefit of early business management engagement is to begin the iterative process of driving all participants to a common set of assumptions and ground rules supporting and enabling the development of reasonable cost estimates.

Success Factors

- Engage business managers early.
- Define requirements, assumptions, and ground rules.
- Establish cost accounting WBS.
- Aggressively challenge the basis for cost estimates.
- Benchmark.
- Plan—get started and adjust as you go.
- Leverage institutional expertise.

Institutional Issues

Functional management organizations exist to support program/project implementation with important administrative support, including enabling and assuring compliance with important external laws and regulations. A key point to recognize is that many external requirements (e.g., environmental, historical preservation, safety and health) are relatively inflexible. Notwithstanding these constraints, it may be possible to seek waivers in certain cases.

Success Factors

- Start early with institutional issues.
- Understand inflexible external requirements.
- Communicate inflexible external requirements to stakeholders.

National Historic Preservation Act and Recordation

Implementation of the National Historic Preservation Act is delegated to state agencies. Early engagement with state agencies as well as Federal regulators is considered an important success factor to clarify roles and responsibilities.

Success Factors

- Engage regulators (Federal and state) up front—before you get started.
- Clarify roles and responsibilities.
- Recognize that each state historical preservation office may want something different.

Environmental Management

NASA Headquarters- and Center-based environmental managers are responsible for ensuring compliance with Federal and state environmental protection requirements. One important aspect of environmental law is remediation of polluted soil and ground water. Program closeout may involve the decommissioning and disposition of facilities that have a significant environmental remediation responsibility extending into the future.

Success Factors

- Conduct or refresh facility baseline assessments documenting historical issues and remediation efforts already in-work.
- Work with Agency environmental managers to identify potential (cleanup) liability beyond costs currently defined and funded within institutional budgets.
- Incorporate additional remediation cost projections into T&R budget estimates.

Personal Property

Personal property disposition was one of the most daunting challenges in SSP T&R. Key takeaways include early engagement with the General Services Administration (GSA) and the need to develop formal processes to manage disposition of large volumes of relatively small items.

Success Factors

- Seek early support from the GSA.
- Understand the applicable laws, regulations, accounting and financial requirements, and Executive Orders.
- Recognize that Government and contractor databases and inventory systems may be different and not necessarily compatible.
- Having an incomplete understanding of hazardous property may impact the initial cost estimate.
- Understand which property in your inventory has export control requirements and that there may be multiple ways to deal with these issues.

- Clarify artifact disposition process.
- Use GSA experience to aid in the artifact pre-screening process.
- Identify and disposition outdated, obsolete, unwanted, unused personal property years in advance of the anticipated end of program.
- Consider transfer of personal property to other enterprise programs and projects—do it early.
- Use authorities to transfer property to other Government entities.
- Use authorities to transfer property to schools.

IT Systems

Transitioning and retiring information technology (IT) systems for large, complex programs may pose significant and unexpected challenges.

Success Factors

- Recognize that you cannot tackle shutting down the IT systems until the end.
- Retain critical IT skills and staffing to manage T&R.
- Define an IT system baseline: identification of applicable security plans, IT systems, applications, records, data, and the collection of last-need events and dates.
- Develop a milestone-based strategy, such as the following:
  - Major events that signal the point in time that an IT asset/system would no longer be needed were identified and used to plan and schedule the excess or transfer of IT assets.
  - For closeout, the "last-need events"—wheel stop, last ferry flight, post processing, contract close, and end of program—were used in conjunction with a last-need fiscal year and quarter when an asset would be available for excess or transfer.
- Establish an Information Technology Service Management (ITSM) tool to manage the disposition of all IT systems and asset activities.
- Streamline internal change control boards as appropriate to support T&R.
- Recognize the complexity of software disposition:
  - What software can be transferred?
  - What software cannot be transferred?
  - How do you know you have gotten rid of all your backup copies?
  - How do copyright laws apply?

Real Property

Real property disposition is another complex challenge that requires the support of multiple Agency function management specialists, most notably environmental management and historical preservation. Developing a strategy to release a facility or capability can be daunting.

Success Factors

- Develop facility retirement logic and strategy.
- Address Historical Preservation Act requirements; involve the applicable State Historic Preservation Officers (SHPO) early.
- Address environmental management requirements.

- Leverage Agency facility management information systems, such as the Demand Forecast Model (DFM).

Human Capital

Human Capital management addressed three critical issues: 1) retaining a competent and capable workforce to safely fly-out the Space Shuttle Program, 2) redeploying the civil servant workforce, and 3) assisting contractors in finding employment for laid-off workers. The secret weapon (success factor) throughout T&R was communication.

Success Factors

- Communicate, Communicate, Communicate.
- Develop partnerships and employ teamwork.
- Conduct focused benchmarking.
- Develop retention incentive strategies.
- Work with local governments.
- Understand the contractor business base and the impact on workforce planning.
- Recognize the commitment of the workforce.

Records Management

Records management is another tough challenge, especially bringing to close a program spanning 30 years. One important consideration is "cleaning out the attic" (disposing of unneeded, outdated materials) while the program remains in an operational mode. Another important step is developing a structure, or knowledge architecture, for documents, along with corresponding tags and key words. Efforts should be implemented early on to identify documents that should not be classified as ITAR (International Trafficking in Arms Regulations, 22 CFR 120–130)—enabling sharing of historical process and procedural documents.

Success Factors

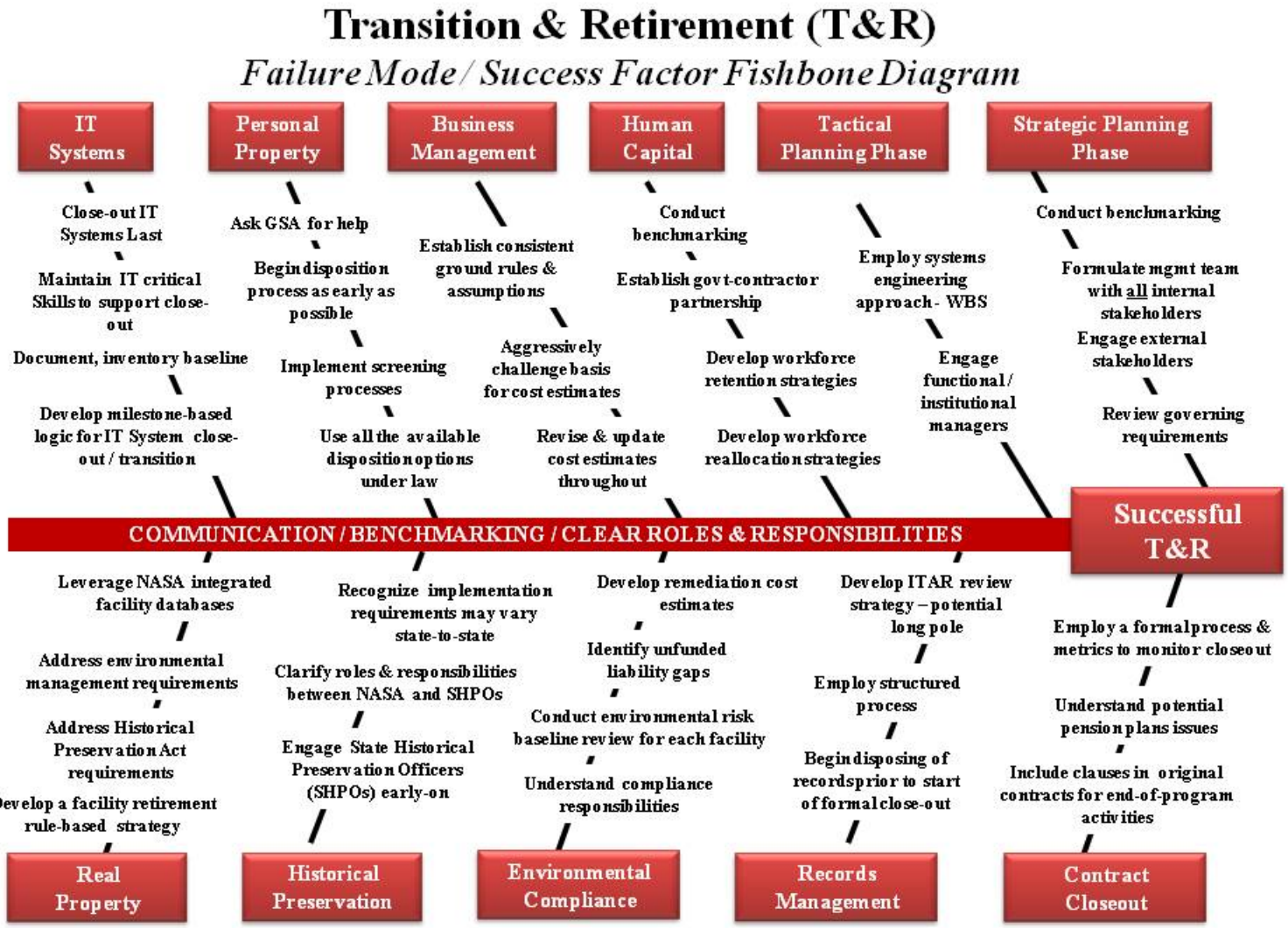
- Implement processes early—categorize data (permanent records, duplicates records, etc.).
- Work ITAR issues early on.
- Implement architecture—seek advice from National Archives and Records Administration (NARA).
- Implement a configuration management (CM) process.

Contract Closeout

Contract closeout is yet another "sleeper"—an activity that was not anticipated years in advance that becomes a serious and expensive undertaking.

Success Factors

- Up front, incorporate hooks in contracts for potential closeout tasks.
- Develop a formal "resource transition documentation process" to manage contractor transition activities.
- Leverage Agency experts in procurement, legal, etc.
- Measure and monitor contractor termination events.
- Recognize the need to support program closeout financial audits conducted by Government agencies (e.g., Defense Contract Audit Agency); contract closeout will continue for years after the program is complete.
- Understand the impacts of program closeout on the vendor base (will closeout put a vendor out of business?).


Transition & Retirement (T&R)
Failure Mode / Success Factor Fishbone Diagram
IT Systems
Close-out IT Systems Last
Maintain IT critical Skills to support close-out
Document, inventory baseline
Develop milestone-based logic for IT System close-out / transition
Personal Property
Ask GSA for help
Begin disposition process as early as possible
Implement screening processes
Use all the available disposition options under law
Business Management
Establish consistent ground rules & assumptions
Aggressively challenge basis for cost estimates
Revise & update cost estimates throughout
Human Capital
Conduct benchmarking
Establish govt-contractor partnership
Develop workforce retention strategies
Develop workforce reallocation strategies
Tactical Planning Phase
Employ systems engineering approach - WBS
Engage functional / institutional managers
Strategic Planning Phase
Conduct benchmarking
Formulate mgmt team with all internal stakeholders
Engage external stakeholders
Review governing requirements
COMMUNICATION / BENCHMARKING / CLEAR ROLES & RESPONSIBILITIES
Successful T&R
Leverage NASA integrated facility databases
Address environmental management requirements
Address Historical Preservation Act requirements
Develop a facility retirement rule-based strategy
Real Property
Recognize implementation requirements may vary state-to-state
Clarify roles & responsibilities between NASA and SHPOs
Engage State Historical Preservation Officers (SHPOs) early-on
Historical Preservation
Develop remediation cost estimates
Identify unfunded liability gaps
Conduct environmental risk baseline review for each facility
Understand compliance responsibilities
Environmental Compliance
Develop ITAR review strategy – potential long pole
Employ structured process
Begin disposing of records prior to start of formal close-out
Records Management
Employ a formal process & metrics to monitor closeout
Understand potential pension plans issues
Include clauses in original contracts for end-of-program activities
Contract Closeout

THE SPACE SHUTTLE PROGRAM

The Air Force and NASA began seriously studying vehicles that resembled space shuttles during the late 1950s and continued throughout the 1960s. The development of the actual vehicle we call Space Shuttle began on 30 October 1968 when the Manned Spacecraft Center (MSC, now the Johnson Space Center [JSC]) and Marshall Space Flight Center (MSFC) released a joint request for proposals (RFP) for an 8-month study of an Integral Launch and Reentry Vehicle (ILRV).

In August 1968, NASA adopted a Phase Project Planning approach for all new major development efforts. In this four-phase process, Phase A was advanced studies, Phase B was project definition, Phase C was detailed design, and Phase D was production and operations. The Agency began the Space Shuttle development before it formally adopted the Phase Project Planning approach, but it retroactively called the ILRV studies Phase A of the process. The essential elements of the Phase Project Planning concept survive as part of the NASA Space Flight Program and Project Management Requirements. Today, NASA Procedural Requirement (NPR) 7120.5E describes a seven-phase process that includes an effort dedicated to closeout (Phase F).[1]

After reviewing the results of the Phase A studies, NASA issued two Phase B contracts on 6 July 1970 that resulted in some truly ambitious, fully reusable two-stage vehicles. All of the concepts would have been expensive and contained potentially large development risks, even if the Agency and contractors were unwilling to admit it fully. In response, MSC redirected the Phase B studies, and MSC and MSFC were each awarded "alternate Phase A" contracts in attempts to lower the development costs and risks by conceiving less capable but more realistic vehicles. The results of these revised studies were some partially reusable concepts that quickly evolved into a vehicle that closely resembled what was eventually built. When the dust finally settled, President Richard M. Nixon approved the development of Space Shuttle on 5 January 1972, albeit with some significant funding limitations.

To save money and time, NASA decided to combine Phases C and D and issued an RFP for the development and initial production of the Orbiter on 17 March 1972. The RFP stated that each Orbiter should have a useful life of 10 years and be capable of 500 missions, but it asked each contractor to provide information on the impact of lowering this to only 100 missions, a figure that was subsequently adopted. As it turned out, the program flew much longer but accumulated far fewer missions than expected.

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[1] "NASA Space Flight Program and Project Management Requirements," NASA Procedural Requirements, NPR-7120.5E, 14 August 2012.

On 26 July 1972, NASA announced that it had awarded the $2.6 billion contract (NAS9-14000) to design and build the Orbiter to the Space Transportation Systems Division of North American Rockwell. MSFC had already awarded the Space Shuttle Main Engine (SSME) contract to the Rocketdyne Division of North American Rockwell on 13 July 1971, although a protest by the losing competitor, Pratt & Whitney, delayed the final award until 14 August 1972. The External Tank (ET) contract went to Martin Marietta on 16 August 1973 and the Solid Rocket Motor (SRM) contract to Thiokol on 20 November 1973, although another protest slowed the initial progress. The contract to manufacture the non-motor components of the Solid Rocket Booster (SRB) was awarded to United Space Boosters, Inc. (USBI), a subsidiary of United Technologies Corporation, on 17 December 1976.

For the first two years of Space Shuttle operations, Rockwell handled most aspects as part of the original 1972 Space Shuttle systems contract. The four other major contractors (Martin Marietta, Rocketdyne, Thiokol, and USBI) participated in operations to support their specific flight elements. In January 1984, all ground operations at Kennedy Space Center (KSC) and Vandenberg AFB were consolidated into the Shuttle Processing Contract (SPC) that NASA awarded to Lockheed Space Operations Company (LSOC). The Rockwell Shuttle Operations Company (RSOC) performed flight planning and operations at JSC under the Space Transportation System Operations Contract (STSOC).

The Space Shuttle Program had always been justified on the basis of a high flight rate, and during 1985 it began ramping up to an anticipated 24 missions per year (20 at KSC and 4 at Vandenberg). In the 12 months ending in January 1986, NASA launched eleven missions from KSC. The last of these, STS-51L, ended tragically when *Challenger* and her crew of seven were lost 73 seconds after lift-off.

A Presidential Commission led by former Secretary of State William P. Rogers investigated the accident. The commission found the accident was caused by a failure in the O-rings sealing a joint on the right Solid Rocket Booster (SRB). More broadly, the report also criticized the failure of both NASA and Morton Thiokol to respond adequately to the danger posed by the deficient joint design and strongly criticized the decision-making process that led to the launch of *Challenger*, saying that it was seriously flawed.[2]

The Space Shuttle Program was grounded for 33 months as NASA and the contractors corrected the problems that had led to the *Challenger* accident. At the same time, Congress authorized NASA to assemble a replacement Orbiter, ultimately called *Endeavour*, using a set of existing structural spares. When the program began flying again, the manifest was reduced to only 5–8 flights per year on average, and the Air Force abandoned all thoughts of launching from the now-mothballed complex at Vandenberg.

In August 1995, NASA wanted to consolidate the large number of Space Shuttle Program contracts under a single prime contractor. Although it was originally going to be competitively procured, on 7 November

[2] "Report of the Presidential Commission on the Space Shuttle Challenger Accident," 6 June 1986.

1995, NASA Administrator Daniel S. Goldin announced that the Agency would non-competitively award the Space Flight Operations Contract (SFOC) to a joint venture of Lockheed and Rockwell called United Space Alliance, LLC (USA). In April 1996, USA assumed management responsibility for both the Lockheed SPC and Rockwell STSOC efforts, and subsequently brought other contracts, such as the USBI SRB effort and the former-IBM flight software effort, into the SFOC. Although the initial intent was to consolidate all Space Shuttle contracts, such as ET, SRM, and SSME manufacturing, into the SFOC, this never happened, and the Pratt & Whitney (SSME), Lockheed Martin (ET), and ATK (SRM) contracts remained intact through the end of the program. When the SFOC contract expired in 2006, NASA awarded the non-competitive Space Processing Operations Contract (SPOC) to USA to support the fly-out of the manifest and program closeout.[3]

Finally, in 1998, the Space Shuttle began performing the mission it had been originally intended for—assembling and servicing a space station. On 4 December 1998, *Endeavour* was launched as STS-88, also called ISS-2A, carrying the Unity module. The crew mated it to the Zarya module (Functional Cargo Block) that had been orbited by the Russians using a Proton launch vehicle from Baikonur Cosmodrome in November 1988, marking the beginning of assembly of the International Space Station (ISS).

Ultimately, Space Shuttle visited the ISS on 36 occasions, consisting of 26 assembly flights and 10 logistics flights. The Orbiter was the only vehicle capable of carrying many of the over-sized orbital replacement units (ORU) that supported the Station. In addition, its ability to generate water as a by-product of fuel cell operations further minimized the need to launch spacecraft just to send water to the ISS. Unsurprisingly, since that had been its original purpose, the Space Shuttle proved a nearly ideal vehicle to assemble and support an orbiting outpost.

Termination of the Space Shuttle Program

Just before the turn of the century, as the Space Shuttle Program approached the 30th anniversary of its birth and the 20th of its flight campaign, NASA was planning a series of upgrades to the vehicles and ground infrastructure that would enable it to continue flying until the year 2020. Unsurprisingly, much of the rationale for the continuance was to support the ISS. But before many of the efforts could come to fruition, an errant piece of spray-on foam insulation liberated from ET-93 and impacted the left wing of *Columbia* during the launch of STS-107 on 16 January 2003. Sixteen days later, on 1 February, *Columbia* disintegrated during entry, killing its crew of seven. It was the second fatal accident of the program.

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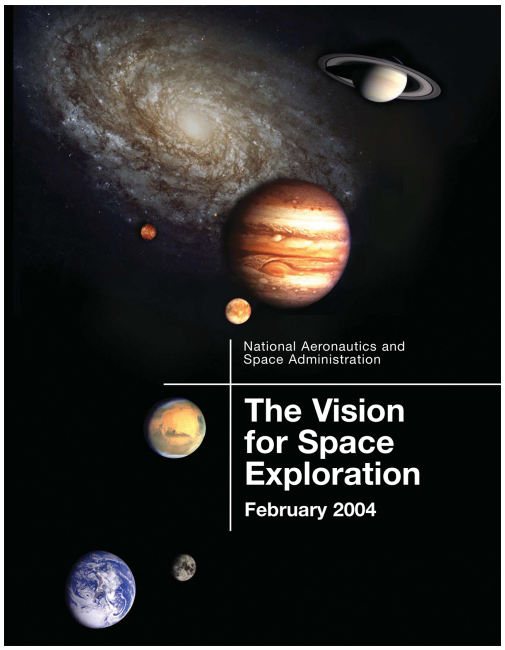
[3] The Space Shuttle Program was not immune from the vast industry consolidation that occurred during the 1990s. North American Rockwell became Rockwell International and was ultimately purchased by The Boeing Company. The Rocketdyne Division became part of Pratt & Whitney, which itself was part of United Technologies. Martin Marietta merged with Lockheed to form Lockheed Martin. Thiokol merged with Morton-Norwich and became Morton-Thiokol before being purchased by Alliant Techsystems (ATK).

The Columbia Accident Investigation Board (CAIB) released its final report on 25 August 2003, severely criticizing many aspects of the Space Shuttle Program and NASA in general. Many of the criticisms contained in the report were, in the words of Sally K. Ride, "echoes of Challenger." The report recommended, "Prior to operating the Shuttle beyond 2010, develop and conduct a vehicle recertification at the material, component, subsystem, and system levels."

However, while the CAIB was investigating the accident, the White House and NASA were formulating an alternate future that did not include the Space Shuttle. On 14 January 2004, President George W. Bush announced the Vision for Space Exploration (VSE), which called for the Space Shuttle to be retired after assembly of the International Space Station was completed in 2010. A new Crew Exploration Vehicle (CEV, later named Orion) would first fly in 2008, replacing Space Shuttle in supporting the ISS and eventually returning humans to the Moon and, later, carrying them to Mars. Somewhat later, NASA formed the Constellation Program (CxP) as an overarching organization to manage Orion and the new Ares launch vehicles.[4]



The cover of The Vision for Space Exploration Report.

The reaction to the cancellation from the international partners participating in the ISS program was not favorable. Kirk A. Shireman, the deputy ISS program manager, remembers, "When we said Space Shuttle is being retired, all of the sudden they wanted to know, is my module going to make it before the Shuttle retires and how do I fit in with all of that?' Then, ultimately, 'are we going to get the utilization out of the Space Station that we were planning?'" Ultimately, President Bush and NASA assured each of the partners that its important payloads would fly on Space Shuttle before the final flight. Still, it only partially eased the concerns.[5]

On 26 July 2005, NASA launched *Discovery* as STS-114, the first Space Shuttle flight since the *Columbia* accident 29 months earlier. Unexpectedly, the problem that doomed *Columbia*—debris separating from the External Tank during ascent—recurred during the launch of *Discovery*. As a result, NASA decided on 27 July 2005 to ground the fleet again pending additional modifications to the External Tank. It was not until a year later, 4 July 2006, that Space Shuttle flights resumed with STS-121.

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4 "Vision for Space Exploration," U.S. Space Exploration Policy, NP-2004-01-334-HQ, January 2004.

5 Interview, Kirk A. Shireman by David M. Lengyel, 14 February 2013.

Subsequent to the findings of the 2009 Augustine Committee that the Constellation Program could not be executed without substantial increases in funding, on 1 February 2010, President Barack H. Obama cancelled the program effective with the FY11 budget request. In April 2011, the President approved the continuation of Orion, this time as the Multi-Purpose Crew Vehicle (MPCV), although it is not planned to carry a human crew until 2020 at the earliest. Obama followed this in September 2011 by approving the development of the Space Launch System (SLS) launch vehicle.

Final Fly-Out

At the time of the *Columbia* accident, NASA planned to fly 34 Space Shuttle missions through the end of 2010. Shortly after *Discovery* launched on the STS-114 return-to-flight mission in 2005, the manifest was showing only 28 missions, all dedicated to completing the assembly of the ISS. The last mission on the manifest was STS-133. However, the cancellation of several ISS components, most notably the Alpha Magnetic Spectrometer (AMS-02), to meet the 2010 deadline for retirement caused considerable controversy, particularly in the science community. In response, the House and Senate committees responsible for the NASA budget provided funding for one additional mission to "deliver science experiments to the station." The Senate passed the NASA Authorization Act of 2008 on 25 September 2008, followed by the House on 27 September 2008. President George W. Bush signed it into law on 15 October 2008. Congressional authorization does not include funding (just permission), so in the spring of 2009, the Obama Administration included funds for STS-134 in its proposed 2010 NASA budget. Ultimately, Congress also authorized NASA to fly the Launch on Need (LON) vehicle that was readied to support STS-134, resulting in the final mission being STS-135. The continual changes to the manifest complicated parallel T&R efforts.[6]

Because of various technical concerns, particularly with the AMS-02 payload and structural stringers on the ET intertank, the final missions were somewhat delayed. In the end, NASA launched the three final Space Shuttle missions on 24 February (STS-133, *Discovery*), 16 May (STS-134, *Endeavour*), and 8 July 2011 (STS-135, *Atlantis*). The official end of the Space Shuttle flight campaign came at 05:57 EDT, 21 July 2011, with the wheels-stop of *Atlantis* on the Shuttle Landing Facility at KSC.

Shuttle Knowledge Capture

In the spring of 2009, the Exploration Systems Mission Directorate (ESMD) Risk and Knowledge Management Officer formed the Space Shuttle Knowledge Capture Working Group (SSKCWG) as part of a formal risk mitigation plan. At the time, there was no centralized or integrated effort for this activity and very little budget had been allocated to SSP knowledge capture. The SSKCWG was anchored around

[6] "NASA argues for extra 2011 shuttle mission," UPI Science News, 22 November 2011, located at: *http://www.upi.com/Science_News/2010/11/22/NASA-argues-for-extra-2011-shuttle-mission/UPI-23991290477821/*.

representatives from ESMD, the Space Shuttle Program, the JSC Engineering Directorate, the JSC Chief Knowledge Officer, the JSC Mission Operations Directorate (MOD), Pratt & Whitney Rocketdyne (PWR), and USA. The goal was to ensure that the data, documentation, and personal experiences would be captured and transferred to the Constellation Program to address current and future knowledge gaps.

The SSKCWG met five times in the next year after identifying the following opportunities to capture, codify, and retain relevant SSP knowledge:

- ESMD developed more than two-dozen SSP "knowledge-based risks" multi-media products.
- JSC Engineering Directorate scanned more than one terabyte of SSP engineering documents.
- KSC Engineering Directorate captured ground processing lessons learned.
- JSC Chief Knowledge Officer created a "Shuttle Knowledge Console" repository.
- United Space Alliance developed a number of lessons learned reports (includes SSP missions, engineering, and rendezvous techniques).
- PWR captured Space Shuttle Main Engine manufacturing and testing lessons learned.
- MOD captured launch and recovery simulations using multi-media methods.

Perhaps even more important than these capture activities was the transfer of SSP personnel to the International Space Station, Orion, and, eventually, the SLS programs, where their knowledge could be put to use. In many ways, the legacy of the Space Shuttle lives on.

T&R PLANNING

"In preparing for battle I have always found that plans are useless, but planning is indispensable."

—General Dwight D. Eisenhower, Supreme Allied Commander

While planning for transition and retirement was not as complex as that for a military operation, it was uncharted waters for NASA. Learning from other organizations that had carried out large-scale program closeouts was a necessity. Many lessons learned derived from these external organizations were applied to Space Shuttle T&R to navigate through the known and unknown hazards.

Initial Planning

At the time of the 2004 announcement, a small amount of what amounted to T&R[7] planning had been ongoing as part of the Service Life Extension Program (SLEP, a.k.a., Shuttle Upgrades). This was mostly because some of the upgrades would have switched vendors, so the SLEP organization was looking at how to closeout several existing contracts and excess leftover hardware after it was replaced by newer versions. These exercises provided limited experience for what was to come. Perhaps more importantly, the organizational structure of the SLEP office provided a convenient place to begin looking at T&R, especially after the upgrades were cancelled in the wake of the presidential decree. In essence this became a separate, shadow program office dedicated to T&R, with a T&R project manager within each of the project offices (ET, SRM, Launch and Landing [L&L], etc.).

The early planning was complicated by not knowing exactly when Space Shuttle might actually be retired, despite the Presidential 2010 decree, mostly because the 2005 NASA authorization bills contained conflicting language about the future of the program. The Senate bill (S. 1281) directed NASA to continue the Space Shuttle Program until a replacement vehicle was available, while the House version (H.R. 3070) directed NASA to unconditionally retire the vehicle by 31 December 2010. The final authorization act (P.L. 109-155) stated only that it was U.S. policy to have human access to space on a continuous basis.[8]

Exactly how many missions were needed to complete the assembly of the ISS was another issue. President Bush confirmed that the United States would meet its commitments to the international partners that needed to fly components on Space Shuttle since no other launch vehicle could accommodate them. Nevertheless, most early plans deleted several important payloads, such as the Alpha Magnetic Spectrometer (AMS-02),

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7 At various times, and in various places, T&R was also known as phase-out, closeout, and termination. This work tends to use "T&R" for the overarching effort and "closeout" when discussing contracts.

8 Marcia S. Smith, "NASA's Space Shuttle program: The Columbia Tragedy, the Discovery Mission, and the Future of Shuttle," Congressional Research Service report RS2140B, 4 January 2006.

and the resulting furor eventually added missions to accommodate some of the payloads, further complicating T&R planning and execution.

The effect on ISS utilization by NASA and its partners was another issue. NASA had intended to service the orbiting outpost using the Space Shuttle since it could carry larger crews than Soyuz and more payload than Progress. In addition, the Orbiter was the only vehicle with any significant down-mass capability and without it, the results of scientific experiments, equipment needing repair, and other items could only be returned if they fit within the small confines of Soyuz along with whatever crewmembers were returning to Earth.

Even more important was the issue of how NASA could continue to ensure flight safety as workers and vendors moved to other projects as the Space Shuttle Program ended. One answer was to use as much of the existing infrastructure (people, vendors, and facilities) as possible for the nascent CxP. In fact, the Senate version of the 2005 authorization bill essentially required this, saying, "The Administrator shall, to the fullest extent possible, consistent with a successful development program, use the personnel, capabilities, assets, and infrastructure of the Space Shuttle Program in developing the Crew Exploration Vehicle, Crew Launch Vehicle, and a heavy-lift launch vehicle." In addition, the bill stated, "The Administrator will ensure that NASA and its contractors will have an appropriate complement of employees to allow for the safest possible use of the Space Shuttle through its final flight."[9]

Throughout 2004 and early 2005, the primary concern of the Space Shuttle Program was returning to flight and safely flying-out the manifest. Nevertheless, during the summer of 2004, G. Lee Norbraten and his SSP Strategic Planning Office (the remnants of the SLEP organization) began looking into how to closeout a large program. As part of the effort, Norbraten, assisted by Edward M. "Mack" Henderson, and others, began drafting a Transition Management Plan (TMP). Much of the early effort consisted of developing contingency plans that accounted for changes in the manifest or even the possibility of continuing to fly Space Shuttle alongside the burgeoning Constellation Program. Eventually, however, the contingency planning was halted as it became evident that the end was nigh.[10]

Lee Norbraten remembers the effort because the "retirement of a large program can be chaotic at best and can be far worse on the other end of that. So we proposed a structure by which an office would be set up to look at the nature of how major programs retired, what would happen to the people, what would happen to the contracts, what would happen to the flight equipment, what would happen to all the ground facilities and things like that, and to begin to build a structure under which that would happen. The first element of that was looking at other similar programs in the military and some large civilian programs that had been

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9 "National Aeronautics and Space Administration Authorization Act of 2005," 109th Congress, Senate bill S.1281, sponsored by Senator Kay Hutchinson (R-TX), 21 June 2005, Section 502.

10 Interview, G. Lee Norbraten by J. Steven Newman, 15 February 2013.

ended and to go research those and to find out what were the problems involved and to proceed from there."[11]

Benchmarking Other Programs

Shortly after the 2004 announcement, a small group from NASA called the Human Space Flight Transition Team (HSFTT), led by Douglas R. Sander, began benchmarking earlier Government efforts to closeout major programs. Unsurprisingly, many of these were in the realm of the Department of Defense (DoD). The HSFTT visited various facilities and talked to the civilian and military officials who had presided over the closeout of the programs. The team, which ultimately numbered about two-dozen people, included Kevin P. Repa, who would become the USA transition program manager, allowing a direct transfer of knowledge to the largest Space Shuttle contractor.

On 5 May 2004, the team visited the Boeing manufacturing facility in St. Louis, Missouri, where the production lines for the AV-8B Harrier and F/A-18C/D Hornet were being closed. Lessons of particular relevance to Space Shuttle T&R included the importance of defining requirements early, retaining critical skill, and communications.[12]

On 26–27 May 2004, the team visited Downey, California, to review the closeout of the NASA Industrial Facility operated by Boeing (former Rockwell/North American). The facility manufactured many parts supporting the Apollo and Space Shuttle Programs. In 1996, Congress directed that NASA transition the Downey site to another use, since Orbiter production was no longer needed for the SSP. No further use could be readily identified for the facility, so NASA and Boeing elected to close the plant and raze most of the buildings.[13]

The closure took two years to plan and two years to execute. Personnel, the majority of whom were Boeing employees, were transferred to other company sites. Any remaining, necessary operations were moved to other NASA sites. These included the cold plate and 17-inch disconnect production that moved to Palmdale, California. The closeout of facilities and transition of the capabilities at the Downey site offered an example of what future SSP site closures might entail. These experiences were related specifically to phase-out strategies and did not relate to the fly-out strategies that were discussed during some of the other benchmarking activities. The major challenges in the Downey closure were personnel transfers, property disposition, environmental issues, and historical preservation. Presaging future developments, the person in charge of closing the Downey plant was Dorothy S. Rasco, who later became the Space Shuttle Program

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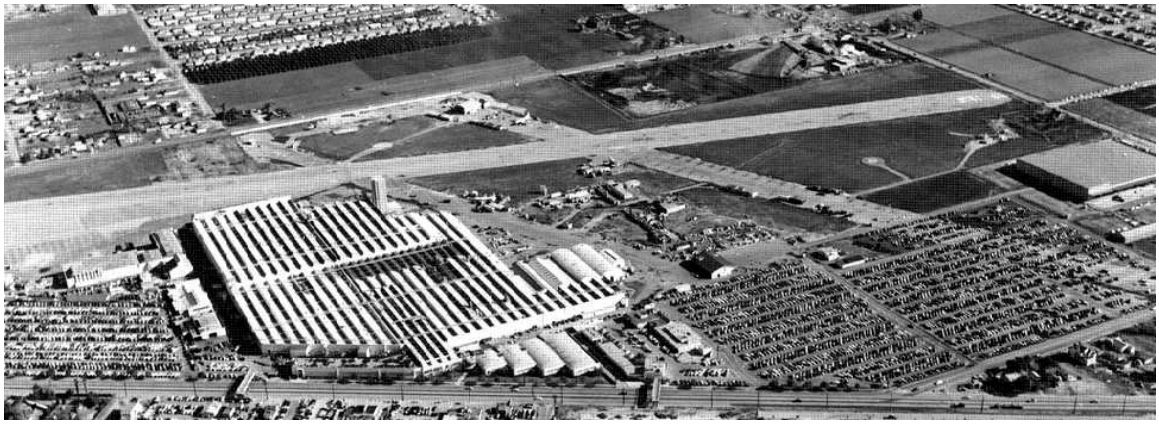
11 Interview, G. Lee Norbraten by J. Steven Newman, 15 February 2013.

12 "Lessons Learned from the Boeing AV-8B and F/A-18 Production Line Transition Strategies," 24 November 2004.

13 A small part of the original art-deco administration buildings survive as offices, and the larger hangar-like building briefly served as a movie set. As of 2013, most of the complex is gone.

Manager during the final part of T&R. Ultimately, closing Downey cost approximately $50M (million).[14]



The Downey facility in its prime. Today all that is left are the four art-deco buildings along the main road. The rest has been redeveloped as a shopping center, a hospital, and various other commercial properties. (NASA)

On 2 June 2004, the team visited the Naval Facilities Engineering Command (NAVFAC) in Arlington, Virginia, to evaluate the closing of NAS Roosevelt Roads in Ceiba, Puerto Rico. Congress directed (P.L. 108-87) the Navy to close Roosevelt Roads as part of the second round of the Base Realignment and Closure (BRAC) process, and the Navy used the closure as a model to reduce the average closure time for other bases in the second round of BRAC. The first round of BRAC involved closing approximately 135 sites and resulted in an average time of nearly 6.5 years to disposition the property, including environmental remediation. One of the primary lessons from the Navy was to address Government-owned contractor-operated (GOCO) facilities and the contracts that govern them early. Of particular importance was avoiding surprises by knowing the language contained in the contracts and the closeout responsibilities of both the Government and the contractor. [15]

On 21–22 July 2004, the team traveled to Washington, D.C., to meet at the Washington Navy Yard. On the 21st, they discussed the closure of the Charleston Naval Shipyard in Charleston, South Carolina. In addition, the Navy presented an overview of the Nuclear Ship Inactivation and Disposal Program taking place at the Puget Sound Naval Shipyard in Bremerton, Washington. The following day, the team met with an official from the General Dynamics Electric Boat Division who presented corporate efforts associated with a significant downturn in submarine production. None of the efforts were directly comparable to

[14] "Lessons Learned from the NASA Industrial Facility Closure in Downey, California," 17 September 2004; Interview, Dorothy S. Rasco by J. Steven Newman, 7 February 2013.

[15] "Lessons Learned from the Department of the Navy Base Realignment and Closure Activities: Closure of Naval Station Roosevelt Roads," 17 September 2004.

Space Shuttle T&R, but the discussions provided some useful insights.[16]

Lee Norbraten and his Strategic Planning Office also benchmarked several internal NASA closeouts, including the Plum Brook Nuclear Reactor Facility at Glenn Research Center, the NASA Yellow Creek site in Mississippi, the 16-foot wind tunnel facility at Langley Research Center, and the Space Shuttle Payload Carrier Program at Kennedy Space Center. The primary lessons included the need to remain flexible since programmatic or regulatory changes could invalidate previous decisions, to develop an integrated schedule, and to ensure that each contract includes closeout language. An interesting finding was, "Do not overanalyze items during the initial assessment. Money and time can be better spent in the later checks with system experts during the disposition schedule."[17]

Much later, during 2008, Richard A. Wickman, the Transition Manager for Infrastructure, and a small team from NASA Headquarters met with representatives from the Air Force and the Defense Contract Management Agency (DCMA) to discuss the closeout of the Lockheed F-117 Nighthawk program. Due to the different nature of the program, there were not many directly applicable lessons, but two things stood out. The first was that the initial $220M Air Force estimate was later reduced to $100M, showing even organizations that have experience shutting down major programs could overestimate the cost significantly. The Air Force reported that Congress complicated closeout planning by requiring the ability to reactivate a certain portion of the F-117 fleet if national security requirements dictated. The other takeaway concerned dispositioning records. The Air Force reported that the program had approximately 16,000 boxes of records and that each box required 2–3 hours of touch labor. Ultimately, the military representatives warned, "Do not underestimate records management—it is 50% of the effort!"[18]

The ultimate conclusion from the benchmarking exercise was that closeout of the Space Shuttle Program would be large (billions of dollars in fixed assets), complex (many stakeholders), expensive (new budget line needed), unchartered (NASA had never closed out a large program), emotional (many jobs on the line), and urgent (needed to start early).[19]

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16 "Lessons Learned from the NAVSEA Reduced Operations and General Dynamics Electric Boats Program Reengineering," 9 May 2005.

17 "Lessons Learned from NASA Program Closures," 22 November 2005.

18 "Defense Contract Management Agency and Air Force Meeting Notes," 18 July 2008.

19 "Transition Planning and Strategy Meeting," MSFC Institute (Intergraph Building), 3–5 August 2005.

Benchmarking Titan IV

The last Titan IV launch.

Of all the programs/projects reviewed by the HSFTT, the Air Force Titan IV closeout was the most similar to the Space Shuttle Program. It dealt with phasing out a decades-long effort while the program itself was continuing to launch its few remaining missions. On the Titan IV program, closeout planning began 5 years ahead of the last launch, and at least 30 percent of asset disposition was completed prior to the last mission. Joyce A. Hayes led the NASA team that visited the Los Angeles Air Force Station in El Segundo, California, on 10–12 May 2004. She concluded, "The Titan IV best practices site visit resulted in very valuable and insightful lessons learned which can be applied directly to the Space Shuttle retirement effort." Perhaps the most critical lesson was how to handle fly-out and closeout at the same time. Titan recommended, "Separating the Space Shuttle Program's retirement activities into fly-out and closeout best serves the size and complexity. The separation of the two processes allows fly-out to maintain its focus on safety and mission success, while closeout operates in the background to efficiently transition or phase out elements as the need for them expires." [20]

Titan IV program managers and senior management placed their emphasis on mission success and safe completion of the remaining manifest. To accomplish this, program closeout efforts were managed and funded separately from fly-out operations. Similarly, the Space Shuttle Program initially separated retirement planning from mainline operations, with both ultimately reporting to and funded by the program manager.

Titan strove to identify equipment that could be transitioned to another program, such as the Evolved Expendable Launch Vehicle (EELV—Delta IV and Atlas V) while continuing to fly-out their manifest. The Titan managers shared how they approached the large, complex matrix of fly-out considerations, trying to drill down to the core issues with a series of successive questions. For instance, once they started looking at spare parts, it drove them to perform a physical inventory and assess special cases. Using contrarian psychology, if someone said a facility was no longer needed, the fly-out manager made that person defend

[20] "Lessons Learned from the Titan IV Program Close-out," 22 July 2004.

why it was needed. If a facility was deemed necessary to fly-out, the fly-out manager challenged that assertion and made the case for why it could be phased out. Ultimately, their message was to dig deeply to make sure that there were sufficient data available to make a decision.

Senior managers realized that fly-out required a fundamental shift in mindset. For example, in normal operations the engineering team kept all data for analysis to improve future launches. However, since there was no "next flight," the data had no material significance. During fly-out, the analysis tasks were modified to support only the remaining flights, not to gather "basic" knowledge.

Approximately 2,000 jobs were lost during the fly-out/closeout of the Titan IV program. The challenge was to retain heritage knowledge and critical skills and to focus employees on doing an excellent job on the remaining missions. Titan managers were successful in keeping the unplanned attrition rate to near zero by implementing an aggressive retention program. This included a Mission Success Accrual Account, a Titan Launch Success Award, a critical skills retention plan, and limited employee sharing with other programs. The goal was to remove financial stability from the employees' concerns so that they could focus on safely accomplishing the mission.

The Mission Success Accrual Account was funded every six months, for which the program had 100% mission success. Congress separately funded the account each fiscal year, so it did not affect program budgets. Employees who worked at least 51% of their time on Titan were eligible and accumulated a significant amount of money during fly-out (at least two weeks' pay and, in some cases, up to one year's pay). Each job task was tied to a specific program milestone, and the payment of the accrual account was made when the employee completed their job assignment.

For the Titan Launch Success Award, approximately $200 was awarded immediately following a successful launch to all employees who worked at least 51% of their time on the Titan program.

Retaining critical skills was perhaps the largest challenge and, ultimately, one of the most notable successes. During the strategic planning for fly-out, Lockheed Martin identified the necessary critical skills. They asked the questions, "Who, by name, must I have to successfully fly out the program?" and "Who can I train to succeed them?" Once agreed to by management, key personnel were given added incentive to stay with the Titan program using a supplemental layoff benefit above standard company policy. The standard layoff benefit was 16 weeks, and those identified in a critical skills position received an additional 10 weeks in the event of layoff prior to fly-out completion. Ultimately, the unplanned turnover for personnel in the Titan program was less than 4 percent.

Sue Leibert, the NASA lead for human capital, summarized the benefits of the benchmarking exercise as, "They were hugely helpful but for me personally, and maybe it's from attending it, talking to the Lockheed folks about Titan was a goldmine. What their employees experienced was so similar to what our employees

experienced that that was a huge help. I'll be honest about two things on the benchmarking: one is we learned a ton so I don't want to discount that at all but the credibility it gave us by telling everybody we benchmarked was huge so it was a twofer kind of deal."[21]

ISOS Transition Report

> **Planning**
>
> **"It took us probably six months to a year to realize that we didn't have to be the experts in every one of those areas; in truth, the experts existed."**

The first Agency-wide, in-depth look at retiring the Space Shuttle began in August 2004 with the chartering of a Transition Panel that would report its findings and recommendations to the Integrated Space Operations Summit (ISOS) at the end of March 2005. The panel ultimately released its final report on 15 April 2005. Lesa B. Roe, the Langley Research Center (LaRC) Deputy Center Director, led the panel that included 42 members from across the Agency and industry. The charter called for the development of assumptions, risks, and milestones associated with Space Shuttle T&R. This required the identification and categorization of assets, including flight hardware, ground support equipment, facilities, industrial capabilities, tools, processes, and human capital. The charter also called for the panel to make strategic recommendations to senior leadership.[22]

The panel employed accepted knowledge-gathering and -structuring techniques to capture and organize information. These included best-practices research, affinity diagramming techniques, brainstorming, weekly telecons, periodic face-to-face meetings, and various briefings and presentations. The panel assumed that 28 Space Shuttle missions would be required through the end of 2010 to complete the ISS, including three flights in FY05 and five per year after that. All three Orbiters would be used for these missions, eliminating the option of retiring one vehicle early. The program would officially end after the last flight in 2010, although property disposition and contract closeouts would take another two years.

One of the first tasks was to determine how large the Space Shuttle Program was. This might seem odd, but the program had been in existence for more than 30 years and had woven threads throughout NASA, the military, and industry. In some locations, the SSP provided, or at least paid for, many infrastructure services used by others. In other areas, the SSP was dependent upon services provided by others and was frequently their largest customer. Roe tasked a sub-team consisting of civil service and contractor personnel with reviewing the numerous and diverse databases used to account for Government-owned property to gain an understanding of the volume, cost, and geographical distribution of these assets.

The panel reported that, at the time, the SSP occupied 640 facilities and employed more than 2,300 civil servants and 15,000 contractors. The program used an additional 3,000 indirect personnel that worked on

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21 Interview, Suzanne B. Leibert by J. Steven Newman, 5 February 2013.
22 "ISOS Space Shuttle Program Transition Panel Final Report," 15 April 2005.

Center-wide contracts and service pools and the equivalent of 35,000 vendor employees. The estimated value of the nearly one million line items of equipment used by the SSP was more than $12B and the program occupied facilities worth another $5.7B, which was approximately one-third of the entire Agency facility inventory by value. There were 1,542 active suppliers and 3,000 to 4,000 qualified suppliers geographically located across the country.[23]

Unsurprisingly, it quickly became apparent that the greatest affect of T&R would be to human capital. The realignment of the workforce, the need to retain specific segments of that workforce, and the transition of knowledge to future programs would invoke a great deal of anxiety. Natural attrition and buyouts would likely not be adequate to handle the reductions in civil servants or contractors. Also, for the first time the Space Shuttle Program became viewed as a short-term effort, an emotional concept for people who had dedicated their careers to the program. The panel concluded, "workforce morale may also be at risk if the agency does not communicate early and often, openly and completely, and with the proper level of details about further plans for the Space Shuttle Program and its workforce. The lack of communication during a change of this magnitude will hinder progress and meet resistance from the workforce."

The panel noted the cost of the T&R effort was not included in the existing budget and could not be quantified because requirements had not been established. However, the panel expected the cost to be "significant" considering the scope and potential risks. At a minimum, the program would incur the costs of closing out contracts and dispositioning property, and it faced potential risks from environmental surveys and remediation, as well as bearing a substantial part of the burden for funding to maintain buildings designated as national landmarks.[24]

Gracefully shutting down a program of this magnitude (particularly a launch program with as large a ground processing footprint as Space Shuttle) while executing the remaining missions was uncharted territory for the Agency. At the time, the two overarching applicable documents, NPR-7120.5, NASA Program and Project Management Processes and Requirements, and NPD-8010.3, Notification of Intent to Decommission or Terminate Operating Space Systems and Terminate Missions, were mostly geared to smaller projects, and even then they did not detail a process to plan the termination of a large program.

The most important ground rule baselined by the panel, although seemingly obvious, was to safely fly-out the manifest and ensure that "the last flight will be as safe as STS-114 will be." For this reason, the panel expected that many capabilities would be retained until the end of the program, furthering the bow-wave effect that would come after the final wheels-stop.

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[23] The 2008 Personal Property Disposition Plan included somewhat different numbers, but the overall magnitude of the effort was similar.

[24] "ISOS Space Shuttle Program Transition Panel Final Report," 15 April 2005.

One of the first large-scale transition planning meetings took place on 3–5 August 2005 at MSFC. Robert M. Lightfoot, the Assistant Associate Administrator for the Space Shuttle Program, and Lee Norbraten briefed representatives from all of the SSP project offices on the status of T&R planning. Unsurprisingly, Lightfoot directed that mission execution (i.e., flying out the manifest) took precedence over T&R. At the time, the manifest still contained 28 flights through 2010, although it was becoming apparent that a more realistic expectation was 18 missions.[25]

At the time, the program foresaw four primary risks that needed to be addressed:[26]

- Skills Retention: How to keep the skills required to fly and at what cost?
- Supplier Base: How to maintain the health of the vendor community as the last flight approached and at what cost?
- Infrastructure: What investments needed to be made to ensure continued operational capability?
- Operational Budget: What was the strategy for taking steep budget reductions while maintaining full operational capability?

In addition, the meeting discussed the role of the Strategic Asset Management Working Group (SAMWG) that began meeting in January 2005. This group initially included only civil service representatives from all projects, but later added contractor members. The group had a broad scope that included assessing what Space Shuttle Program assets should be retired or retained and developing schedules and initial cost estimates.[27]

The SAMWG also oversaw the evolution of the Transition Management Plan into what was supposed to be Volume XIX of the NSTS-07700 requirements document. This evolution included a move away from an executable process document to a more formal requirements specification. By the time it was finished, the SSP Risk Management Plan became Volume XIX, so the Transition and Retirement Requirements document was assigned Volume XX. The baseline issue was approved by the Space Shuttle Program

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25 "Transition Planning and Strategy Meeting," MSFC Institute (Intergraph Building), 3–5 August 2005.

26 "Transition Planning and Strategy Meeting," MSFC Institute (Intergraph Building), 3–5 August 2005; "Transition and Retirement Requirements," NSTS-07700, Volume XX, 10 September 2009.

27 "Transition Planning and Strategy Meeting," MSFC Institute (Intergraph Building), 3–5 August 2005.

Control Board[28] (PRCB) on 28 February 2007 (PRCBD S062804), and a major revision was released on 10 September 2009 (PRCBD S062804A).[29]

Notwithstanding the evolution of the requirements, the program still required a T&R process management document. On 16 January 2007, NASA released the first draft of the Space Shuttle Program Transition Management Plan, NSTS-60576. The PRCB approved the document on 11 April 2007 (PRCBD S063552). The document underwent only a single revision (5 August 2010) through the end of the program.

Perhaps the largest issue confronting the program from 2004 to 2006 was exactly when the flight campaign would end and how many missions would be launched in the interim. During the August 2005 Transition Planning and Strategy meeting at MSFC, the ET Project highlighted this issue by asking how it needed to deal with "the termination of flight hardware beyond the 28 + 1 requirements reflected in the ET budget. As of today, the project has not been given authority to issue a stop work order and excess flight hardware continues to accumulate." Determining exactly how to terminate the production contracts, close the associated facilities, and disperse the workforce proved to be a major uncertainty. In addition, all of the projects reported their production and operations contracts did not contain language allowing the contractors to begin planning for closeout, or to execute closeout when the time came.[30]

The ISOS Transition Panel developed a dozen recommendations that held fairly true throughout the eight-year T&R effort.

ISOS Transition Panel Recommendation	
1	Develop an integrated Space Shuttle Program transition plan to include integration, implementation, management, and schedule.
2	Create a transition manager position outside of the SSP to oversee the implementation of the process, authorize funds as required, lead the agency transition team, and advise agency boards during the decision-making process.
3	Develop an agency-wide transition process through which SSP assets will be evaluated for future needs and dispositioned appropriately.

[28] Historically, a defining characteristic of NASA program management is to maintain tight control over a program's "baseline" in order to make sure all the disparate elements of the program remain in synch. A baseline can refer to any codified element of a program or project, such as engineering designs, deviations or waivers to standards, schedules, budget allocations, and risk posture. In NASA parlance, a "control board" is a decision-making body that has authority to set and amend technical and programmatic baselines within its certain span of control (again, usually a program or project). Later, this paper will also reference another type of body called a "working group." A working group is generally focused on facilitating solutions across organizational boundaries on a particular topic, rather than the integrated set of issues associated with managing a whole program or project. More importantly, a working group can only work within an existing baseline or offer up changes to a baseline to a control board; it does not have authority to establish or change a baseline itself.

[29] "Transition Planning and Strategy Meeting," MSFC Institute (Intergraph Building), 3–5 August 2005; "Transition and Retirement Requirements," NSTS-07700, Volume XX, 10 September 2009.

[30] "Transition Planning and Strategy Meeting," MSFC Institute (Intergraph Building), 3–5 August 2005.

ISOS Transition Panel Recommendation	
4	Develop a detailed budget estimate of SSP retirement costs, including retirement planning activities, transition/phase-out implementation, and human capital retention and reductions. Provide for an independent cost analysis with interaction from the program elements. Establish a separate funding line for transition.
5	Develop, coordinate, and deliver strategies to address workforce communications, employee morale, stability, attrition, and other workforce climate indicators with respect to program phase out plans and impacts.
6	Establish an agency-wide, agency-level transition workforce team to coordinate all Agency workforce teams and activities for unified processes and results.
7	Begin working with the Office of Space Operations, the various functional offices, legislative affairs, and other stakeholders to understand potential policy/legislative needs to support transition.
8	Develop an acquisition strategy for SSP transition and an implementation plan for contract modifications required for program phase-out.
9	Establish an agency capital account or other appropriate mechanisms to fund former SSP assets that are to be retained for follow-on programs during the gap in their utilization.
10	Establish an agency-level environmental management team composed of representatives from NASA HQ, Centers, Space Shuttle Program, and project elements to develop an environmental transition plan and implement the plan.
11	Develop agency-wide knowledge management policy prior to transition.
12	Engage center historic preservation officers to develop an agency-wide plan to manage disposition of current and potentially historic facilities and equipment.

Grieving and Mourning

It is not often discussed, especially in technical organizations, but people naturally have a tendency to become attached to projects for which they have developed an emotional attachment. This is particularly true in the case of the Space Shuttle Program, whether people worked on it for 30 weeks or 30 years. Sue Leibert remembers, "One of the things we learned from Titan was that people have worked on these programs (and Titan was the same way as shuttle) for 30 years and it's part of who they are, so when the program really gets ready to shut down they will go through a grieving process. That may happen when they get laid off, or it may happen at the end of the program, but that will be something real and it's something you've got to watch out for." Supervisors on both the NASA and contractor sides were asked to watch for signs of emotional distress. Leibert: "Part of it was just having that frank discussion to say it's ok to ask somebody very flat out 'how are you doing; are you in a good place; if you're not in a good place let's go talk to some people.'" Every large organization provided counseling for those who needed, or wanted, it.[31]

Kevin P. Repa, the USA transition program manager, and Sherri K. Lee, the USA human resources director, worried about similar issues, as did all of the other contractors. Everybody began to understand that there

[31] Interview, Suzanne B. Leibert by J. Steven Newman, 5 February 2013.

would be a mourning period as the program wound down and the Government and contractors all started making extra efforts to maintain morale, such as distributing awards and souvenirs and throwing parties. For instance, at KSC there was a party in the Vehicle Assembly Building (VAB) after the last launch where management provided barbeque and beer for the employees and Jimmy Buffett gave an impromptu concert. After landing, there were free hot dogs and ice cream in front of the Orbiter Processing Facility (OPF).

NASA employees and contractors crowd together to get a glimpse of Atlantis as it rolls toward the OPF after STS-135, the last Space Shuttle mission. (NASA/Paul E. Alers)

The professionalism of the workforce, civil servant and contractor, is worthy of note. Despite the obvious stress and concern, everybody continued to perform as they always had; the last flight was as safe as the one before it and closeout proceeded smoothly and efficiently. It should also be noted that an expected high contractor attrition rate never materialized, even after fly-out was complete. For the most part the workforce was dedicated to the program, and continued to be so until the end.

Early Cost Estimates

Shortly after the 2004 announcement, NASA asked two support contractors not directly tied to the Space Shuttle Program to evaluate how much it would cost to closeout the program. With no firm requirements, and only limited vision of how T&R might work, the estimates were considered worst-case planning numbers. The estimates were startling. SAIC estimated that closeout would cost approximately $3B, while Valador had a range of estimates from $3B to $4.5B. Essentially, this meant that closing out the program would cost about the same as one year of operations. However, Dorothy S. Rasco later mentioned that the $4B number was obviously way off: “Because I was in the business office, I just did a quick calculation of

$4 billion meaning we needed 10,000 people per year for two years because a lot of our activity is mostly people. It's not material and it was like what are 10,000 people going to be doing when you're shutting down this program? So it just didn't make sense to me. It wasn't logical."[32]

As with the technical side, the early budget planning came out of what had been the SLEP office. Karen D. Lucht was the business manager for the SLEP project and her role transitioned into leading the business activity for the T&R planning. As with Lee Norbraten and Mack Henderson, Lucht was unsure what the future would bring. She remembers, "we were really challenged with how do you take proactive progress on closing down a program when you're not sure, in the end, that the agency will end up closing out the Shuttle program. It really was another four or five years before it became inevitable that the program was indeed going to be closing down."[33]

During the early planning, Dennis R. Davidson was the deputy business manager for the Space Shuttle Program, working for Rasco, and served as the interface to the Norbraten T&R group. Davidson remembers, "Since I assessed all of the operations budgets, I also did assessments on T&R for the overall program. So as the initial T&R program was coming up with their plans, I was assessing them just as I assessed everybody else." Davidson provided necessary continuity for the T&R effort, sticking around until the very end as the deputy program manager under Rasco.[34]

The Agency decided early that a separate financial structure would be required for closeout. Lucht remembers, "We wanted to avail the programs and projects the ability to actually capture the true cost for the program but not unduly burden them in their day to day operations and how they record their time and all of that…. It was a pretty extensive effort only because there were a lot of opinions on what level of detail constitutes the right level of accounting. So that went all the way through the agency, I think even to the Administrator…. So we established a separate WBS within the financial structure, and that had to be levied upon, of course, all the program projects and then out to the contractors and that type of thing. So that was a pretty extensive amount of work I'd say to just create the structure." The structure developed by the early planning group became the basis for strategic planning and the initial budget estimates, and it held relatively constant through execution. The structure, however, had some notable flaws. For instance, all KSC civil servants charge their T&R effort to a single account (charge number). This made it difficult to determine how much effort was spent on a specific task, such as preparing a particular Orbiter for delivery. Since each display site was responsible for reimbursing the Government for this effort, a more refined system (such as the one used by USA) would have been useful.[35]

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32 Interview, Dorothy S. Rasco by J. Steven Newman, 7 February 2013.
33 Interview, Karen D. Lucht by J. Steven Newman, 6 February 2013.
34 Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.
35 Interview, Karen D. Lucht by J. Steven Newman, 6 February 2013.

As important as structure, however, was defining the assumptions that were used for the planning effort. It quickly became apparent when planning for Space Shuttle T&R that different organizations, particularly Space Operations Mission Directorate (SOMD) and ESMD, were using different assumptions. This led to overlapping budgets in a few instances and budget gaps in others. Lucht remembers, "If you're not starting from the same point of departure in each one of those areas it's difficult to integrate and quantify the overall risk and what was covered and what wasn't because we didn't have consistent assumptions." [36]

The initial estimates were based on parametric studies of similar programs and a lot of best guesses. By 2006, the program began engaging the different project offices (ET, SRM, SSME, L&L, etc.). These estimates began converging on better technical numbers, but they still lacked significant input from the institutional side for things like property disposal and records management. When Dorothy Rasco and Dennis Davidson looked at these estimates, they found them almost as high as the operational budgets.

From the very beginning, T&R understood it was going to be hamstrung by Government regulations. Early on, Norbraten and the business office asked everybody to identify regulations that could be waived—any regulation, any requirement, either internally generated or via a Government regulation—to improve the process. Davidson remembers, "We had that question out there as part of the PPBE [Program Planning and Budget Execution] cycle and as part of other things that were going on and we went probably the better part of a year and a half, maybe two years, looking for things that we could do. We talked about property, hazardous materials, and different things, but nobody came up with anything that would help as a program, so we never took anything forward." [37]

Despite the official lack of progress, in reality things did change. Davidson says that, "looking back, there were a lot of things that people did almost internally, but it tended to be different center-to-center, like bulk dispositioning of line items in personal property. It doesn't necessarily require a waiver because you're not doing anything against a law or regulation. It just requires somebody to wave their hand over the process and say for this particular function that's okay, but it was different almost center by center, contract by contract. So, although our answer back to the agency was 'no there's nothing we can do to help,' in fact there were a lot of little things that did help. It kind of looked like a failure at first since we didn't come up with anything, but in reality we forced a lot of things to a lower level that just got implemented on their own."[38]

Unsurprisingly, the estimates changed drastically as the Agency began to better understand the scope of T&R and how to execute the closeout. The initial PPBE input, beginning in 2007 for PPBE-09, consisted of high-level Rough Order of Magnitude (ROM) estimates that were primarily based on engineering judgment

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36 Interview, Karen D. Lucht by J. Steven Newman, 6 February 2013.
37 Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.
38 Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.

and for the most part did not take into account efficiencies that could be gained in disposition/closeout of assets or possible changes in requirements. Most estimates were provided on a "business as usual" basis with the assumption that all processes and requirements implemented during operations would be maintained throughout T&R. The primary reason for this business as usual approach was a lack of experience on both the NASA and contractor sides with closeout of a major program. Nevertheless, the PPBE-09 submission was approximately half of the lowest SAIC or Valador estimate.

As the process evolved and became better understood by the projects and their contractors, the PPBE-10 submission again fell by approximately half. So now, rather than a potential $4B effort, NASA was looking at something closer to $500M.

$ in millions

T&R Procurement Cost Estimates

	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	Total
SAIC	-	-	-	-	-	-	-	-	-	$ 3,000
Valador	-	-	-	-	-	-	-	-	-	$ 3,500
PPBE-09	23	60	90	190	580	450	295	105	-	$ 1,793
PPBE-10	-	-	83	153	377	166	70	31	17	$ 897
PPBE-10 Rev 1	-	-	70	100	262	104	-	-	-	$ 536
PPBE-11	-	-	43	90	246	117	-	-	-	$ 496
PPBE-12	-	-	63	260	222	-	-	-	-	$ 545
PPBE-13	-	-	-	-	98	263	106	-	-	$ 467
Budget	-	47	49	84	127	302	72	4	-	$ 685
Actuals	-	30	40	57	99	253	70	-	-	$ 549

The estimates became more refined beginning with PPBE-10 as experience was gained from initial T&R activities, including the closeout of the Palmdale assembly facility. The development of more formal end-state vehicle safing and configuration requirements also contributed to better estimates that led to substantial reductions beginning with PPBE-10. In addition, assisting with these revised estimates was actual work experience in property assessment, equipment safing, and facilities.

Although the magnitude of subsequent estimates did not change significantly, the time phasing did. In particular, the program experienced two significant changes to the expected schedule: the first in October 2010 with the addition of STS-134, and again in April 2011 with the addition of STS-135. These events significantly lengthened the time needed for T&R since much of the work could not begin until after the wheels-stop of the final mission. Nevertheless, formal T&R activities began picking up speed in October 2010 as certain pieces of the infrastructure were released from operations. NASA authorization to implement final closeout execution and vendor closeout came in August 2011.

Alternate (and Extreme) Possibilities

As a matter of completeness, NASA investigated many methods to dispose of Space Shuttle Program assets. Although there were a myriad of alternatives, two of them—one that was possibly within the realm of reality and one that always seemed well outside that realm—are briefly discussed below.

At some point in 2008, NASA conducted a brief look at the possibility of disposing of Space Shuttle assets by dumping them in the Mariana Trench in the Pacific Ocean; this idea was dismissed for obvious reasons. A more likely alternative was to store some assets, including possibly the Orbiters, at the Department of Defense Aerospace Maintenance and Regeneration Center (AMARC) at Davis-Monthan AFB in Tucson, Arizona—also known as the "boneyard." Officials at SOMD submitted a request for information to the Air Force and visited AMARC to discuss the potential for long-term storage and eventual excessing of Space Shuttle hardware. AMARC ultimately responded that they were not capable of supporting NASA storage requirements, nor were they capable of performing safing of the Orbiters.

Site visits and technical evaluations by the National Museum of the United States Air Force (NMUSAF) resulted in a similar assessment by their Restoration Division; namely, that NASA has an infrastructure built specifically for servicing complicated components/systems (the hypergolic systems, in particular) of the Space Shuttle that could not be reasonably duplicated elsewhere.

Budget Dilemma

As NASA began to put the President's Vision into place, a strange thing happened. During the Exploration Systems Architecture Study (ESAS) that essentially defined the path forward for what became the Constellation Program, NASA zeroed out the Space Shuttle T&R budget. Dennis Davidson remembers, "They just assumed Shuttle was done, they don't need any money. So when we came back and started looking at T&R and the initial budgets said upwards of 4 billion dollars to go shut the program down, there was no way the Agency was going to fund that."[39]

Coming up with a reasonable cost estimate for T&R proved difficult, and time consuming, for the T&R organization. Davidson recalls, "Every year we would, with the small dedicated team that was working it, spend basically the whole year from one PPBE to the next refining those numbers. It took three or four iterations."

By February 2006, the transition management structure was beginning to emerge. At this point, W. Michael Hawes was the SOMD transition manager (an additional duty as deputy associate administrator of the program integration office) and Robert M. Lightfoot was the SSP transition manager, with LeRoy E. Cain

[39] Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.

as his deputy. Karen D. Lucht led the business office and Suzanne B. Leibert ran the human capital office. Each of the major Centers had an integration office, led by Jon B. Olansen at JSC, George W. Jacobs at KSC, and Sandra C. Coleman at MSFC. Lee Norbraten continued his role in the Strategic Planning Office.[40]

The controlling board structure was largely in place. At the top was the Strategic Management Council at NASA Headquarters followed by the Joint Integration Control Board (JICB), chaired by William H. Gerstenmaier (SOMD) and Scott J. "Doc" Horowitz (ESMD). Tactical decisions were the domain of the SOMD/ESMD Transition Control Board (TCB), while strategic decisions were deliberated in the JICB; Gerstenmaier and Horowitz chaired both boards. Robert Lightfoot chaired the biweekly SSP Transition Program Requirements Control Board (TPRCB) that was responsible for transition requirements, budgets, schedules, and approving SMRT documents. The TPRCB was authorized by the Space Shuttle Program Requirements Control Board (SSPRCB) on 23 February 2006 and held its first official meeting the following day.

By the summer of 2006, the major milestones for FY07 had been decided. Since the Space Shuttle Program was still flying, only limited progress could be made toward transitioning active facilities or equipment. However, as the end of the flight campaign approached, the program could begin getting rid of facilities and capabilities that were no longer needed for flyout. To start, the program would begin to transition LC-39A and the oldest launch firing room (FR-1) at KSC and one test stand (A-1) at SSC to the Constellation Program. In addition, the program was going to begin shutting down the SSME manufacturing capability and start excessing tooling at Palmdale and the Michoud Assembly Facility (MAF).[41]

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[40] Lee Norbraten, "Space Shuttle Program Transition Structure," presentation to the Transition Control Board, 15 February 2006.

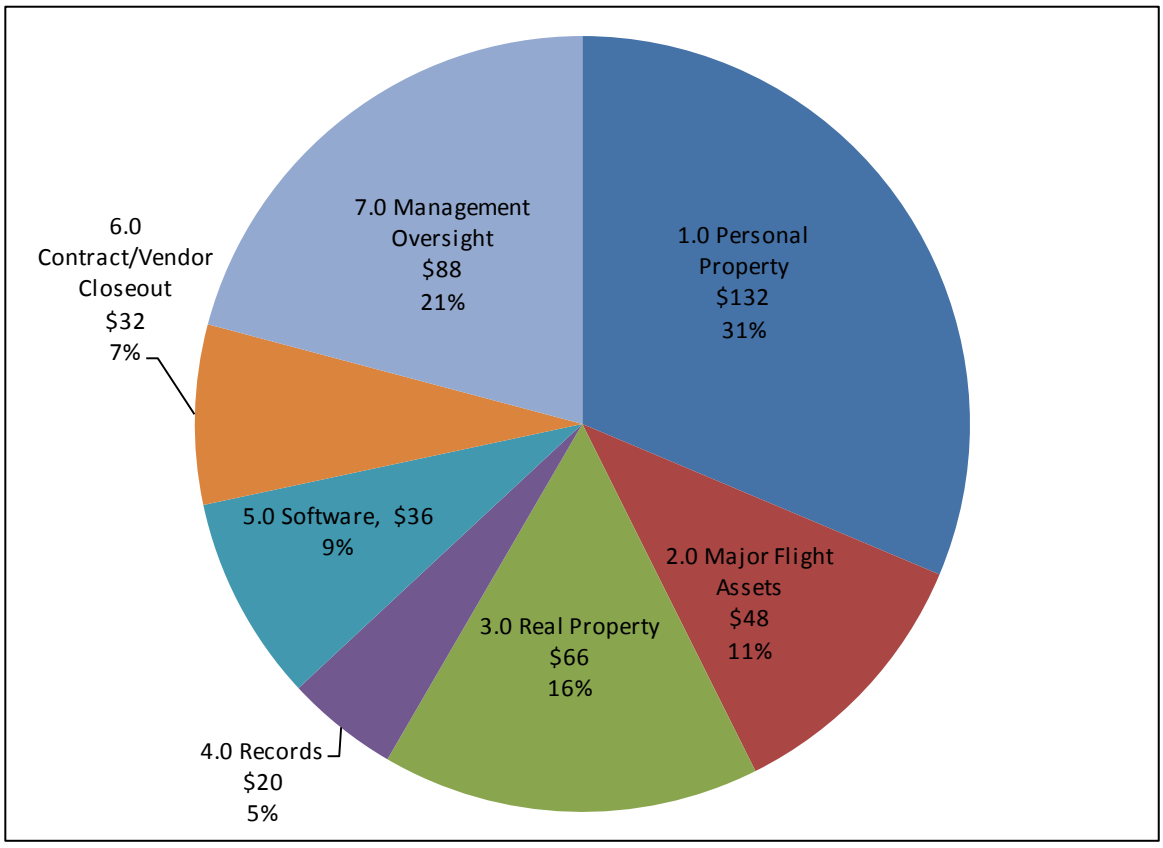
[41] Lee Norbraten, "Space Shuttle Program FY07 Transition Action Plan," presentation to the Transition Control Board, 18 August 2006.

One of the first facilities to be retired from the Space Shuttle Program was LC-39B at KSC. This launch pad was transitioned to the Constellation Program and essentially razed to make way for a new "clean pad" concept. (NASA/Kim Shiflett)

The program was developing a master schedule based on the current manifest that provided detailed guidance for the PPBE-08 and for later budget submits. Lee Norbraten also began defining metrics to measure the progress of T&R once it started in earnest. Sue Leibert was developing an employee survey that would be rolled out in October 2006 and extend through about May 2007. In addition, Leibert was defining a plan to address critical skills retention and Steve E. Glover was preparing an environmental plan and environmental assessment process that would comply with the National Environmental Policy Act (NEPA). Mario Busacca began a historical preservation survey to evaluate all SSP real property. Presaging something that would become a major effort for T&R, Michael E. Corbin began defining a data management approach to identify and archive all SSP records.

Finally, it came time to stop planning. The first real baseline cost for T&R came with the PPBE-10 cycle. Dennis Davidson remembers, "It was close enough to the end where you really couldn't wait. We were going to have to get started." Ultimately, the Space Shuttle T&R effort cost just under $421M from FY11 through FY13, plus an additional $165M of ops funding from FY08 through FY11. Unsurprisingly, the

majority of the effort was in personal property, as shown in this chart showing FY11 through FY13 actuals.[42]



Governance

Just to be clear, there were two separate but parallel management structures. The first was the SSP Strategic Planning Office led by Lee Norbraten that reported to the Space Shuttle Program Manager. The second was the SOMD Transition Office, led by Joel K. Kearns, which reported to the SOMD Associate Administrator. The SSP transition effort would largely get folded back into the mainstream program after 2008, but the Headquarters effort remained separate until 2010, when it too was folded back under a single Headquarters Space Shuttle management structure.[43]

In 2006, NASA released the Human Space Flight Transition Plan pursuant to Section 502(b) of the NASA Authorization Act of 2005. The plan delineated how NASA would safely fly-out the manifest and also described the process to effectively transfer personnel and facilities from the SSP to the exploration efforts (what became the Constellation Program). Also included were a description of the organizational structure,

42 Dennis R. Davidson, "Space Shuttle Program: PPBE13 Program Manager's Recommend," 10 My 2011.
43 Interview, Kevin C. Templin and Jonathan M. Krezel by David M. Lengyel, 22 February 2013.

management approach, processes, products, and tools to manage T&R. The authors of the plan relied heavily on the efforts of the ISOS Transition Panel.

In 2008, Joel Kearns (Space Operations Mission Directorate Transition Manager) and John M. Olson (Exploration Systems Mission Directorate Transition Manager) revised the transition plan into a joint SOMD and ESMD document, JICB-001, NASA Transition Management Plan, with largely the same content. The transition activities would be conducted in a manner consistent with the intent of NPD-1000.0, NASA Strategic Management and Governance, and NPR-7120.5D, NASA Space Flight Program and Project Management Requirements, as well as established Agency systems engineering and integration processes. Kearns was interested in retiring the Space Shuttle and disposing of its assets, while Olson was focused on receiving assets from Space Shuttle as the exploration projects stood up.[44]

Kearns remembers, "What I focused on when I got there was to try to revamp the strategic planning document that was called the human spaceflight transition plan. This was a headquarters document and I tried to put in more detail into the Space Shuttle Program's closeout planning that they were doing both for standard quarterly management reviews as well as their PPBE submit. Then we would have a better set of cost estimates and schedules for each of the performing organizations as well as center institutional offices so that we understood better the cost and duration that the T&R effort was going to take."[45]

The overarching transition goals were the following:[46]

- Take no action that would impede the ability to safely and effectively fly-out the manifest.
- Perform T&R in a cost-effective manner.
- Provide an interface to other programs and institutional elements for capability transition.

For the Space Shuttle Program, these overarching goals were flowed into the SSP Transition Management Plan, NSTS-60576. The program released the initial version of this plan on 16 January 2007, followed by updates on 9 May 2007 and 5 August 2010. This plan contained specifics that included a number of transition objectives.[47]

Transition Objectives	Rationale
Maintain flight safety	First and foremost, SSP T&R must not impact safety of flight. Each decision is to be made with a clear understanding of its effect on the risk posture of the SSP and the informed approval of the responsible managers.
Maintain ground safety	SSP T&R must not impact safety of ground support personnel and assets. T&R of ground facilities and tools are also to be assessed for risk

[44] Interview, Joel K. Kearns by David M. Lengyel, 11 February 2013; Interview, John M. Olson by J. Steven Newman, 1 March 2013.
[45] Interview, Joel K. Kearns by David M. Lengyel, 11 February 2013.
[46] "NASA Transition Plan For Implementing the U.S. Space Exploration Policy," JICB-001, August 2008.
[47] "Space Shuttle Program Transition Management Plan," NSTS-60576, 9 May 2007.

	prior to execution by management.
Make efficient use of resources	Transition is to strive for expeditious decision-making and implementation to avoid waste, minimize closeout costs, and maximize funding available for follow-on programs.
Preserve critical skills for use within NASA	Human capital planning is to ensure the retention of critical skills and knowledge required for successful fly-out and follow-on programs.
Preserve SSP physical assets for use by other NASA programs	The SSP T&R requirements are to provide good stewardship of NASA infrastructure to facilitate use by other programs.
Preserve critical single-source suppliers for use by other NASA programs	Best efforts are to be made to assure the availability of goods and services needed by follow-on programs in instances of limited or single-source availability and high-risk vendors.
Advise the SSP Planning, Programming, Budgeting, and Execution (PPBE) process	Transition planning and processes are to produce products and guidelines that help shape SSP element/project budget formulation in order to enable transition processes and reduce total SSP program costs as soon as possible.
Manage Environmental Risks	SSP transition plans and processes must identify and mitigate environmental risks and associated tasks to assure environmental laws and regulations as well as NASA policies and guidelines are followed.
Meet legal/Federal Acquisition Regulations (FAR)/contractual constraints	Transition closeout and transfer activities must fulfill contractual obligations and be consistent with FAR.
Meet historical preservation guidelines	Transition decision-making must accommodate federal, state, and local historical preservation policies. Transition processes are to ensure historical preservation is factored into budget formulation.
Maximize stakeholder consensus	Successful transition of the SSP requires buy-in from both external and NASA stakeholders. Decision-making processes are to solicit the views and desires of the stakeholders and provide due process prior to a decision.
Be responsive to political concerns	The SSP and NASA Headquarters (HQ) transition management must provide adequate public visibility into SSP transition planning and decision-making to ensure political issue resolution without undue delay. NASA SSP transition teams are to generate frequent and substantive status reports to support external requests for information.
Minimize negative impacts to morale	Mission execution and T&R planning and execution are to include measures to minimize adverse impacts to morale. Sensitivity to the concerns of people involved is essential to successful SSP retirement.

NSTS-60576 2010 version also contained a number of ground rules, constraints, and assumptions that supported the management of SSP T&R activities.

- Program complete is defined as the successful completion of the manifest while maintaining full confidence in the integrity of the system throughout the schedule.
- The SSP will not make T&R decisions that compromise safety to the crew, to ground teams, or to the public.
- The mission execution and T&R emphasis is to maintain capability for only as long as it is needed to safely execute the manifest, and then to disposition the capability.

- SSP T&R activities utilize existing NASA institutional processes to the greatest extent possible.
- SSP T&R will use existing budgetary processes, with transition requirements being captured as specific elements under the existing budgetary structure as requirements are identified.

Kearns realized how difficult this was going to be. He remembers, "There was a clear written and discussed philosophy that we needed to plan and execute the T&R in a way that did not negatively affect fly-out and also did not negatively affect Constellation's development. So there would be conflicts that would have to be settled; for example, if Constellation wanted to get a Space Shuttle facility or a piece of equipment earlier than Space Shuttle could release it and have a safe fly-out on schedule, how could you settle that conflict…. We relied on a lot of iterative management meetings and tag ups with the Space Shuttle Level 2 to develop and issue detailed requirements and planning guidance based on the policy direction we were getting out of headquarters. We relied on Constellation to do the same thing on their side and we encouraged them through tri-program boards they established at JSC since both programs were headquartered out of JSC for level two.… So there wasn't a giant detailed requirements book held at headquarters; it was a top level set of requirements and policy and the more detailed requirements were at lower levels down."[48]

Within about a year, it became clear that the T&R would need a great deal of assistance from the institutional side of NASA. So Kearns went to Olga M. Dominguez, the Assistant Administrator of the Office of Strategic Infrastructure, and asked her to name a lead to settle issues on what were institutional or statutory or regulatory requirements for SSP, CxP, or ISS. After some discussion, she appointed Rich Wickman as the Transition Manager for Infrastructure.

In 2008, the Space Shuttle Program Manager, Wayne N. Hale, changed the reporting structure for T&R within the SSP. Instead of having a separate, shadow track for T&R, Hale directed that closeout be integrated into the regular management function. It was proving difficult for the separate organization to integrate across the projects and elements as T&R moved out of the planning phase and toward execution.[49]

Both the original management structure and this realignment flew in the face of the lessons learned from the DoD. Dennis Davison recalls, "The T&R Office had done a lot of the benchmarking, lessons learned, and fact finding from other folks that had shut down programs. And the lesson was very clear from DoD that T&R needed to be a separate program, but it needed a program manager who was at the same level as the ops program manager so that they were peers on equal footing and they could make trades against one another without one just having that big stick where they controlled the entire discussion. So the lesson from DoD was you need to have two separate but equal program managers and what we initially set up was, in my opinion, separate, but not equal, to where it never really gave the initial T&R office a chance to be successful."[50]

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48 Interview, Joel K. Kearns by David M. Lengyel, 11 February 2013.
49 Interview, Dorothy S. Rasco by J. Steven Newman, 7 February 2013.
50 Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.

If "separate but equal" is not achievable, the second best option is to fully integrate T&R into the mainstream and not have a separate office. Davidson remembers, "When you looked at that and said we either need to bump this one up and make it separate but equal, or you need to just integrate it in. So if you go look at your different operational projects in support of a program a lot of them didn't care about T&R and it didn't affect them, but the business office did. Again, if you're not going to have it separate and equal, then the business office is really the place to manage and get it done. I don't know that that would change DoD's mind if you shared with them our experience of having it integrated instead of separate, but I think it's one of those where you don't want to be half pregnant. It's got to be one way or the other." Once NASA decided that the T&R office was not going to be at the same level as the SSP program manager, changing it made sense.[51]

This largely eliminated the separate transition manager position that was begun by Lee Norbraten. In his place, the SSP Business Office managed by Dorothy Rasco would coordinate the T&R efforts. Rasco had Davidson as her deputy and brought Kevin C. Templin into the office as the transition integration manager. The Space Shuttle Program officially ended in August 2011 and Rasco became program manager of the new Space Shuttle Program Transition and Retirement Office, with Davidson as her deputy.[52]

This realignment of the T&R function back into the mainline Space Shuttle Program also largely eliminated the special change boards that had been dedicated to T&R. Instead of using the TCB, changes now used the normal PRCB process. The JICB also largely went away. In retrospect, most people associated with the program, while acknowledging that there was a need to coordinate decision making between SOMD and ESMD at the Headquarters level, were not certain the TCB or JICB best served that purpose, particularly given the opportunities to elevate issues through the normal Space Shuttle Program and Constellation Program change processes.[53]

All of this was different from how Headquarters treated T&R, where it always resided in a separate office within SOMD that was led by Joel Kearns. In 2010, Kearns retired and his deputy, Jonathan M. Krezel, took over as the lead of the SOMD Space Shuttle Transition and Retirement function under the Assistant Associate Administrator for Space Shuttle at Headquarters. He continued in this role after NASA combined the SOMD and ESMD directorates into the Human Exploration and Operations Mission Directorate (HEOMD) in 2012. Krezel believes Kearns left him a "very mature organization in terms of the processes that people thought we would be executing to. We had some tweaks that we did throughout, but mostly what I dealt with was the day to day execution of those policies and dealing with issues that came up."[54]

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51 Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.
52 Interview, Kevin C. Templin and Jonathan M. Krezel by David M. Lengyel, 22 February 2013.
53 Interview, Dorothy S. Rasco by J. Steven Newman, 7 February 2013; Interview, William C. Hill by Jonathan M. Krezel and David M. Lengyel, 20 February 2013.
54 Interview, Kevin C. Templin and Jonathan M. Krezel by David M. Lengyel, 22 February 2013.

However, the coordination between SOMD and ESMD had its moments. One of the major pieces that needed sorting out was which organization was going to pay for things such as keeping facilities or contracts operating during the transition. ESMD wanted to use a "buy by the yard" philosophy, mostly to minimize their costs, in which they paid for support as they needed it but declined to pay for the broader infrastructure and day-to-day operations. Krezel remembers this created issues such as, "Who pays for the MAF floor space while its being transferred after SSP doesn't need it anymore, but before ESMD is ready to take it over?" Parceling out the costs of a facility between two organizations was largely new to the human space flight area of NASA and required new accounting procedures and practices. Krezel believes that "ESMD was trying to use this 'buy by the yard' philosophy to really drive a conversation about how much the Agency spends on infrastructure."[55]

Institutional support to the Space Shuttle Program was provided by organizations managed by the applicable Center. Each Center had a designated Center Transition Manager that provided integration with the Space Shuttle Program. Each Center Transition Manager developed a Center Transition Management Plan (TMP) and led a Center-wide forum to support T&R integration and coordination. The forums were the JSC Transition Management Working Group (JTMWG), KSC Transition Working Group (KSCTWG), and the MSFC Transition Working Group (MTWG).[56]

The manifest dated 2 January 2007 shows the retirement of Atlantis after the last Hubble Space Telescope servicing mission and the last approved flight as STS-132, with STS-131 and STS-133 as "contingency logistics flights."

SMRT Process

As early as the 2005 ISOS Transition Panel report, NASA realized that some subcontractors and vendors would be terminated early in the retirement process. This was because, in some cases, the amount of flight hardware accumulated was already sufficient to meet the 28-mission manifest through 2010. However, since the next launch vehicle requirements were not currently defined, NASA took the risk of terminating a vendor that could possibly be needed for Exploration.

The ISOS report noted that the SSME Project was currently fabricating the components for the final new SSME and that many vendors and manufacturing processes would be coming to an end by early FY07. In fact, several suppliers delivered their final SSME parts as early as FY05. Another vendor that received a great deal of early attention was Pechiney Rolled Products, which supplied aluminum lithium (Al-2195) to the ET Project. Just before the *Columbia* accident, NASA had awarded Lockheed Martin a follow-on contract for 60 ETs, and the company began procuring large amounts of raw material to support

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55 Interview, Kevin C. Templin and Jonathan M. Krezel by David M. Lengyel, 22 February 2013.
56 "Space Shuttle Program Transition Management Plan," NSTS-60576, 5 August 2010.

production. By 2005, the ET project had procured more than enough Al-2195 to complete the number of ETs needed to meet the expected 28-mission manifest. However, terminating the Pechiney procurement could have potentially impacted the Ares launch vehicle program, since the company might not be willing to begin production in the future since NASA was the only customer. Similarly, the Ladish Company was the sole-source provider of large-diameter seamless forgings in the United States. The Reusable Solid Rocket Motor (RSRM) Project expected to begin shutting down this capability in 2005, resulting in losing the only U.S. manufacturer producing one-piece, weld-free, large solid rocket motor pressure vessels.[57]

To assist in determining exactly when a subcontract could reasonably be terminated, NASA initiated the Space Shuttle Management Resource Transition Document (SMRT) process. The same process ended up being used to determine when a capability (such as shutting down the ET production line or closing a test stand at Stennis) could be released.

Jon B. Olansen explained the SMRT process this way: "The SMRT document provides a body of relevant information from which decisions can be rendered, communicated, documented, and tracked. The document contains a business case platform as well as creditable, consistent, and accurate information, all in a standardized format." A SMRT document was required if the following occurred:[58]

- An SSP capability, as established in the Strategic Capabilities Assessment Database, was being partially or fully terminated before the last Space Shuttle flight was complete through post-landing safing. This included capabilities being directly transferred to CxP.
- An SSP capability transfer or termination was pending but required TPRCB or TCB authorization to establish priorities, provide gap funding, or address other issues.
- Any significant SSP resource, asset, or capability was being dispositioned (transferred, closed-out, excessed, etc.) and met certain criteria.

It is important to note that the SMRT process was not applicable to every transition action. For instance, terminating a vendor that supplied "non-unique equipment or material through purchase orders" (such as office supplies) did not require an SMRT. Terminating the fuel cell or auxiliary power unit vendors did.

Typically, an SMRT document was prepared by the cognizant Level III organization (the Project level, such as ET, SRM, L&L, etc.) and was reviewed by a designated Center lead. The document was then submitted to the TPCRB as an SR. In some cases, the TPCRB could approve the termination, while in others the document had to be raised to the TCB (later, to the SSP PRCB). Ultimately, several hundred SMRT documents were developed and approved during T&R.

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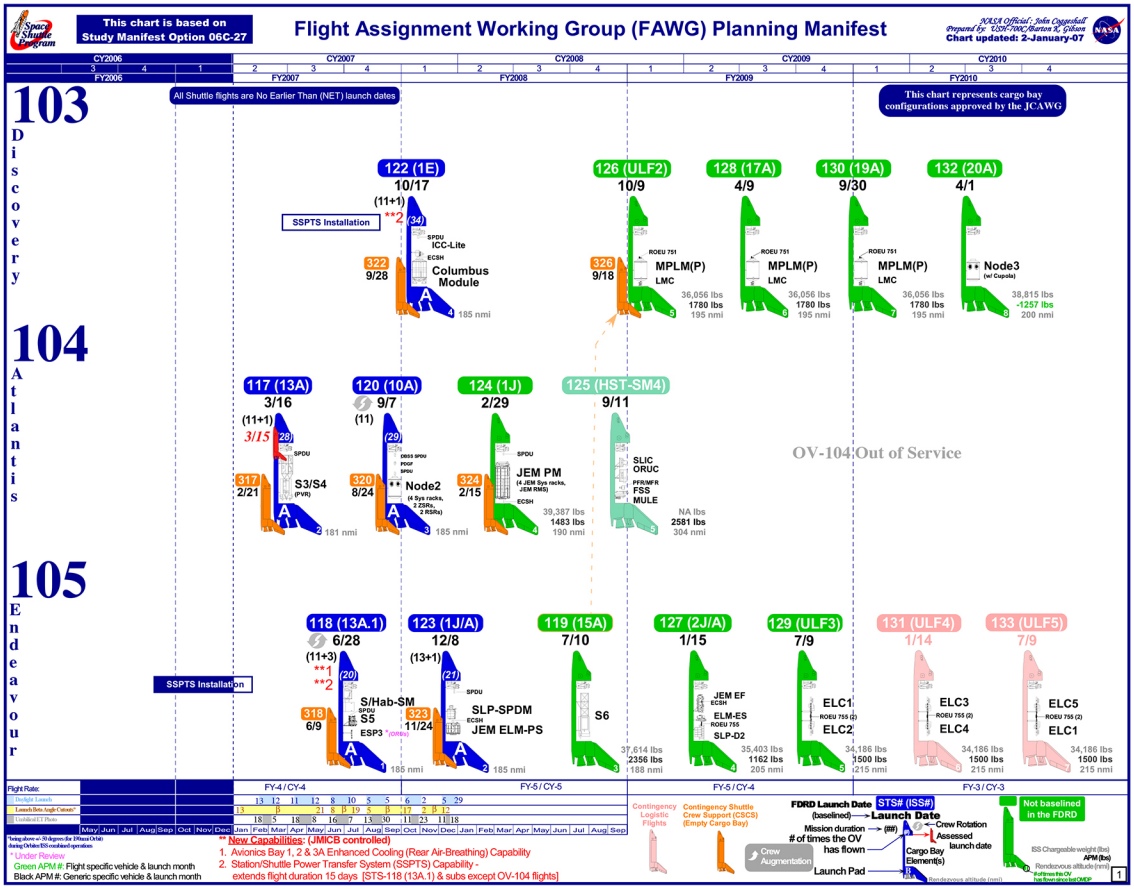
57 "ISOS Space Shuttle Program Transition Panel Final Report," 15 April 2005.
58 Jon B. Olansen, "SMRT Document Update," 26 January 2007.

Frank Lin remembers, "The SMRT document was the document, the mechanism by which they'd fill out and get it processed in order to get approval to excess the hardware, or to transfer it to somebody because it's in excess to Shuttle's needs. So a SMRT document was something that the logistics warehouse or somebody says, 'Well, I don't need this anymore, but I just cannot get rid of it without program approval.' So they went ahead and do the SMRT document, they sent a ticket to the PRCB, and the PRCB says, 'There's no need for this anymore. I'm ok with getting rid of it.' But once we stop flying, pretty much the SMRT document just dies."[59]

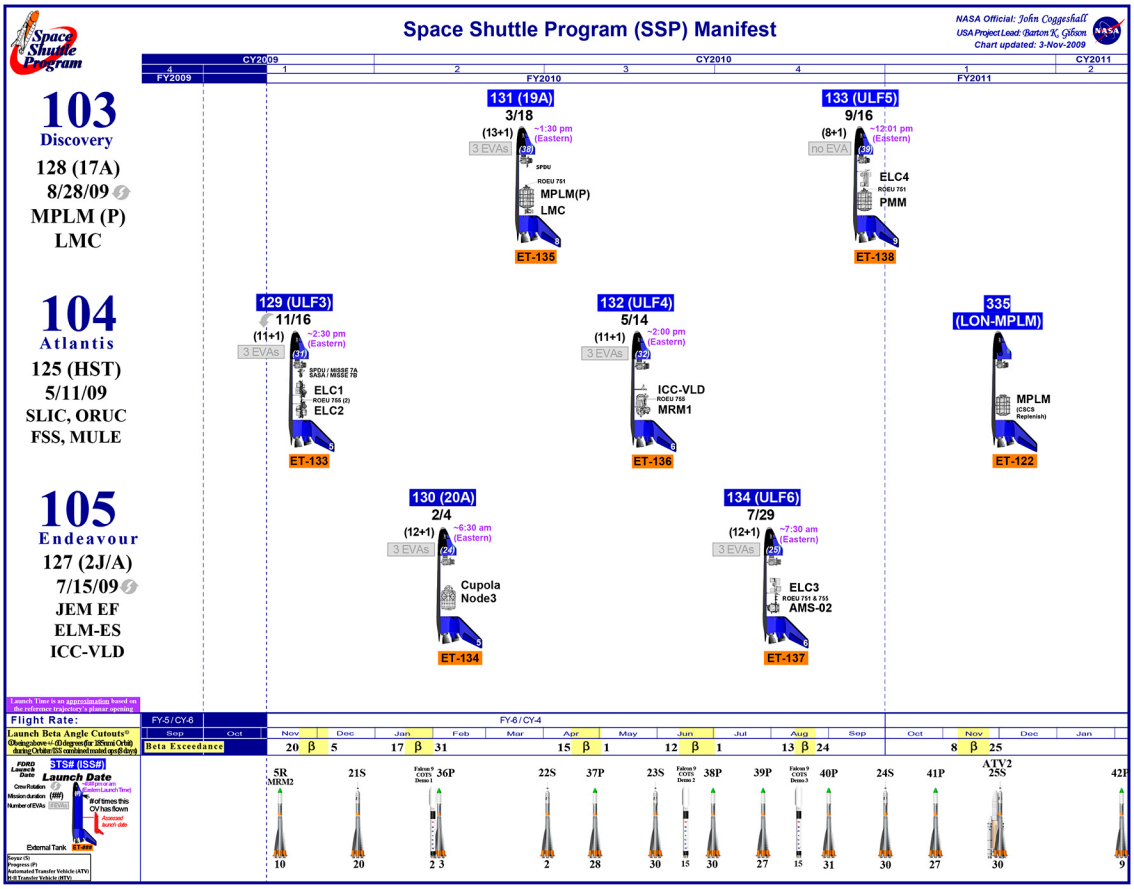
Additional Missions

Figuring out exactly when the Space Shuttle Program was going to end was difficult right up to the very end. The initial, 2005-era, 28 + 1 mission, return-to-flight manifest (which extended to STS-141) was cut back to 14 missions in early 2006, expanded to 18 missions, and then stabilized at 20 missions by mid-2006 (although two of the flights were being carried as "contingency logistics" missions). In this planning, *Atlantis* would be retired after STS-125 in August 2008, *Discovery* after STS-132 in April 2010, and *Endeavour* after STS-133 in July 2010. Despite a what-if manifest extension study in early 2008 that examined the possibility of flying 13 additional missions through the end of FY15, the official manifest held steady and continued to show STS-133 as the final mission, although the actual Orbiter assignments shifted due to technical and schedule priorities.

[59] Interview, Frank Lin by David M. Lengyel, 13 February 2013.



In February 2008, the multi-program manifest showed STS-133 as the final Space Shuttle mission, with a ghosted STS-134 flight still a possibility. In August 2008, the Agency added the STS-334 LON mission to support possible contingencies on STS-133. At the time, there was no intent to fly STS-334, but the vehicle and all of its associated hardware and infrastructure would be processed to allow a rescue flight if needed. However, in early 2009, Congress authorized and funded STS-134 (the former STS-334 LON) to carry the $1.5B Alpha Magnetic Spectrometer (AMS-02) payload to the ISS. The manifest now showed 21 missions since the return-to-flight. A few months later, planners added the STS-335 LON mission to support the new STS-134. This started a great debate on whether to fly the final LON vehicle as a final logistics mission to ISS, although doing so would mean there was no LON available for that crew. The ISS program was highly in favor of this as a hedge to the likely slips in the commercial resupply effort. By this point, the manifest showed STS-133 as a *Discovery* mission, STS-134 as an *Endeavour* mission, and STS-335, if it flew, as an *Atlantis* mission.



Soon, the STS-335 contingency mission was formalized as STS-135. Flying STS-135 would use the last of the super lightweight ETs that had been completed, although parts of several additional tanks were in various states of assembly on the now-closed production line at Michoud. There was one additional ET available, the last of the "deferred build" lightweight tanks (ET-94) that had been used to support the *Columbia* accident investigation, but nobody wanted to fly the tank. This meant that there would be no further debate after STS-135; the end was set.[60]

The STS-133 mission was affected by a series of delays due to problems with the ET and, to a lesser extent, the payload. The launch, initially planned for September 2010, was pushed back to October, then to November. After the ground team noted a large crack in the insulation on the ET intertank, the mission management team postponed the launch until the start of the next window on 30 November.

In the process of removing the cracked foam, technicians found two 9-inch cracks on either side of one of the ET intertank stringers. This exercise proved a decision that had been made early in T&R: to not release all of the engineering talent until after fly-out was complete. It cost money to keep the expertise around

[60] ET-94 was the only complete ET remaining after the final Space Shuttle mission and will be displayed at the Michoud Assembly Facility.

without much to do when everything was working well, but it was highly prized when things broke. Engineers developed a repair plan, but technicians found two additional cracks on an adjacent stringer while they were preparing the original area for repair. The additional repairs slipped the launch date to 3 December. However, engineers determined that more extensive analysis were required that would push the launch beyond the 3–7 December window. NASA management set a new launch date no earlier than 3 February 2011 to allow sufficient time to understand and correct the ET problem. Following a tanking test on 17 December, NASA rolled the vehicle back to the VAB for repairs on 22 December.

The last Space Shuttle stack was planned as the STS-335 LON mission in case the crew of STS-134 needed to be rescued. However, many within the Space Shuttle and ISS programs had always wanted to fly the mission as a final logistics flight to the Station. After all, most of the cost of the mission (hardware procurement, Orbiter processing) would have already been incurred just to get the vehicle ready as a possible LON mission. In 2010, Congress authorized the mission, although it had no appropriation in the NASA budget. On 20 January 2011, program managers changed STS-335 to STS-135 on the flight manifest to allow training and other mission-specific preparations to proceed. On 13 February 2011, Charles F. Bolden, the NASA Administrator, announced that the mission would fly. The mission carried the smallest crew (four) since STS-6 because there was no LON vehicle available and if anything happened, the crew would depend on Soyuz capsules to return home, one at a time, over the course of 10 months. All STS-135 crewmembers were custom-fitted for a Russian Sokol spacesuit and molded Soyuz seatliners for this possibility. The reduced crew size also allowed the mission to maximize the payload carried to the ISS.

CROSS-PROGRAM IMPACT

Large, complex organizations have a tendency to do a good job in establishing clear vertical lines of communications and reporting processes but a less than adequate job of horizontal communications. Space Shuttle transition and retirement made a conscious effort to overcome this tendency as a matter of necessity, and care was taken to establish cross-program management forums from the Shuttle element level and Center functional level through the Headquarters cross-directorate level. Shuttle transition and retirement impacted and created risks for the International Space Station, the Constellation Program, and Commercial Cargo and Crew Program in different ways, which is the focus of this section.

Impact on ISS

The retirement of Space Shuttle was a drastic blow to the International Space Station. Kirk A. Shireman, the ISS deputy program manager, remembers, "Our whole program was built around having a very small number of ORUs. The idea was to keep the depots up and if an ORU failed we would unhook it, place the spare in, fly the old one home on a shuttle, take it to the depot, and repair it. Then we would fly it back up and it would be a new spare." Many of the ORUs were large enough that Space Shuttle was the only vehicle capable of carrying them. In addition, without the Shuttle, the only available down mass was what little could fit in a Soyuz capsule, which was not much.[61]

The ISS program quickly discovered that since they were no longer going to be able to repair ORUs at the depots, they did not have enough spares. Ultimately, ISS had to procure additional spare ORUs, resulting in a several-billion-dollar hit to its budget. In addition, engineers found that "all our equipment was built to the shuttle environments and so we are today recertifying equipment every time we want to fly it on a SpaceX or Orbital or HTV [H-II Transfer Vehicle] or an ATV [Automated Transfer Vehicle]. We have to go do basically a delta certification on the box the first time to make sure it can withstand that environment." Other ORUs were simply too big to fit in a Dragon, HTV, or ATV. In these cases, the ISS program had to procure additional spares and launch them on a Space Shuttle prior to the final mission. Shireman remembers, "Now all of the sudden the Shuttle's not going to fly, so we needed to basically create an external spares warehouse. So we built five external logistic carriers [ELC] that could hold spares and some payloads and flew those up to ISS. We actually only flew three of those but we built five and in the end didn't have to fly the remaining two. So all that took budget; we had to have budget to build the ELCs, we had to have budget to build additional spares, we had to have budget basically to fly and put those spares outside, so that was a very significant line item."[62]

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61 Interview, Kirk A. Shireman by David M. Lengyel, 14 February 2013.
62 Interview, Kirk A. Shireman by David M. Lengyel, 14 February 2013.

Following the retirement of Space Shuttle, the ISS had to depend on Russian Soyuz capsules to transport crews to and from the Station. Here, the Soyuz TMA-03M spacecraft is lifted onto the launch pad at the Baikonur Cosmodrome in Kazakhstan (NASA/Carla Cioffi)

In addition, there was a hidden relationship between SSP and ISS. Shireman explains, "All of our cargo (the food and the water and all that) that was flying up and down on shuttle, we (ISS) were not carrying any budget for that; Space Shuttle Program had its own budget so we basically got the transportation costs of our cargo for free. Now in this new world, all of the sudden we have to contract that out with SpaceX and other companies. So we had a huge budget upper just for the transportation costs and as you guys know we signed about a $2.6 billion net contract between SpaceX and Orbital to fly cargo up through 2015. We'll have to sign another contract to carry us all the way out to 2020, so there are very definite and very large impacts to the ISS program as a result of Space Shuttle being retired."[63]

Then there was the entire issue of down mass. Space Shuttle was unique among spacecraft in that it could carry almost as much payload back to Earth as it took to orbit. Shireman began "encouraging all our payload and science customers to do everything without having any or extremely limited down-mass." Fortunately, as NASA began competing the commercial cargo contracts, SpaceX announced that it could accommodate a limited down mass on its Dragon capsule, "so that changed our thinking a little with

[63] Interview, Kirk A. Shireman by David M. Lengyel, 14 February 2013.

respect to scientific utilization payloads and also for some of our spares." That allowed NASA to back off slightly on the types and number of spare ORUs that it procured because now it was possible (in theory) for small items to be returned, repaired, and reflown.[64]

In addition to ORUs, the other major players that needed down mass were the life science investigators. Shireman remembers, "When we started doing this, one of the big uses of the down-mass was life sciences; they want samples of tissue and urine and saliva and other things. Tissue samples not only from humans but also from plants and ultimately from rodents, and all of these require cold. They take these samples, freeze them, and then they bring them home. So we started manufacturing these cold packs that keep the science cold for really, really long periods." Limited samples could be returned on Soyuz, but Dragon can accommodate powered freezers that allow much larger samples to be returned. Not as much as Space Shuttle, but vastly more than Soyuz.

Another issue was ISS crew size, which was limited after the *Columbia* accident and was based on the Soyuz capabilities. For the most part, NASA did not rotate crews using Space Shuttle, although there were a few ShRCs (Shuttle Rotating Crew Members). However, there was no longer the ability to swap out entire crews. The ISS was designed for a crew of seven, but Soyuz could only carry three people. Typically, there would be two Soyuz capsules docked at the ISS, meaning that six people could return home in an emergency; therefore, the ISS crew was limited to six persons. The ISS program expects that having a commercial crew capsule docked in addition to the two Soyuz capsules will allow the Station crew to expand to seven.[65]

As the Space Shuttle Program wound down, each mission began leaving excess material at the ISS, particularly food, laptop computers, and printers. It all made sense since the cost of procuring the items and transporting them into space had already been absorbed by the SSP, so it was essentially "free" to the ISS program.

One of the more daring ideas was to leave an Orbiter Boom Sensor System (OBSS) arm at the Station. After the *Columbia* accident, NASA had equipped each Orbiter with a 50-foot extension arm that the crew attached to the Shuttle Remote Manipulator System (SRMS) so that they could inspect the thermal protection system for damage. Kirk Shireman remembers, "After the issue with a torn solar array where we tore a solar array trying to redeploy it and we couldn't reach it, we used the shuttle boom that was really built to inspect the underside of the Orbiter. We actually used that boom, put an EVA crewmember on the end, and he went way out on the end of the solar array and sewed it up. We decided that we would really like to have one of those booms before you go away, so we worked out a plan with the SSP to leave one on station. It had very real impacts on the Space Shuttle Program since it prohibited them from doing a post-docked inspection of the Orbiter. It increased risk to the Orbiter to give us that boom. We didn't have

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64 Interview, Kirk A. Shireman by David M. Lengyel, 14 February 2013.
65 Interview, Kirk A. Shireman by David M. Lengyel, 14 February 2013.

concrete plans for using the boom; we just knew that one of these days we might need a 50-foot extension and there was one."[66]

The utility of having an OBSS available had already been demonstrated during STS-120 when the ISS's Canadarm2 had used *Discovery*'s OBSS as a platform to repair a damaged P6 solar array. In that instance, Canadarm2 grabbed the OBSS on its center grapple fixture and astronaut Scott E. Parazynski stood at the end of the boom to make the repair. The OBSS that was left on the ISS during STS-134 differed from the normal Space Shuttle OBSS in several ways, including the addition of a Power Data and Grapple Fixture that enabled the mating of the robotic arm on the end of the boom with a Canadarm2-compatible grapple fixture. *Endeavour* left her OBSS at the ISS at the end of the STS-134 mission.

The ISS program also inherited many players from the Space Shuttle Program. For instance, John C. Coggeshall had been the person in charge of the Space Shuttle manifest; now he is in charge of the ISS manifest. When Donald L. McCormack was finished managing the Orbiter ferry flights to the display sites, he moved to ISS. John P. Shannon left NASA but became the ISS program manager for Boeing. As Shireman remarks, "Lots of human capital has been shared between the SSP and the ISS."[67]

Planning for Commercial Cargo and Crew

Simultaneously with the retirement of the Space Shuttle, NASA began planning to use commercial services to resupply the ISS. On 23 December 2008, NASA announced it had awarded two contracts—one to Orbital Sciences Corporation of Dulles, Virginia, and one to Space Exploration Technologies (SpaceX) of Hawthorne, California—for commercial cargo resupply services. At the time of award, NASA ordered eight flights valued at $1.9B from Orbital and 12 flights valued at $1.6B from SpaceX. These fixed-price, indefinite delivery, indefinite quantity (IDIQ) contracts began on 1 January 2009 and are effective through 31 December 2016. The contracts called for the delivery of a minimum of 20 metric tons of cargo to the Space Station, and NASA set production milestones and reviews to monitor progress. The maximum potential value of each contract is about $3.1B, but based on known requirements, the value of both contracts combined was projected to be $3.5B.[68]

Kirk Shireman and his boss, Michael T. Sufferdini, were extremely nervous about counting on the commercial providers. Shireman remembers, "We were very nervous about them meeting the schedule they had signed up to and if you remember that schedule was pretty much right on top of when the Shuttle was

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66 Interview, Kirk A. Shireman by David M. Lengyel, 14 February 2013.
67 Interview, Kirk A. Shireman by David M. Lengyel, 14 February 2013.
68 "NASA Awards Space Station Commercial Resupply Services Contracts," NASA contract release C08-069, 23 December 2008.

going to retire. We were extremely nervous about that. We fought, together with our Shuttle Program friends, to add a flight [STS-135] and in the end we did."[69]

This was understandable since the commercial providers did not even fly a test flight until 2010, the year Space Shuttle was supposed to retire. SpaceX launched their first Falcon 9 and a boilerplate Dragon capsule on 4 June 2010. The first NASA flight, Commercial Orbital Demonstration Services (COTS) Demo Flight 1, took place on 8 December 2010, demonstrating the Dragon's multiple orbit capability, its ability to respond to ground commands, and the ability to communicate with the TDRS constellation. On 15 August 2011, SpaceX announced that NASA had combined the objectives of the second and third COTS Demo Flights into a single mission, with the COTS 3 validation tests beginning only if all of the COTS 2 objectives were successfully demonstrated first. SpaceX launched COTS Demo Flight 2+ on 22 May 2012. The mission successfully delivered cargo to the ISS and landed in the Pacific Ocean on 31 May, where the capsule was recovered, demonstrating its potential down mass capability. On 23 August 2012, NASA announced that the Agency had certified SpaceX to begin their CRS flights.[70]

Although the commercial cargo, and the commercial crew, efforts seem to be going well, the ISS program still has concerns. Shireman: "When the Shuttle was flying and we had a problem on the Shuttle we, NASA, but certainly the Space Station Program, knew exactly what was going on. We probably knew too much about any problem and were able to find out every detail about it. Now, we have these commercial guys and if they have a problem with their vehicle to some extent it's their problem. We aren't leading the investigation, we aren't telling them what to do; they're off doing it. We only get to control the operation when they're up close to the ISS; when they're far away from the ISS they're completely in control and they don't have to ask us anything. So there's been a fundamental shift in philosophy in how we operate vehicles. So that's a big deal."[71]

There are also a lot of different relationships. Shireman relates, "Back when it was just the Shuttle we had Europeans and Japanese and we had the Shuttle. Now we have European, Japanese, SpaceX, Orbital, Sierra Nevada, Commercial Crew Program, and there are a lot more players. So the interfaces for analysis and the amount of times we redo analysis are much greater than we ever imagined when we were first setting this up. We had planned our analysis budget to go down significantly, but instead we found that we have to redo the analysis much more often with these guys than we did with the shuttle just because the shuttle guys knew what they were doing and got everything right the first time or at worst the second time. These guys are changing all the time so the analysis has to be redone. They were slipping a lot in the years waiting for their first flight and it all had to be redone, so we ended up having to carry a larger analysis

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69 Interview, Kirk A. Shireman by David M. Lengyel, 14 February 2013.

70 "NASA Administrator Announces New Commercial Crew And Cargo Milestones," NASA news release, 23 August 2012; "NASA Commercial Orbital Transportation Services," located at: *http://www.nasa.gov/offices/c3po/about/c3po.html*.

71 Interview, Kirk A. Shireman by David M. Lengyel, 14 February 2013.

team." It is all part of the learning process, but it was an expense that the ISS program had not accounted for during their budget planning.[72]

The Europeans had long suggested that one of the Multi-Purpose Logistics Modules (MPLM) that Space Shuttle used to carry supplies to the ISS could be modified as a Permanent Multipurpose Module (PMM) to house spare parts and supplies. The Europeans estimated the costs for such MPLM modifications at $20M to $40M per unit, but NASA initially rejected the idea. However, as the ISS program further evaluated the need for additional spare parts to compensate for the lack of Space Shuttle resupply flights, the idea gained traction. On 5 August 2009, NASA announced that STS-133 would leave an MPLM permanently attached to the Station, and in October 2009, NASA confirmed that Leonardo would be the MPLM converted to a PMM.[73]

Shireman remembers that the last mission, STS-135, did "not have a LON flight so it was a fundamental shift in the [rescue] capability. It would take a bunch of cargo to protect us for the commercial guys slipping to the right. That was a huge benefit to the ISS. We're still living off the margin that was provided by that last Shuttle flight, so that was a huge benefit."[74]

Cancellation of Constellation

The FY11 President's Budget Request (PBR) on 1 February 2010 called for the cancellation of CxP and replacing the immediate development of new crew and launch systems (Orion and Ares, respectively) with a focus on generic technology investment. This direction obviously had significant implications for Space Shuttle retirement, since so many of the SSP's capabilities (including skilled workers, contracts, and property) were to be transferred from SSP to CxP once Space Shuttle operations were complete. Over the next nineteen months, there was a vigorous debate between the Obama Administration and Congress over this new direction, and particularly over the proposed cancellation of the Orion and Ares projects. So in addition to the uncertainty for SSP T&R planners over the SSP flight manifest, a new and even more significant uncertainty emerged—whether or not Space Shuttle would continue to transfer billions of dollars of assets to CxP or its successor as planned, or whether the vast majority of the Agency's material and intellectual investment in human space flight would be excessed for sale or scrap. Until this uncertainty was resolved, SSP was compelled to have detailed plans available to execute to either of these diametrically opposed scenarios.

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72 Interview, Kirk A. Shireman by David M. Lengyel, 14 February 2013.

73 Chris Gebhardt, "STS-133 refined to a five crew, one EVA mission—will leave MPLM on ISS," Spaceflight.com, 4 August 2009.

74 Interview, Kirk A. Shireman by David M. Lengyel, 14 February 2013.

It was a short-lived celebration. In 2007, officials hailed the transition of the KSC Operations and Checkout (O&C) building to Orion as a step toward the future of the Constellation Program. Barely three years later, Constellation would be cancelled, although Orion morphed from the Crew Exploration Vehicle (CEV) into the Multi-Purpose Crew Vehicle (MPCV). (NASA)

Immediately after the PBR was released, officials in ESMD established the CxT Study Team chartered to define a timeframe, philosophy, and process to terminate the CxP. The direction included a focus on rapidity and cost effectiveness to preserve maximum resources for future investment in the new exploration initiatives. In addition, NASA established seven other senior study teams to outline plans for exploration-related planning initiatives described in the FY11 PBR and to assess workforce, facilities, procurement, and other issues to ensure that people and facilities were best used to meet the needs of the new missions. The teams included: Heavy Lift and Propulsion Technology, Commercial Crew and Cargo, Exploration Robotic Precursors, Flagship Technology Demonstrations, Enabling Technology Development and Demonstration, 21st Century Launch Complex, and Space Technology.[75]

[75] "Constellation Transition Plan," revision 3, undated but sometime in late 2010.

The CxP cancellation was different from the SSP T&R efforts in that SSP had planned for the closeout of the program for several years. The CxP cancellation resulted in a much more immediate near-term impact and had a serious effect on the civil servant, contractor, and support contractor communities. One of the primary efforts of the CxT was to determine how to transition assets, knowledge, and resources to new exploration initiatives, other NASA elements, or other Federal entities. Ironically, the FY11 PBR provided $1.9B for CxP transition and closeout in FY11 and $600M in FY12, substantially more than SSP was receiving. To maximize efficiency, the CxP transition effort leveraged the SSP T&R framework and processes, including using existing SSP facility databases and property inventories where possible.

The CxT faced many of the same issues the Space Shuttle Program initially faced, with the added complication of not having a new program to transition assets to (a problem that also affected SSP after CxP went away). One of the primary focus areas was the identification of the scope of the Agency civil service and contractor workforce that would be affected by CxP cancellation. This included collecting data associated with the affected workforce (civil servant and contractor: numbers, skills, locations, etc.); identifying issues associated with the cancellation (policies, practices, employee assistance, community coordination, etc.); identifying areas of crossover impacts to other elements of the Agency; and the evolving interactive workforce allocation, planning, and assignment activities for the new exploration initiative and other NASA mission areas.

The CxT also had to address each of the Constellation-related facilities that were under construction to recommend proceeding with construction, stopping at a prudent safe point, "graceful" termination, or ceasing at the current condition. This is one area that greatly impacted the SSP and the Centers since CxP essentially cancelled the transition of former SSP facilities, forcing the SSP and the Centers to take other actions to safe and close the facilities.

Similarly, approximately half of the SSP personal property had been marked to transition to CxP, and with the cancellation came the need for SSP and the Centers to dispose of the property in other ways (usually through GSA excess). At the time of the cancellation, essentially no personal property had actually been transferred since SSP was still flying-out its manifest. As of 29 October 2009, the amount of personal property requested by CxP had totaled 431,851 line items out of the SSP inventory of more than one million line items.

Shuttle Hardware	Project/ Element	Total Line Items	Line Items Requested	% Requested	Line Items Not Requested	% Not Requested	Line Items Pending	% Pending
RSRM	Ares FS	201704	182394	90%	19310	10%	0	0%
SRB	Ares FS, GO	56426	37237	66%	19189	34%	0	0%
*ET Tooling	Ares V/US	7757	56	1%	7414	96%	287	4%
ET O&M Equipment	MSFOC	94203	94203	100%	0	0%	0	0%
MSFC SSME	USE	131000	584	0%	130416	100%	0	0%
SSC SSME Test	USE	7840	6549	84%	1291	16%	0	0%
**Integrated Logistics - GFAC +~6K NSLD	GO	112000	25	0%	0	0%	111975	100%
Ground Ops Equipment	GO	24573	9223	38%	15350	62%	0	0%
Orbiter Element	Orion	71000	0	0%	71000	100%	0	0%
***Integrated Logistics - Orbiter	Orion	166000	4980	3%	161020	97%	0	0%
Flight Crew Equipment	ISSP	115000	96600	84%	18400	16%	0	0%
White Sands Test Facility	Orion	13000	0	0%	13000	100%	0	0%
Orbiter Project Offi ce MAF Items	Orion	32000	0	0%	32000	100%	0	0%
Total		1032503	431851	42%	488390	47%	112262	11%

A similar dilemma affected the IT world, where many SSP systems now needed to be turned off rather than transitioned to Constellation. That was the same for records management. All of this was complicated by the potential need to transition some of this material to the Orion MPCV and SLS programs, although their requirements were largely unknown and would probably remain so during the period of SSP T&R.

Then there were concerns about the NASA industrial base (which also, to some degree, affected the Air Force). The industrial base was being negatively affected as the Space Shuttle Program wound down and contracts were closed. The financial pressures on contractors intensified with the termination of CxP, resulting in a major loss of skills, capabilities, product offerings, and suppliers, as suppliers either diversified into other markets or went out of business altogether. The CxT feared that this could have a major impact on the cost, schedule, product quality, and the ability to execute on future and current Government space programs, some of which are vital to national security. Moreover, in some instances, it could also have a similar impact on the commercial space providers on which NASA is now depending to provide services in place of CxP. Some of these capabilities could take years and a significant amount of capital to reconstitute if required.

For example, a 2009 report to Congress on the solid rocket motor industry by the Office of the Deputy Under Secretary of Defense for Industrial Policy reported a case in which the loss of one lower tier supplier would have cost the Government more than $100M and resulted in several years of schedule delays. Although NASA accounts for less than 20 percent of the domestic space market, it accounts for approximately 66 percent of the Government R&D funding for the space industrial base. With the cancellation of both SSP and CxP, this left little R&D funding flowing into the space industry.[76]

[76] "Defense Industrial Base Assessment: U.S. Space Industry Final Report," Air Force Research Laboratory, August 2007; "Solid Rocket Motor Industrial Capabilities Report to Congress," Office of the Deputy Under Secretary of Defense for Industrial Policy, March 2009.

HUMAN CAPITAL

For anyone who attended the Space Shuttle Program Top Risk Reviews from 2008 through mid-2011, an obvious contributor to the risk posture of the program was a family of human capital risks. These were divided into the two parent categories of civil servants and contractors and sub-divided into children risks by program element (e.g., Orbiter, External Tank, Solid Rocket Booster, and so on). The overarching goal of the program was to safely fly out the Space Shuttle manifest, which required keeping the requisite skills onboard until that was accomplished. This section provides the story on how that was accomplished successfully and provides a template for program managers and human capital specialists for the future.

Initial Planning

In early 2005, the ISOS Transition Panel had concluded, "The phaseout of a major NASA program has enormous implications for the workforce. If not executed properly, morale and possibly mission success may suffer. In addition, the loss of intellectual capital and increased training costs will make it difficult for the Agency to retain its core capabilities and competencies. Finally, increased cost in terms of unmanaged attrition, reductions in force, buy-outs, and the acquisition of contingent workers will take their toll on the total Agency resources."[77]

At the time, the Space Shuttle Program employed the "equivalent" of 2,300 civil servants, 15,000 contractors, and 35,000 subcontractors and vendors. NASA and some of its contractors use a "matrix" form of management: employees are organized by technical skills and assigned to work on programs and projects. As a result, the actual number of employees who worked on the SSP full- or part-time was much higher. Of the civil servants, 870 worked at JSC; 523 at MSFC; 469 at KSC; 81 at Langley; 29 at Stennis; and 50 were spread between Ames, Dryden, Glenn, and Goddard.[78]

Based on the Transition Panel recommendation and their needs, the Space Shuttle Program had two primary goals for human capital:

- Maintain a capable and committed civil service and contractor workforce for mission execution and retirement.
- Manage the people transition process in a way that balanced organizational and employee needs.

To accomplish this, the program and projects needed to identify mission-critical skills and the number of positions needed for mission execution, develop a workforce profile by project element, and then define retention and transition initiatives. The SSP Human Capital Management Plan would guide all of this. This plan focused specifically on the overarching strategies that the Space Shuttle Program would use to ensure the retention of critical skills to fly-out the manifest. It also provided direction for the smooth transition of

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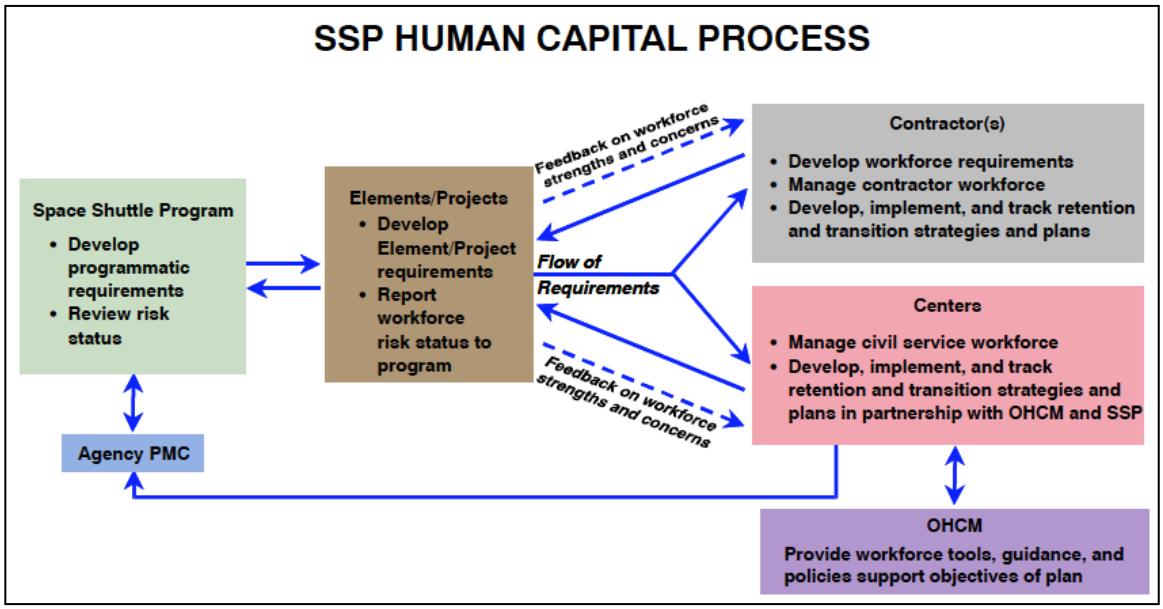
77 "ISOS Space Shuttle Program Transition Panel Final Report," 15 April 2005.

78 "Transition Planning and Strategy Meeting," MSFC Institute (Intergraph Building), 3–5 August 2005.

SSP skills, as appropriate, to the Constellation, International Space Station, and other NASA programs.[79] The diagram below depicts the approach laid out in the SSP Human Capital Plan and the relationship between the projects/elements and their contractors and the supporting NASA Centers.



Ultimately, each NASA Center and prime contractor developed their own human capital plans focused on identifying and monitoring the critical skills needed to fly-out the program, developing a retention plan for those critical skills, and developing a workforce transition plan when the Shuttle work was complete. The SSP projects and contractors and NASA Centers worked together to develop appropriate metrics and measures on the effectiveness of the retention and transition strategies. Keeping personnel up-to-date on the status of their work, benefits, entitlements, and follow-on employment opportunities was an essential element of successful mission execution and transition.

Human Capital

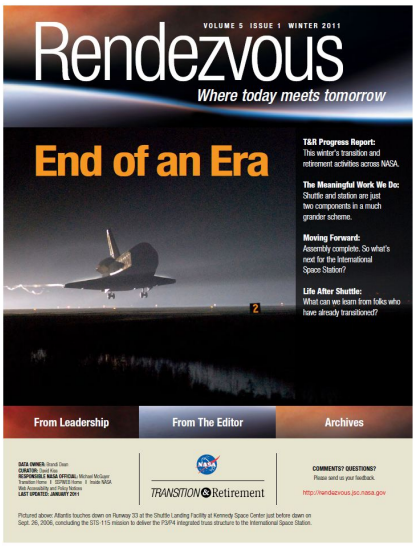
"I think that our top lesson learned was really communicate, communicate, communicate—the right information and in a consistent manner."

Perhaps the most meaningful lesson learned from the Titan IV closeout was about people. Sue Leibert, the Shuttle Lead for Human Capital, remembers, "We spent a fair amount of time benchmarking the Titan Program and one of our key takeaways was all about communication and retention. They had some accidents or incidents, if you will, as they were closing down the program and they realized that part of that was because their folks were distracted. So they took a step back and did a fair amount of work involving: one, communication; two, making people feel comfortable that they would be taken care of at the end of the process; three, help people recognize that they were still valued in the process even though the program

[79] "Space Shuttle Program Transition Management Plan," NSTS-60576, 5 August 2010.

was going away. That was a huge takeaway for us."[80]

The early message was relatively simple: there is a future and it is called Constellation (later, Exploration). Ashley K. Edwards developed the messaging plan, which included a glossy magazine, called *Rendezvous*, that later became a web-based magazine. Leibert remembers, "She had tons of tools; she developed just some amazing things on the web." Leibert and Edwards worked with the major contractors to ensure consistent messages were reaching all employees—contractors and civil servants. Nevertheless, there were necessary differences between civil servants and contractors. Leibert recognized this and "tried to use all the different options that we could recognizing that our audiences were different. What you needed to communicate and what was important to some of the contractors that knew they were going to be laid off versus the contractors that might not be laid off versus the civil servants that knew they would not be laid off; those are all very similar but there are some key differences in that process."[81]



NASA's Rendezvous *magazine cover, Volume 5, Issue 1, Winter 2011*

Civil Servants

One early concern was the retention of critical skills. Although this was more of an issue for the contractors, since the workforce was fairly mobile and frequently moved between companies, it was still a minor concern for the civil servants. The ISOS Transition Panel had noted, "Downsizing strategically while maintaining critical competencies for mission safety and success is difficult."

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80 Interview, Sue Leibert by J. Steven Newman, 5 February 2013.
81 Interview, Sue Leibert by J. Steven Newman, 5 February 2013.

In 2005, one of the Strategic Asset Management Working Group splinter teams, co-chaired by Michelle Kelly at KSC and Sue Leibert at JSC, considered offering retention bonuses to a very small number of key civil servants. These incentives would be targeted to specific individuals who had unusually high or unique qualifications and were likely to leave the Agency without the allowance. The incentive could be up to 25 percent of base pay for individuals and up to 25 percent of base pay for groups. As it turned out, this incentive program was not needed and was never executed.[82]

This splinter group evolved into the Shuttle Human Capital Working Group (HCWG), comprised of human resources specialists and program representatives from NASA Headquarters and Centers. Later, the Group expanded to include representatives from the contractor community. The purpose of the HCWG was the following:

- Share information on the Space Shuttle Program. For example, the SSP manifest changed toward the end of the program—NASA added flights and had to change launch dates due to technical issues.
- Share information on the Constellation Program. The path to future work and positions was a key tenant of all of the retention plans (more for some organizations, less for others). The proposed cancellation of the Constellation Program had the potential to greatly affect those retention plans—and information flow was critical.
- Share issues and potential solutions among the Centers and contractors. For example, organizations shared their approaches to educating and equipping supervisors to help employees before and during the layoff process.
- Share best practices and lessons learned. A number of classes and ideas were shared across the Centers and contractor organizations, including a program based on the book *Love 'Em or Lose 'Em,* successful partnerships with community support organizations, and use of web sites for two-way communication.

Although the focus was on wanting to retain critical personnel, the ISOS Transition Panel worried about how to reduce the overall size of the civil service workforce. The final report noted, "While some attrition is expected and normally planned for in the operation of multiyear programs, this attrition pattern for the entire Agency workforce alone will not reduce the SSP workforce in a natural manner between 2005 and projected program completion. The option of buy-outs and early retirements for the civil service workforce to deal with phase out/fly-out of a major program such as SSP…is not without its own costs." In the end, buyouts and early outs did prove to be effective tools to resize the workforce after the SSP was complete. Civil service attrition was exceptionally low for those working on the SSP and gradually increased after the last flight in July 2011.

To help with workforce planning and individual employee transition, the Agency conducted "employee mapping" exercises—essentially mapping how skills and competencies would transition from Space Shuttle to Constellation. The Agency knew that the new program would not need some Space Shuttle

[82] "Transition Planning and Strategy Meeting," MSFC Institute (Intergraph Building), 3–5 August 2005.

skills—for instance, there was no landing gear on the new capsule. Other skills had a clear path from one program to another, and some skills would transition but might require training or an expanding of the skill set. The mapping exercise not only helped with the skill transfer but also helped identify potential excesses or shortages of skills.

To further expand the workforce toolset, President George W. Bush signed the NASA Workforce Flexibilities Act that provided new flexibility for recruiting and retention for NASA's highly skilled workforce. In addition, many of these tools could be used to make it easier for the Agency to reassign or redistribute the workforce. For example, qualifications pay and relocation incentives could be used to encourage the movement of employees to new positions or Centers where they were most needed, either to maintain safe and reliable operations of the SSP or to support future work. The act also provided some additional flexibility to reshape the workforce in terms of technical skills needed for future missions and dealing with excess capacity at some Centers over the long term.[83]

Lastly, as mentioned earlier, the Agency and SSP focused on letting employees know about NASA's future work, how the Agency planned to work the transition, and about tools and options open to them to manage their own transition. In addition, the SSP wanted to hear from the employees about their plans, concerns, and suggestions. So, starting in 2006, the Program conducted an annual survey of the civil servant employees at KSC, JSC, MSFC, and SSC asking employees about their intent to stay with the program until the end, their perception of the quality and quantity of communication, what influenced them to stay, and their suggestions and concerns. Most importantly, the survey gave employees a voice on what was working or not working; their concerns, perceptions, and suggestions; and their intent to stay with the program until the end.

Contractors

By 2006, NASA was working with the contractors to develop incentive programs to retain critical skills for the Space Shuttle fly-out. This was a major issue at Lockheed Martin, since the External Tank work would end early, and at United Space Alliance, where it was recognized that Constellation would never be as large as the Space Shuttle Program at its peak. This was less of an issue at ATK and Pratt & Whitney, both of which saw the development effort for the Ares launch vehicles happening early and meshing nicely with the downturn in Space Shuttle work.[84] However, with the changes in the Constellation Program and the eventual cancellation of the Program, all of the SSP prime contractors and most of the sub- and support contractors were affected.

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83 2004 NASA Workforce Flexibilities Act.

84 Interview, Sue Leibert by J. Steven Newman, 5 February 2013.

Lockheed Martin Space Systems (External Tank)

At Lockheed Martin Space Systems in Michoud, Cheryl Alexander was the Director of Human Resources. External Tank manufacturing was one of the early closeout casualties because the tanks needed to be ready well in advance of their scheduled mission. One of the first tasks was identifying the people that were needed to fly-out the manifest. Alexander remembers, "We developed the skills first, determined who was best to perform these skills, then what rewards and recognition we were going to provide our employees." While this was happening, Alexander began meeting with her counterparts on the Titan IV Program to see how they dealt with the Titan closeout.[85]

The closeout at Michoud was complicated by having to simultaneously deal with recovering from Hurricane Katrina, which had devastated many areas around Michoud and caused major damage to the facility. Alexander remembers, "We were really gauging the climate in the post-Katrina environment. We continued to address needs and concerns because we had employees that were back working, but their home was not up and running. We had employees doubling up with employees who maybe had a home to stay with them. So it became a really close knit group of employees."[86]

The State of Louisiana set up placement services for Lockheed Martin employees (in a facility across the street from the main plant) and contributed $500,000 for retraining. The City of New Orleans also set up on-site offices to help place employees. Lockheed Martin, the city and state, and other companies held job fairs on site. Lockheed was a large company and many employees opted to transfer to other locations and programs. Some decided to support fly-out and then retire. Others found new jobs or careers in different industries in the local area.[87]

Lockheed offered a severance package—1 week of severance pay per year of service, up to 26 weeks. The Lockheed plan was based on milestone bonuses that were accrued by the covered workforce each time an External Tank was delivered or there was a successful launch and landing. Each milestone was worth approximately $900 but was paid only when employees were laid off (it was forfeited if the person transferred to another Lockheed Martin position). Of the approximately 2,100 employees, roughly 15 percent forfeited their bonuses for one reason or another. There was also a smaller group of employees, around 10 percent of the total, that were considered critical, and they had an additional bonus program if they stayed through the end of closeout.[88]

Because their draw down was first among the NASA contractors and compounded by the impacts of Katrina, Lockheed Martin was the "fleet leader" for many of the retention, transition, and closeout

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85 Interview, Cheryl Alexander and Sherri K. Lee by J. Steven Newman, 21 February 2013.
86 Interview, Cheryl Alexander and Sherri K. Lee by J. Steven Newman, 21 February 2013.
87 Interview, Cheryl Alexander and Sherri K. Lee by J. Steven Newman, 21 February 2013.
88 Interview, Cheryl Alexander and Sherri K. Lee by J. Steven Newman, 21 February 2013.

activities. They implemented a program based on the book *Love 'Em or Lose 'Em* initially to retain employees after Hurricane Katrina and later to help with retention and transition at the end of the Shuttle Program. Alexander and her staff developed extensive training to help employees understand their benefits and entitlements when their employment ended, such as company benefits, benefits from the state or Federal governments, what happened to defined benefit plans and 401k defined contribution pension plans, and what retraining and job location assistance was available. In addition, they developed training specifically for supervisors on how to help employees go through the layoff process. And when the time came, Alexander and her staff ensured that Lockheed Martin recognized their employees for their contributions to the External Tank Project and the Space Shuttle Program and helped the employees leave with dignity.

Alexander and her staff were the first to be able to share lessons learned and best practices with the rest of the Space Shuttle Program and Human Resources Communities. Many of their programs and approaches were successfully transferred to other contractor and civil servant organizations.

United Space Alliance

At the time, USA policy was not particularly set up to deal with mass layoffs. The policy included two weeks of severance pay for relatively new employees or four weeks for people who had been with the company/program for a long time. The policy also included only two weeks of notice, although the Worked Adjustment and Retraining Notification (WARN) act would trump this. Lee remembers, "We started a plan, not only were we going to give a notice, but we were going to expand our severance policy to equate to one week of pay for every year that you had in credited service up to 26 weeks. So that's one thing we did and that was for the whole population and the intent of that was to allow people time, if they were laid off, to find another job before they were very panicked financially." In this case, "credited service" could mean time with USA, credited time with one of the heritage companies (Boeing, Lockheed, or Rockwell), or, especially at KSC, "site seniority" that included time with other companies performing the same task at KSC. These changes, of course, required approval from the NASA contracting officer, since ultimately the Government, not USA, would be paying the bill. One of the conditions that the Government placed on paying the severance was that it would be paid in 10-week increments and only if the person was not employed with another NASA contractor within a 50-mile radius of their last employment location. Reasonably, the Agency did not want to be paying for somebody twice: as a working employee and as a laid-off employee receiving severance.

Sherri K. Lee was the Director of Human Resources for USA in Houston and, beginning in 2007, began benchmarking other companies to determine how they had handled a large closeout. Lee remembers that even while this was ongoing, the company started the

Human Capital

"You shouldn't underestimate how emotional it's going to be, not just for the employees but for yourself."

Love Em or Lose 'Em program, in which a manager met with every employee twice per year to determine "where they were, what they were willing to do for us, what their career objectives were, and what we could do to make the environment better." The company also began working closely with Sue Leibert at NASA.[89]

It should be pointed out that, at the time, USA was still actively bidding on new work and expected to be a viable company well into the future. There was little doubt that the company would be smaller, perhaps with a different skill set, but there would still be a USA. It was not until several years later that Boeing and Lockheed Martin decided USA would go away when the Space Shuttle Program ended. The following year, USA began working with the Florida and Texas workforce commissions. The Texas commission opened an office within the USA facility, and USA ensured that its subcontractors also had access to the services. USA developed transition training that consisted of a three-hour session that was half on work time and half off work time, since the company felt it could benefit the employees personally with their planning. All employees were invited to attend, but first preference went to anyone who was at risk for a pending layoff within the next six months. The class discussed benefits from the company, benefits from the state or Federal governments, what happened to pensions and 401k plans, and what retraining and job location assistance was available. Simultaneously, USA trained the entire management team to answer questions and communicate more effectively.[90]

[89] Interview, Cheryl Alexander and Sherri K. Lee by J. Steven Newman, 21 February 2013.
[90] Interview, Cheryl Alexander and Sherri K. Lee by J. Steven Newman, 21 February 2013.

At KSC, Rep. Suzanne Kosmas of Florida talks to the media and community leaders about the $15 million Florida will receive from the Labor Department's National Emergency Grant Program to assist workers after the retirement of the Space Shuttle Program. The grant money, which was awarded to the Brevard Workforce Development Board, would be used for job recruiting, screening, education, and training, as well as incentives for new growth in science, technology, and research. (NASA/Kim Shiflett)

In Florida and in Texas, all of the contractors worked closely with the local workforce boards and commissions to provide job-seeking assistance—including retraining, interviewing and résumé-writing skills, job fairs, individual counseling, and access to computers and resources. This allowed the contractors to focus on company-specific training and assistance while still providing employees with a wide range of services and support.

For the largest Space Shuttle Program contractor, skills retention was critical. USA implemented a couple of measures to motivate people to stay until they were no longer needed. In the end, the company offered up to 15 weeks of pay for specific people to stay through the end of fly-out. As a side note, the specific details of the retention bonus caused some problems for closedown activities, since it expired nine months after final wheels-stop. Many employees felt that they should be laid off regardless of whether there was a continuing need for them or not, which was problematic because closed down activities lasted almost two years after final wheels stop. USA management tried to assure each person that if they stayed and became ineligible for their bonus, they would not be laid off for at least 15 weeks, essentially providing the same

monetary compensation, but many folks were still upset, feeling they had "missed out" on a bonus that had been promised to them.

It was a lesson to use milestones instead of a calendar. Sue Leibert remembers, "We had one instance where the contract…was supposed to end in 2010. We knew that you have to plan for some contingency but we ended up in a situation where, I think, one of the contracts was ending and we tied the payout to the end of the contract, where in hindsight I wish we would have tied it to the end of the program." The Titan model was much better, as it was structured as a milestone completion bonus.[91]

Because of the size of the layoffs, USA was required to provide 60-days notice under the WARN act, but the company committed to providing even more notice of impending layoffs. In addition, the company offered opportunities for employees to "self-nominate" for layoffs (they could not "volunteer," since that eliminated many government benefits). Management used these "self-noms" for information but could accept or reject them as operational requirements dictated.[92]

Interestingly, the WARN notices ended up being very helpful in retaining skills. With the employees given so much advance notice of the layoff, there was less stress and anxiety than there would have been with only two-weeks' notice. This allowed employees time to pursue future employment and still remain with T&R for as long as they could. USA provided an internal charge number that allowed employees who had received WARN notices the opportunity to attend some training (on how to write a good résumé, for instance), job fairs, and other activities partially on company time.

The WARN regulations also provided USA with flexibility in instances where a notice had been issued but circumstances changed and the company needed the employee longer; the company was able to extend the layoff date or withdraw the WARN for reissue at a later date.

Early on, USA formed the Workforce Planning Council, made up of executive management and other key personnel, to talk about workforce retention issues and plan appropriate future layoff dates. Toward the end of the Shuttle Program, the situation at KSC, in particular, was fluid. One of the potential contracts was cancelled, which left KSC without a contractor to maintain the ground support equipment after SSP operations ceased. Pending the award of the future operations contract, KSC initiated a modification to the USA contract that funded roughly 300 engineers and technicians to maintain the ground support equipment. This postponed that many layoffs and increased the likelihood that those individuals would be picked up by the eventual follow-on contract.

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91 Interview, Cheryl Alexander and Sherri K. Lee by J. Steven Newman, 21 February 2013; Interview, Sue Leibert by J. Steven Newman, 5 February 2013.

92 Interview, Cheryl Alexander and Sherri K. Lee by J. Steven Newman, 21 February 2013.

Job fairs, such as this one in Cape Canaveral, were used extensively at all of the NASA Centers to help employees with future planning and placement as the Space Shuttle Program came to an end. Recruiters included Federal, state, and local government agencies and organizations, as well as private companies from across the country. (NASA/Jack Pfaller)

During the final year of fly-out, and into T&R, USA significantly increased the amount of communications from senior management, including the use of web sites and blogs. Lee remembers, "That was risky for us. We had never had a blog. We also allowed people to post anonymously. Also a little risky because people will say things when they're anonymous that they wouldn't necessarily say when you have to put your name on it, but we took that chance. We wanted to make sure employees knew that we were willing to answer really difficult questions and, to this day, we still have the blog and we're still continuing to answer those questions."[93]

Sue Leibert at NASA thought the blog was "very helpful for them (USA) and they were good enough to share that with us [NASA] and it was helpful for us as a program. They asked senior USA managers to write a column: it might be on changing benefits, it might be on the future, it might be on business practices for United Space Alliance. Then they allowed their folks to comment and what was very interesting in that process was how, in general, positive people were."[94]

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93 Interview, Cheryl Alexander and Sherri K. Lee by J. Steven Newman, 21 February 2013.
94 Interview, Sue Leibert by J. Steven Newman, 5 February 2013.

Pratt & Whitney Rocketdyne (PWR)

The most unique feature of the PWR human capital effort was the multiple locations and contract mechanisms involved. Although PWR was based out of Canoga Park, California, they also had workforce located in West Palm Beach, Florida, Stennis Space Center in Mississippi, and at Kennedy Space Center in Florida. Additionally, the workforce at KSC was comprised of employees who worked directly on the PWR prime contract and employees who worked on a subcontract to USA. While PWR wanted to use the same retention plan for all of its employees, USA wanted the employees who worked on their subcontract to have a retention plan that more closely aligned with the USA plan. Ultimately, the companies worked it out and the employees were covered by a retention plan. In the beginning of Shuttle transition, PWR clearly had work and workforce that would transition from Shuttle to Constellation. Over time, the gap between the programs shifted to the point that Shuttle employees would not be able to transition to the new program. As a result, PWR increased communication to explain the changing circumstances to the employees. In addition, they offered training targeted to help supervisors manage during challenging times—focusing on how to help managers help employees who would be laid off. Further, PWR offered training for employees who would be laid off on benefits, community services, and general job-seeking skills.

Alliant Techsystems (ATK)

ATK had a different set of challenges from the other prime contractors. Originally, their employees had a direct path from Shuttle to the Constellation Program, although there was a concern about timing between the programs. In addition, the ATK workforce was highly matrixed, so most employees worked on multiple programs, which helped with workforce transition in the beginning. Over time however, the gap between programs widened and deepened until Constellation, the follow-on program, was proposed for cancellation. In addition, ATK's work on the Minute Man Program was finishing up. Essentially, the direct path to future work was gone for most employees. Due to the nature of the solid rocket motors, ATK's facilities were very remote from other industry, creating additional challenges for workforce transition. To retain their critical skills, ATK proposed to the Project Manager that ATK would focus on the 10% of the workforce most critical to flying out the Space Shuttle Program and to the transition and retirement work that would follow the last flight. ATK's retention plan was a percent of pay for a specific group, which would be paid out when the employee's Shuttle work was complete. In addition, similar to the other contractors, ATK had a healthy severance policy, focused on increased communication, and worked closely with the community on job fairs and other transition assistance.

Subcontractors

A number of the subcontractors also choose to use retention plans. These subcontractors typically provided a specialized service to the Space Shuttle Program with unique technical skills that could not be easily replaced. In most circumstances, the employees knew they would not have follow-on work in the new

Program and typically received only 2 or 4 weeks of severance pay. To help these employees feel comfortable staying until the end of the program, the contractor management worked with the projects/elements to increase the "safety net" for the employees. This was a mix of milestone payments or longevity bonuses (earned but not paid until the employee was laid off), increased severance coverage, or retention bonus based on pay.

It is interesting to note that each of the four major SSP contractors implemented retention in a different fashion. USA used a pool of money that would be split among all eligible employees based on who was let go within 9 months of the end of the last Shuttle flight. Lockheed Martin, because of the situation in the New Orleans area following Katrina, needed to use retention pay for both direct and indirect (overhead) employees and based their payouts on events such as External Tank deliveries and launches. ATK provided retention only for a very small group of direct employees who had no potential for follow-on work with the company and were critical to the company meeting their Space Shuttle Program commitments. Lastly, the PWR retention program targeted all critical and essential employees, regardless of whether they were targeted to be laid off after the program ended.

Ultimately, the major Space Shuttle contractors laid off 9,800 people: 6,700 from USA, 1,300 from ATK, 880 from Lockheed Martin (ET), 620 from Pratt & Whitney Rocketdyne, and 300 from Lockheed Martin's Facilities Development & Operations Contract (FDOC). This total was approximately 2,800 more people than had been expected two years earlier, mostly reflecting the cancellation of the Constellation Program. NASA reimbursed the contractors $454M for severance and retention, an increase of $36M from the earlier estimates.

How successful were these retention efforts? John Shannon, the Space Shuttle Program Manager, noted, "There were no workforce issues (civil servant or contractor) that affected the safe fly out of the Shuttle Program and when you lay off nearly 10,000 employees across the country…that's extraordinary." The contractor and civil service employees' commitment to the Shuttle Program was remarkable. "In many cases, the employees wanted to stay until the last flight…we just had to find a way to make them feel comfortable with that decision," Shannon reflected.[95]

Space Shuttle Transition Liaison Office

In 2009, NASA established the Space Shuttle Transition Liaison Office (SSTLO) in response to direction in the NASA Authorization Act of 2008 (P.L. 110-422), and the office will continue until July 2013. The Agency was directed to assist local communities affected by the termination of the Space Shuttle Program by offering nonfinancial, technical assistance to the identified communities and to identify services available from other Federal, state, and local agencies to assist in such mitigation. Essentially, the Office

[95] Interview, John Shannon by David M. Lengyel, 11 January 2012.

served as a clearinghouse by gathering and disseminating information to the affected communities about opportunities available through other Federal, state, and local agencies; it served as a key point of contact for the community beyond NASA for information about how the Agency is working with local communities to provide nonfinancial, technical assistance during transition.

At the early meetings, Leibert remembers senior NASA Transition Managers speaking about the current status of NASA Programs and activities, the states of Florida and Louisiana sharing their best practices, and the SSTLO sharing information on available and proposed Recovery Act grants. Participants at the meetings came from a number of organizations, including NASA Headquarters, the NASA Human Space Flight Centers, Shuttle prime contractors, and state and local workforce and economic development organizations in communities affected by Shuttle retirement.

To help the communities affected by Shuttle retirement, the SSTLO worked with other Federal agencies, including the Employment and Training Administration and the Office of Faith-Based and Neighborhood Partnerships, Department of Labor; Economic Development Administration, Department of Commerce; the Office of Economic Adjustment, Department of Defense; the Manufacturing Extension Partnership at the National Institute of Standards and Technology, Small Business Administration, Office of Personnel Management; and the Presidential Task Force charged with assisting Florida with economic plans as a result of the impacts of the retirement of the Space Shuttle Program. And all meetings included best practices from the workforce boards and economic development organizations across the affected communities.

Sue Leibert remembers, "we ended up coming together and they would talk about what programs they had and what they needed from us and they would talk about what they were offering so that the contractors didn't duplicate what was already being done in the community. They didn't need to do all of the training because it was there in the community and it was very effective. So a lot of it was trying to get people linked up to the right resources and knowing what each other had and coming together as a team, and that was hugely effective."[96]

[96] Interview, Suzanne B. Leibert by J. Steven Newman, 5 February 2013.

T&R EXECUTION

Transition and retirement execution benefitted from a disciplined approach to planning. During the execution period, standard program management processes such as continuous risk management were implemented. The top risks in the system were not technical but were cost-related and dealt with the question, can we closeout this program on budget? This section outlines the key execution activities performed during this timeframe.

The Players

During the final fly-out of the Space Shuttle Program, NASA began closing-out the production contracts with ATK (RSRM), Lockheed Martin (ET), and Pratt & Whitney Rocketdyne (SSME and Alternate Turbopump). In reality, NASA rescoped the ATK and Pratt & Whitney Rocketdyne contracts for use by the SLS but, from the perspective of the Space Shuttle Program, the results were largely the same.

Execution

"When you're at headquarters, your center of gravity is not in execution, it's in planning and policy and requirements."

On the NASA side, Dorothy S. Rasco was the program manager for the Space Shuttle Program, with Dennis R. Davidson as her deputy and Kevin C. Templin as the transition integration manager. Krystine O. Bui was the NASA contracting officer (CO) at JSC responsible for the SPOC effort, and Frank C. Lin was the SPOC contract officer's technical representative (COTR) responsible for the technical direction to USA. Because of the scope of the effort, he delegated responsibilities to a set of technical management representatives (TMR). George W. Jacobs was the Launch & Landing TMR at KSC; Jill D. Lin was the Orbiter TMR (including Flight Crew Equipment and Logistics) at JSC; Michael D. Allen, and later Jeffery L. McCaleb, was the SRB TMR; and Patrick J. Cullen was the TMR for the business management office. It should be noted that this TMR structure was greatly simplified from the 13 separate TMRs that existed during operations. Jonathan M. Krezel led the T&R effort within the SOMD at Headquarters.[97]

For T&R, Frank Lin was a new COTR, having only recently taken over the SPOC contract from Richard A. Schmidgall, who went to manage the Lockheed Martin Orion MPCV contract. Lin agrees that, "from a lessons learned perspective, it is obviously preferable to have the same COTR that was in the operational contract to follow through with the closeout contract for a couple of reasons. First of all, a lot of the work that we are doing in closeout, it's related with what happened back in the days of operations. A lot of things that we are now dealing with are decisions that were made during operations by the COs [contracting officers] at the time, or by the COTR at the time. So it does make things easier from the standpoint of doing

[97] Interview, Frank Lin by David M. Lengyel, 13 February 2013.

that work if I would have had all the knowledge that Rick had. In my particular case it wasn't as critical because, as the TMR for the Orbiter beforehand, I had a basic idea of how SPOC was run already."[98]

The original SPOC statement of work had not included any T&R activities, although Lin remembers that NASA "essentially added a statement within the statement of work that said that the SPOC contract would also include 'go do work on closeout,' but the definition, content, or requirements for that scope had not been defined yet." [99]

Kevin P. Repa was the USA program manager in Houston, with Carolyn D. Sower as his deputy. A "core team" of two-dozen senior technical and business personnel handled the day-to-day operations at JSC and KSC. The NASA and contractor personnel formed a cohesive team that worked well together doing a difficult and often emotional task.

The initial attempt to add T&R content to the SPOC contract (called "Amendment 1") was abandoned as the manifest continued to change. In its place, NASA negotiated several 6-month options that would allow USA to support fly-out while continuing to plan for T&R. When it became clear that the manifest would not extend beyond STS-134 or STS-135, NASA issued a request for proposals for Amendment 2. The accompanying statement of work assumed that most of the KSC workforce, property, and equipment would transition to the Exploration Ground Launch Services (EGLS) contract to support the Constellation Program. Therefore, the RFP/SOW, and the resulting USA proposal, focused mostly on the JSC efforts. After the 2010 cancellation of Constellation and the resultant non-award of EGLS, the statement of work was revised as Amendment 3 to include T&R of the KSC assets. This time, the contracting effort flowed to completion. In September 2011, USA and NASA negotiated and signed the 24-month Amendment 3 extension for an estimated cost of just under $400M. [100]

Eventually, NASA tried to move up the T&R completion date to December 2012, but this proved impossible given the magnitude of the effort (particularly personal property and records). Instead, USA largely finished the effort in March 2013, with some final personal property and IT tasks remaining through September 2013. Lin remembers, "USA was very good and they worked with us to get everything done. What we had to do was sit down with USA, look at all the requirements on the contract, and scrub the requirements. Fortunately, we did not have to de-scope any work, so USA was able to prioritize all the work to get it all done. Think of it this way, they essentially phased it such that they would do all of their work in the beginning part versus at a later part [of the contract period of performance]. It ended up saving

98 Interview, Frank Lin by David M. Lengyel, 13 February 2013.
99 Interview, Frank Lin by David M. Lengyel, 13 February 2013.
100 Interview, Frank Lin by David M. Lengyel, 13 February 2013.

the government some money when they did that because NASA didn't have to keep that 'army' around beyond March and that's where the saving was." [101]

However, Amendment 3 did not cover the entire scope of T&R because of the way NASA was required to handle the Orbiters, with two display sites reimbursing NASA for display preparation and ferrying, one funded by NASA, and one using a stand-alone contract between USA and a NASA visitor center concessionaire. The Amendment 3 statement of work could not include that effort since NASA did not have obligated funds to pay for it. Amendment 3 did include the effort for *Discovery* since NASA was paying for that, but *Atlantis*, *Endeavour*, and *Enterprise* were largely missing from the scope. The display preparation and ferry flight tasks for these Orbiters would be added to the USA contract via other means as NASA received funds from the display sites.

A couple of contract mechanisms were implemented to allow these, and other, tasks to be added to the contract. Amendment 3 allowed for IIDIQ tasks, and NASA and USA negotiated IDIQ rates and put them on contract. USA implemented a streamlined internal process to provide quick responses to NASA IDIQ requests. NASA issued Task Orders to authorize IDIQ efforts and issued periodic (monthly or quarterly) contract modifications to add to the scope and contract value of the IDIQs. During operations, USA had made an approximately 11.5% fee for its work. Dorothy Rasco felt this was too high for the T&R effort, resulting in a constant battle between NASA and USA during the negotiations for the T&R IDIQ task orders. Ultimately, USA settled for approximately 6.5% for most of the work based on its less complex and critical nature, with an exception being made for the work that directly concerned the Orbiters.[102]

The other mechanism implemented was Technical Direction (TD) that allowed Frank Lin a streamlined method to issue changes to existing work regardless of whether that change had a cost impact. Lin also authorized the four TMRs with the ability to issue no-cost TDs, but TDs that had a cost impact required the approval of both the CO and COTR. There was sufficient oversight and controls of the process to prevent scope creep. Periodically (approximately quarterly), USA submitted a Request for Equitable Adjustment (REA) to receive contract value for the cost impact TDs.

During SSP operations, the SPOC contract was very broad and there was a $1M change threshold. It became normal business for USA to give the Government whatever they asked for, since any reasonable request fell within the existing scope. The T&R scope was not nearly so broad and required a major cultural shift within USA. It proved very difficult to keep the engineers and technicians from acting upon NASA requests for additional work. One of the methods used to clarify what was in and out of scope was to refer to the detailed Basis of Estimates (BOE) prepared as part of the closeout proposal. These provided details of both what the effort that had been planned was and an understanding of the requirements as negotiated.

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[101] Interview, Frank Lin by David M. Lengyel, 13 February 2013.
[102] Interview, Dorothy S. Rasco by J. Steven Newman, 7 February 2013.

Capturing and Segregating Costs

The final structure of T&R had multiple funding sources. Even within the normal NASA funding scheme, each TMR managed their budget separately. This required the contractors, particularly USA, to track and report expenditure using a detailed WBS. The division of responsibilities between TMRs was, at times, complex. For instance, the preparation and delivery of *Discovery* was a Ground Operations TMR responsibility, but the Orbiter TMR funded the preparation and delivery of *Enterprise*, despite the operation using the same equipment and crews at Dulles International Airport. This forced a level of bookkeeping that USA was not used to performing, although in the end it all worked fine.

Because NASA had to seek full reimbursement for work performed on the Orbiters that benefited non-Federal government museum recipients, the display preparations for each Orbiter were funded by separate sources, dictating that all costs be segregated by vehicle. Some tasks proved difficult to precisely segregate. For example, some support was generic—the person manning the tool crib responded to any request for a tool without knowing what it would be used for. In the end, the cost of such support was simply split evenly between however many vehicles were being supported at the time. At other times, the meticulous bookkeeping was overcome by events. For instance, work on the Replica Shuttle Main Engines (RSME) was tracked depending on which vehicle the nozzles would be installed on so that the display site could reimburse the cost. But at the last minute, the OV-105 nozzles were installed on OV-104 because of schedule changes. This did not materially affect costs since the effort expended on each set of nozzles was roughly equivalent, but it shows the challenges of establishing a system to ensure tight accounting control in a fluid operational environment.

Scheduling

The contractors each developed an Integrated Master Schedule (IMS) and provided weekly status to NASA. The Integrated Master Plan (IMP) structure held together reasonably well throughout T&R because of good up-front planning. Nevertheless, the IMP/IMS was re-baselined about halfway through execution to accelerate timelines due to NASA budget reductions. The USA IMS was the largest and was initially structured with facility turnovers as a waterfall effort so as not to overburden limited resources, but that ended up causing additional work because multiple turnover packages had to be created rather than a single one encompassing a logical grouping of facilities.

One area that proved problematic was that the completion criteria for some Significant Accomplishments (SA) were not clearly defined or understood. There was some confusion in reporting completion of the SAs when multiple organizational elements were responsible for the completion of the subordinate Accomplishment Criteria (AC). The support effort inherent in some of the ACs, when performed by a different organization than the one identified as the owner of the AC, was not always considered when claiming completion. For example, a facility operating organization might have completed all of the

technical work required to hand over a facility, but the records, environmental, or personal property effort was not complete. This could impact facility handover dates and should be an important consideration when working against hard dates for facility handovers and real property lease expirations.

Metrics and Reporting

NASA and USA agreed upon an initial set of metrics for each WBS to show the burndown of property, records, facilities, and IT. As time progressed, the metrics were revised and expanded. In some cases, the original metrics were not providing sufficient information to adequately measure progress; in other instances, NASA requested a lower level of detail to better report progress to Headquarters.

There was some initial difficulty collecting data for the metrics. For instance, the inventory systems used during operations did not have the capability or level of detail to provide metrics on excessing and archiving or to provide them broken out by TMR. Fortunately, USA developed ways to pull various pieces of data from existing systems and to combine the data to provide more meaningful metrics without having to develop entirely new systems. Some of the metrics reporting was created from data normally collected and then manually compiled and segregated to provide it at the level requested by NASA.

The relationship of the program-level WBS metrics to the lower-level metrics was clear. However, the traceability and relationship between other lower-level metrics, schedules, and stoplight charts and the program reporting were not as well defined. Ultimately, this lack of traceability was not an issue because the TMRs were focused on their individual work shares and were not as concerned about the integration across the program.

Metrics and reporting at the lower levels within SPOC were often out of sync with the metrics and reporting occurring at the program level, mostly due to the timing of when the data were collected and presented to the NASA customer. In addition, a normal lag in cost reporting and variance analyses meant the technical, cost, and schedule reporting to NASA could not be conducted any earlier than the 4th week of each month. This reporting delay meant senior management, including the CO and COTR, reviewed data that were more than one month old. The inevitable lag between the compilation of data and its presentation to program and Agency management was a recurring challenge, particularly when metrics had to be synched up between the program and other institutional customers for the data.

The number of reviews seemed excessive to many contractors but were essential to various levels of NASA management. There was a monthly program review conducted for the COTR and attended by all of the TMRs and all of the USA core team members. In itself, this was a reasonable review and provided a forum for communication across all the WBS and TMR elements. The results proved to be beneficial for integrating and identifying risks, but the process of getting to the final review often required many pre-meetings. For each TMR, USA personnel prepared presentations, which then had to be vetted by local USA

management. Once this was accomplished, the presentations had to be vetted by local NASA management (the TMR). Then all of the presentations were combined and vetted by the broader USA management before being presented at the monthly program review.

In addition, each TMR wanted a local monthly review, often including different data (or data formatted differently) than required for the monthly program review. A similar set of internal USA reviews also required slightly different data (or formatting). Many USA core team members and mid-management NASA personnel spent a great deal of time preparing status presentations.

A weekly tag-up was conducted, based on lessons learned from closing-out the Space Station Freedom Program. The attendees to the tag-up were intentionally kept to a small group of key decision-makers from NASA and USA. This tag-up was used to address concerns that cropped up and to address them in a timely manner before they could grow into major issues and cause unnecessary delays. Because there were many contract and business issues related to the evolving requirements, a follow-on business meeting was added to the weekly tag-up. The attendees to this meeting were a smaller subset of the preceding meeting. Both of these meetings proved to be extremely beneficial in keeping abreast of unforeseen concerns that always surface on a dynamic project. These weekly tag-ups proved very useful and required a minimum of preparation, so they did not distract the core team from other duties.

Internal status meetings were held weekly with the core USA technical and business leads. A monthly status meeting was held with a larger segment of the closeout team to communicate changes or new information. The weekly meetings were a good forum for the various organizations to communicate progress, issues, and concerns that might affect their efforts or have an impact on other organizations' efforts.

Periodic Technical Integration Meetings (TIM) provided a focused, in-depth discussion on a specific area of work such as property disposition. These were attended by both NASA (program, project, and institution) and USA and were invaluable for communicating processes and developing solutions. Some of these TIMs were held early in closeout, and crowds of people attended because they were eager to learn more about the T&R activities. However, despite the advantages of engaging a larger audience, all concerned acknowledged that the meetings were more productive if the attendance was controlled to prevent the group from growing so large that nothing got accomplished.

In addition to regular meetings at the program level, there were regular working group meetings at the WBS element level to address specifics related to those processes and issues. NASA and USA jointly managed these working groups, and issues and concerns not solved there were communicated to the program level.

There were also regular meetings, reviews, and decision-making boards at the TMR level that included both NASA and USA participation. Some of these meetings also included representatives from the follow-on programs who had a vested interest in receiving SSP assets. This cross–customer/contractor/program communication was vital in getting timely decisions and in the most effective use of the excess SSP assets.

Most of the meetings were attended by telecom, even if all the players were at the same Center, because it was less time-consuming. The monthly CO/COTR meetings were also, usually, attended via telecon and WebEx, partly to save travel time but mostly to save travel costs. In general, this worked well. However, because T&R was executed in multiple locations, it was important to periodically conduct face-to-face meetings to foster cooperation and coordination. These face-to-face meetings took many forms, such as one-on-ones or mini-TIMs to address a specific topic, or a series of smaller breakout-type meetings. They all went a long way toward creating an environment for a fluid exchange of information.

In addition to in-person and telecon communications, the T&R effort made extensive use of SharePoint, an electronic collaborative tool. Both USA and NASA used private SharePoint sites to prepare and share financial and contract data, while other SharePoint sites allowed both NASA and USA access to share technical data. NASA and USA also used shared data stores (share drives) that allowed select individuals access to specific data. There was also an extensive set of web sites that contained data and information related to T&R.

Risk Management

Unlike the operations environment when the emphasis was on human space flight risk, during T&R most of the risks were associated with the Orbiters (mostly schedule); workplace safety (personnel and equipment); and cost, schedule, and supportability (in the context of closeout)

NASA implemented a more streamlined and less formalized method of technical risk management for T&R than had been used during operations. Nevertheless, risk identification was continuous and used many venues, including IMS statusing and program reviews. Formal risk boards were not established, but risk working-groups were established and effectively used to vet risks without any loss of process effectiveness. This approach required Larry Shaw, the program risk manager, to be more actively involved in identification of risk at the element level than in a typical implementation approach where the risk manager was the facilitator of the process.

The risk management tools were essentially the same as those used during operations and included a risk scorecard that was customized to the goals and objectives of T&R. The risks identified during the operation phase were archived immediately after wheel stop. These factors allowed the risk manager to maintain risk and concern status that included only the risks resulting from the T&R process. This was done with the understanding that the T&R risks would be archived in the same manner at the end of T&R. During T&R,

the contractors continued to provide a status of their risks to NASA. The risks were discussed and properly vetted, and only those that were agreed to by the customer were elevated and entered into the IRMA database.

Top Risks

Almost from the beginning, T&R had two primary risks: budget and safely flying out the manifest. Bill Hill remembers that T&R "was not a risk other than what it would cost the agency in the long run and we'd have to figure it out, even if we just dumped everything on the institutional folks and they took forever. We still had Apollo stuff leftover so there was some level of precedence. It might take decades, but you may get there someday."[103]

Regarding budget, Jonathan Krezel remembers, "everybody's eyebrows were raised with the initial [$4B] estimates, but even after the end when we had a pretty good handle on what we thought this was going to cost, there was always concern about having enough resources to carry out the job."[104]

There were, however, more worrisome risks to both fly-out and T&R. Bill Hill recalls, "The biggest risk we dealt with was the contractor workforce. Across the program contractors knew they were going to get laid off once we finished." Therefore, Hill believes one of the significant challenges for managers across the program was to keep the workforce motivated as evidenced by all managers, but more specifically by the efforts of Rita G. Wilcoxon from NASA-KSC and Patricia J. "Patti" Stratton from USA, who were instrumental in keeping the Florida workforce motivated and easing the effects of the eventual layoff. [105]

[103] Interview, William C. Hill by Jonathan M. Krezel and David M. Lengyel, 20 February 2013.
[104] Interview, Kevin C. Templin and Jonathan M. Krezel by David M. Lengyel, 22 February 2013.
[105] Interview, William C. Hill by Jonathan M. Krezel and David M. Lengyel, 20 February 2013.

PERSONAL PROPERTY

Disposition of Personal Property

"I think that NASA and a lot of organizations are really good at big element integrated planning but they're not good at something that almost looks like chemical process engineering flow."

An astute senior NASA executive involved in transition and retirement observed that NASA is very good at program and project management, and at developing one-of-a-kind scientific and technical marvels, but that the Agency is not so adept at "quantity problems," in this case meaning dispositioning large quantities of personal property. That was certainly true early on during T&R, but with institutional and external support, the Agency learned by doing and mitigated the risks to an acceptable level in this important area. This section describes the challenges associated with dispositioning personal property on a grand scale.

Initial Planning

Personal property is formally defined as all assets not classified as real property that are owned by, leased to, or acquired by the Government. This includes material, Agency-peculiar property, special tooling, and special test equipment. It also includes Government-furnished property made available to the contractor for use and contractor-acquired property for the performance of the contract where the title of the property is vested in the Government, including items fabricated by the contractor or its subcontractors.[106] Essentially, personal property is anything that is not a building or permanently affixed to a building.

According the Title 40 of the U.S. Code, the GSA is responsible for Government-wide asset management and disposal. In particular, Section 521 of 40 USC authorizes the GSA to prescribe policies to promote the maximum use of excess Government personal property by executive agencies. In response, GSA writes regulations that are contained in 41 CFR Chapter 102. Once notified that excess property is available, GSA manages the process to dispose of the property.[107]

In a December 2003 study, "General Services Administration Personal Property Utilization and Donation Study," the GSA concluded that only nine percent of excess Government assets were actually transferred to another Agency for reuse, and only five percent were donated through state agencies to eligible recipients. The paper reported a Government-wide 38 percent drop in the use of donation for property disposition since 2000. It endorsed the use of "want lists" as a way to increase efficiency in the use and donation process for intra- and inter-Agency transfers. The paper emphasized the Government's underused potential for "social benefits through the donation of assets to state and local governments and non-profit

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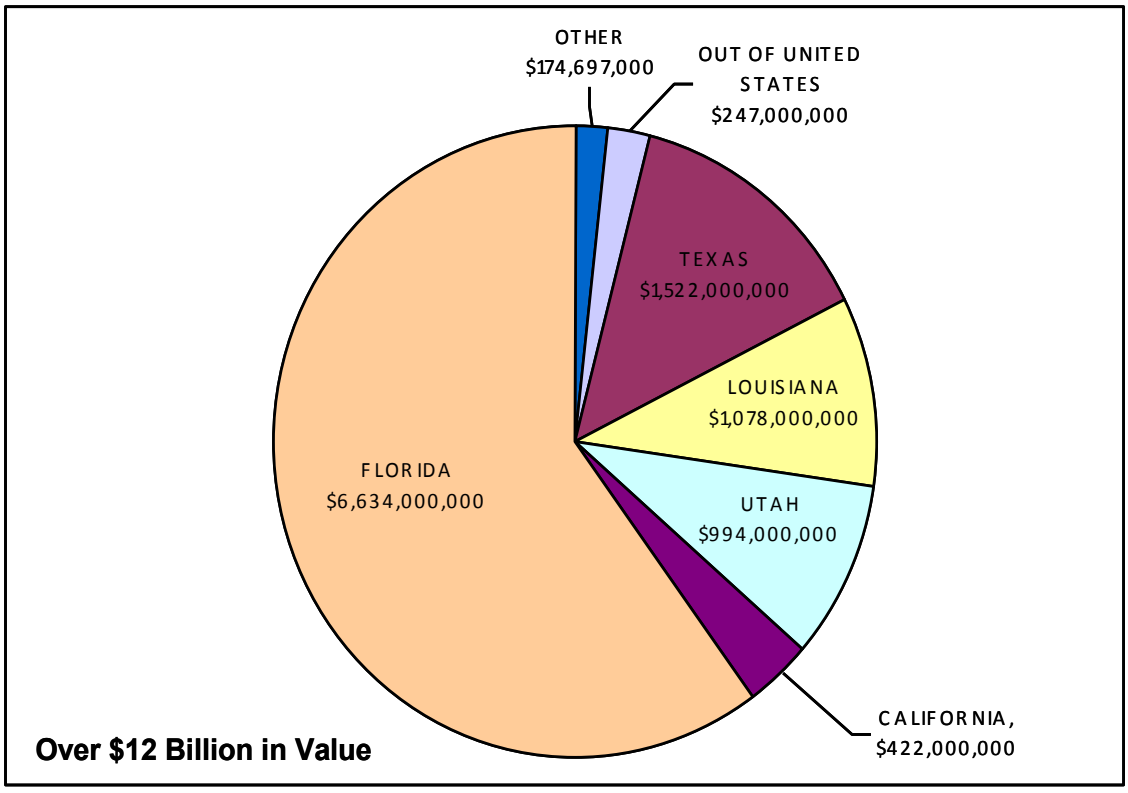
106 "Space Shuttle Program Transition Management Plan," NSTS-60576, 9 May 2009.

107 Interview, David M. Robbins (GSA) and Robert A. Holcombe (GSA) by J. Steven Newman, 27 February 2013.

organizations." Several of the general concepts mentioned in the study shaped how the Space Shuttle Program and GSA ultimately excessed personal property.[108]

The 2005 ISOS Transition Panel attempted the first comprehensive survey of the amount of personal property used by the Space Shuttle Program. The panel obtained the NF-1018 (NASA Property in the Custody of Contractors) reports for each major contract, including the ET, RSRM, SSME, Alternate Turbopumps, and Space Shuttle Remote Manipulator System production contracts, and the SFOC. Each contractor provided the databases that contained the inventory reported in the NF-1018 to allow the Transition Panel to better evaluate the data.[109]

SFOC included the Orbiter, Program Integration, SRB, Flight Crew Equipment, Mission Operations, and Launch and Landing (L&L) elements. The panel further defined the material held by USA, including that material actually held by USA subcontractors, and its geographic location. The panel noted, "There are literally hundreds of locations where Government property is used, but for the purpose of this effort, the distribution is depicted where the majority were located or the remoteness is significant."[110]



[108] "General Services Administration Personal Property Utilization and Donation Study," General Asset Sales report, 19 December 2003.
[109] "ISOS Space Shuttle Program Transition Panel Final Report," 15 April 2005.
[110] "ISOS Space Shuttle Program Transition Panel Final Report," 15 April 2005.

Eventually, the SSP divided personal property into three general categories. Davidson remembers, "our original set of numbers said we've got three classes of things (simple stuff, medium stuff, and highly complex hazardous stuff); that highly hazardous was really a small number. This allowed us to refine how much technical supervision we need to deal with that sort of stuff versus how much could be done by the property folks that were just turning the crank and running it through. Property always was our driver in terms of what we were doing and once we got through that database to see what we really had. The numbers just continued to come down." Nevertheless, personal property was one of the long-poles throughout T&R.[111]

GSA Involvement

From the GSA side, David M. Robbins, the Director of the Office of Personal Property Management at the GSA Federal Acquisition Service, and Robert A. "Bob" Holcombe, the Director of Personal Property Policy at GSA Office of Government-Wide Policy, took the lead to help the T&R process.

Holcombe was impressed that NASA brought GSA into the process so early. He remembers, "Usually we're brought in pretty much at the eleventh hour, at 11:30, and have to catch up and get through the process. I think this was a very well planned activity." Robbins was also grateful, indicating, "NASA

[111] Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.

wanting to partner and plan for an orderly transition was key to this, because we are generally not brought in far enough in advance for planning like this."[112]

However, the Space Shuttle Program had some unique requirements. Especially the International Traffic in Arms Regulations (ITAR, 22 CFR 120–130), which complicated everything. Susan Kinney, the Agency Director for Logistics at NASA Headquarters, remembers that the amount of property being excessed eliminated any possibility that the Export Control Office could evaluate every piece. Instead, as Kinney remembers, "we declared all Space Shuttle property to be ITAR export controlled."[113] Because of this declaration, Michael Eaton, the Agency Property Disposal Manager at NASA Headquarters, remembers, "There was a requirement that Space Shuttle property could only be sold to U.S. citizens. GSA programmed their sales module to accommodate that. In addition, NASA's export control personnel required the U.S. citizen couldn't be on any denied parties or denied persons lists, so GSA came up with a package that would check to see if the person was on any barred list."[114]

Disposal

Initially, NASA intended much of the Space Shuttle personal property to be transferred to ESMD for use on what would ultimately become the Constellation Program (CxP). By some projections, CxP needed up to 50% of all SSP personal property. To facilitate the transfer and disposition process, the Space Shuttle Program was to evaluate its requirements for personal property and identify when it was no longer needed to support specific capabilities. This property was to be released by SSP at the earliest possible date when it no longer presented a risk to flying-out the manifest. Therefore, the key task for property transition efforts was to determine, as early as feasible, SSP's last need dates for serviceable property and to generate disposition decision packages for property with potential for follow-on use, significant historical value, or other issues that required SSP or Headquarters decisions.[115]

Conceptually, the disposition process was simple. The property is screened to see if it has potential for re-use within other NASA programs (mostly CxP) or within other Federal agencies (including the Smithsonian's National Air and Space Museum). If GSA determines that there are no Federal requirements for an Agency's excess personal property, it becomes surplus property and is available for donation to state and local public agencies and other eligible non-Federal activities. In reality, the program prescreened property with other Federal agencies to expedite the disposition process.

There were two significant public donation routes. The first, called the Federal Surplus Personal Property Donation Program, involved the transfer of property to eligible recipients through their respective State

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112 Interview, David M. Robbins (GSA) and Robert A. Holcombe (GSA) by J. Steven Newman, 27 February 2013.
113 Interview, Robert S. Sherouse, Susan Kinney, and Michael T. Showers by David M. Lengyel, 4 February 2013.
114 Interview, Michael Eaton by David M. Lengyel, 4 February 2013.
115 "Space Shuttle Program Transition and Retirements: Personal Property Disposition Plan," November 2008.

Agency for Surplus Property (SASP). Title 40 provides for the establishment of one SASP per state. GSA can donate surplus property to the SASPs, who may, in turn, convey the property (including artifacts) to eligible state and local government agencies and eligible non-profit organizations, such as museums. Recipients were responsible for all costs associated with the donation of property to their activity, including pickup, transportation, packaging, preparation, and extra storage charges if the property was stored after transfer.[116]

The second process involved the direct transfer of educationally useful property to eligible schools and museums under the Stevenson-Wydler Act (Executive Order 12999). The Stevenson-Wydler Act provided additional authority for NASA to direct equipment to universities and non-profit research institutions. It is important to make a distinction that transfers/donations under the Stevenson-Wydler Act were executed directly between NASA and the recipient under NASA authority and not through an SASP or under GSA authority.

In the event that property was not retained by NASA, transferred to another Federal Agency, donated to an eligible recipient, or scrapped, GSA advertised the property for sale. For Space Shuttle property, 90 percent of the proceeds were returned to NASA for use in new programs, with GSA keeping the other 10 percent to cover its sales and overhead costs.[117]

The cancellation of the Constellation Program greatly complicated property disposition planning and the planned proceeds retention for property sale under exchange sale authority. Much of the property at the field centers had been marked for transfer to Constellation, a process that was mostly a paperwork effort and seldom required moving or deservicing (safing) the equipment. Without another program to transfer the property to, the property was instead tagged for disposal as excess, which almost always involved deservicing the property and moving it to a disposal site. This significantly increased processing time, handling, and overall disposal costs.

The large volume of property that required disposition (either excess or transfer) within such a short period of performance seemed to beg that certain regulations be waived during the course of closeout. During the T&R planning phase, the NASA Personal Property Transition Officer worked with USA to develop a Memorandum of Understanding (MOU) between both parties to document which regulations could be waived or modified. The development of the MOU allowed NASA and USA to review and modify existing processes and introduce new ones that would allow more efficient disposal of Government property. The MOU was originally divided into two sections: (1) disposition allowances for property prior to the end of the program, and (2) different allowances for disposals after the end of the SSP. As closeout progressed and the MOU evolved, the divisions were no longer needed.

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116 Interview, David M. Robbins (GSA) and Robert A. Holcombe (GSA) by J. Steven Newman, 27 February 2013.
117 Interview, Michael Eaton by David M. Lengyel, 4 February 2013.

The MOU eliminated the need for detailed physical inventories provided that the property accounts had previously met a 99% accuracy rating. This waiver allowed personnel who were previously dedicated to inventorying to be sent to the staging areas for excess, significantly reducing the number of contractor hours.

Material records reconciliation was no longer required under the MOU. Instead, the excess documentation would reflect the quantities recorded in the property system rather than an accurate count of what was physically on hand. This allowed material bins and shelves to be quickly excessed or transferred. The MOU also allowed USA to lot by Federal Supply Classification (FSC) and to scrap all special tooling, again significantly increasing the disposition rates. Other areas that the MOU addressed included the following:

- Limited research was required for losses of property valued under a certain dollar threshold.
- Physical removal of NASA or Government markings on the property was no longer required.
- Internal 5-day screening process of excess property was no longer required.
- Itemized attachments of residual or non-controlled property to disposal documentation were no longer required.
- Relieved USA of transportation requirements.
- Existing work orders on excess property could be closed administratively.

The MOU guidance was not without flaws, however, property could be card-tagged and included with non-controlled property, lotted, and placed in tri-walls (large boxes) for excessing. This led to the requirement to reconcile controlled items that proved to be time-consuming.

It is important to note that the MOU agreement was between NASA and USA and not between USA and the receiving contractors, which did not have the same leniency. The receiving contractors were still required to inventory what they received and redline the DD1149 (Requisition and Invoice/Shipping Document) forms appropriately. This caused long delays in the ability to get the property off the SSP books because a receiving signature was required to drop the record. The physical movement of the property to the receiving entity also caused delays in acquiring signatures, causing significant delays in being able to drop the record to show the disposition.

Artifacts

Artifact identification, screening, and transfers became a unique aspect of Shuttle property disposition. Much effort was made to identify artifacts as a way to preserve and share artifact heritage with the public. Artifacts also provide an excellent and effective way to reach our youth and encourage outreach while fostering emphasis in Science, Technology, Engineering, and Mathematics.

Artifacts

"Disposition procedures need to include a clear definition of 'artifact' and property management departments need to be considered the process owner in order for artifact disposition to be successful."

Section 1.2 of NPR-4310.1, Identification and Disposition of NASA Artifacts, offers the following definitions:

- Artifacts, as applied to NASA, are unique objects that document the history of the science and technology of aeronautics and astronautics. Their significance and interest stem mainly from their relation to the following: historic flights, programs, activities, or incidents; achievements or improvements in technology; our understanding of the universe; and important or well-known personalities.
- Space-related artifacts may include, but are not limited to, objects such as major program vehicle components, unique devices, prototype and proof test articles, payloads or individual instruments, flight spares, astronaut tools and paraphernalia, design concept models, and high-fidelity simulators. Aeronautics artifacts include, but are not limited to, experimental aircraft, test and simulation devices, prototype systems, structural and test models, and flight-tested materials.

Despite the definition established in the NPR, there was a lot of subjective assessment in interpreting these definitions. Joel Kearns remembers, "You couldn't say to someone 'use this criteria and this will tell you what an artifact is; go screen all your equipment and come back next year and tell me how many are artifacts' because the criteria was very subjective." In essence, just because a museum wanted an item did not necessarily make it an artifact.[118]

NASA always understood that much of the surplus property from the Space Shuttle Program, particularly flown items—including the Orbiters—would be in high demand from museums and similar institutions. To facilitate this, in 2008 the Agency created a Space Shuttle Artifacts Working Group to develop a way to collect and evaluate the requests for the property. A list of potential artifacts would be offered first to NASA technical programs and then to NASA visitor centers and the National Air and Space Museum (NASM, which was considered the visitor center for NASA Headquarters). The hardware would then be prescreened for use by other Federal agencies, state agencies, non-profit museums, universities, and other groups.

Requesters would be asked to cover all expenses including special handling requirements, packing, and transportation. To ensure good stewardship of potential artifacts, each recipient needed to demonstrate competence to provide reasonable care for national treasures. Since essentially all SSP property was determined to fall under the ITAR/EAR regime, all requesting organizations had to be American-owned and -operated.[119]

In mid-2008, Headquarters published a pamphlet to disseminate information on how these organizations could obtain SSP artifacts. This was the beginning of a long and involved process of helping transfer

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118 Interview, Joel K. Kearns by David M. Lengyel, 11 February 2013.

119 "Prescreening Criteria Guidance," Agency Space Shuttle Program Artifacts Working Group presentation, 9 October 2008. An exception to the American rule was the return of a single Remote Manipulator System (RMS) arm to Canada. Although not the same physical arm that Canada had supplied to NASA in the late 1970s, the return satisfied a Canadian request to have the original hardware returned at the end of the program.

thousands of items of property to museums. The pamphlet stated that historical significance could be grounded in:[120]

- Events (missions, extravehicular activities, etc.);
- People (astronauts, managers, engineers, technicians, etc.);
- Technologies (engines, tiles, spacesuits, spacecraft components, etc.);
- Processes (tests, manufacturing, mission operations, etc.);
- Research (scientific instruments, experiments specimens, etc.); or
- Memorabilia (patches, pins, posters, awards, collectibles, etc.).

It further explained that NASA would use certain criteria for judging the significance of potential artifacts:

- Priority I: Items that had flown in space.
- Priority II: Items that had not flown, but were qualified to do so (flight spares, test articles).
- Priority III: Items that had not flown and were not intended to fly, but represent the development and practice of space flight (prototypes, boilerplates, wind tunnel models, etc.).

Of course, ultimately the significance of any artifact is in the eye of the beholder.

Because of the large amount of potential artifacts to be excessed, NASA sought a partnership with the GSA to leverage technology and develop a way to offer artifacts to appropriate recipients. To this end, GSA agreed to advertise potential artifacts before they were officially excessed (i.e., prior to actual availability) while following the basic tenets of the normal property disposal process. The process allowed educational institutions to prescreen property for future acquisition under the Stevenson-Wydler Technology Innovation Act authority, and allowed museums and other non-profit organizations to obtain property under the GSA Federal Surplus Property Donation Program.

This NASA Headquarters partnership with the GSA resulted in the development of a GSA Artifacts Module web-based tool to conduct prescreening of SSP artifacts by internal and external entities with the goal of making early predeterminations on the placement of artifacts. Prescreening was to provide an opportunity for potential artifact recipients to plan for facility requirements and to budget for costs associated with receiving the artifacts allocated to them well in advance of the SSP actually releasing the property for transfer. This planning period was particularly important for larger artifacts with complex logistical and installation requirements.[121]

GSA controlled the screening times for anything that went into GSAXcess, normally set at 21 days. Michael Eaton wondered if this could be reduced to help move the large volume of excess property that was hitting the module all at once. Robbins realized that a lot of the NASA equipment was going to be

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120 "Space Shuttle Program Artifacts Information Pamphlet," April 2008.

121 "Space Shuttle Program Transition and Retirements: Personal Property Disposition Plan," November 2008; "Space Shuttle Program Transition Management Plan," NSTS-60576, 5 August 2010.

technical and of limited value to most recipients, so the GSA coordinated with their major stakeholders to get opinions about a shortened timeframe. With no stakeholder objections, GSA reduced the normal 21-day screening period for property from JSC, KSC, and the White Sands Test Facility (WSTF) to 7 days so that property did not sit for as long before going to public sale.[122]

Property prescreened in the GSA Artifacts Module and not requested by anyone was no longer treated as a potential artifact. Such "property" was declared excess and was processed for sale. Eventually, prescreening property as artifacts before they were released by SSP (during flight operations) gave way to actually screening larger amounts of property as potential artifacts after the property was turned in by SSP and received by the Property Disposal Officers (PDO). This transition occurred once Shuttle flight operations ended and the program finished processing the Space Shuttles for retirement.

For recipients, this transition limited strategic planning opportunities because recipients requested, were allocated, and were expected to pick up their artifacts within a matter of weeks, rather than months, as had been the process during the prescreening process. During prescreening, recipients were often afforded time and opportunity to "visit" a Center to evaluate their special handling logistics obligations well in advance of receiving their artifact. However, once prescreening ended and screening began as part of the normal disposition process, timelines compressed significantly and property was moved or shuffled between storage areas with increased risk of damage. Moving property to a disposal site or shuffling property between high-demand storage areas before a recipient could pick up their artifact carried some risking of damage. Nevertheless, recipients remained excited and pleased with the process and the opportunity to get artifacts.

In April 2009, Richard A. Wickman, the Transition Manager for Infrastructure at Headquarters, gave a presentation on property and artifact disposition at the annual Smithsonian Mutual Concerns of Air and Space Museums Conference in Ottawa, Canada. Wickman addressed several areas, including a revised process for excessing artifacts and other property. In particular, he emphasized the roles of the SASP since NASA had statutory authority to transfer property to these agencies. Wickman also covered the revised prescreening process that was to be developed within the GSAXcess module.[123]

In practice, the Space Shuttle Artifacts Working Group formatted and sent a property list to GSA. GSA reviewed the property items and uploaded them in a special GSAXcess prescreening module. Recipients registered and then prescreened and requested in hopes to attain a piece of SSP history. The Artifact Working Group made the allocation predeterminations. During the first three prescreening cycles,

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122 Interview, David M. Robbins (GSA) and Robert A. Holcombe (GSA) by J. Steven Newman, 27 February 2013.

123 Rich Wickman, "Space Shuttle Program (SSP) Property and Artifacts Disposition," a presentation given at the Mutual Concerns of Air and Space Museums Conference, Ottawa, Canada, 18–21 April 2009; "Audit of Personal Property Management Donation Program," Federal Acquisition Service report A080104/Q/5/P09003, 25 August 2009.

recipients assumed an understanding that the artifact they were allocated might not be available at all, and would not be released until after Space Shuttle fly-out ended. In fact, NASA pulled some prescreened artifacts back for Space Shuttle Program re-use. As of the publication date of this report, there were 18 artifact-screening periods, recipients screened 33,000 items, and 3,983 artifacts have been allocated. It is worth noting that, while only 0.3% of the Space Shuttle Program's 1.2 million line items of property ultimately ended up being allocated as artifacts, those artifacts required an inordinate amount of time and effort to process compared to the rest of the SSP property.

Overall, this approach worked well, although many of the museums considered it cumbersome because the item descriptions were often cryptic and undecipherable by the layman. As with any new and developing program, however, nearly four years of refinements greatly improved the process. Early on, GSA screenings resulted in separate lists of artifacts provided to pertinent contractors under the disposition management of DCMA and PDOs. The contractors were tasked with ensuring that the property in their possession was not dispositioned without proper notification to the contracting officer and annotations on the turn-in documents. Proper documentation required the contractors to ensure that Identification Control Numbers (ICN) from artifact property lists were added to the turn-in documents. Different databases, different locations, and different processes presented unique management challenges to the contractor property managers.

Artifact tracking is required as part of the property management regulations, and NASA guidance was required to handle the anticipated quantity of property. Additional difficulties developed when the first listing arrived and contained vague descriptions of the property with no corresponding part numbers, tag numbers, or serial numbers. Some property systems had the capability to add a field for the artifact designation, but others did not. Therefore, the responsibility was shifted from property managers to the technical community to properly identify the artifacts within their program databases. Unfortunately, the databases did not always accurately reflect the property management databases.

In addition to the original prescreening artifacts list (sometimes called the artifact wish list), NASA required that artifact determinations be made to all property being turned in to the PDO, regardless of whether or not it was on the original artifact wish list. Initially, lack of procedural guidance and confusing document annotations created confusion with respect to documents identifying pre-screening allocations and documents indicating that the item might be worth screening as an artifact. This caused endless discussions and differing opinions amongst the contractors and NASA technical organizations until clear procedural guidance was provided.

Although the prescreening concept worked well, the fact that much of it was done well before the items were actually available for transfer caused some problems for the SSP (although it undoubtedly helped the recipients). Michael Eaton remembers, "By the time the property was actually turned in to the Property

Disposal Officer, many of the original requestors had either retired or moved on. That took more time for us to go in and find out who replaced that person and determine whether they still wanted the artifact. If so, then did they have the money to move it? If they didn't want it, were there other people who had requested the property? There was a ripple effect because of the delay from the time that someone identified they had an interest and when we actually excessed the property."[124]

Disposing of Orbiter Thermal Protection System (TPS) tiles turned into a special project of its own. NASA created the *Tiles for Teachers Program* encouraging schools to request tiles for educational purposes. There were approximately 7,500 tiles available, and NASA arranged for a commercial partner to handle distribution. For a fixed price of $23.40, any school could receive a tile. After distributing approximately 4,100 tiles to schools, NASA opened the program up to museums. NASA expanded the program to include space-food items and plans to add SSME turbine blades. Susan Kinney, the Director for Logistics at NASA Headquarters, remembers, "So, rather than throwing this all away, we're getting letters back from schools and kids saying it was really inspirational." Oddly, Robert S. Sherouse, the transition manager for the Office of Infrastructure at NASA Headquarters, remembers, "The education side of NASA didn't embrace it as readily as we would have expected them to."[125]

Complications

Some of the initial estimates of personal property, especially hazardous property, held by the SSP were truly scary. Dennis Davidson remembers that T&R needed "a level of detail beyond which we'd ever really collected in the program before, at least in terms of going across centers, across projects, getting everybody to put the data in the same format, at least trying to. They all managed to find a way to manipulate the database so there never was one format for everybody. At the very beginning, people would tell you stories about hazardous property and they'd go and show it to you. They would take you out to Pad A and say look at this, see this panel, see the chemical, the fluid, the flow through, all the things it's got to do, what it's going to take. Initially, you might get an estimate that said 20–30% of your stuff is highly hazardous."[126]

Closer examination, however, showed a somewhat different story. Davidson remembers, "When you forced them to go fill out the database and truly looked at the number of line items you had and what fell into hazardous, the numbers went way down. It was still your overall cost driver because the hazardous stuff just took more funding per item than anything else, but in terms of the magnitude of the problem, it was much smaller than anything we'd ever imagined and it turned out something less than 5% of our stuff was actually hazardous and a cost driver."[127]

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124 Interview, David M. Robbins (GSA) and Robert A. Holcombe (GSA) by J. Steven Newman, 27 February 2013.
125 Interview, Robert S. Sherouse, Susan Kinney, and Michael T. Showers by David M. Lengyel, 4 February 2013.
126 Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.
127 Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.

On 15 October 2008, President George W. Bush signed the NASA Authorization Act of 2008 (P.L. 110-422). Section 613 of the act required the NASA Administrator to submit a plan to Congress describing the disposition process for the remaining Orbiters and other Space Shuttle Program personal property. This Personal Property Disposal Plan determined that the program occupied more than 654 facilities and used more than 1.2 million line items of hardware and equipment valued at over $12B, spread across hundreds of locations across the country. It was largely the same answer that the ISOS Transition Panel had reached three years earlier.[128]

Coordination within NASA (mostly between programs and Centers) required constant vigilance and fine-tuning. Given the volume and nature of Space Shuttle property being processed, it is not surprising that the process was not always smooth. Some property that went through the disposition process, with no expressed interest from other NASA programs, was later requested at the 11th hour by a NASA organization as the property was being processed for disposal. This caused unexpected work to retrieve the property from the property disposal area (such as Ransom Road at KSC) and transfer it to the requesting organization. Alternatively, some items designated for transfer between programs were processed as transfers and then turned in to the PDO for disposal. The additional document processing workload and potential for multiple handling of these items created frustration and unnecessary potential for risk of property damage.

As part of the DD1149 transfer process, there were a lot of new individuals that now had responsibility for approving the release of property. While many of the Program boards approved the disposition of items at a high level, it was the DD1149 process that was the final and critical step. This process ensured that the line items of property being dispositioned matched the intent of the programmatic decisions. The proper review of the DD1149 assured that no items were dispositioned before their last need date and that no artifacts were accidentally excessed. Unfortunately, the large volume of DD1149s made this a very arduous process, and if managed incorrectly it could become a bottleneck in the property disposal process. It is imperative that anyone involved in this process not only be trained on their technical responsibilities for providing approvals but also on the issues that arise if the approval cycle does not perform in a timely manner.

But while the real risks and costs associated with dispositioning hazardous property were brought down over time through established processes, external financial auditing requirements added an unexpected burden to these efforts. Amended Generally Accepted Accounting Principles (GAAP) required that Federal agencies estimate their unencumbered environmental liability (UEL) for personal property, or the estimated costs to safe any environmental hazards if that property were to be excessed. These particular GAAP requirements came out long after the Shuttle program was flying and most of the program's major capital property was acquired. At the time of T&R, NASA had no policies in place for calculating UEL for either

[128] "Space Shuttle Program Transition and Retirements: Personal Property Disposition Plan," November 2008.

new or existing stocks of property. Nor was a UEL calculation particularly useful from a programmatic perspective, since the costs of environmental safing were only a small part of the total cost of dispositioning all the property for a program as large as Shuttle. Estimating this one small slice served no obviously useful purpose. Nevertheless, NASA spent a great deal of effort trying to satisfy annual financial audit inquiries into SSP's (and only SSP's; no other NASA program was scrutinized to the same degree for this accounting requirement) UEL without wasting resources adopting totally new property management systems for a program that was soon to be retired. Failure to adequately address those inquiries was a constant threat to a clean financial audit, and a clean audit was one of the highest priorities for the NASA leadership. While Shuttle never fully satisfied the financial auditors on this issue, SSP (in concert with a dedicated team of professionals at the Centers and in the Chief Financial Office) managed to provide answers that were "good enough" to prevent SSP T&R from becoming a significant material weakness. In 2012, NASA received a clean financial audit, the first for the Agency in over ten years.

Disposition

Property disposition was complicated by the fact that it was a many-to-many relationship. The PDOs at the Centers had to interface with projects from multiple Centers. The projects had to interface with PDOs at different Centers. The projects also had to interface with Plant Clearance Officers at the prime contractor locations. Because each location had unique "efficiencies" built into their processes based on the types of hardware they routinely handled, it was important that the projects adjust to each unique situation and work through the established process at each location.

For the property physically located at KSC, "staging areas" were established to accumulate property in specific locations so it could be excessed in larger groups. Excess property would physically reside at the staging area until the NASA transportation organization could remove and relocate it to Ransom Road, the Center's property disposition area. With such a wide geographic area and large amounts of property to excess, staging the property in specific locations was paramount to gaining efficiencies. However, NASA and USA underestimated the quantity of staging areas that would be active at any given time and were not able to assign as many personnel as needed, resulting in property remaining at the staging areas longer than planned. At JSC, most of the USA-accountable Government property was moved to a staging area located within one of the USA off-site facilities. The JSC PDO, working with USA, established a Mobile Disposal Unit concept that allowed USA, once the property was dispositioned, to move the items to a designated area within the facility where NASA and GSA could conduct screening and sales. This eliminated the need for transportation to move the property on site to the Redistribution and Utilization warehouse. However, not everything sold quickly and the NASA-designated area grew to twice the size of the agreed space. When it came time for USA to relinquish its lease, NASA needed to move the remaining property to a warehouse on JSC.

Government-owned personal property associated with the MSFC elements was located at the prime contractor sites, MSFC, KSC, supplier/vendor sites, and various other sites around the country. The total amount of SSP personal property that had to be dispositioned for all elements was more than 400,000 line items. The property items included facilities/plant equipment, tooling, production equipment, work-in-process, supplies, hardware, and raw materials. The prime contractors, in general, served as the Government's agents responsible for management and control of personal property assigned to their respective projects. Although T&R planning was in place to proceed with property disposition at the end of the SSP in late 2010, it was prudent to delay actual disposition pending decisions from the follow-on launch programs, CxP and SLS, regarding retention and re-use of selected production tooling, equipment, and other property. Maximum re-utilization of existing property resources represented potentially large cost avoidance benefits to the programs. Property disposition proceeded as SLS decisions were made regarding specific pieces of tooling, hardware, etc., and the primes were given permission to scrap those items of no benefit to the SLS Program.

Not unexpectedly, each of the MSFC Shuttle propulsion elements encountered unique property disposition challenges along the way, including the introduction of the new MAF Manufacturing Support & Operations Contractor (MSFOC) into the property disposition planning and implementation process and the identification of SSME complex assets that required more in-depth management attention to achieve disposition. RSRM disposition planning began with the premise that essentially all of the legacy hardware would be transferred to the follow-on program, and fairly late in the game, that premise changed to reflect only a limited amount of property to be transferred. The balance flowed through the disposition process. Each of the elements discovered notable amounts of property that had been unplanned but required disposition. The MSFC elements utilized DCMA for the disposition of property located at the vendor sites, which involved different DCMA Plant Clearance Officers across the country. Although the level of support and timeliness of DCMA action varied somewhat, on the whole, DCMA was a significant contributor to the success of MSFC elements completing vendor closeout in accordance with the T&R program schedule.

Due to the number of items that came under the jurisdiction of the ITAR regulations, innovative methods were needed to "de-mil" some hardware before it was dispositioned. Since the individual handling of thousands of parts can be time consuming and expensive, the program occasionally resorted to other means. For instance, there was a stock of 7,000 spare turbine blades for the Pratt & Whitney alternate turbopumps. The accepted practice to de-mil these would be to grind the serial numbers off each individual blade. Instead, the program decided to melt the blades. Jonathan Krezel remembers, "You've eliminated the serial number that way, you've eliminated the part that way, and that is a case of doing something in batches. You can have somebody from DCMA there to witness that and say 'parts disposed of.'"[129]

[129] Interview, Kevin C. Templin and Jonathan M. Krezel by David M. Lengyel, 22 February 2013; Interview,

Property Management Systems

Due to the size of the Shuttle Program and the number of contracts supporting the program, numerous property management systems existed to manage Shuttle property. These systems were not conducive to use during the initial planning activities for T&R. To aid in the planning process, each Element T&R Manager employed different data collection methodologies, often pulling from the property management systems, and established unique planning databases when developing their overall property disposition plan.

The use of different systems and different "counting" methodologies created problems when establishing property disposition plans that would be used when comparing the actual items dispositioned to the established plan to report progress metrics. Because the post-dispositioning actual counts were pulled from data derived from the property management systems, the plan-versus-actuals were often skewed due to differences in how things were counted for the plan versus how things were counted for the actual reporting. The bottom line is that having many different property databases that cannot easily talk to one another complicates the job of dispositioning all assets at the end of a major program like Shuttle.

At KSC, USA implemented weekly tag-ups with the KSC PDO and institutional contractor to coordinate upcoming priorities for staging area pickups. This tag-up significantly increased the productivity of the institutional contractor by providing a forum for everyone to understand, schedule, and coordinate priorities.

As closeout progressed, it appeared that the actual disposition rate was not meeting the technical organizations' planned rates. To better measure performance, it became beneficial to run the actual metrics bi-monthly instead of just at the end of the month (when it was too late to catch up). These metrics gave property management the ability to research significant deltas so that explanations could be provided at monthly technical, cost, and schedule review (TCSR) meetings or, more importantly, to work to ease bottlenecks and other issues during the course of the reporting period.

The contractors believed that collecting and reporting many of the metrics was an onerous task, but the Government (which was ultimately paying for it) believed that it was critical to the success of T&R. Frank Lin remembers, "In order for us to really understand and monitor how T&R was doing, we had to have this monthly data to be able to report out [to Headquarters]." In terms of personal property, the metrics quickly showed USA was capable of getting rid of property much quicker than the institutions were able to process it. Lin recalls, "The bottleneck was the centers, not us. Or the bottleneck now is at the individual subcontractor facilities or the vendor facilities where we need DCMA support. Without the insight from the data we get on a monthly basis, I would not be able to know." [130]

Dorothy S. Rasco by J. Steven Newman, 7 February 2013.

[130] Interview, Frank Lin by David M. Lengyel, 13 February 2013.

IT SYSTEMS

This section provides the story on the significant and unexpected challenges associated with disposition of IT hardware and software from the Space Shuttle Program. First, there existed almost no benchmark or set of best practices to guide the activity. Second, no one realized the importance of retaining critical IT systems personnel and critical skills. Third, despite a desire to get started early (and to work in parallel with other T&R activities), managers quickly discovered that IT shutdown needed to be tackled near or at the end. In spite of challenges, there emerged a set of effective processes, practices, and lessons learned (summarized in Section 2) providing a template for IT program managers and specialists for the future.

Sorting out the IT systems on the Space Shuttle Program turned into something of a Rubik's cube. Over the years, many of the IT systems were interconnected and became interdependent to reduce operating costs. The result was that many "NASA" web sites and services were hosted on USA computers interconnected with various combinations of NASA, USA, and other networks.

Part of the problem was just how long the SSP had been in existence. The program had begun largely before the computer age arrived, but had fully embraced the digital age by the end. Previous programs had not had to deal with extensive IT systems during closeout, so there was nothing to compare to in terms of the amount of software and systems. Dennis Davidson remembers, "There should be a nice, standard process, but if there was a nice standard way of doing it we never found it. So, the whole IT issue—what do you have to do with the hardware, what can you do with the software, what software can be transferred, what software can't be transferred—there were no lessons learned from anybody to go by and it was all brand new."[131]

One of the things the program finally discovered was that you could not really tackle shutting down the IT systems until the end. Davidson remembers, "We knew it was going to be the schedule driver. So it's kind of been sitting there. We pushed hard to get some systems done early so we could get our own internal lessons learned of what worked, what doesn't, where do you run into hiccups, where do you have to deal with the records manager versus the IT manager, who really was the controlling authority over what it was you were trying to disposition. It was different. So, again, we pushed some of it early just to get done what we could to learn, but even then the lessons we learned seemed to change from location to location."[132]

The systematic disposition of IT systems followed an approach that began with the identification of applicable security plans, IT systems, applications, records, data, and the collection of last-need events and dates. This information was housed in the Transition and Retirement Information Technology (TRIT)

[131] Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.
[132] Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.

database. TRIT supported the integrated assessment of software and hardware, and it was used to identify when records were removed from a system.[133]

TRIT provided the capability for all Space Shuttle Program contractors to pre-plan and publish the disposition of the IT assets managed by their respective companies. TRIT was also designed to serve as a catalog for other programs/contractors to review potential available IT assets and to indicate the potential funding source to transfer the IT assets. Each element/project was required to collect and populate the TRIT database. The last need events and dates for software applications and records directly drove the disposition determinations for the associated hardware. The IT Working Group (ITWG) representative from each element/project ensured that all statuses in TRIT were current.

During operations, SPOC had multiple systems tracking program assets. However, a single authoritative system was required to effectively manage the assets during transition or disposal. Since the requirement for closeout-specific data impacted each existing system differently, a single system meant that these requirements were only implemented once.

Major events that signal the point in time that an IT asset/system would no longer be needed were identified and used to plan and schedule the excess or transfer of IT assets. For closeout, the Last Need Events—wheel stop, last ferry flight, post processing, contract close, and end of program—were used in conjunction with a last-need fiscal year and quarter when an asset would be available for excess or transfer. This allowed scheduling of the disposition of IT assets based on an event, such as a facility closing, rather than a calendar date that was subject to change due to unforeseen or uncontrollable circumstances, such as slips in the fly-out manifest. The last need event, fiscal year, and quarter were reviewed and updated as needed to maintain the schedule for completing closeout actions.

The operations concept for disposing of IT assets was established prior to executing T&R and outlined the processes used to disposition IT assets and closeout the use of assets for the contract and program. Existing processes were tailored and scaled down where possible and new processes established as needed. The ITSM tool was used to manage all IT systems and asset activities. The required internal change control boards were scaled down and streamlined as appropriate to support T&R.

Because of the complexities of the SSP IT architecture, NASA directed USA to use a data discovery tool that would help map interdependencies and relationships. The initial attempt to use the tool to improve the understanding of existing system configurations and interactions was not successful. The principle lesson was that hardware asset discovery was relatively easy, but these were already well understood and documented. The software assets were somewhat more difficult, with commercial off-the-shelf (COTS) software assets easier than custom applications to identify.

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[133] "Space Shuttle Program Transition Management Plan," NSTS-60576, 5 August 2010.

Ultimately, it was the system relationship data that led to the abandonment of the discovery tool. There were a number of contributing factors, but the lack of configuration data at the system level was a major factor. The inability to relate the interfaces between systems and system components with specific communication paths (port pairing and protocol) was another major factor. The existence of multiple authoritative sources, with different data semantics and in some cases overlapping scope, added to the difficulty. A more mature Information Technology Infrastructure Library (ITIL) v.3 configuration system could have contributed to overcoming these obstacles on the systems where it existed, although the data aggregation over multiple systems would still be an issue.

Dennis Davidson observed, "I think IT is always the hardest just because when people can't see it and touch it—it's not the servers it's the software on the servers—it's just harder to deal with. It's harder to know exactly what you need to do. It's harder to know when you're done. The copyright laws, in terms of if you've got a copy what can you do with that? And, how do you know you've gotten rid of all your backup copies of everything that you're supposed to get rid of before you turn something over?"[134]

If there was a real lesson from the IT closeout, it was workforce retention. Davidson: "I don't think we did a good job at all of retaining our IT workforce. Workforce retention was geared at ops. We really didn't intend it to be for the T&R workforce. The thinking all along was, once we're done with ops, we'll do T&R with whoever is around. Whoever is available, we'll make it work. The one exception to that might be IT. Those folks are in such a demand that they're not going to stay until the doors are closed and you need them at the very end. The flipside of that is there's not a whole lot specific. You need smart IT people. You don't necessarily need people who have been here for 20 years. So you either need a way to retain the folks that have been around, the IT folks, or acknowledge the fact you might have to go do some hiring in the last 6 months, or year, to get the right IT people in."[135]

[134] Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.
[135] Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.

REAL PROPERTY

The subject of real property is much more than a "brick and mortar" story. It involved the dispositioning of Space Shuttle facilities, historic preservation, recordation, and environmental remediation. One manager recounted that the Apollo Program, by and large, just "walked away" from most of the retirement activities that the Space Shuttle Program had to deal with. In fact, most of the environmental conditions of facilities at KSC were preexisting from the Apollo era. As in other transition and retirement areas, a common pair of key takeaways were planning and communicating.

Initial Planning

Real property is defined as all land, buildings, and other structures and their associated built-in systems that cannot be readily moved without changing the essential character of the real property.[136]

NASA facility assets are quantified and documented in the Real Property Inventory (RPI) that provides basic information about NASA-owned facilities, including building number, location, type, size or capacity, age, estimated current value, and easements. The RPI tracks all property owned by NASA, regardless of whether it is operated by NASA, a contractor, or another Agency. The RPI does not track facilities that are owned and operated by contractors since these are not considered NASA assets, even if NASA is the sole customer. NASA also tracks other information about real property, such as condition and utilization, through studies and database tools constructed from the RPI information.

The initial 2005 ISOS Transition Panel used a study conducted by Rand Corporation to identify the facilities used by the Space Shuttle Program and to quantify the facilities impacted by T&R. The report listed 640 facilities, representing about a third of the total Agency real property. In addition, the SSP shared the use of another 170 facilities, valued at 10 percent of the total Agency real property. The SSP also supported a vast infrastructure of networks, power distribution, utilities, and other assets that were nearly impossible to sort through or quantity until they began to be shutdown or the program stopped paying for them.[137]

As could be expected, there was a great hesitation on the part of the SSP to give up facilities, at least initially. When the decisions finally came, it was usually to give up part of a capability and to keep the other part to support fly-out. Examples included one of the SSME test stands at Stennis, one of the launch pads at KSC, and some of the floor space at MAF. Dennis Davidson remembers, "Those were all copy 1 of 2. It wasn't the entire full up capability. So when you shut down a SSME test stand, you still had an SSME test stand. When you decided to turn over a pad, you still had a pad. When you decided to get rid of MAF floor space it was this square footage, there's some identical square footage over here. It was when you got

[136] "Space Shuttle Program Transition Management Plan," NSTS-60576, 9 May 2009.
[137] "ISOS Space Shuttle Program Transition Panel Final Report," 15 April 2005.

to the decisions to finally close all the test stands at Stennis that you really pushed and, in essence, we probably did that six months to a year later than we really could have just because the ops guys were nervous and they were never at the point where an independent T&R organization could come in and shut them down."[138]

One of the arguments for integrating the T&R function into the mainline SSP management structure came to light during these discussions. Davidson: "Getting rid of the final one, that final piece that says the program will no longer have this capability, mentally, emotionally; I don't think the program would have ever accepted that from an outsider. It was a decision that had to come from within that said this is something we've got to do. At that point, you weren't ever going to sell it on a business argument or on a T&R argument. It had to come from an ops argument that proved beyond a shadow of a doubt that the capability just wasn't needed anymore."[139]

Davidson remembers, "We had a mantra from the beginning that we were not going to create anything new if we could find any way to avoid it and Dorothy hammered that into us that we would use the center processes, we would use the institutional processes. We're just going to do it their way and fit it in. Real property was the one area where we were, by far, the most successful in terms of we really didn't need anything that was unique to shuttle. The institutional processes for real property worked just fine and it's not like you're dealing with a million lines of property or with all the records. You're dealing with 50 or 100 buildings and the institutions deal with the buildings all the time. In most cases, they're going to another organization. They know what needs to be done. You really can just do it the way they've always done it and that seemed to work better in real property than it did anywhere else."[140]

During this planning timeframe, the Constellation Program conducted an exercise known as Exploration Requirements for Infrastructure and Capability (ERIC). The bulk of these facilities were located at KSC and they were budgeted for by the program. Kelly Gorman recalls, "From a KSC perspective, there wasn't a specific real property risk because we had a ground rule in real property from day one back in 2006 that said if a program or an institution says they want to keep a facility active for reuse and have it assigned to them, they must start paying for the facility on day one."[141]

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138 Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.
139 Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.
140 Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.
141 Interview, Kelly Gorman by J. Steven Newman, 28 February 2013.

Historical Preservation

Because of the national and international importance of Space Shuttle to human space flight, NASA was responsible for ensuring the proper documentation of its history and contributions in compliance with the National Historic Preservation Act (NHPA, 16 USC 470) of 1966 that directs Federal agencies to inventory and maintain properties of historic significance. The term historic property means any site, building, structure, or object included in or eligible for inclusion on the National Register of Historic Places, including artifacts, records, and material remains related to such a property or resource.[142]

Many facilities throughout NASA used by the Space Shuttle Program were designated national landmarks because of their association with the Apollo, Gemini, and Mercury projects. At present, there are no facilities within NASA that have been designated national landmarks solely because of their use by the Space Shuttle Program.

Section 106 of the NHPA specifies a methodology by which Federal agencies should identify historic resources, evaluate their significance, and devise means to mitigate impacts to resources listed in or eligible for listing in the National Register of Historic Places. Section 110 further requires Federal agencies to establish "a preservation program for the identification, evaluation, and nomination to the National Register of Historic Places, and protection of historic properties" and instructs agencies to manage and maintain historic properties in a way that "considers the preservation of their historic, archaeological, architectural, and cultural values." Section 106 regulations, 36 CFR 800 ("Protection of Historic Properties") of the NHPA requires Federal agencies to take into account the effect of their undertakings on properties included in or eligible for inclusion in the National Register of Historic Places and to afford the Council a reasonable opportunity to comment on such undertakings. In addition, most states have legislation that outlines requirements for such facilities within their jurisdictions.

In response to the NHPA-governed mandate for Federal agencies to preserve historic resources, NASA formed the Space Shuttle Program Historic Preservation Working Group (HPWG) in 2006 to provide Agency-level oversight and execution of NHPA-mandated activities prior to the retirement of the Space Shuttle. The JSC representative was responsible for compliance with NHPA, while the NASA Federal Preservation Officer advised and resolved issues that were in disagreement with regulators. The HPWG membership included the Historic Preservation Officers (HPO) from the four main SSP Centers (KSC, JSC, MSFC, and SSC), the Management Integration and Planning Office Transition Lead, and one component facility (Michoud).[143]

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142 "Space Shuttle Program Transition Management Plan," NSTS-60576, 9 May 2009.

143 "Space Shuttle Program Transition and Retirements: Personal Property Disposition Plan," November 2008.

In response to NHPA requirements, NASA conducted an historical survey and evaluation of all NASA-owned facilities and properties associated with Space Shuttle Program activities (real property assets) to determine their eligibility for listing in the NRHP. Such facilities included, but were not necessarily limited to, those used for research, development, design, testing, fabrication, and operations. The historical survey also included certain resources that were considered "personal property" under Federal regulations, such as the Space Shuttle Orbiters, retrieval ships, and mobile launch platforms.

The specific historic contexts and survey results were presented in a series of draft reports that were reviewed by the Center HPOs in consultation with the relevant SHPO. SHPOs have a great deal of authority to set requirements for Federal agencies in the area of historic preservation, and they are not obliged to consider cost in their judgments. However, the program found that there was room to discuss the SHPO's requirements in the context of what was reasonable from both a programmatic and historical perspective. SHPOs did not necessarily understand the nuances of the program, and the program learned the intricacies of protecting the Shuttle heritage for posterity. The lesson is that there is always an opportunity to discuss issues and to try to find a reasonable accommodation.

Using the information from the historical survey, the HPWG developed a list of historically significant assets that supported the Space Shuttle. Depending on future NASA programmatic needs, these assets may be transferred in their current state, modified to meet future program requirements, or demolished if it is determined that NASA no longer requires the infrastructure. The role of the HPWG is to provide coordination and general Agency oversight in determining forward planning of the historic assets and, in particular, ensuring that proper mitigation strategies are in place prior to engaging in an undertaking (i.e., any change that alters the asset's historical significance).[144]

Recordation

Recordation, even though it has the word record in it, is not a record. It is a narrative telling the story of something, in this case the Space Shuttle Program.

Historical preservation is an integral part of property management and environmental management. NASA strove to identify landmarks and properties of historical significance as early as possible in the T&R process to ensure that adequate time was available to resolve technical and funding issues and to minimize implementation delays.[145]

The HPWG performed an Agency-wide site survey to assess SSP property for historical significance in compliance with the NHPA of 1966 and to support the programmatic environmental assessment performed in compliance with the National Environmental Policy Act (NEPA).

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144 "Space Shuttle Program Transition and Retirements: Personal Property Disposition Plan," November 2008.
145 "Space Shuttle Program Transition Management Plan," NSTS-60576, 5 August 2010.

Every NASA Center associated with the Space Shuttle Program was required by the NHPA to do a survey of all properties associated with the program. The National Historic Preservation Act is the responsibility of the National Park Service under the Department of the Interior.

NASA had a contractor conduct the survey and identify properties considered eligible for listing on the National Register of Historic Places. Those reports were coordinated with the Space Shuttle Program and then forwarded to the appropriate SHPO for concurrence. Normally, these actions are only applicable to real property (buildings), but in this case it was decided that the Orbiters were historically significant as well. Ultimately, although almost every NASA Center participated in the Space Shuttle Program in some capacity, everybody agreed that only DFRC, JSC, KSC, and MSFC needed to be included in a Memorandum of Agreement (MOA) for compliance related to the Orbiters, and that JSC would take the lead since the Orbiters were maintained on the JSC property records.[146]

Recordation

"The requirement for the recordation is to write it at the level that it could be understood by a high school junior."

The NHPA requires a process called recordation that thoroughly documents historic properties that are eligible for listing on the National Register. There are three possible levels of documentation for the resultant Historic American Engineering Record (HAER). Level 1 is the most in-depth, with detailed measured drawings, followed by Level 2, which uses existing drawings, and then Level 3, which uses recording. Initially, the Space Shuttle Program was not certain if they wanted to pay for a Level 1 effort (since it was expensive), but they ultimately agreed that the Space Shuttle Program was so significant to the nation that it needed a Level 1 effort. NASA negotiated this position with the National Park Service the Advisory Council on Historic Preservation, and the State Historic Preservation Officer from California, Texas, Florida, and Alabama. All of these parties ultimately signed an MOA that reflected this philosophy.

Oddly, the Stennis Space Center never engaged in the program recordation effort, although they worked separately with the Mississippi SHPO to document several test stands. In addition, there were separate efforts between individual Centers and their SHPOs to document facilities at JSC, KSC, MSFC, WSTF, Palmdale, and the Santa Susana Field Laboratory and to comply with Section 106 of NHPA.[147]

NASA held a kickoff meeting in Austin, Texas (home of the Texas SHPO) to draft the MOA. Additional meetings were held at each of the Centers, as well as the ATK plant in Utah, the Boeing facility in Huntington Beach, and Lockheed Martin at MAF. Each meeting included the NASA Historical Preservation Officers from the Centers, the SHPOs from each of the states, the National Park Service, and the NASA Federal Preservation Officer.

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146 2013 Interview, Perri E. Fox and Barbara R. Severance, by J. Stephan Newman, 13 February 2013.
147 2013 Interview, Perri E. Fox and Barbara R. Severance, by J. Stephan Newman, 13 February 2013.

The focus of the program recordation effort was the Space Shuttle stack, including OV-103 (*Discovery*), ET, and SRBs. A team led by Archaeological Consultants, Inc., in Sarasota, Florida, wrote the HAER, a 729-page report for the Library of Congress.

The final HAER contains narrative, photography, video, drawings, and interviews that cover the Space Shuttle Program from "cradle to grave." A particular challenge for the Space Shuttle HAER was dealing with ITAR regulations. In particular, this meant that engineering drawings could not be used, so NASA subcontracted to the National Park Service to produce interpretive drawings that were detailed enough for the report but sufficiently vague to satisfy the ITAR rules.

In addition, because the program had agreed to do a Level 1 report, the National Park Service required 4×5-inch medium format monochrome photographs of the vehicles and properties. Since the recordation is expected to last hundreds of years into the future, the National Park Service requires that everything be captured on archival-grade film and paper, and at this point in time, it does not recognize digital formats because they are evolving too quickly.[148]

The important thing to remember is that the historical requirements are negotiable with the National Park Service. Neither the Park Service nor the SHPOs necessarily know the importance or significance of the program being closed out; it is imperative that a mutual understanding be reached to eliminate the possibility of spending a great deal of money on tasks that have no or little future value. In the case of Space Shuttle, these negotiations produced an acceptable outcome for all parties and produced documentation that will serve future historians well.

Environmental Remediation

Many of Space Shuttle Program assets had environmental risks and other liabilities associated with them as transition efforts were implemented. However, even before 2005, the Agency was making progress on much of the required remediation. For example, MAF had a very active site remediation program that has made much progress on cleanup of several contaminated sites. Many sites have been cleaned up, and work continues on other sites. Assessments/studies, site restoration, control, and monitoring will be required at MAF for a number of years into the future. Government-owned assets are located on Government-owned property, as well as located at properties owned by prime contractors and subcontractors, which will further complicate the transition implementation. Asset disposition will require close coordination and support from the various Center property management, facility, procurement, legal, and environmental offices. Transition implementation will involve integration and coordination of a number of representatives from NASA Headquarters, the Centers, the Space Shuttle Program, various contractors, the Environmental

[148] 2013 Interview, Perri E. Fox and Barbara R. Severance, by J. Stephan Newman, 13 February 2013.

Protection Agency (EPA), and state and local authorities.[149]

At KSC, George Jacobs recalls, "As we exited the facility we would do an environmental baseline condition assessment where they would look at the history of that building and they would do a sampling if needed. Before we were able to turn [a facility] over to the center for either abandonment or to a new owner we would have to complete that assessment and therefore you would have a new baseline."[150]

Locals knew the Santa Susana Field Laboratory (SSFL) in Ventura County, just north of Los Angeles, simply as "The Hill." From the late 1940s through 2006, Santa Susana was "one of the largest and most diversified liquid rocket test facilities in the world," offering "research and development testing as well as production acceptance testing on liquid rocket engines ranging from relatively small thrust to a quarter million pounds of thrust." After Boeing purchased Rocketdyne as part of their 1996 acquisition of the aerospace assets of Rockwell International, it began phasing out the remaining operations at Santa Susana. On 2 August 2005, Pratt & Whitney purchased Rocketdyne from Boeing, but it declined to acquire SSFL as part of the sale.[151]

Sixty years of operations at Santa Susana, including more than 30,000 rocket engine tests and 4 nuclear accidents, left an environmental nightmare. In September 2010, the Department of Energy, NASA, and the State of California reached agreement on remediating the nuclear contamination in Area IV, but cleaning up the rest of the laboratory is still in limbo. Once the site is remediated, Boeing intends to "preserve its 2,400 acres of land at Santa Susana as open space, and voluntarily donate it to serve the public for future generations."[152]

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149 "ISOS Space Shuttle Program Transition Panel Final Report," 15 April 2005.

150 Interview, George Jacobs by J. Stephan Newman, 28 February 2013.

151 Joan Deming, Patricia Slovinac, and Karen J. Weitze, "Historic Resources Survey and Assessment of the NASA Facility at Santa Susana Field Laboratory, Ventura County, California," Archaeological Consultants, Inc. and Weitze Research, March 2009.

152 "Nuclear Cleanup Set for Boeing Property Near LA," *The Everett Herald*, 3 September 2010; "Future of Site," located at: *http://www.boeing.com/aboutus/environment/santa_susana/future.html*.

RECORDS MANAGEMENT

Records Management

"Engineers never throw data away. They keep it forever; they just can't always find it."

Like many processes, the science, art, and even the bureaucracy of records management has matured over the years. What has not changed is the need to access, read, and digest previous program records by NASA personnel. The Constellation Program, with its focus on returning to the Moon, poured over Apollo documentation to assess architectures, systems, and operations information for lessons learned. At the same time, Constellation propulsion personnel requested that information associated with, for example, the Space Shuttle Solid Rocket Booster not be archived because even though the Ares I and Ares V booster systems called for a larger (5 segment) booster, the heritage data would still be useful. This section describes the challenges and risks associated with the scope of the records management activities during transition and retirement in a "one size does not fit all" environment.

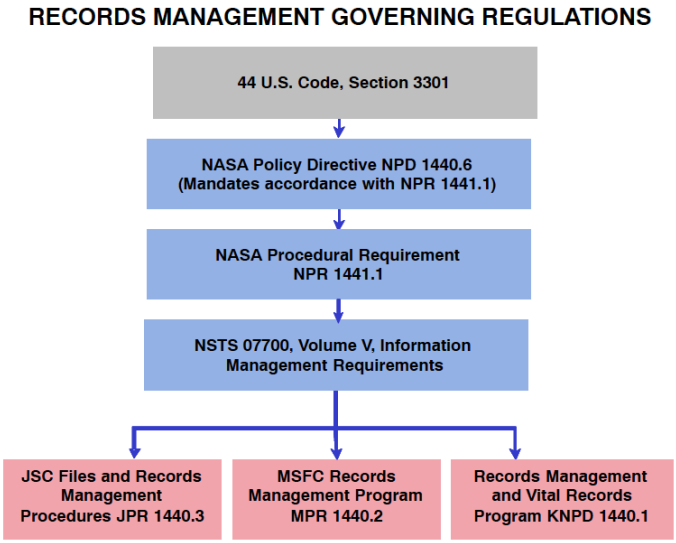
Initial Planning

The statutory definition of records is contained in 44 USC 3301, Definition of Records, which reads:[153]

> As used in this chapter, "records" includes all books, papers, maps, photographs, machine readable materials, or other documentary materials, regardless of physical form or characteristics, made or received by an Agency of the United States Government under Federal law or in connection with the transaction of public business and preserved or appropriate for preservation by that Agency or its legitimate successor as evidence of the organization, functions, policies, decisions, procedures, operations, or other activities of the Government or because of the informational value of data in them. Library and museum material made or acquired and preserved solely for reference or exhibition purposes, extra copies of documents preserved only for convenience of reference, and stocks of publications and of processed documents are not included.

It should be noted that "official records" cover only Government data, not contractor records. However, if the contractor generated data for the Government, then it is considered Government data and can become a record if it meets all the other criteria. In fact, contractors hold most Government data while it is being generated and used.

[153] "Space Shuttle Program Transition Management Plan," NSTS-60576, 5 August 2010.



NPR-1441.1, NASA Records Retention Schedules, provides specific direction for the categorization and retention of records. In addition, NSTS-07700, Volume V, Information Management Requirements, provided specific Space Shuttle Program direction for records management and retention schedules. T&R records disposition was performed using the existing records management policies and processes, although for T&R they were documented in Volume XX, Book 2, Appendix 5.[154]

However, because the Space Shuttle Program extended over such a long time period and across several prime contractors, there was no clearly established agreement on exactly what was an official record prior to T&R, since the interpretation of the NPR-1441.1 definition changed over time.

On 2 November 2005, Patti F. Stockman, the Agency Records Officer, and Michael E. Corbin, the SSP records manager, discussed records management at the second transition TIM chaired by Lee Norbraten. Stockman proposed a high-level process to identify where the records were, what they were, and what the appropriate retention schedules were that should be associated with each category of record. Then she proposed to take the actions necessary to properly disposition them, whether that involved the ultimate destruction of temporary records or the transfer of permanent ones to the NARA.[155]

Stockman also asked the record holders to identify what electronic format the records were in, whether they were National Security classified or otherwise access-restricted, and then, very importantly, to identify which retention schedule from NPR 1441.1 covered that grouping of records. There were several schedules for the program and project records, the longest of which was for permanent, historically significant records that would be transferred to the National Archives. Then there were several levels of temporary records and lengths of time that records needed to be retained based on (a) the nature of the program or project, (b) the

154 "Space Shuttle Program Transition Management Plan," NSTS-60576, 5 August 2010.
155 Interview, Patti F. Stockman by David M. Lengyel, 31 January 2013.

nature of the record or how it was used in a program or project, and (c) what its retention value was to the Agency beyond the life of the program or project.[156]

After the TIM, Mike Corbin set up the Records Management Working Group (RMWG) with participation from every Center as well as from each of the projects. Specialists from NARA attended the working group meetings, mostly via telecon. Much of the challenge of records management can be attributed to the 30-year duration of the program and the monumental changes in technology that had occurred during those years. In addition, the definitions of what were records, and the way records were stored, had changed considerably. In the early years of the program, a strong central repository had kept the official record; the computer revolution made it more difficult to determine exactly which copy was the official record versus a working copy.[157]

Contractors were required to have records management programs in place throughout operations, but there was much discussion and many changes negotiated with the JSC/KSC T&R Working Group and the MSFC Shuttle Retirement and Transition Team (SRTT) over what was an official record and needed to be archived as well as what would be beneficial to future programs.

Records Management

"Anything you can do during operations is free. So, look for those things that you can do, like getting your records folks to make everything electronic up front, getting them to go through records on a yearly basis, not as part of a retirement effort."

Patti Stockman thinks that USA "did a very good job of managing records" because NASA had inserted a contract clause that "required the contractor to manage those records that qualified as federal records in accordance with federal requirements and agency policy." USA took that contractual responsibility seriously and they worked through the years in collaboration with the JSC records manager, retiring inactive records to the Federal Records Center just as the program office was doing. Stockman remembers, "I was really pleased that USA, on their own, self-identified the records they were creating and/or maintaining that qualified as federal records. It wasn't something we had to go and take them to task for, or beat them over the head, to make them recognize that those weren't their records, that they were NASA's records. That's unusual from my experience."[158]

Stockman believes KSC, for example, established a good cost estimate on what it was going to cost the Center to process records. "The guy that helped the records manager [Janice R.] Jan Justice in the actual development of their cost estimates was Roger [S.] Rudig. The initial cost estimates were extremely high, largely because nobody knew how many records existed or exactly how to process them. But the program only considered and reported forward to Headquarters what were going to be the costs to the *program* of

156 Interview, Patti F. Stockman by David M. Lengyel, 31 January 2013.
157 Interview, Michael E. Corbin, 25 February 2013.
158 Interview, Patti F. Stockman by David M. Lengyel, 31 January 2013.

getting the job done." Because of this, Stockman believes, "NASA management didn't have a concept of what the full cost would be including the center's ability to cope with, and store or process, the records once the program dumped them on the centers' records managers."[159]

Then there was the entire issue of ITAR restrictions on records. Many early Space Shuttle records were transferred to the National Archives before ITAR existed. However, once most program data was deemed ITAR restricted, it created a problem. Stockman: "The National Archives accepts *electronic* records that are ITAR-restricted, or that we think are probably ITAR-restricted, if we identify them as such. But the National Archives will not accept *paper* records, or other formats of records, that are ITAR-restricted, or that we believe are probably ITAR-restricted."[160]

It should be noted that the only time the Agency Records Officer gets involved in the records disposition process is in reviewing and signing off on the transfer of records to the National Archives—that is, transferring actual ownership from NASA to NARA. The Center records managers handle all of the other records activities. In instances of hard copy records that are probably ITAR-restricted, the Center records managers oversees on-Center storage until NARA can accept them or they are destroyed.

Historically, inactive records were shipped to the Federal Records Centers, which stored them until they were due for destruction or for transfer to the National Archives. The Federal Records Centers are run by NARA but are simply Federal warehouses that store records that belong to the agencies. They sit there until (a) the records either come due for destruction because they're temporary, in which case NARA notifies the centers when the series/collections of records are due for destruction, or (b) they are formally transferred to the National Archives.

Archiving

Dennis Davidson has a suggestion for future programs: "If I were to talk to Space Station about all their records I would say, first and foremost, start now. Whatever it takes every year to get rid of all your paper and just make it 100% electronic because you can get to the point where it all fits on a server, whatever size room you need to get, however big a server you need, but you can put it all in one space. It's not like thousands and thousands of square feet of warehouse that you need for the paper."[161]

The numbers can be staggering. For instance, at MSFC there were 122,000 cubic feet of paper documents that needed to be categorized. In the end, program officials deemed that only 12,000 cubic feet of them were official records. Davidson believes that all of the paper should be scanned prior to closing out a program: "you can then take that 12,000 cubic feet and put it on a couple of thumb drives, a couple of hard

[159] Interview, Patti F. Stockman by David M. Lengyel, 31 January 2013.
[160] Interview, Patti F. Stockman by David M. Lengyel, 31 January 2013.
[161] Interview, Dennis R. Davidson by Jonathan M. Krezel 26 March 2013.

drives, whatever it is that you need, and you're done. You've got it all in one place." However, he also believes this should be accomplished during operations, not T&R. The reason is simple: "we found if anything you did during ops was essentially free and the longer and longer you waited the more it cost to do it through T&R. So, it's one of those things where you'd like to get your existing ops workforce in whatever time they have available, converting everything over from paper to electronic so that when you get to the point that you're ready to archive it's the flip of a switch and not a big research study that you got to go do to figure out what's there."[162]

Even given the magnitude of the Space Shuttle Program, sometimes things were smaller than expected. Dennis Davidson remembers that the program bought a server and provided it to USA to use for records transfer. The plan was for USA to fill it up and transfer it to the JSC records manager, who would then go through the archival process. However, Davidson remembers, "Turns out we bought too big a server, because they never did fill it up and we only did it once and it was only a 10 terabyte, maybe, server for all those files. We were looking at the institutional metrics all along and they were making zero progress with electronic records because USA was sending nothing to them because they hadn't filled up the server yet. We finally got to a point and said it doesn't matter it's not full. Transfer something. Let them get to work on it and really if people are comfortable looking at a zero for progress on one side, we could have waited until the end and just let them do it. Storage is cheap and you really can buy just one unit and fill it all up with everything that you need and then one bulk transfer and you're done."[163]

In reality, this process did not result in handling each electronic record twice. USA determined which were records as they loaded them on the server. When they sent them over, the institutional process was just to check the indices and make sure that what was supposed to be there was there, but they did not open up every single record.

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[162] Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.
[163] Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.

CONTRACT CLOSEOUTS

Contracts

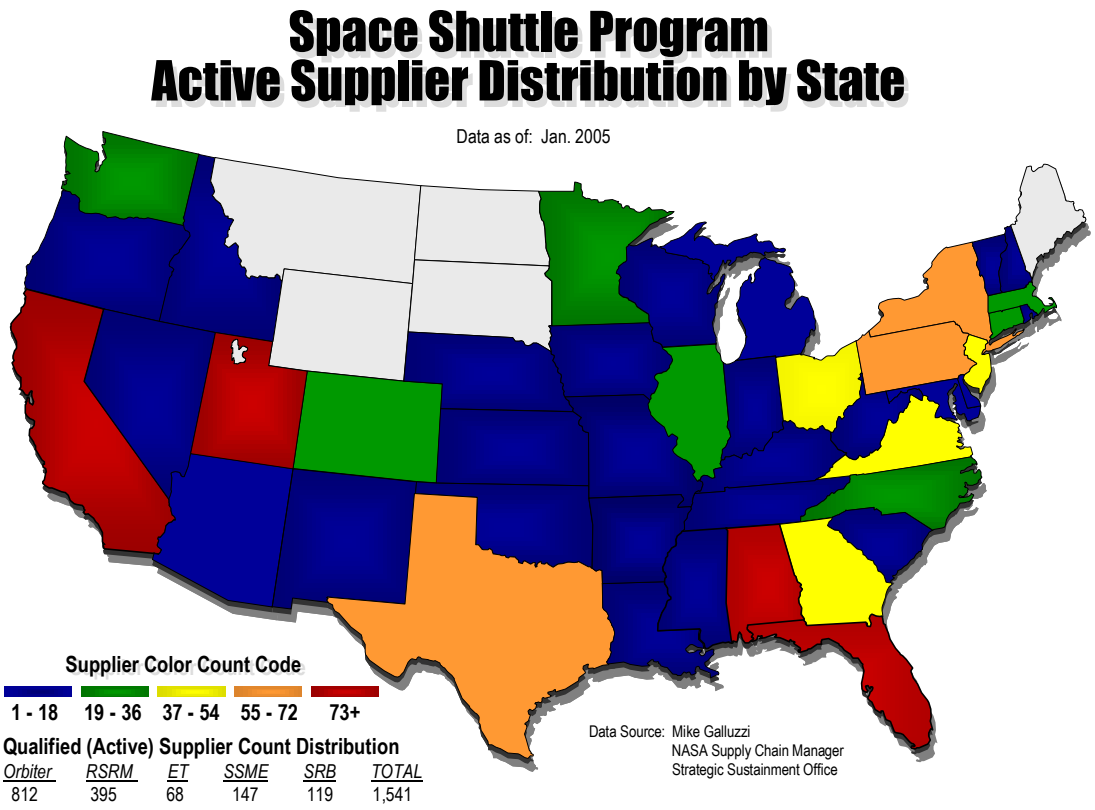
"So find a way to be creative and innovative and still being legal, to turn on jobs quickly for those fast turnaround items."

The concept of "when in doubt, read the contract—and when you're not in doubt, read it anyway" was definitely on the minds of Shuttle transition and retirement personnel in many ways during both planning and execution. Procurement personnel are an important part of the transition and retirement process, particularly when these activities are not part of, or are not well-defined in, existing contracts. Part of the challenge in this area was to ensure that the Agency was effectively administering these procurement closeout activities on time and on budget in order not to negatively impact follow-on programs.

Initial Planning

NASA has always realized that without public and congressional support, a successful human space flight program would not have been possible. This support is usually derived from one of two sources: positive economic impact on a select population demographic or a positive social perception by the majority of the population, which in most cases influences congressional support. A highly visible, strong supplier base is an example of the former. The ISOS Transition Panel attempted to identify the geographic diversity of this supplier base to assist in identifying possible state economic impacts caused by terminating contracts associated with the Space Shuttle Program. This map shows the 1,541 active suppliers by state.[164]

[164] "ISOS Space Shuttle Program Transition Panel Final Report," 15 April 2005.



This map did not show the 3,000 to 4,000 inactive suppliers that were qualified to support or had previously supplied materials to the program. Active suppliers were defined as having received a purchase order from any of the project offices within 48 months of December 2004. Unsurprisingly, California, Florida, and Utah had the most active suppliers, with a total of 350, 242, and 146, respectively.

The timing of the 2010 retirement was awkward from a contracting perspective since none of the five major support contracts were effective for that long, yet it was too short a period to justify a new competition for any of them. In 2005, the five major contracts and their end-dates were as follows:[165]

Contract	Contractor	Items	End Date
NAS9-20000	United Space Alliance	Space Flight Operations Contract	September 2006
NAS8-97238	ATK	Reusable Solid Rocket Motor	May 2007
NAS8-00016	Lockheed Martin	External Tank	September 2009
NAS8-01140	Boeing Rocketdyne	Space Shuttle Main Engine	December 2006
NAS8-36801	Pratt & Whitney	SSME Alternate Turbopumps	September 2005

[165] "Transition Planning and Strategy Meeting," MSFC Institute (Intergraph Building), 3–5 August 2005.

NASA was already in the process of defining a non-competitive follow-on contract for USA. The new Space Program Operations Contract (SPOC) would cover performance through the end of FY10, with a series of options to extend it for a few more years to cover the final fly-out and closeout activities as needed.

NASA officials at MSFC were rebaselining the propulsion contracts in a two-phased approach. The first covered extensions through March 2006 to support the changes and delays incurred by the *Columbia* accident. The second phase included non-competitive extensions through the end of FY10, again with options to extend a few more years as needed to fly-out the manifest and perform closeout.[166]

However, in some ways that was just the beginning of the contractual complications. For instance, the SFOC (and later SPOC) contracts provided support to the ISS program and the JSC Missions Operations Directorate that needed to continue after the end of the Space Shuttle Program. And Center-wide support contracts at JSC, KSC, and MSFC provided support to the Space Shuttle Program that would no longer be needed, resulting in significant changes to those efforts.

SPOC

United Space Alliance began planning for the contract closeout during 2004 with Kevin P. Repa as the program manager. USA was a limited liability company (LLC) owned by Boeing and Lockheed Martin. For all intents, USA was a single-contract company. Although it had recently signed on as a subcontractor to several development efforts (most notably, Orion and ISS), that represented a small part of its business.

Although most of SPOC (and USA) ceased to exist in early 2013, the financial and contract closeout will likely persist for another 10–20 years. Much of this is because the Defense Contract Audit Agency (DCAA) is significantly behind on their contract audits. Davidson points out, "They continue to audit subcontracts that are closed out. This is 2013 and they just completed a partial audit for 2007. They continue to audit all sorts of different items and this is routine for contract closeout. It does not happen overnight or even in 5 years or so. It takes a while and it is outside of NASA's control. It is entirely up to DCAA. They've got all the records. They will do that audit. They'll go back to USA and ask for additional supporting data. At that point in time, whoever owns the USA records, whether it's Boeing, or Lockheed, or whether USA is still there, would have to supply the data to the auditor and they'd look at the information and come back with a finding of the government was overcharged, or undercharged, and the adjustment would be made."[167]

Dorothy Rasco, who led the closeout in Downey, remembers that the final bookkeeping from that effort lasted 10 years. She warns, "Is it going to be big bucks? No, but you never know what is an unknown

[166] "Transition Planning and Strategy Meeting," MSFC Institute (Intergraph Building), 3–5 August 2005.
[167] Interview, Dennis R. Davidson by Jonathan M. Krezel, 26 March 2013.

unknown that, on a high tech operations program, you could lay all your risk in. So you don't know what's going to come up that you never planned for in contract closeout."[168]

One of the major tasks for United Space Alliance, as the prime Space Shuttle contractor, was to closeout all of the subcontracts it maintained with other vendors. The entire effort was handled as a separate Task Order (IDIQ) from NASA to USA.

Based on direction from NASA, USA issued RFPs to suppliers that directed firm fixed price proposals unless sufficient rationale was provided for an alternate contract type. In the end, the majority of supplier proposals were fixed price, although a few of the larger efforts were proposed at cost. Unfortunately, the direction from NASA was not detailed and provided little guidance regarding the desired supplier proposal structure. The USA proposal reviewers were generally satisfied with the level of detail provided by the suppliers, but the NASA technical reviewers desired more information and cost breakdowns. This resulted in extended fact-finding.

USA conducted a series of Pre-bid/Pre-RFP meetings at selected subcontractors to ensure that the vendor and USA had a mutual understanding of the scope and terms of the closeout effort. In addition, more than 40 subcontractors held Government property that was accountable to SPOC and would require disposition. The USA team visited most of the larger subcontractors with significant amounts of property or unique or complex situations. It was not necessary to visit all subcontractors; several had a minimal amount of Government property.

During the meetings, USA provided a detailed review of the requirements, including a Memorandum of Understanding established between USA and NASA that provided guidance and opportunities to streamline the property disposition process. This was flowed to each subcontractor via an earlier subcontract change order. While this agreement was beneficial, since it was a departure from the norm, USA reviewed it in detail with each subcontractor and their associated DCMA Plant Clearance Officers to ensure that they understood the intent and potential benefits of this agreement. Most of the vendors provided tours of their facility to further understanding the complexity, size, location, and any unique aspects of dispositioning the items. This pre-coordination ensured a smoother understanding of the magnitude and complexities involved at each supplier. Short closeout proposal turnaround times were supported, and both USA and the supplier better understood unique closeout and site-specific requirements

NASA delegated responsibility to the DCMA Plant Clearance Officers to manage the disposition process associated with Government property and worked closely at the appropriate levels with DCMA. For this reason, USA believed that it was important to include them at each of the pre-bid meetings. This activity proved extremely successful and DCMA supported, in person or via teleconference, nearly all of the

[168] Interview, Dorothy S. Rasco by J. Steven Newman, 7 February 2013.

meetings. With few exceptions, the Plant Clearance Officer provided timely disposition instructions much sooner than previous experience would have indicated.

MSFC Contracts

At MSFC, Michael D. Allen was the COTR or deputy COTR for the three propulsion contracts: ATK for the RSRM, Lockheed Martin for the ET, and Pratt & Whitney Rocketdyne for the SSME (and Alternate Turbo Pump). He remembers that the overarching goal for T&R was to "disposition the records, and we had to get all of the property, both real and personal, that was left over after the last launch." It took about a year to write new statements of work for the three contractors, concentrating largely on "how we would track this effort, who we reported to, how often, the process that went with it."[169]

Initially, much of the RSRM (and USA SRB) hardware was destined for Exploration for use on what would become the Ares I and Ares V launch vehicles. In addition, most of the proceeds from the sale of surplus property from the three propulsion contracts were going to be funneled back into the Exploration (later Constellation) efforts. Exploration planned to use most of the RSRM and SRB hardware but almost none of the SSME hardware, so MSFC directed Pratt & Whitney (P&W) to dispose of it. Allen remembers, "When Constellation went away, it changed the look, and all the plans that we had as far as transferring what hardware needed to go and what hardware didn't." In the post-Constellation world, the new SLS wanted only minimal amounts of RSRM and SRB hardware (mostly to support the first few launches), but it wanted almost all of the SSME hardware, including the 15 flight engines at KSC. According to Allen, "The changes there were pretty dramatic. It caused us to do a lot of re-evaluation, re-formulation of budget, and re-formulation of plans of the contracts themselves."[170]

[169] Interview, Michael D. Allen by David M. Lengyel, 20 February 2013.
[170] Interview, Michael D. Allen by David M. Lengyel, 20 February 2013.

THE ORBITERS

Dispositioning of the Orbiters was undoubtedly the most visible aspect of the Space Shuttle retirement effort. National media coverage of *Discovery*, *Enterprise*, and *Endeavour* being transported by the Shuttle Carrier Aircraft (SCA) from KSC to Washington, D.C., New York City, and Los Angeles, California, was memorable for those able to witness it and bittersweet for the NASA Space Shuttle Program family both past and present. Safing and preparing the Orbiters for delivery to museums for display was successfully carried out, and now these national treasures are all on display for generations of human space flight enthusiasts to come.

Initial Planning

Although President George W. Bush announced in 2004 that the Space Shuttle Program would end when assembly of the International Space Station was complete, it was not until 2007 that NASA began to seriously consider the question of what to do with the Orbiters once they were retired. Michael D. Griffin, the NASA Administrator at the time, initially espoused the view that the Orbiters should be displayed at the NASA Centers with the greatest connection to the Space Shuttle Program and that the disposition decision should be made by the Administrator without soliciting public input. However, this approach would have required NASA to absorb the entire cost of safing, preparing for display, and transporting the vehicles to their new homes—a cost that the Agency estimated at the time to be $42M for each of the flown Orbiters. Based primarily on this factor, key civil servants at the Agency urged a different course—that NASA determine the level of interest among museums and other organizations in paying for the preparation and transport of an Orbiter. Ultimately, Griffin acquiesced to this view and, in December 2008, NASA issued its first request for information (RFI) to "gather market research for NASA to make decisions regarding development of strategies for placement of Space Shuttle Orbiters and Space Shuttle Main Engines for public display after conclusion of [the Space Shuttle Program]."[171]

As the plans for transition and retirement began to solidify, NASA initiated a process to identify locations to display the soon-to-be-retired Orbiters. In this process, NASA sought to (1) place the Orbiters where they would be preserved for posterity and be seen by the greatest number of visitors, and (2) save taxpayer dollars by awarding the Orbiters to institutions that were willing to reimburse the Agency for the multi-million dollar cost of preparing them for display and transporting them to their new homes.

Display Site Selection Process

The NASA Authorization Act of 2008 required the NASA Administrator to submit to Congress a detailed plan describing the proposed disposition process for the Orbiters and other related hardware. In response,

[171] "Review of NASA's Selection of Display Locations for the Space Shuttle Orbiters," Office of the Inspector General special report, 25 August 2011.

NASA produced the "Space Shuttle Program Transition and Retirement Personal Property Disposition Plan" describing five principles that it would strive to meet during the disposition process:[172]

- Support the safe completion of all remaining Space Shuttle missions;
- Be disciplined, fair, transparent, and compliant with laws and regulations;
- Provide personal property placement opportunities to preserve the history of the Space Shuttle Program;
- Balance potential value to the public with the least cost to the taxpayer; and
- Include appropriate stakeholders and subject matter experts in the planning phase of the disposition process.

In the Property Disposition Plan, NASA indicated that it expected that one flown Orbiter (most likely *Discovery*) would be placed at the Smithsonian and that it planned to issue an RFI to gauge interest by museums and other qualified institutions in acquiring the remaining Orbiters and other major flight hardware. NASA indicated that it would only consider U.S. museums open to the public, U.S. Governmental entities, or U.S. institutions dedicated to educational outreach. The Agency also said that it would evaluate the information received in response to the RFI to develop further selection criteria and to make Orbiter placement determinations. Responding entities needed to be prepared to enter into Reimbursable Space Act Agreements (RSAA) with the Agency to cover the cost of Orbiter display preparation and transportation.[173]

Cost reimbursement was a tricky subject. NASA had always budgeted to safe the Orbiters since it needed to be accomplished regardless of what the final disposition of the vehicles was (sent to museums, scrapped, or stored for future use). Therefore, safing was included in the NASA 2010 Authorization Act and NASA paid for the safing activities out of its existing budget. This essentially meant that the display sites could not pay for safing because Federal law states that an Agency cannot supplement or replace appropriated funds with non-appropriated funds. However, NASA did not need to configure the Orbiters for display or to move them, and Congress had not appropriated funds for these efforts, so the display sites could pay this portion of the costs.

Courtney Graham, one of the HQ legal counsels, remembers, "So we looked at the difference between what NASA was obligated to do as the custodian, or owner, of that property to move it off its roles and what might be needed for a recipient who wanted to have that Orbiter in a display condition. We determined that we weren't going to run into that appropriation fiscal law issue if we accepted reimbursement from the recipient to move the Orbiter from that safe state into a display condition because that work would be done

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172 "Disposition of Shuttle-Related Assets," NASA Authorization Act of 2008 (P.L. 110-422) Section 613(a); "Space Shuttle Program Transition and Retirements: Personal Property Disposition Plan," November 2008.

173 "Review of NASA's Selection of Display Locations for the Space Shuttle Orbiters," Office of the Inspector General special report, 25 August 2011.

for the recipient and wasn't something that NASA had appropriated budget for because NASA would not be doing that display as part of the T&R effort."[174]

Therefore, the Orbiter costs were broken into three major categories. The first was safing the vehicles, and NASA was responsible for this cost. The second was called "display preparations" and consisted of putting the vehicles back together after safing and changing the configuration to match the desires of the display site. In the case of *Enterprise*, performing the necessary repairs to make the vehicle ferry-worthy was considered the same as display preparation. The third category was transporting the vehicles to an airport near the display site (or, in the case of *Discovery*, into the Smithsonian). Determination regarding whether NASA or the Smithsonian would pay for the display preparation and ferrying of *Discovery* was settled by congressional direction to NASA for the Agency to pay for all associated costs.

Graham also remembers that NASA wanted to "ensure the curatorial presentation of the Orbiter was accurate, that NASA would be available to consult with them if they needed help, that they needed to be accurate, scientific, and that sort of thing." The result was that each display site ended up with two agreements. One was the Reimbursable Space Act Agreement that covered the display prep, ferry flight, and whatever work was required after ferry, such as removing the tailcone (for *Endeavour*). All of that effort was fully reimbursed under a statement of work between the recipient and NASA. Then there was a transfer agreement, which was essentially the document that affected the title transfer and defined the relationship going forward for 20 years.[175]

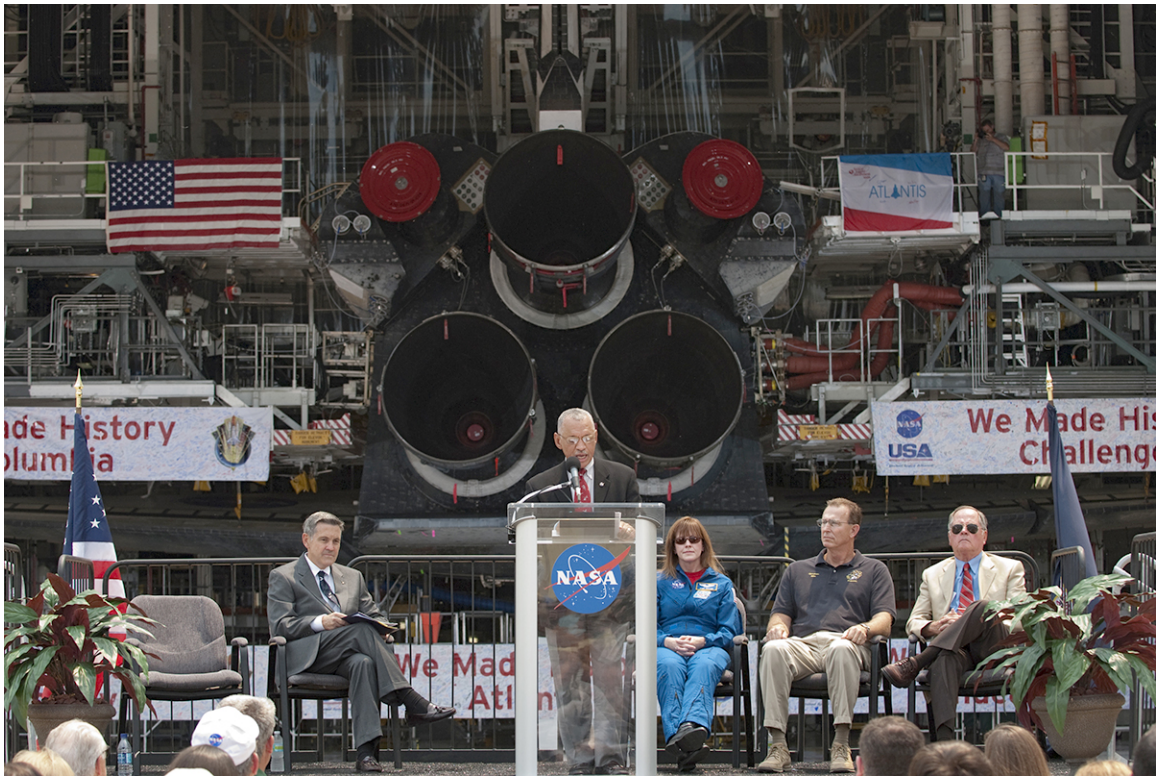
In 2008 and 2010, NASA published RFIs to "determine interest that may lead to selection of specific organizations to receive a Space Shuttle Orbiter." In response, the Agency ultimately received expressions of interest from 29 organizations. NASA formed a team of civil servants from various offices to review the RFI responses and make a recommendation to NASA Administrator Charles F. Bolden, Jr., regarding placement.[176]

Display Site Announcements

On 12 April 2011, the 30th anniversary of the launch of STS-1, Bolden announced that the three Orbiters that had flown in space—*Discovery*, *Atlantis*, and *Endeavour*—would be placed, respectively, at the Smithsonian National Air and Space Museum, the Kennedy Space Center Visitor Complex, and the California Science Center. *Enterprise*, then on display at the Smithsonian, would be moved to the Intrepid Sea, Air, and Space Museum in New York City. According to Bolden, he chose these locations to "provide

174 Interview, Courtney B. Graham by David M. Lengyel, 25 February 2013.
175 Interview, Courtney B. Graham by David M. Lengyel, 25 February 2013.
176 "Review of NASA's Selection of Display Locations for the Space Shuttle Orbiters," Office of the Inspector General special report, 25 August 2011.

the greatest number of people with the best opportunity to share in the history and accomplishments of NASA's remarkable Space Shuttle Program."[177]



In a ceremony held in front of OPF-1 at KSC, NASA Administrator Charles Bolden announced the display sites where four Orbiters would be displayed. (NASA)

The announcement, while greeted with excitement at the chosen locations, was not well received by some members of Congress who represented states that did not receive an Orbiter, particularly representatives from Texas and Ohio. Some members raised concerns that in making its selections, NASA failed to follow the law and instead allowed politics to dictate the result. In light of these concerns and public interest in the matter, the NASA Office of Inspector General (OIG) examined the process for selecting the display sites.

Ultimately, the OIG found that the decisions regarding Orbiter placement were the result of an Agency-created process that emphasized above all other considerations locating the Orbiters in places where the most people would have the opportunity to view them. The Agency was not required to and did not consider a location's ties to the Space Shuttle Program but, as directed by the 2010 NASA Authorization Act, considered whether the chosen locations had a connection to NASA's human space flight program. The report concluded, "We found no evidence that the Team's recommendation or the Administrator's

[177] "Review of NASA's Selection of Display Locations for the Space Shuttle Orbiters," Office of the Inspector General special report, 25 August 2011.

decision were tainted by political influence or any other improper consideration. While the Administrator was subject to a great deal of pressure from members of Congress and other interested parties, we found no evidence that this pressure had any influence on the Administrator's ultimate decision on where to place the Orbiters. Moreover, we found no attempt by White House officials to direct or influence Bolden's decision making. We also found that NASA's process was consistent with applicable Federal law." The report did little to quiet the uproar in some parts of the media, but it allowed work to continue.[178]

Each of the display sites was obligated to provide a Logistics Plan, a Transportation Plan, and a Financial Plan to NASA prior to signing RSAAs and transferring title to the vehicles (where applicable) and starting display preparation work. These three plans provided reasonable assurance that the vehicles would be appropriately displayed and cared for after turnover and provided insight into how the display sites would pay NASA for the display preps and delivery. Each of the vehicles involved a different legal precedence.

The California Science Center required an RSAA that detailed the work that NASA (via USA) would perform at a certain estimated cost. The RSAA also outlined how the Science Center would maintain *Endeavour* and contained myriad legal details covering various Federal laws, such as ITAR/EAR, and NASA regulations. Once both parties signed the RSAA, and the Science Center made its first progress payment, NASA transferred legal title for *Endeavour* in October 2011. However, since USA continued to work on the vehicle until it was delivered to the Los Angeles International Airport in September 2013, the Science Center bailed the Orbiter back to NASA, which then placed it back on the USA property account, thereby providing legal protection (indemnification) against accidental damage.

The Intrepid Sea, Air, and Space Museum also required an RSAA for *Enterprise*. In this case, legal title transferred from NASA to the Sea, Air, and Space Museum while the Orbiter was still on display at the Smithsonian and, once again, the vehicle was bailed back to NASA and placed on the USA property account. In this instance, this protected both USA and the Smithsonian. It is important to note that the Smithsonian held title to *Enterprise* from 1985 to 12 March 2011; however, the Smithsonian elected to revert the title back to NASA by means of a "de-accession" agreement. The Smithsonian de-accessioned *Enterprise* to NASA so that *Enterprise* could be included in NASA's Space Shuttle placement decision. As a byproduct of the de-accession back to NASA, this simplified the legal aspect of NASA and NASA contractor work on *Enterprise* as it was being prepared for transfer to the Intrepid Sea, Air, and Space Museum.

Since Congress had directed NASA to cover the cost of preparing and delivering *Discovery* to the Smithsonian, no RSAA was necessary. The vehicle was covered by the 50-year-old "Agreement Between the National Aeronautics and Space Administration and the Smithsonian Institution Concerning the

[178] "Review of NASA's Selection of Display Locations for the Space Shuttle Orbiters," Office of the Inspector General special report, 25 August 2011.

Transfer and Management of NASA Historical Artifacts," informally called the "NASA-NASM Agreement." *Discovery* formally transferred to the Smithsonian once it was in its final location in the Udvar-Hazy Center and the post-delivery work (removing the tailcone, etc.) was complete.[179]

Atlantis remained NASA property on loan to the KSC Visitor Complex. In this case, Delaware North Companies, the concessionaire that ran the complex for NASA, entered into a commercial contract with United Space Alliance to perform the display preps and used a local heavy moving company to deliver the vehicle from the VAB to its final home. NASA directed the work, but USA was working under a contract funded by Delaware North. The vehicle was transferred from the Space Shuttle Program to the NASA organization (KSC-EX) that controlled the KSC Visitor Complex. This was probably the most confusing, and complicated, contractual arrangement because of various liability and indemnification issues between Delaware North, USA, and NASA.[180]

Except for *Discovery*, NASA could not proceed with preparing or delivering the vehicles until the display sites provided funds for the activities. This presented some contractual issues between NASA and USA. Under Federal law, NASA could not even solicit a bid from USA until the Agency had the funds to cover the work. This required the RSAA to be in place (a process that took longer than expected) and for the display site to raise the funds. The result was that the work on each vehicle was handled under a separate contractual agreement (an IDIQ task order) between NASA and USA. Since USA was in the process of drawing-down its workforce, it added a level of complexity to future planning—the company knew it would need certain skills to perform the display preps, but it had no contract (or funding) to retain the required personnel. The strict firewalling of the efforts, necessary to provide a clean accounting trail to each display site for reimbursement, also complicated the work and eliminated some natural synergy.

Regardless of who held the legal title to the vehicles, NASA and USA were responsible for *Discovery* until the vehicle was placed in the Udvar-Hazy Center and configured for display. For *Enterprise*, NASA and USA were responsible for making the vehicle safe for ferry, on-loading of the vehicle at Dulles International Airport, the ferry flight, and off-loading at the John F. Kennedy International Airport; once the vehicle was lowered onto its transporter, Intrepid was responsible for transporting it from JFK to the Intrepid Sea, Air, and Space Museum location on the west side of Manhattan.

Similarly, NASA and USA were responsible for transporting *Endeavour* to the Los Angeles International Airport (LAX), offloading it from the SCA, and removing the tailcone and performing other minor preparations. After that, the California Science Center was responsible for transporting it through the streets of Los Angeles to the final display location in Exhibition Park. The responsibility for *Atlantis* transferred at

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179 Interview, Valerie Neal by David M. Lengyel, 28 February 2013; "Agreement between the National Aeronautics and Space Administration and the Smithsonian Institution Concerning the Transfer and Management of NASA Historical Artifacts," 20 August 2008.

180 Interview, Courtney B. Graham by David M. Lengyel, 25 February 2013.

the VAB. Delaware North was responsible for transporting the vehicle from the LC-39 area to the new "Atlantis Home" exhibit just outside the Titusville gate of KSC.

Safing the Vehicles

For some time before the display site announcement, NASA and its contractors studied what needed to be done to safe the Orbiters for display. In addition to working internally, NASA sought recommendations from the National Air and Space Museum and the National Museum of the United States Air Force on what levels of hazards were acceptable for public display. All parties wanted the vehicles purged of any hazardous gases and liquids, such as hypergolic propellants, ammonia, and Freon. Several hundred pieces of pyrotechnics were removed from each vehicle. Ultimately, NASA decided that all of the "softgoods" (seals, etc.) that had touched hypergols would need to be removed to ensure that the vehicle did not outgas any hazardous vapors while on display (although this was contrary to Air Force policy). This involved gutting the Forward Reaction Control System (FRCS) module and both Orbital Maneuvering System (OMS) pods and aft RCS stingers of essentially all plumbing and tankage; all that remains in any of them are a few helium tanks. In addition, the fuel cells, auxiliary power units (APU), galleys, and potties were removed, thoroughly purged and cleaned, and either reinstalled or shipped separately to the display sites, as preferred by each display site.

The top-level Orbiter safing requirements were documented in the Orbiter Fleet Safing Document (OFSD), NSTS-60584, written by the Boeing, NASA, and USA team and first released on 15 September 2010. The document defined the top-level plans to safe the Orbiter fleet for long-term storage and/or public display and documented the minor hazards and precautions for materials that remained installed in each Orbiter. NASA considered these residual hazards acceptable since the vehicles would be on "controlled public display," defined as "visual plus very limited controlled contact." In other words, NASA never envisioned the public being able to touch or enter the Orbiters while they are on display. Nevertheless, the OFSD contained a detailed list of all potentially hazardous substances on the Orbiters and the precautions needed at the display site to mitigate the hazard.[181]

All of the safing requirements were incorporated into the End-State Subsystems Requirements Document (ESSRD), NSTS-60585—also a combined effort of Boeing, NASA, and USA—which defined the details of how to perform the safing. Unlike operational processing, safing operations were not subject to the normal Operations Maintenance Requirements and Specification Document (OMRSD) rigor, although, in reality, much the same discipline was used only because that was how the technicians were trained.[182]

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181 "Orbiter Fleet Safing Document (OFSD)," NSTS-60584, 15 September 2010.

182 "End-State Subsystems Requirements Document (ESSRD)," NSTS-60585, 22 July 2010.

For instance, work was conducted under an industry standard called "generally clean" instead of the rigid cleanliness used when preparing a vehicle for space flight. However, many things did not change. The need for industrial safety remained since the work still involved hazardous chemicals and heavy objects. The vehicles still needed to be certified for their final ferry flights, resulting in the need to follow some processing rules to the letter. Engineers at USA wrote many new procedures to accomplish the work, although many were derivatives of similar procedures used during operations or for heavy maintenance during OMPD/OMM periods. Perhaps the most obvious change was the elimination of the bunny-suits. Stilson remembers, "when you're processing a vehicle for space flight you wear a full suit of garments anytime you go inside the vehicle. We were able to downgrade from that to where technicians and engineers going into the vehicle would only have to wear booties. They could go in in street clothes because we were no longer protecting the vehicle for spaceflight, where if you had any type of foreign object debris in the vehicle in orbit it could be a very big detriment to the safety of the crew and the vehicle."[183]

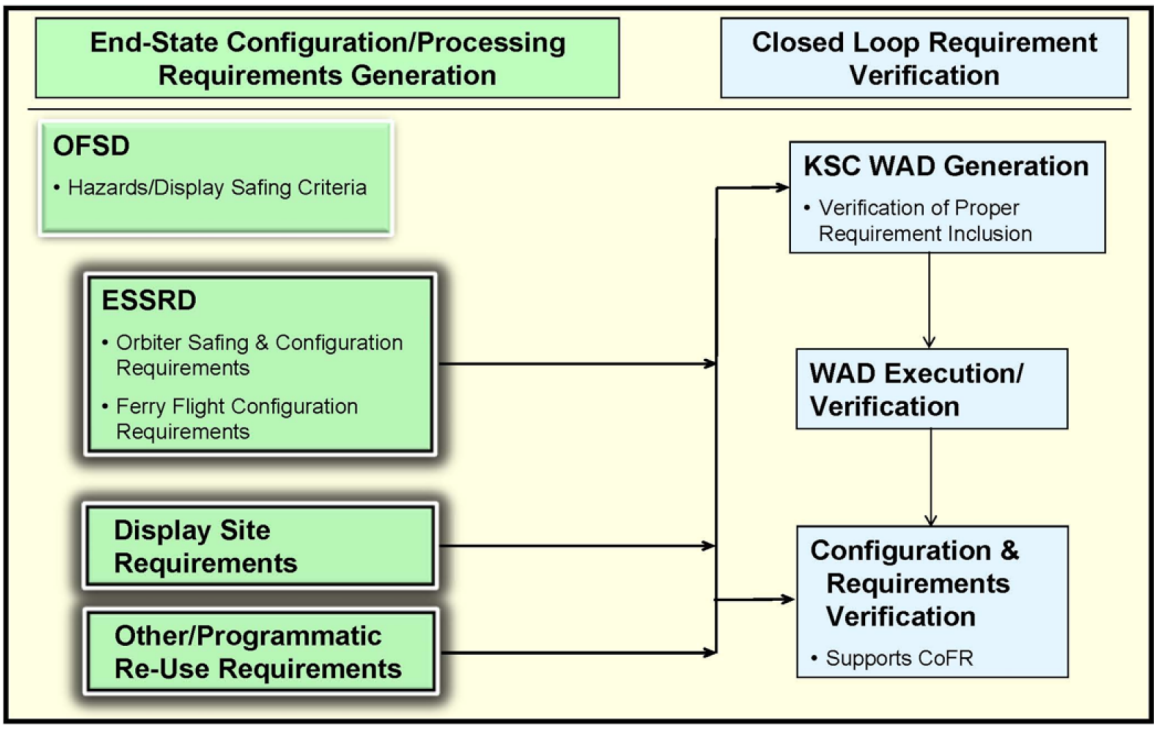
After 30 years of processing the vehicles under extreme rigor, it took some getting used to. Stilson: "So that was a little bit difficult at first just because we had engrained those rules and regulations into the workforce for so long it was really a culture shift to back off of that and so we constantly were having to remind the team that these vehicles were no longer flying in space. So, although we want to treat them very well and take very good care of them and deliver them in the best condition possible, we don't have to treat them as if they're flying in space."[184]

The same thing happened when crews deployed from KSC to the Smithsonian to work on *Enterprise*—they tended to treat it as a flight vehicle, despite having been in a museum for more than 20 years. Valerie Neal, the Space Shuttle curator at the Smithsonian, recalls, "They didn't know how to do it any other way. We found that when they came here to work on *Enterprise*, they did the same thing. They had to remind each other from time to time, 'you know, this isn't a flight vehicle anymore. We can do such and such a little differently here.' But they had to remind themselves and consciously decide to do it differently because they were so well trained and committed to doing it the right way for flight."[185]

After Charles Bolden announced the display sites in April 2011, Stephanie S. Stilson and Bartholomew A. Pannullo at KSC headed an effort to develop a set of unique Display Site Requirements for each Orbiter. Based on the desires of each individual display site, and the available hardware, these defined the precise configurations of such items as middeck lockers, seats, fuel cells, auxiliary power units, and the like. The Smithsonian kept *Discovery* as close to flight-like as possible, while the other sites opted to retain many components outside the vehicle for separate display. Stilson remembers, "We worked with them to develop

183 Interview, Stephanie S. Stilson by J. Steven Newman, 15 February 2013.
184 Interview, Stephanie S. Stilson by J. Steven Newman, 15 February 2013.
185 Interview, Valerie Neal by David M. Lengyel, 28 February 2013.

those requirements and documented those requirements on a spreadsheet that was kept under configuration control and approved by the program before execution."[186]



Simultaneous with the safing effort, numerous components were removed from the vehicles. The Space Shuttle Program always intended to retain any components deemed useful for Orion or other NASA programs. The Russians requested that the Orbiter Docking System (ODS) hardware be returned to them, and the Canadians wanted one of the Remote Manipulator System (RMS) arms. Various communications security (comsec) devices and the radar altimeters were returned to the Department of Defense. The ISS program wanted two of the three external airlocks for possible future use.

During 2010, NASA allowed other internal organizations, primarily at JSC and MSFC, to request parts of the Orbiters under a process known as STS-Last, to support various engineering studies and tests. After the cancellation of the Constellation Program and the formation of the SLS, components were removed from the Main Propulsion System (MPS) in each Orbiter to provide certified hardware for the initial SLS launch vehicles. None of these removals affected the outer mold line and, from a display perspective, the vehicles look intact. The view inside the aft compartment of *Atlantis* and *Endeavour* is somewhat less so.

T&R sometimes highlighted the extent to which seemingly narrow technical decisions took on greater strategic importance. One example was deciding where to safe the FRCS and OMS pods of dangerous hypergolic propellants. The baseline plan was to do this work at the Hypergolic Maintenance Facility

[186] "Space Shuttle Closeout Requirements," NSTS-07700, Volume XX, Book 1, 7 March 2011.

(HMF) at KSC, near where the Orbiters were being processed for display. Instead, NASA Headquarters decided that the FRCS and OMS hypergolic safing work would be done at WSTF in New Mexico. While WSTF had done this work in the past, shifting safing from KSC to WSTF introduced a number of notable technical challenges, including ensuring the safety of transporting the pods across country, ensuring that WSTF had the appropriate fixtures and procedures to process the hardware, and ensuring that WSTF personnel were current on their certifications and procedures. From a strictly technical perspective, the decision to do this work at WSTF significantly complicated processing of the Orbiters for display and deprived KSC of work that could have been used to maintain workforce skills there. However, from an Agency perspective, the FRCS and OMS safing work meant much more to WSTF than it did to KSC, which by dint of its size and missions had a significantly larger portfolio of work. It is not rare to see these kinds of broader strategic considerations leak into technical and operational decision-making, but those tensions between the strategic and the tactical can take on even greater significance as a major program closeout puts unprecedented strain on the organizational systems that support the program.

Delivering the Vehicles

A group at KSC, later called the Orbiters on Display Working Group (OODWG), led by Stephanie S. Stilson from NASA and Dennis R. Jenkins and Casey B. Wood from United Space Alliance (USA), began planning the deliveries beginning in late 2009. Since this was long before the display site locations were announced, the group primarily concerned themselves with developing plans for the offload of the vehicles from the Shuttle Carrier Aircraft and explored alternate ways to transport the Orbiters once they were off-loaded.

Orbiters

"Face-to-face meetings sometimes work best…it really allowed us to create a win-win situation for both organizations so that we had very minimal impact on the airfield, but were also able to accomplish our task in the shortest amount of time possible."

Much of the technical work had been accomplished early in the program when engineers developed plans to load the vehicles onto the Shuttle Carrier Aircraft (SCA) at a contingency landing site. The process involved using two large cranes to lift the Orbiter instead of the mate-demate devices (MDD) normally used at KSC or DFRC. Variations of the process were used to off-load and load *Enterprise* at Redstone Arsenal in 1978 for the Mated Vertical Ground Vibration Tests (MVGVT) at MSFC; to load *Columbia* after the STS-3 landing at White Sands in 1982; again to off-load and load *Enterprise* at Mobile, Alabama, for the 1984 World's Fair in New Orleans; and to off-load *Enterprise* at Dulles in 1985 when it was delivered to the Smithsonian.

However, crane technology improved substantially in the intervening 25 years and both OSHA and NASA safety regulations and risk tolerances changed significantly. In addition, none of the personnel involved in

the earlier operations were still employed by NASA. Although a basic set of drawings existed, the OODWG needed to develop and test new processes and procedures.

To build confidence in the procedures and to exercise some equipment, such as the wind restraint system that had not seen daylight for more than 20 years, the OODWG organized a practice run on the ramp in front of the KSC mate-demate device. The team used cranes available at KSC, which were a good deal smaller than the cranes that would ultimately be used at the display sites, but they provided adequate stand-ins for the test. All of the ground support equipment was setup in its proper place and exercised, although nothing was actually lifted except the vehicle sling (i.e., there was no Orbiter or simulator). Stilson believes that "doing those dry runs gave us a great deal of confidence in our ability to perform the task with the actual Orbiter in a remote location. That was invaluable."[187] The program saw the value in performing this critical lift test and agreed to fund it as a risk mitigation activity.

Even before Charles Bolden announced the display sites, some in NASA had been looking at how to use the delivery flights as an opportunity to showcase NASA. One concept was for the Shuttle Carrier Aircraft to make a grand tour of the United States during one or more of the ferry flights. This Shuttle Public Outreach Tour (SPOT, more often called Shuttlepallooza by those on the inside) would be a 4-, 6-, 12-, or 16-week ferry flight. Donald L. McCormack was the ferry manager at JSC, a role he had also played during the final fly-out of the manifest, and remembers that "a lot of discussion early-on about just exactly how we were going to do these missions."[188]

The display sites were concerned about the increased risk of loss or damage to the SCA and "their" Orbiter during the tour, especially given the Orbiters were irreplaceable artifacts and uninsurable. Eventually, the Executive Council killed the Shuttlepallooza idea and directed McCormack to plan the final ferry flights along the most direct routes, although it authorized fly-overs of specific areas along the route and extensive fly-overs of the destination cities. These required McCormack and chief SCA pilot Jeffrey L. Moultrie to coordinate closely with the Federal Aviation Administration (FAA), Transportation Security Administration (TSA), as well as Homeland Security and the Department of Defense to arrange the appropriate clearances and permissions. These were complicated somewhat by the need to use chase aircraft, either T-38s or F/A-18s, to photograph the fly-overs for NASA and the display sites.

In addition to delivering the flight Orbiters, there was an expectation that *Enterprise* would be moved from the Smithsonian to a new display site. Given that the vehicle had been in storage or on display for more than 25 years, NASA considered it prudent to conduct a thorough evaluation of the vehicle's ability to be ferried. Jill D. Lin, the Orbiter Project Office TMR, authorized an inspection that was conducted by a USA team led by Alan R. Ling. Boeing, NASA, and USA engineers carefully evaluated the results of the

[187] Interview, Stephanie S. Stilson by J. Steven Newman, 15 February 2013.
[188] Interview, Donald L. McCormack by J. Stephan Newman, 28 February 2013.

inspection and approved *Enterprise* for a one-time ferry flight. After engineers evaluated the results of the inspection, Stilson and Jenkins brought a team to the Smithsonian to prepare *Enterprise* for her final ferry flight. The work included reactivating the hydraulic system to retract the landing gear, removing the plywood display-only OMS pods and installing the ferry-capable set of pods originally used for the Approach and Landing Tests (ALT), cleaning the insides of any loose debris and foreign objects, and performing a weight and balance check.

Once Charles Bolden announced the specific display sites, the OODWG began making detailed plans for the deliveries. At least two, and often three, face-to-face planning meetings were conducted with each display site. In addition to the OODWG members and officials from the display sites, these meetings included representatives from the FAA, TSA, JSC, NASA/HQ, and in some instances local or state transportation agencies, the Coast Guard, and other potentially affected groups. Although mostly concerned with the technical aspects of offloading the vehicles at the nearby airports, the meetings discussed public affairs events, legal concerns regarding the turnover of the vehicles, transporting the vehicles from the airports to the display sites, and the configuration of the vehicles.

Stephanie Stilson remembers, "We had multiple planning meetings starting way in advance to open up chains of communications with all these different organizations that we were not used to working with, meaning air field operations, security, TSA for badging and access to the air field, as well the actual display site recipients. I am a strong believer that if we had not done that the way we did, we would have had many issues even getting started once the Orbiters arrived at the airfields, or actually once our team arrived at the airfields for set up, because there was about a month's worth of work that occurred before the vehicle arrived. Without the tremendous amount of pre-planning that was done especially by our contractor [USA], we would not have been as successful as we were. There were a lot of different activities that had to be coordinated ahead of time to make it run as smoothly as it did."[189]

The magnitude of the task should not be underestimated. The OODWG negotiated with the Washington Metropolitan Airports Authority (MWAA) to use a large piece of concrete, called Apron W, between two active runways at Dulles International Airport. Because this apron was normally used for deicing airplanes before takeoff, it could not be released to NASA until after 15 April when the weather had warmed. Fortunately, this coincided nicely with when *Discovery* would be ready and when the Smithsonian wanted to take delivery. However, the location inside the Air Operational Area (AOA) security perimeter meant that the NASA and USA personnel would need to undergo background checks and threat evaluations and be badged by the airport. It also meant drivers needed to be trained and vehicles inspected. Convincing the airport engineering organization to allow USA to drill 200 holes in their concrete ramp to secure ground support equipment provided a lesson in diplomacy (USA filled the holes when the operation was finished).

[189] Interview, Stephanie S. Stilson by J. Steven Newman, 15 February 2013.

Setting up the offload area required 20 truckloads of equipment from KSC, in addition to renting forklifts, fences, light banks, office trailers, portable restrooms, and other equipment from local vendors. Then there were the two large cranes, the larger of which required 70 trucks to move it on site. Ultimately, the offload team consisted of 75 people, although for most of the 30-day period the staffing was closer to 30–40. Since the work area was between two active runways, constant coordination was necessary with airport operations and the FAA, especially once the cranes were erected. The location closed one frequently used taxiway and restricted the use of another. Although MWAA provided all conceivable cooperation, the entire activity was a major distraction for the airport and one they were happy to see come to an end. However, while *Discovery*, and later *Enterprise*, was on Apron W, it was a major attraction for pilots and passengers of hundreds of flights taxiing nearby.

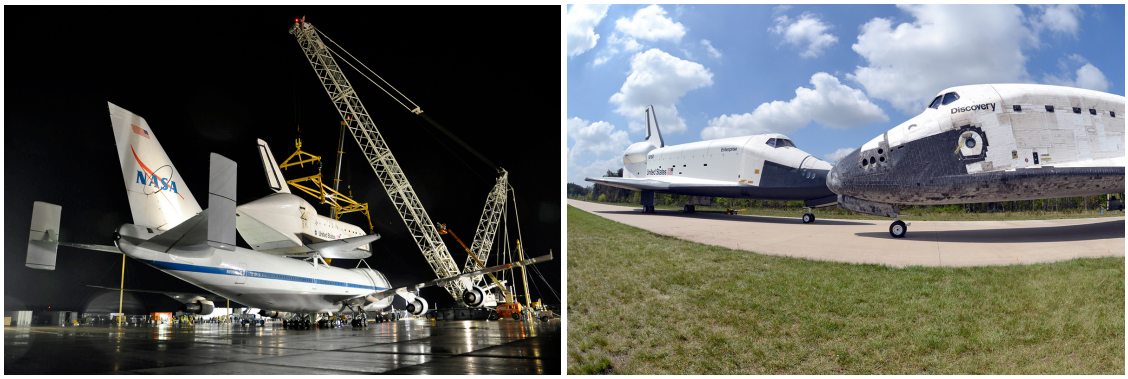
With the exception of not loading an Orbiter on an SCA, operations at John F. Kennedy International Airport (JFK) in New York and LAX were generally similar. Thankfully, the offload areas were close to the perimeter of the airports, which relaxed some security and training requirements. In addition, JFK and LAX enjoyed somewhat shorter schedules gained by a more experienced team and only about half the workload.

Ultimately, during her ferry flight, *Discovery* flew over the Cape Canaveral area and then made an extensive series of fly-overs around the Washington, D.C., area before landing at Dulles. For *Enterprise*, there was a fly-over of the New York City area before landing at JFK. The *Endeavour* ferry was a bit of a grand tour for some of the NASA facilities along the way. Again, the SCA flew over KSC and the Cape Canaveral area after departure, and then made a low pass over the Stennis Space Center and Michoud Assembly Facility on its way to a refueling stop at Ellington Field near JSC; the crew performed a fly-over of parts of Houston and JSC before landing. After departing Ellington, there was a low pass of downtown Houston, followed by a low pass over Austin while en route to a refueling stop at Biggs Army Airfield. After departing Biggs, the SCA made a low pass over the White Sands complex and then over Tucson to honor Representative Gabrielle D. "Gabby" Giffords and her husband, astronaut Mark E. Kelly. Then there was a low pass over the Dryden Flight Research Center before landing at Edwards. Primarily at the request of the California Science Center, the following day saw the one major deviation to the "most direct route" guidance. After departing Edwards, the SCA made a low pass over Lancaster and Palmdale before heading north to show the vehicle over Sacramento and the Bay Area, and then performed a series of low passes over the Los Angeles basin before landing at LAX.[190]

The excitement generated by these scaled-back fly-overs makes one wonder how much publicity would have been generated by the original Shuttlepallooza idea, but in the end, everyone agreed that the potential risks were simply not worth it.

[190] Email, Donald L. McCormack to Dennis R. Jenkins, 13 March 2013.

The offload at each display site went nearly flawlessly, and *Discovery*, *Endeavour*, and *Atlantis* were delivered on time; *Enterprise* was delayed somewhat by adverse weather.



Above: Discovery being off-loaded at Dulles International Airport (left). At right, Enterprise (on the left) meets Discovery on the tow-road from Dulles to the Udvar-Hazy Center.

Above: Endeavour being off-loaded at LAX. A few minutes later, the SCA was backed out from under the Orbiter.

Above: Enterprise being lowered onto its transporter after off-loading from the SCA at the John F. Kennedy International Airport.

SUMMARY

By 2010, the Space Shuttle Program was entering its fourth decade at NASA. Every NASA Center was or had been involved in the program during that time span. The STS-135 crew completed the assembly and resupply of the International Space Station, the raison d'être for even having a Space Shuttle, during the summer of 2011. Press coverage of that final mission led many uninformed observers to believe that was also the end of NASA. For them, the Space Shuttle Program's retirement was nearly synonymous with retiring the space Agency.

Every project/program has a lifecycle. The majority of NASA flight projects/programs are 48 months in design, development, test, and evaluation (DDT&E), and then they are launched. Mission lengths vary but most are generally no more than 6–8 years. Retiring a project/program of this nature is normally uneventful. If one were to judge the importance of the retirement phase of a program by how many times it is called out in an organization's command media—in this case, NPR-7120.5E, NASA Space Flight Program and Project Management Requirements—one would surmise that it is not critical and therefore not complicated. In fact, NPR-7120.5E mentions retirement just once and only within the context of a program's safety and mission assurance plan.

The reality, however, is that retirement can be more complex than the DDT&E or operations phases of a program. The complexity stems from an initial state of less-than-adequate knowledge and experience in transition and retirement coupled with having to deal with new risks and a much different set of players and interfaces. Just as Dorothy in the *Wizard of Oz* discovered that the ruby slippers she was wearing all along could get her back to Kansas, SSP managers discovered that the Agency had the requisite experience and expertise to guide the program through some of the previously-thought-to-be-complicated processes of recordation and property dispositioning.

In the end, the SSP and the institutional players within the Agency scripted a set of critical processes, managed the risks, and ultimately brought the program to closure within budget and schedule. The legacy of this wonderful program lies not only within the scientific, technical, and operational achievements but also within the masterful transition and retirement processes and the derived lessons learned for the future.

ACRONYMS

Acronym	Meaning
ACI	Archeological Consultants, Inc.
AFB	Air Force Base
ALT	Approach and Landing Tests
AMARC	Aerospace Maintenance and Regeneration Center
AMS	Alpha Magnetic Spectrometer
APU	Auxiliary Power Units
ATV	Automated Transfer Vehicle (ESA)
BMO	Business Management Office
BOE	Basis of Estimate
BRAC	Base Realignment and Closure
CAIB	Columbia Accident Investigation Board
CEV	Crew Exploration Vehicle
CM	Configuration Management
CO	Contracting Officer
COTR	Contract Officer's Technical Representative
COTS	Commercial Orbital Transportation Services
COTS	Commercial Off the Shelf
CRS	Commercial Resupply Services
CxP	Constellation Program
DCAA	Defense Contract Audit Agency
DCMA	Defense Contract Management Agency
DD1149	Requisition and Invoice/Shipping Document
DFM	Demand Forecast Model
DFRC	Dryden Flight Research Center
EAR	Export Administration Regulations
EELV	Evolved Expendable Launch Vehicle
EGLS	Exploration Ground Launch Services
ELC	External Logistics Carrier
EPA	Environmental Protection Agency
ERIC	Exploration Requirements for Infrastructure and Capability
ESAS	Exploration Systems Architecture Study
ESMD	Exploration Systems Mission Directorate
ESSRD	End-State Subsystems Requirements Document
ET	External Tank
FAA	Federal Aviation Administration
FAR	Federal Acquisition Regulations
FR	Firing Room

Acronym	Meaning
FRCS	Forward Reaction Control System
FSC	Federal Supply Classification
FY	Fiscal Year
GOC	Ground Operations Capabilities (part of SPOC contract)
GOCO	Government-Owned Contractor-Operated
GSA	General Services Administration
GSE	Ground Support Equipment
HAER	Historic American Engineering Record
HEOMD	Human Exploration and Operations Mission Directorate
HMF	Hypergolic Maintenance Facility
HPO	Historic Preservation Officer
HPWG	Historic Preservation Working Group
HSFTT	Human Spaceflight Transition Team
HTV	H-II Transfer Vehicle (JAXA)
ICN	Identification Control Number
IDIQ	Indefinite Delivery, Indefinite Quantity (contracts)
ILRV	Integral Launch and Reentry Vehicle
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
IRMA	Integrated Risk Management Application
ISOS	Integrated Space Operations Summit
ISS	International Space Station
IT	Information Technology
ITAR	International Trafficking in Arms Regulations
ITIL	Information Technology Infrastructure Library
ITSM	Information Technology Service Management
ITWG	Information Technology Working Group
JFK	John F. Kennedy International Airport (New York)
JICB	Joint Integration Control Board
JSC	Johnson Space Center
JTMWG	JSC Transition Management Working Group
KSC	Kennedy Space Center
KSCTWG	KSC Transition Working Group
L&L	Launch and Landing Project
LAX	Los Angeles International Airport
LC	Launch Complex
LLC	Limited Liability Company
LON	Launch on Need
LSF	Logistics Support Facility

Acronym	Meaning
LSOC	Lockheed Space Operations Company
MAF	Michoud Assembly Facility
MDD	Mate-Demate Services
MOA	Memorandum of Agreement
MOD	Mission Operations Directorate
MOU	Memorandum of Understanding
MPCV	Multi-Purpose Crew Vehicle
MPLM	Multi-Purpose Logistics Module
MPS	Main Propulsion System
MSFC	Marshall Space Flight Center
MTWG	MSFC Transition Working Group
MVGVT	Mated Vertical Ground Vibration Tests
MWAA	Metropolitan Washington Airports Authority
NARA	National Archives and Records Administration
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NASM	National Air and Space Museum
NAVFAC	Naval Facilities Engineering Command
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMUSAF	National Museum of the United States Air Force
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
NRHP	National Register of Historic Places
NSTS	National Space Transportation System
OBSS	Orbital Boom Sensor System
ODS	Orbiter Docking System
OFSD	Orbiter Fleet Safing Document
OIG	Office of Inspector General
OMM	Orbiter Major Modifications
OMDP	Orbiter Maintenance and Down Period
OMRSD	Operational Maintenance Requirements and Specification
OMS	Orbital Maneuvering System
OODWG	Orbiters On Display Working Group
OPF	Orbiter Processing Facility
OPM	Office of Personnel Management
ORU	Orbital Replacement Unit
OSHA	Occupational Safety and Health Administration
PBR	President's Budget Request

Acronym	Meaning
PDO	Property Disposal Officer
PMM	Permanent Multipurpose Module
PPBE	Program Planning and Budget Execution
PRCB	Program Requirements Control Board
PRCBD	Program Requirements Control Board Directive
RCS	Reaction Control System
RFI	Request for Information
RFP	Request for Proposals
RMS	Remote Manipulator System
RMWG	Records Management Working Group
ROM	Rough Order of Magnitude
RPI	Real Property Inventory
RSAA	Reimbursable Space Act Agreement
RSME	Replica Shuttle Main Engine
RSOC	Rockwell Shuttle Operations Company
RSRM	Reusable Solid Rocket Motor
SAIC	Science Applications International Corporation
SAMWG	Strategic Asset Management Working Group
SASP	State Agency for Surplus Property
SCA	Shuttle Carrier Aircraft
SFOC	Space Flight Operations Contract (predecessor to SPOC)
SHPO	State Historic Preservation Officer
SLEP	Service Life Extension Program
SLS	Space Launch System
SMRT	Space Shuttle Management Resource Transition Document
SOC	Space Operations Center
SOMD	Space Operations Mission Directorate
SOW	Statement of Work
SPC	Shuttle Processing Contract
SPOC	Space Processing Operations Contract
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SRTT	Shuttle Retirement and Transition Team
SSC	Stennis Space Center
SSFL	Santa Susana Field Laboratory
SSME	Space Shuttle Main Engine
SSP	Space Shuttle Program
SSTLO	Space Shuttle Transition Liaison Office
STEM	Science, Technology, Engineering, and Math

Acronym	Meaning
STS	Space Transportation System
T&R	Transition and Retirement
TCB	Transition Control Board
TCSR	Technical, Cost, and Schedule Review
TDRS	Tracking and Data Relay Satellite
TIM	Technical Interchange Meeting
TMP	Transition Management Plan
TMR	Technical Management Representatives
TOSC	Technical Operations Support Contract
TPA	Transition Property Assessment
TPRCB	Transition Program Requirements Control Board
TPS	Thermal Protection System
TRIT	Transition and Retirement Information Technology
TSA	Transportation Security Administration
USBI	United Space Boosters, Inc.
USC	United States Code
VAB	Vehicle Assembly Building
VSE	Vision for Space Exploration
WAD	Work Authorization Document
WARN	Worker Adjustment and Retraining Notification (act)
WBS	Work Breakdown Structure
WSTF	White Sands Test Facility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SHUTTLE
PROGRAM