PART TWO

EVALUATING THE SHUTTLE PROGRAM

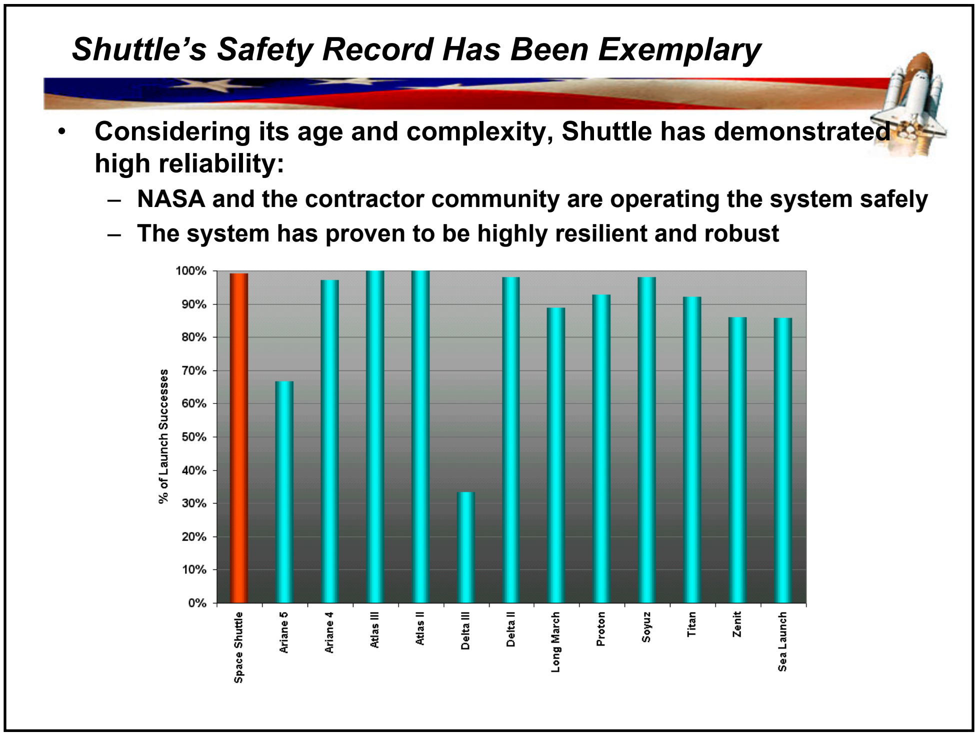
Outline

SHUTTLE SAFETY AND THE PROSPECTS FOR COMPETITIVE SOURCING

Safety has always been paramount in the Shuttle program. It was imperative that the Task Force understood NASA's approach to assuring Shuttle safety and the complex processes involved in the management and engineering activities that were associated with the safety process. It was not the job of the Task Force to evaluate the effectiveness of the Shuttle safety processes. However, the Task Force reviewed many documents associated with Shuttle safety, such as the reports of the Aerospace Safety Advisory Panel (ASAP), that have drawn conclusions related to the on-going safety of the Shuttle system.

The goal of the Task Force was to gain a firm appreciation of how NASA assures the safety of the crew and equipment and to assess the implications of competitive sourcing in that regard. Today, private firms perform many functions related to Shuttle safety and, in some areas, are demonstrating leadership. Competitive sourcing could result in the private sector assuming a larger role in Shuttle engineering and operations and NASA transferring leadership in an increasing number of areas. It is imperative, therefore, that the private sector be ready for any added responsibility and capable of assuring safety and mission success. Some senior NASA officials expressed the conviction to the Task Force that Shuttle safety would be compromised by any competitive sourcing option that resulted in loss of NASA oversight or in the private sector playing a greater operational role. The Task Force was sensitive to these concerns and focused a good deal of attention on both the readiness of the private sector and the many unique aspects of operating a complex system like the Space Shuttle.

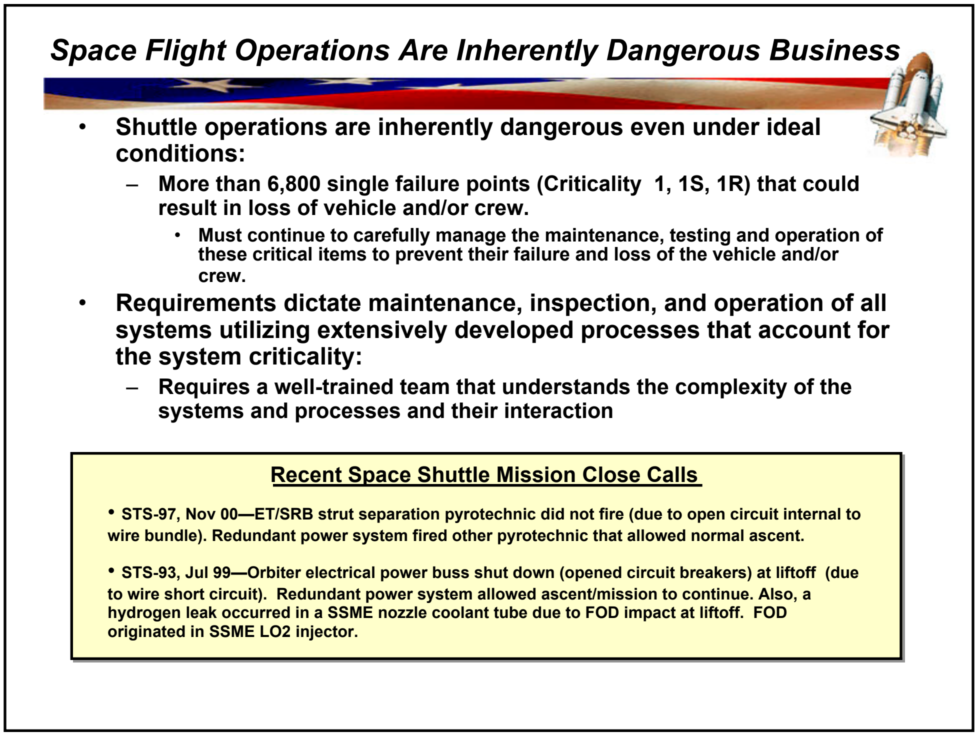
The Task Force's approach to safety issues was to: (1) understand the current state of Space Shuttle program safety, including the cultural approach and attitudes toward safety, (2) examine complex, privately owned enterprises where there is great potential for loss of life and property and identify safety "best practices," and (3) identify the attributes essential to ensuring that competitive sourcing can preserve or improve Shuttle safety.



Compared with the entire launch vehicle industry, the Shuttle's safety record is exemplary. Considering its age and complexity, the Shuttle vehicle and supporting systems have demonstrated a comparatively high degree of reliability. The program owes much of its success as a reliable launch platform to its robust design and extensive redundancy. No less important are the culture and safety processes that have evolved over the years at NASA and the contractor community. The system is unique in that its components are used for multiple flights. Each orbiter receives an extensive refurbishment prior to being mated with launch subsystems for another flight.

This unique capability poses a set of problems, however—obsolescence, aging, and uneven modification that has left each orbiter to a certain extent unique. Extensive observation, inspection, and testing are required to ensure safe Space Shuttle operations. NASA, in designing and operating the SSP, has relied upon a "healthy tension" between designers and operators of the Shuttle. Each is set up to challenge the other as the total system responds to problems. Safe practices are endemic to both.

The process of managing requirements needs some special mention, as it is the primary means today for NASA to maintain control over Shuttle equipment, processing, and operations. Since the Shuttle system is being continuously modified due to obsolescence, aging, and modification, changes to the requirements for testing, inspection, and operations are necessary. The "requirements management process" and the personnel who implement it must remain vibrant through the life of the program to ensure the requirements will protect against flying discrepant hardware and software. These requirements establish the steps necessary to certify that the Shuttle is being operated safely and are critically important to mission success.



Space Shuttle operations are inherently dangerous. Failure at one of more than 6,800 single failure points can result in the loss of the vehicle or crew.[1] The associated dangers also extend to the ground crews, due to the significant amount of hazardous work required for every mission.[2] A disaster in the human spaceflight program also implies political and economic consequences beyond the direct effects.

One explanation for the Shuttle's high degree of reliability has been NASA's strict adherence to carefully developed requirements and the infusion of those requirements into the Shuttle system's operational practices. The culture surrounding the Shuttle program is heavily focused on the *processes* (maintenance, inspection, test, etc.) associated with assuring safety.[3] Changes to requirements are closely managed and

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[1] Based on date provided by John Casper, Failure Mode Count Summary, JSC, May 31, 2002.

[2] In the wake of the *Challenger* loss there is a natural focus on the loss of the Shuttle during the ascent phase. It is important to note, however, that this may not be the worst-case scenario for the system. A catastrophic event in the Vehicle Assembly Building (VAB), for example, where one or more orbiters can be located, as well as hundred of employees, could effectively end the Shuttle program.

[3] In many ways the NASA desire for a "healthy tension" between requirements and operations seeks to encourage personnel to challenge processes and procedures. The

designers and operators must resolve differences before alterations are permitted. Certified technicians perform most of the work on the Shuttle. Their tasks are defined by procedures and checklists that implement system requirements.[4]

The NASA safety effort is augmented by safety personnel assigned to respective Shuttle program contractor companies. As such they are part of a separate safety organization responsible to their own corporate leadership but operate within the Shuttle assigned workforce. For example, within the USA contractor this number is about 680 personnel.[5]

Design, observation, inspection, and validation all contribute to safe operations. The Task Force reviewed ASAP and Shuttle program reports on the Shuttle system and noted that there have been several close calls (two examples are noted in the chart) in which the basic robustness of the original design was the primary factor in maintaining safety.[6]

SSP's OSMA seeks to foster and value challenges to requirements from operations so that problems can be worked with deliberate process (e.g., Certification of Flight Readiness [CoFR]). Feedback and valuing input from all levels in the process seem to be crucial to guarding against the negative qualities in a process culture. The December 1999 Space Shuttle Independent Assessment Team listed as its number two concern, "The past successes of the Shuttle Program do not preclude the existence of problems in processes and procedures that could be significantly improved." National Aeronautics and Space Administration, Space Shuttle Independent Assessment Team, *Report to Associate Administrator Office of Space Flight, October–December 1999*, March 7, 2000.

[4]NASA's approach lays out very detailed training, certification and currency requirements for technicians working on the Shuttle. NASA and contractor engineers carefully control the procedures that contractor technicians follow. Very high standards are maintained for Shuttle technicians; however, there are no comparable standards for the engineering community. Maintaining engineering proficiency at NASA so that requirements can be properly maintained is a major concern of the SPO as both the system and the engineering staff age.

[5]Discussions with Shuttle Program OSMA, July 2002.

[6]Discussion with KSC personnel during Task Force visit and in follow-up phone interviews. Data were also gathered from the Space Shuttle Program Inflight Anomaly Database.

Safety Drives Necessarily Complex Processes

- **Processes are based on extensive knowledge, engineering and technical analysis of hardware, software, the flight environment, and operations:**
  - **Codified in over 150 requirements documents, millions of design drawings, and tens of thousands of pages of documentation:**
    - **Defined at an appropriate level to be understood by the implementer**
    - **Traceable to the implementer**
  - **Covers all areas related to SSP—from forecast wind models of KSC launch and landing environment to hazardous inspections of OMS pods**
- **Risk management process assures:**
  - **Safety is evaluated in the decision process**
  - **Systems are designed with safety as a priority**
  - **Close calls are investigated via the "close call system:"**
    - **NASA and contractors perform root cause analysis on mishaps, major incidents, and significant flight and ground anomalies**
- **Process works today:**
  - **Culture at NASA understands inherent risks—*EVERYONE thinks SAFETY*—this is typical of safe organizations in other industries**
  - **NASA and contractors are proud of safety accomplishments**

  BUT, there are concerns:
  - **Flight and ground hardware and software obsolescence and deferment of safety upgrades and aging infrastructure repairs**
  - **Budgetary constraints affect personnel and resources required for maintenance and upgrades**
  - **Continued schedule pressure**
  - **Reporting mechanisms that may not assure worker anonymity in reporting safety concerns**

Processes should be modified only after thorough assessment of technical merit, history of requirements, and potential consequences.

In the Shuttle's current arrangement, the PM is responsible for Shuttle program safety.[7] The PM can, by NASA's rules, delegate much responsibility to contractors. However, the NASA program/project manager must maintain an awareness of steps being taken to ensure safety and is responsible for a safe outcome. Awareness can be in the form of *oversight* or *insight*. Oversight is a more detailed function requiring NASA to retain extensive engineering capability; insight is a term used to define a less active government role with more responsibility being placed under contractor control. NASA has relied more on insight as contractor skills have grown in terms of Shuttle operations. In some key areas, though, such as the external tank (ET), reusable solid rocket motor (RSRM), and Space Shuttle main engine (SSME) components, NASA has maintained vigorous oversight.

Here again, the SSP's technical requirements and resultant processes dictate how Shuttle safety is to be assured. These processes cover everything from weather forecasting to between-mission inspection

[7]National Aeronautics and Space Administration, *Program and Project Management Processes and Requirements*, Chapter 4, Section 5: "Safety and Mission Success, and Environmental Management," NPG-7120.5A, Washington, D.C., April 3, 1998.

requirements for hazardous systems.[8] Along with the insight and oversight provided by supporting civil servants, the SSP manages the requirements, validates requirement compliance, and prepares the CoFR.[9] The PM is supported by a dedicated Safety and Mission Assurance (SMA) organization, but, additionally, disparate safety organizations aligned under NASA Headquarters and the NASA field centers also have an input into the safety process.[10] Each prime contractor also maintains a safety organization. The Headquarter-based Office of Safety and Mission Assurance (OSMA) monitors the SSP's accomplishment of safety and the preparation of the CoFR. In this way, OSMA plays a significant role in determining launch go/no-go decisions.[11] OSMA monitors the resolution of any unusual events such as "out-of-family" anomalies that do occur from time-to-time.[12] OSMA also establishes the NASA-wide SMA policy and so influences the practices used by field center organizations.

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[8]NASA, Space Shuttle Program Description and Requirements Baseline, NSTS-07700, NASA JSC, Houston, TX, undated.

[9]The COFR process, documented in NSTS-08117, is a complex affair. According to the process, the contractors certify that their products (hardware, software, procedures, etc.) comply with the requirements levied upon them by NASA. NASA, in turn, certifies that the contractors have given a valid and complete set of requirements, and the SSP certifies that the Shuttle capability is ready to meet the mission requirements. The NASA SSP's SMA organization certifies they have provided proper insight on the process and any associated issues. Certification consists of signatures from all responsible managers. Prior to launch, a Flight Readiness Review (FRR) is conducted at which point the Associate Administrator (AA) of the Office of Space Flight (OSF) polls both NASA and contractor managers. The AA of OSMA is also polled to approve that the system is ready for launch. As currently configured, NASA has the final go/no-go authority. After the FRR, the CoFR process is conducted by a mission management team made up of the NASA and contractor managers and led by the NASA Launch Integration Manager (LIM). During the countdown to launch it is the LIM who has the final go/no-go authority to launch.

[10]SMA organizations support the SSP at the key Shuttle field centers. Beyond the SMA offices, it is important to appreciate that many NASA engineers and managers support safety *assurance* by both managing requirements and helping to resolve "out of family" events (see footnote 12). This is one of the main oversight roles that NASA retains and it involves many hundreds of civil servant FTEs.

[11]Greenfield, M., *The Office of Safety and Mission Assurance—An Overview*, Washington, D.C.: NASA Headquarters, August 2001.

[12] NASA defines the term "out of family" as a category of anomalies that involve one or more or the following: first-time occurrence of a failure mode; equipment with limited operational life; event that could restrict hardware or software use; affect the performance or reliability of critical functions; affect hazard control; result in a weight change in excess of 2 pounds (equivalent weight to orbit); affect flight or ground operating procedures that are controlled by the government; change software or hardware configuration; allow use of hardware that does not meet performance specifications, exceeds certification limits, or surpasses time, age, or cycle life limits (waivers/exceptions); close or defer resolution of an unexplained anomaly; requires

In practice, the PM must oversee a distributed safety organization with many elements that are not under the PM's direct control. It was not clear to the Task Force that these elements truly serve an independent function and that they could, given adequate analysis, act to challenge decisions that could affect safety. In general, the relationship between safety offices and the SSP organizations performing assurance activities, though diffuse, has worked to produce a system that is safe. However, as NASA considers additional changes to the Shuttle system, of the type implied by a competitive sourcing initiative, it is not clear that the current structure could assure the same levels of safety.

There are other factors that the Task Force noted during its assessment of safety that must be factored into decisions related to competitive sourcing; these are:

- ***Funding problems*—**a combination of downward budget pressure and SSP funding prioritization has left funding gaps that make it difficult to meet requirements. For instance, facilities maintenance significantly lags program need. This ultimately creates hazardous working conditions and affects morale. [13]
- ***Contract terms and conditions***—the duration of the large contracts influences the level of investment that a private firm is willing to make. With short contract terms, as a contract reaches a point of renewal, contractors are naturally disinclined to make investments or recommend improvements that could otherwise affect their competitive position. Incentives placed in contracts may also influence safe operations. For example, incentives in the current SFOC result in schedule pressure (as do most contracts)—financial inducements to launch on time. Alternative strategies could maintain contractor incentives for performance but remove the linkage between launching on time and profit. Schedule incentives applied to an aging, complex system like the Space Shuttle seem inherently unwise.

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government design element analysis or assistance; or affect critical hardware manufacture or repair processes.

[13]This was a recurring theme for several organizations that the team visited. NASA contractors have expressed concern that the NASA-provided workspace is not sufficiently safe. It was mentioned by NASA safety personnel who recognized the same safety shortfalls and by organizations like the Florida Space Authority, who see their participation as a solution to the problem. We should mention that there is a built-in incentive for vehicle upgrades to be identified as "safety upgrades" by contractor and NASA personnel due to the "safety first" culture at NASA. How upgrades are valued within the program may need greater visibility. This could be an issue no matter what date is selected to transition the Space Shuttle to another generation system.

The picture that emerged as the Task Force reviewed how NASA accomplishes Shuttle safety was that while safety is endemic to the NASA spaceflight culture and, thereby, a guiding principle in Shuttle operation, there are aspects that create future concerns. This was confirmed in reviews of the ASAP reports made available to the Task Force. Given the complexity necessary to operate the Shuttle safely, these circumstances require careful thought as NASA pursues competitive sourcing. Efforts to consolidate functions and elements, providing the PM with increased authority over operations, as well as steps to assure that NASA has assured access to independent safety assessments, could assist in meeting future Shuttle safety goals.

NASA Has a Leadership Role in Shuttle Safety at Many Points

- **Today, NASA's safety system is partitioned between HQ, field centers, and SSP**
  - **In general, NASA *establishes and manages* the safety requirements**
  - **Safety *requirement implementation* is performed by NASA and contractor per approved safety plans**

Safety Functions		Current Implementation Lead: NASA	Current Implementation Lead: Contractor	Current Implementation Lead: Other Govt.
Management Functions	Requirements Management*	●		
	Configuration Control*		●	
	Vendor Certification*		●	
	Process Certification*	●		
	Certification of Flight Readiness*	●		
	Risk Assessment*	●		
	Range Safety*			●
Inspection, Audit, Surveillance Functions	Requirements Compliance		●	
	Workers Certification		●	
	Safety Training		●	
	Inspection*		●	
	Environmental Health*		●	
	Employee Health*		●	

Indicates NASA/Govt. establishes top level performance requirements.

- **It should be noted that NASA has some insight or surveillance activity in all of these functions and still performs oversight of Criticality 1 inspections as well as launch and mission operations.**

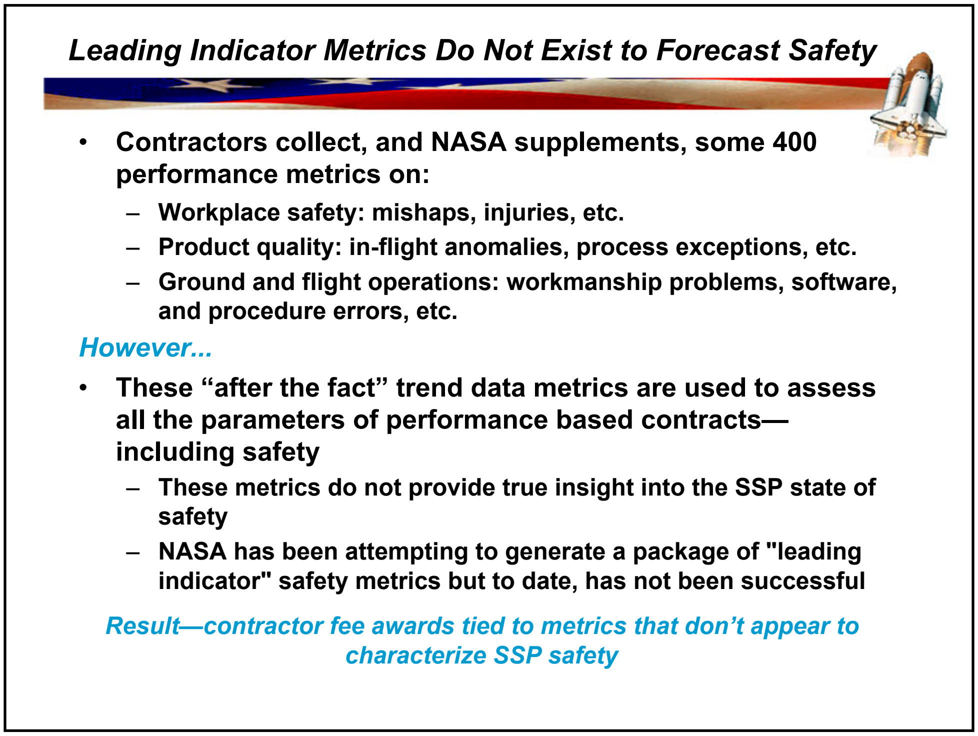
As the table above indicates, contractors do maintain leadership in many safety areas. This is a delegation that has occurred naturally as NASA assumed more insight (as opposed to oversight) and was accelerated during the creation of SFOC. However, NASA establishes and maintains safety requirements with the implementation being performed by contractors per approved plans. In the CoFR process, there are discrete roles for NASA headquarters, the Shuttle Program Office, and the contractors. The result is that NASA remains, as the asset owner, the primary agent in assuring Shuttle safety.

A competitive sourcing strategy could shift this nexus, permitting contractors to play an increasing leadership role and partnership involvement in the CoFR process. Even if the private sector does not assume ownership of Shuttle assets it is viable to consider increasing contractor leadership and additional evolution of the roles shown in the above table.

The table above also indicates that safety is clearly a distributed function. Based on analysis of NASA personnel data, the Task Force found that more than 300 civil servant FTEs support the Shuttle safety function. Contractor personnel support these employees, some assigned to the various NASA field center safety offices.[14] As indicated earlier, the PM may not exercise as much authority over these functions as will be needed in the future to continue to assure safety.

Today, an independent safety assurance function is provided by the Headquarters-based OSMA. This office, however, relies to a significant extent on SSP analysis and program resources. It is likely, that under a competitive sourcing strategy that NASA will continue to step back from extensive oversight. As NASA performs less oversight, the information that OSMA currently relies on would be increasingly unavailable. Competitive sourcing would, therefore, require an organization with a self-contained engineering, operational, and analytical capability, with extensive Shuttle experience, to perform an adequate assurance function.

[14]Often these contractor personnel are under contracts not under the direct control of the SSP; instead they are managed by field center offices.



NASA and its contractors collect information on more than 400 performance metrics. These metrics, however, present after-the-fact trend information that does not forecast safety.[15]

It is vital that NASA maintain *operational cognizance* of the Shuttle system—a clear link between the technical requirements and how they are carried out to maintain safety. Maintaining this link is increasingly important as the Shuttle system ages (including loss of key staff due to retirement and vendors going out of business). The strength of the link depends on cognizance of day-to-day operations. Ideally, cognizance would be supported by the collection of detailed operational data, but such data are difficult to collect on a system like the Shuttle. Unlike an airliner that can dispatch several times in a day the Shuttle launches

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[15]There are currently more than 500 discrete metrics applied to the various SSP contracts. These are generally not prescriptive metrics, however, and do not provide a firm basis for predicting safety trends. For example, metrics which track workplace mishaps and injuries, while important, only tell you how safe the workplace "was" and do not forecast how safe it is expected to be in the future.

infrequently. An airline can collect extensive data, for example, on flight crew performance, and make corrections that result in improved safety.[16]

The SPO is aware of the need for forward-looking safety metrics and is putting more effort into measuring processes to develop leading and predictive indicator metrics. Part of this effort relies on field center's risk management initiatives that require program components, including contractors, to identify the current baseline, a future expectation and a plan to reach the expectation. Endemic is a desire to gain greater insight into how *process escapes* happen, and to encourage personnel at all levels to take control of their processes and responsibilities within the Shuttle program.[17] This is similar to programs within industry that seek not just to manage risk with specific metrics, but also to understand and develop strategies to reduce the incident/accident rate.

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[16]For example, United Airlines uses a forecasting metric that measures aircraft deviation from a maximum descent rate at a particular point on approach to landing. "Sink rate" is important because excessive sink rates can cause landing mishaps. In some cases, pilots who consistently violate airline-approved sink rates are given additional training to improve performance. In other cases, it may be that the approach to the airport requires an excessive sink rate. In such instances, United works with the FAA to try to improve the approach. Thus this metric allows proactive action to reduce the risk of an accident and improve safety. This is a classic example of using "incident data" to reduce "accident rates."

[17]A process escape is defined as any technical, schedule, or cost issue that is found after it should have been determined by established management processes.

Private Sector Operates Systems with Great Risk and Liability

- **Like Shuttle, many industry operations are inherently dangerous and pose a significant safety and financial risk**

Place	Date	Substance	Unit	Event	Losses and Effects			
					Killed	Injured	Other	Financial [$]
Flixborough, UK	June 1974	Cyclohexane	Caprolactam plant	Vapor cloud explosion	28	104		$232M
Seveso, Italy	July 1976	Trichlorophenol	Chemical facility	Dioxin vapor cloud			Contaminated countryside, new legislation	
Three Mile Island, PA	March 1979	Radiation	Nuclear reactor	Partial Meltdown			Core damage, radiation release; NRC overhaul of industry	
Mexico City, Mexico	Nov 1984	Liquid petroleum gas	Chemical storage facility	Vapor cloud fire	450			$20M
Bhopal, India	Dec 1984	Methyl-isocyanate	Storage tank	Toxic gas release	Approx 2,800 during accident, 14,000 total	200,000		$470M fine, unestimated damages
STS 51-L	Jan 1986	Various	Solid rocket booster	Explosion	7		2 year program delay	> $1B Orbiter replacement
Chernobyl, Ukraine	April 1986	Radiation	Nuclear reactor	Explosion	31		300 square miles evacuated	
Alpha Piper, North Sea	July 1988	Gas, oil	Compression unit, offshore drilling platform	Explosion, fire	165			$1.8B
Pasadena, TX	Nov 1989	Isobutane	Polyethylene plant	Vapor cloud explosion	23	~103		$750M
Exxon Valdez	March 1989	Gas, oil	Oil tanker	Oil spill			100,000 seabirds killed, unestimated coastline damage	$2B cleanup, $5B punitive damages
Channelview, TX	July 1990	Gas, oil	Chemical facility	Explosion	17			$12M

Although it is difficult to find an industry that conducts operations precisely analogous to spaceflight, there are many industries whose activities are extremely complex and whose potential failure poses catastrophic consequences for life and property. World accident history demonstrates that the human, environmental, and financial consequences of an accident can be monumental.[18] Many of these tragedies have prompted immediate tightening in the regulatory environment, within which firms in the affected industries must learn to operate.

For example, the partial core meltdown mishap at Three Mile Island in 1979 led to a complete regulatory overhaul of the nuclear industry. Although there were no fatalities directly related to this mishap, the awareness of looming catastrophe caused understandable frenzy among the public. The *Exxon Valdez* oil spill resulted in no loss of human life, but the environmental damage was massive. Marine life along an extensive coastline was severely affected. The punitive damages award of $5 billion were the largest in history. (In 2001, the Ninth Circuit Court of Appeals found the award to be excessive and remanded the case to the district court for a redetermination of the punitive damages award.) Exxon

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[18]M&M Protection Consultant study of larger property damage losses as cited in Burk, 1994.

survived the crisis, but the entire oil and gas industry was increasingly restricted by requirements such as the Oil Pollution Act of 1990.[19]

Clearly, private industry operates extremely hazardous ventures. The liability exposure surrounding such ventures can be huge. Despite some terrible accidents, profitable industries persist in operating these endeavors, and are continually improving their safety records.

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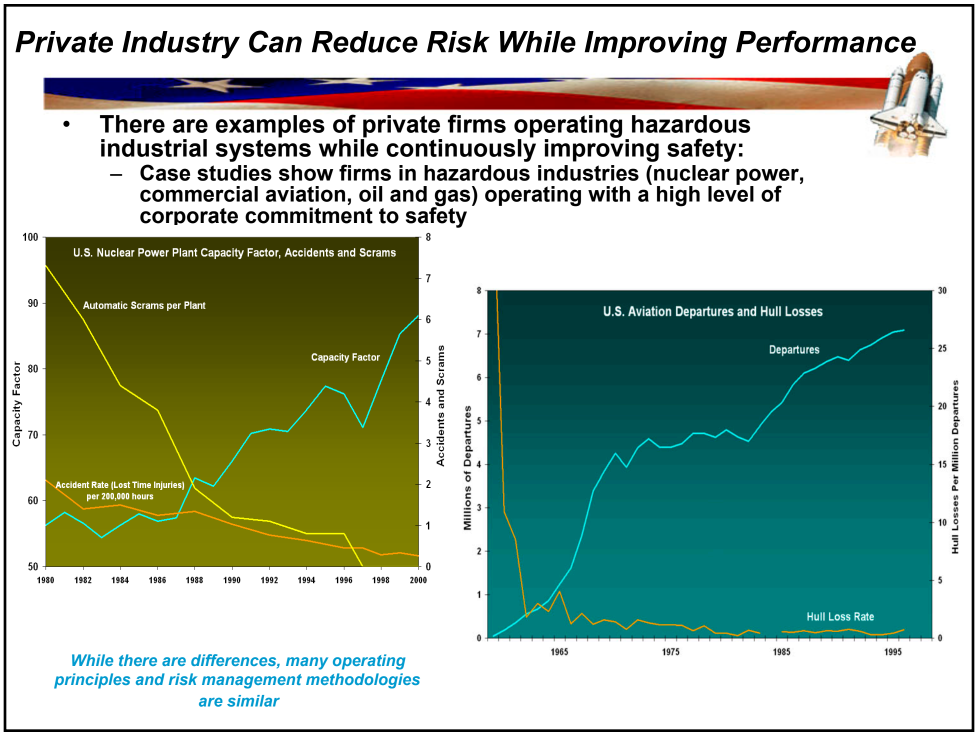
[19]Anderson, C. M., and LaBelle, R., "Update of Comparative Occurrence Rates for Offshore Oil Spills," *Spill Science & Technology Bulletin*, Vol. 6, May 6, 2000, pp. 303–321.



A safe company will benefit from higher efficiency when employees are comfortable with their work environment and confident that their superiors value employee safety over company revenues. In some cases this is true of consumer safety also; for example, many people will choose to fly an airline that they know has a better safety record than others, even if the ticket may cost a little more.

Three clear examples of private industry improving safety as it strives to improve operating performance appear in the aviation, nuclear, and oil and gas industries. Deregulated in 1978, airline travel is now an indispensable part of domestic and international transportation. Hull losses have been decreased partially by improvements in technology, but also by the industry’s ability to predetermine risks before accidents happen. Despite burgeoning demand, airline travel today is safer than ever.[20] The nuclear industry has mastered operational excellence demonstrated by driving incident records down to the point that some metrics, such as automatic shutdowns, or SCRAMs, return annual values

[20]Boeing Commercial Airplane Group, *Statistical Summary of Commercial Jet Airplane Accidents, Worldwide Operations, 1959–2001*, Seattle: Boeing Commercial Airplane Group, Airplane Safety Engineering, 2001.

of zero.[21] In addition to improving safety performance, most domestic reactors have increased operational capacity that on average nears 90 percent.[22] Crude oil movement has seen a great increase in the recent decade, while significantly minimizing oil spills both at sea and in port. These examples illustrate the point that there are companies operating within very hazardous industries that have a high level of commitment to safety.

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[21]The term SCRAM ("Safety Control Rod Axe Man") refers to the man stationed to cut the rope holding the control rods of the first experimental reactor if radiation levels became too high. If the SCRAM used his axe and split the rope, gravity would take over and the control rods would fall into the reactor slowing the atomic reaction.

[22]From WANO 2000 Performance Indicators.

Significant Differences Remain Between SSP and Private Sector

Operating Characteristic	SSP	Nuclear Power Station (Diablo Canyon)	Implications
Staff	> 20,000 total	1250	Intergroup communication becomes difficult as number of staff rises.
Annual Budget	$4,000M	$187M	
Equipment	Orbiters and ground hardware are unique units.	Reactor vessels from standard family, custom plant design	SSP is more susceptible to obsolescence and vanishing vendor problems. Both require highly specialized workforce.
Procedures	Tens of thousands, contained in over 150 requirements documents	Over 4,000	Insight into work process is critical but may be more difficult in SSP.
Number of Work Items	1,000,000	90,000	
Requirements Development and Management	NASA controls all requirements, contractor implements	NRC provides regulatory oversight and high-level requirements, plant/utility control low-level maintenance requirements.	Evolution and improvement of low-level processes is easier for nuclear power.
Operational Profile	4 flights per year	>300 days/year	Industrial systems must operate continuously at high performance levels.
Maintenance Profile	200,000 hours per flight	Ongoing scheduled	SSP operates in two distinct regimes

Although industry furnishes several relevant lessons for Shuttle operations, the Shuttle program hardly parallels an airline or petrochemical plant. The Space Shuttle is a unique, highly specialized piece of machinery that is not easily upgraded or changed.[23] Furthermore, the Shuttle flight rate is comparatively low (e.g., four flights per year), the ground processing time is over 90 days per flight. This is in contrast to private-sector operations that tend to be high volume.

There are other important differences between the Space Shuttle Program and private industries. Probably the main difference is that in the nuclear power industry, for example, the equipment and operations are more normalized, since there are many more nuclear power plants than Space Shuttles and they use common equipment and procedures. In the Shuttle program, most activity is primarily aimed at processing and returning the orbiter for another launch.[24] Time operating on orbit is relatively small.

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[23] NASA Office of Inspector General Audit Report, *Space Shuttle Safety Upgrades,* IG-02-020, 2002.

[24] A full description of Shuttle processing can be found in National Aeronautics and Space Administration, *Schedule and Status Summary: Enhancement Analysis—KSC Processing Summary Data ("Gray Book")*, USA Contractor Report DRD-1.1.7.c, Volume 2, Edition 13, Houston, Tex.: JSC, March 27, 2002.

Processing (recovering, refurbishing, integrating the payload, building the mission, and mating the orbiter with launch systems) takes up much of the scheduled Shuttle operations activity. Under current NASA processes, each part must be either inspected, tested, or be previously certified for reflight. This is the major driver for Shuttle processing work content between missions. Processing work continues year round just as in other industries.

Nuclear power stations employ a large number of employees to constantly observe mostly *automated* processes, but the numbers do not compare to the workforce required to support the Shuttle. One of the keys to running a safe operation is constant communicating among the workforce. Given the size and distribution of the Shuttle team, communications represent a significant challenge. The Shuttle is a highly customized system with few common elements; there are, for example, significant configuration variations between each of the orbiters. Only those who have worked on the machine for years fully understand the interrelations between components and the many potential failure sources.

Obsolescence is another key concern for the Shuttle industry activity. Although the nuclear industry experiences constant oversight provided by the Nuclear Regulatory Commission (NRC) and several independent organizations, low-level process change remains possible in an increasingly deregulated energy environment.[25] For the Shuttle and support systems, though, NASA controls the requirements and the contractor implements them. Much of this is deliberate so that every change receives a robust look prior to acceptance. Due to the complexity of the system and the complicated communication between primary operator and contractor and between all field centers, even low-level change must be reviewed carefully.

In industry, the person responsible for the program is responsible for safety. As noted, this is the case under NASA directives that put this responsibility on the PM, but whereas in industry there is a focused safety organization helping him to gain insight, the Shuttle safety functions are distributed between many NASA organizations. Under industrial practices, a safety function works best when it reports to the highest level charged with safe operations and is focused on gaining insight over organizational and systems performance. Each of the cited commercial examples has government regulatory organizations that provide certification for hardware, personnel, and directives that determine how

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[25]Shiffer, J. D., "Issues for Nuclear Plants in a Deregulated Electricity Supply Industry," *Nuclear Energy*, Vol. 38, No. 4, 1999, pp. 259–264.

often some processes are performed. All of these activities are currently the responsibility of the Shuttle PM, but he must use supporting safety offices or rely on the requirements process to accomplish the work.[26]

[26]Discussion with Shuttle Program Office, July 2002.

Private Industry Best Practices and Shuttle Safety Practices Have Commonalities

- **Requirements based; management of requirements is critical (NASA & Industry)**
  - **Requirements are managed by the implementers (Industry)**
- **Strong safety organization exists (NASA & Industry)**
- **Measurement and data collection are critical**
  - **But, meaningful data needs to be collected and analyzed in order to forecast and eliminate safety incidents (Industry)**
- **Employees are motivated to report issues/incidents; even anonymously (NASA & Industry)**
- **Safety is a component of all program actions; a commitment to safety at all levels promotes efficient and effective operations (NASA & Industry)**
- **Safety issues are addressed while being insulated from profit, schedule, and other pressures (NASA & Industry)**

The Shuttle and NASA safety programs share some characteristics with industry best practices, but there are important and concerning differences. An important difference is the fact that NASA personnel are moving farther and farther from an ability to implement, manage, and improve the requirements that they generate. The decision to create the SFOC set in motion a process that inextricably continues to transfer operational responsibility to the private sector. In many areas, NASA is performing functions that resemble a regulatory role. In other areas, such as managing "out of family" incidents and procuring main propulsion system elements, NASA continues to have a prominent *operational* role with strong oversight of contractor activities.

From a safety perspective, NASA is now straddling two worlds—the realm of operations and the realm of regulation. Some competitive sourcing options would press NASA to make additional choices to transfer operational activities, moving the focus of NASA responsibilities more toward insight of Shuttle activities. Other options would increase NASA's operational roles. The Task Force was concerned that NASA may now be in a precarious position, attempting to maintain leadership in more areas that it can with available human resources and skills. Tough choices lie ahead and a means of assuring the independence of safety oversight will be needed as these choices are made.

Current SSP Safety Practices Provide Solid Foundation

- **Maintain the culture where safety is endemic and permeates throughout the organizations—from VPs to custodians**
- **Continued astronaut involvement in critical decisionmaking forums essential**
- **Maintain "Constructive Natural Conflicts/Healthy Tension" checks and balances**
  - **Healthy tension between operators/maintainers and independent safety organization/government customer is good**
- **Make process execution to established requirements paramount**
  - **Requirements changes/process changes/waivers require review board approval**
    - **Changes require significant forethought and an in-depth technical understanding of the systems, history of requirements, and potential consequences**
- **Allow private firms to partake in safety goal setting:**
  - **Examine new business practices that have worked in other sectors**
  - ***Allow the private operator to share Certification of Flight Readiness (CoFR) responsibility***

Competitive sourcing is consistent with efforts to improve safety beyond today's high standards

Competitive sourcing can rely on, and should be clearly built upon, the safety processes in place today. NASA processes, built on the premise of a "healthy tension" in key ways mimic industry practices built to preserve "constructive natural conflicts." These are principles that must be retained in any new or expanded effort to involve the private sector in Shuttle operations.

The important tension incorporates the critical interrelationship of design knowledge and tacit or substantive knowledge that evolves during the operation of complex systems. How well organizations recognize and value each of these components is an important factor in being able to maintain safety and overcome unforeseen challenges.[27] It is important to note that this "healthy tension" is not between operations and the safety organization. Safety is part of design requirements *and* operations.

Clearly defined processes engender safe operations. Future management approaches must continue to require the operators and maintainers to make process execution to established requirements paramount and not

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[27]Brown, John Seely, and Paul Dugid, *The Social Life of Information*, Boston: HBS, 2000. Here the Task Force also benefited from discussions with Dr. Constance Perin, Program in Science and Technology and Society, MIT.

allow changes to be made without careful consideration of the systems, their interactions, and the potential consequences of the proposed changes.

Based on the private sector's ability to operate complex, hazardous systems safely, NASA can consider transferring additional responsibility, including more leadership in the CoFR process. It would also help to encourage more "ownership" if the contractor held some liability in Shuttle operations.

Potential Safety Gains Are Consistent with Competitive Sourcing

- **Aerospace Safety Advisory Panel (ASAP) 2000 & 2001 Annual Reports:**
  - **NASA and Contractors exhibit "high levels of safety consciousness and sincere efforts to place safety**
  - **"Nevertheless, the Panel's safety concerns have never been greater…. Budget cutbacks and shifts in priorities have severely limited the resources available to the Space Shuttle and ISS for application to risk-reduction and life-extension efforts"**
- **ASAP 1998 & 1999 Annual Reports: "Workforce issues remain among the most serious safety concerns of the panel":**
  - **Cutbacks reduce size below a critical mass**
  - **Reorganization eliminates critical skills and experience**
- **Launch schedule pressure remains a factor:**
  - **USA profits tied to meeting schedule**
  - **Possible conflict with safe operation of vehicle**
- **Shuttle safety is a larger issue than the potential for ascent loss:**
  - **There are many hazards on the ground that could result in greater loss of life and property than an ascent accident**
- **Decaying infrastructure and shuttle component obsolescence, repeatedly noted in various NASA reports, are significant contributors to a future declining safety posture.**
- **Competitive sourcing option should address known safety concerns and include plans that incorporate *validated financial needs* of what it will take to ensure safe Shuttle operations**

Launch schedule pressure remains a factor—competitive sourcing initiative must find ways to provide incentives while reducing schedule pressure

Competitive sourcing is being considered in an environment where concerns about safety are becoming more prominent. The Task Force noted these concerns and considered ways in which competitive sourcing could help address some of them.

The future concerns raised by ASAP could become significant safety issues if they are not addressed soon.[28] Decaying infrastructure and Shuttle component obsolescence, repeatedly noted in various NASA reports, are significant contributors to a declining safety posture. Field center facilities are being maintained at a level where some contractors are becoming concerned that their people may not have safe working conditions.[29] Having contractor profits tied to schedule performance

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[28]Dittemore, Ronald D., Concept of Privatization of the Space Shuttle Program, SSP, September 28, 2001.

[29]The Task Force noted two examples while touring NASA field center facilities. One example was the Self-Contained Atmospheric Protection Ensemble (SCAPE, or hazmat suits) which are sometimes not being maintained and replaced when needed. Another example was a 20-pound concrete slab from a Shuttle-maintained building that fell within a few feet of a Shuttle processing workstation in the Vehicle Assembly Building (VAB). Both occurrences were the responsibility of NASA facility administrators and institutional safety personnel. The expectations of the contractor work force for a safe working facility were greater than they were for NASA. In the case of the SCAPE suits

seems contrary to ensuring safe maintenance and operations. Competitive sourcing must find ways to address such issues.

While some within NASA express the opinion that a private firm is less concerned with safety than with making profits, this is not usually true in practice. Indeed safety and profitability are inextricably linked—a competitive sourcing option must be carefully crafted to ensure that this linkage is established and remains strong. Private firms can demonstrate an extraordinary commitment to safety. NASA itself believes this and has adopted industry safety practices in redesigning safety procedures.[30] It is likely that a private operator of the Shuttle system would be exceptionally rigorous in maintaining equipment and infrastructure to ensure safety. The economic livelihood of the contractor could well depend on demonstrating that the flight crew, ground personnel, and equipment under their purview remain safe and in proper working order. Also, the reputation of the firm, so vital to business success in other sectors, would be at stake. In short, while NASA's reputation will remain closely associated with the Shuttle program, so too will the contractor's.

Competitive sourcing options that transfer more authority and responsibility to the private sector would likely lead to budget requests that more accurately reflect the funding required to maintain flight and ground infrastructure at a level not attained today in the Shuttle program.[31]

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the contractor offered to purchase the suits at contractor expense and was denied. In industry, a safe working environment can also mean a more productive workforce. This may be one reason why the contractor in the above example was willing to pay for the SCAPE suits, which were listed as part of the NASA maintained facility.

[30]National Aeronautics and Space Administration, SSC, *Business Management Manual*, SPG 8730.1, January 3, 2001.

[31]The Task Force looked to streamlining within the SSP as a means of internally generating the funds required to improve/upgrade/maintain elements of the Shuttle infrastructure.

Competitive Sourcing Should Incorporate Safety Attributes

- **Organizations committed to safety exhibit common attributes**
- **In studying competitive sourcing options it is imperative that these attributes be present**
- **An independent safety organization reporting directly to top management is an *essential ingredient***

Attributes compiled from:

- Det Norske Veritas
- Center for Human Performance and Risk Analysis, University of Wisconsin
- Edmond Soliday, Director of Corporate Safety (Ret.) United Airlines
- DuPont Safety Resources
- Dow Environment, Health and Safety

Attribute
Every employee is responsible and accountable for safety
Self-reporting encouraged, non-punitive and often rewarded
Anonymous reporting of safety concerns
Ongoing training and worker education
Management is responsible and accountable for safety and has authority and resources to execute safe operations
Operations are process driven
Processes designed to be safe, efficient and easy to execute
Employees trained to recognize and report safety problems
Continuously improving
Safety organization is independent
Reports to highest level of organization
Is not driven by profit/loss considerations
Has technical and engineering depth
Sets safety metrics and goals
Gathers and organizes data
Advises corporate direction and actions on safety
Constructive natural conflicts/healthy tension are present
Data drives empirical decisions on safety
Collected for all system maintenance and operations procedures
Normal system operation well understood
Consistent taxonomy of safety issues and anomalies
Trend analysis detects out of family system behavior
Risk model drives process change and decisions

In a review of the literature and private sector best practices, the Task Force collected specific attributes common to organizations committed to safety.[32] As NASA procedures indicate, successful organizations do not consider safety a "tacked-on" program. Safe operations emerge from leadership priorities and from the industrial design and work processes' organization and execution. This can be facilitated by a safety function reporting to leadership. In fact, the Task Force found that one of the most important attributes is the presence of a vigorous *independent* safety organization that reports directly to top corporate management, insulated from operations profit/loss priorities or other pressures such as schedule considerations. These pressures exist in all organizations. Dealing with them successfully needs senior executive guidance and direction to place them in the proper context for safe operations. Likewise, it is not enough to say that safety is the top priority; management must have direct means

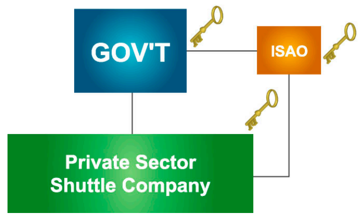
[32] Attributes compiled from: Det Norske Veritas; Aerospace Corporation; Center for Human Performance and Risk Analysis (University of Wisconsin); Edmond Soliday, Director of Corporate Safety (retired) United Air Lines; DuPont Corporation's Safety Resource Division, and the Dow Corporation's Environment Health and Safety Group. The Task Force's review of a wide range of corporate practices was conducted at a high level. More work is needed for any competitive sourcing option selected to insure that the emergent Shuttle operations has an appropriately configured safety organization.

for viewing operations and design processes through a safety lens. An independent safety function, free of any chain-of-command filters and empowered with sufficient engineering depth to ensure that a healthy tension exists, is a key element of long-term safety.

Independent of operational pressures, the independent safety organization remains a tool for the leadership to foster safe practices and gain insight. In industry, the safety organization does not set standards or create requirements, as much as it helps ensure that all elements of the organization are working together with deliberate purpose for safe operations. Through its independence, such an organization can initiate its own analyses that can help anticipate where incidents and problems may arise.

NASA Should Consider an Independent Safety Office

- **Although Shuttle should be "operationalized" as much as possible, launching humans into space has no real parallels—a unique check on safety is required**
- **An "Independent Safety Assurance Office" could be utilized to provide insight and oversight of Shuttle operations for ANY of the competitive sourcing options NASA considers**



- **The ISAO could hold one of the keys in a *"three key" CoFR process:***
  - **The government, the operating contractor, and the ISAO participate in a "go/no-go" launch decision—three keys, three greens, or no launch**
  - **ISAO should report directly to most senior gov't leadership**
- **Many of NASA current safety functions could be transferred to the ISAO**

After 20 years of operation, the Shuttle remains a complex vehicle to operate. A point has been reached where some operations are fairly routine and additional operations could be made more routine if decisions could be made by NASA to defer further modifications to the system. However, the Shuttle will never attain airline-type operations; it will remain a complex vehicle to operate. Because the Shuttle is operationally unique and a high-value national asset, the Task Force found that competitive sourcing should include additional safety features to help ensure on-going success.

One notion that the Task Force members found especially appealing was the creation of an Independent Safety Assurance Office (ISAO). Its purpose would be to provide unbiased assessments of Shuttle safety, to continually monitor safe operations, and to inform NASA corporate leadership. It would be formed by combining some elements of current NASA safety offices. Its role could expand in the future to monitor other human space transportation systems and assurance functions performed by the SSP.

The ISAO could be a government or a private enterprise, but it would be designed to operate in a competitively sourced environment. The Task Force viewed the ISAO as an important adjunct in a strategy of placing operations more in private hands. Also, if contractors play more of a role in the formulation of requirements, a robust and independent safety organization could be important in gaining and maintaining insight into the system. Methods used by NASA to maintain insight will be increasingly crucial in an environment where skills continue to erode due to natural aging of the workforce.[33]

The ISAO could hold one key in a three-key CoFR process that would require the government, the ISAO, and the Shuttle operating contractor to all give a "go" for launch. In other words, any one of the three entities could provide a no-go launch if they did not believe it was safe to launch. It is interesting to note that under today's commercial launch operations there are many launch stakeholders, each with an interest that can affect the decision to launch.[34]

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[33]It is important to note that the Air Force maintains/augments its insight role in relation to the launch of ELVs by employing the Aerospace Corporation is a role similar to the recommended ISAO. The Aerospace Corporation plays a key role in the launch go/no-go decision. While the Air Force retains launch authority, the company plays an approximately co-equal role.

[34]For example, the commercial insurer could be viewed as effectively holding a key to the launch decision.

NASA Could Accept a New Role in Shuttle Safety

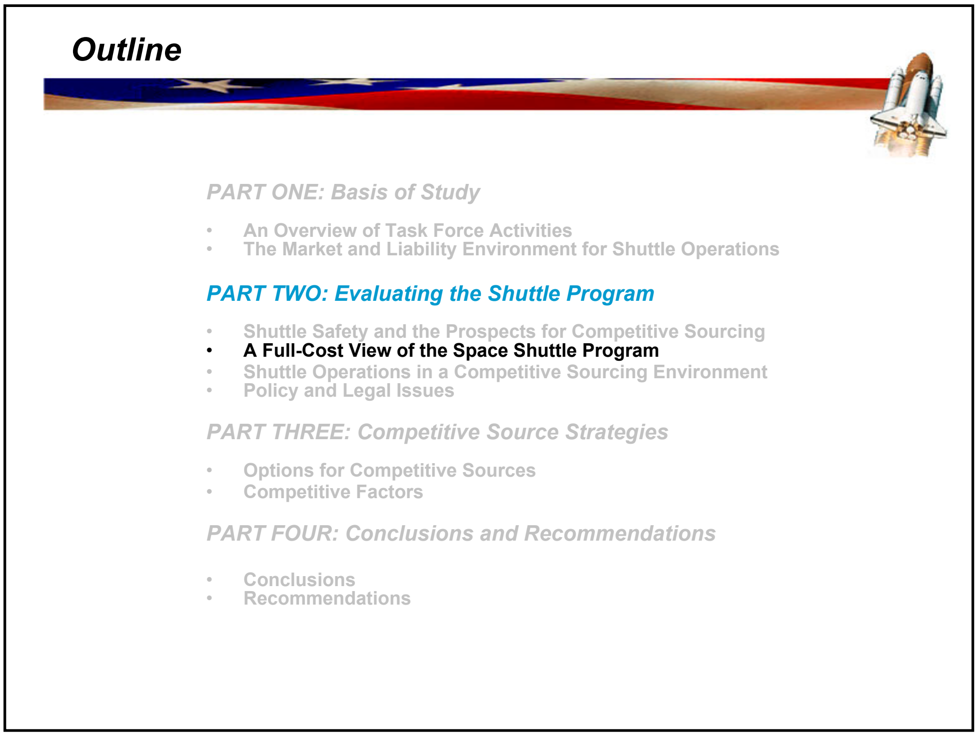
- **Competitive sourcing could significantly expand private-sector responsibility for safety:**
  - **Remaining NASA safety functions could be consolidated as much as practical**

Safety Functions		Current Implementation Lead: NASA	Current Implementation Lead: Contractor	Current Implementation Lead: Other Govt.	Potential ISAO Role
Management Functions	Requirements Management*	●			●
	Configuration Control*		●		No change
	Vendor Certification*		●		●
	Process Certification*	●			●
	Certification of Flight Readiness*	●			●
	Risk Assessment*	●			●
	Range Safety*			●	No change
Inspection, Audit, Surveillance Functions	Requirements Compliance		●		●
	Workers Certification		●		No change
	Safety Training		●		No change
	Inspection*		●		●
	Environmental Health*		●		No change
	Employee Health*		●		No change

**** Indicates NASA/Govt. establishes top level performance requirements.***

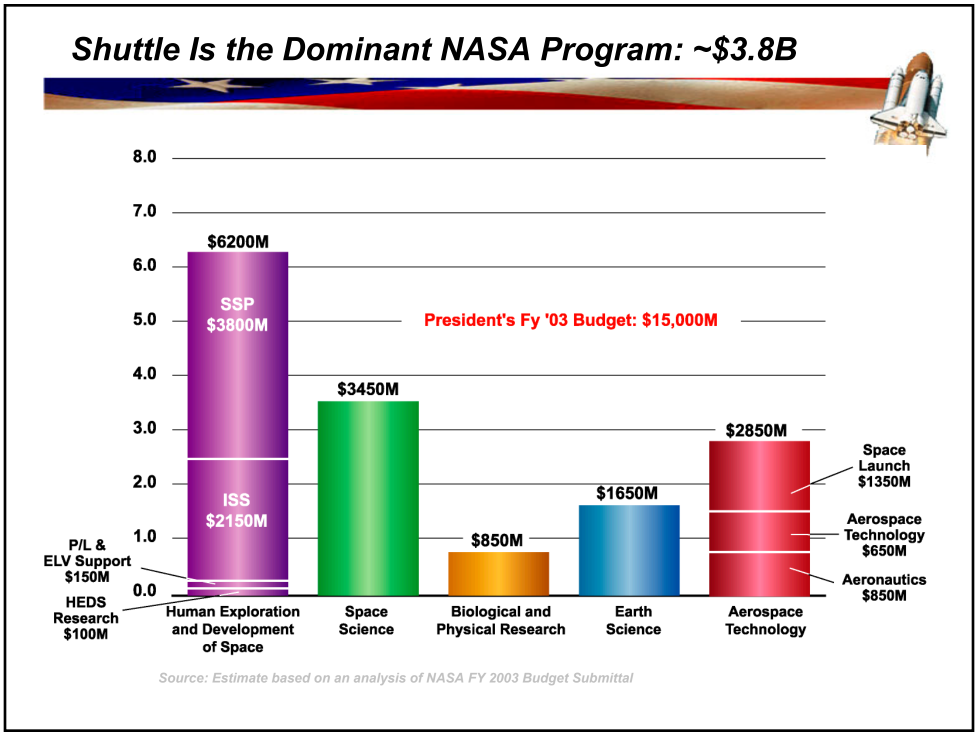
NASA could choose to accept a new safety role in a competitively sourced environment by transferring some functions to an ISAO (potential areas for transferring roles to an ISAO are shown in the right-most column in the table above). Other functions related to safety could be transferred to the private sector for operations and development as NASA evaluates the expanded capabilities of contractor staff.

NASA must, of course, focus on retaining the engineering and managerial staff needed to ensure proper insight and oversight. These roles will change over time requiring continued vigilance and caution. The transition that occurred during the creation of the SFOC demonstrated that such transfers can be successfully accomplished, but they are complex and costly. Such transfers are, however, important to address if NASA staff are to address growing responsibilities in other research areas, and if the contractor community is to grow in capability to supply future human space transportation services.

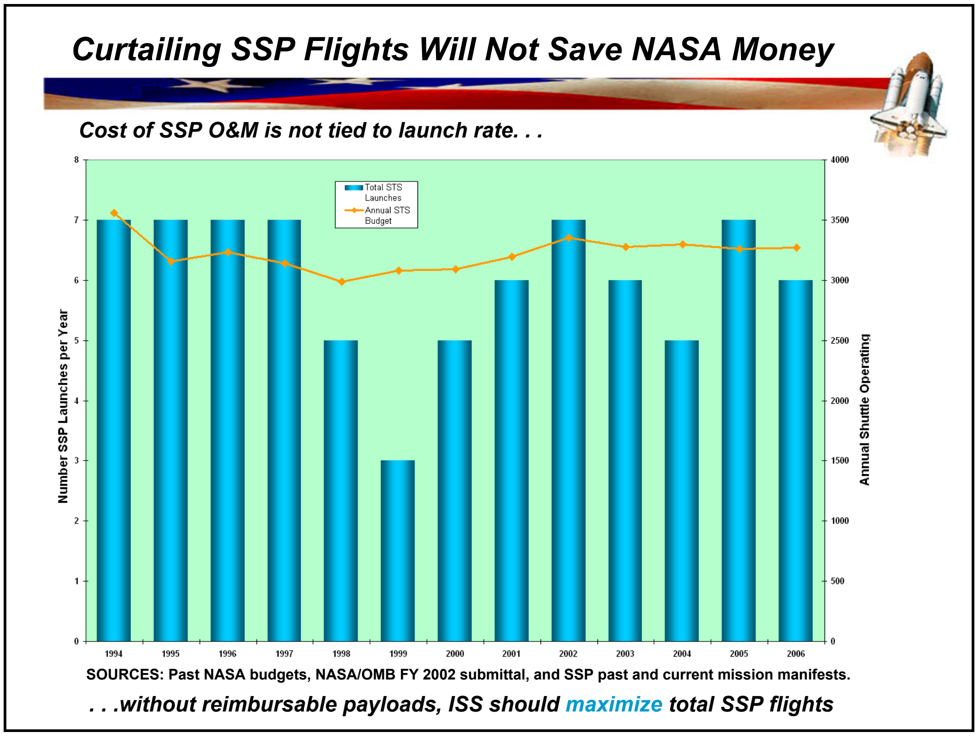


A FULL-COST VIEW OF THE SPACE SHUTTLE PROGRAM

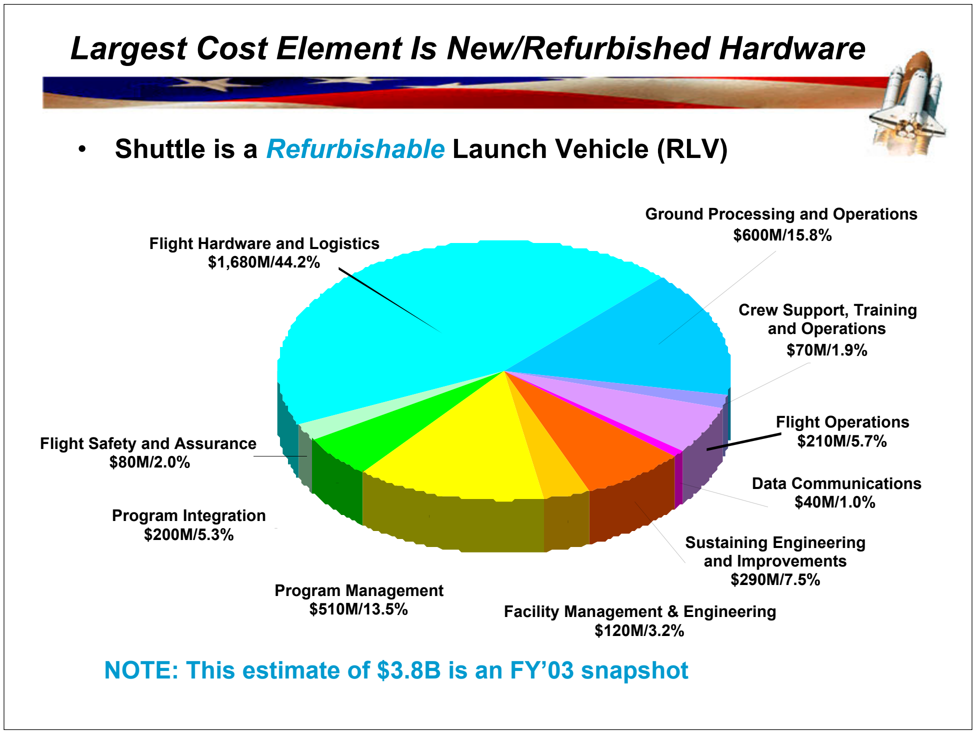
What is the true cost of operating the Shuttle? Any competitive sourcing option requires a comprehensive answer to this question. In this section, we examine the Space Shuttle's cost profile. The Task Force analyzed three aspects of this profile—its financial status, the cost implications of its workforce, and the cost of the Shuttle infrastructure.



To begin our assessment of the Shuttle's financial status, we reviewed NASA's FY2003 budget. We organized the budget by enterprise and product line, with support costs distributed to show the full cost of the elements. The Shuttle, at $3.8 billion, is clearly the dominant program in the Agency. Adding the Space Station, the remaining elements of Human Exploration and Development of Space (other than payload and ELV support), and the SLI, nearly 50 percent of the agency's budget is programmed to support human spaceflight.



As this chart illustrates, the costs of operating the Shuttle have not varied significantly with changes in the flight rate. Thus, if NASA maintains the current Shuttle infrastructure, curtailing flights will not lead to major cost savings.



The Shuttle is a "refurbishable," as opposed to a "reusable" launch vehicle. Over 44 percent of the cost is due to flight hardware and logistics. Included is the ET, RSRM, solid rocket booster (SRB), SSME, and orbiter refurbishment.

Operations and training represent nearly 25 percent of the Shuttle cost—over $900 million per year. These are predominantly labor costs, and represent the "standing army" that is available to ready the Shuttle for launch and manage it during orbital operations.

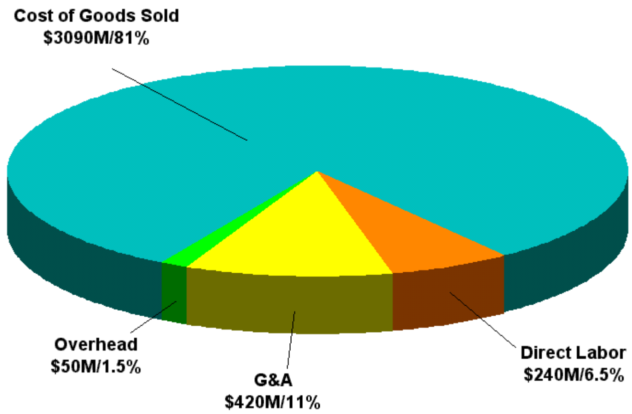
Program management, program integration, and safety account for over 20 percent of the annual cost. This nearly $800 million cost per year is also labor intensive, and is also relatively invariant with respect to launch rate.

Sustaining engineering and improvements and facility management and engineering are about 10 percent of the total, just over $400 million. These funds do more than maintain the status quo of the system. These efforts are intended to improve system components, such as improved cockpit instrumentation and refined external tank assembly procedures.

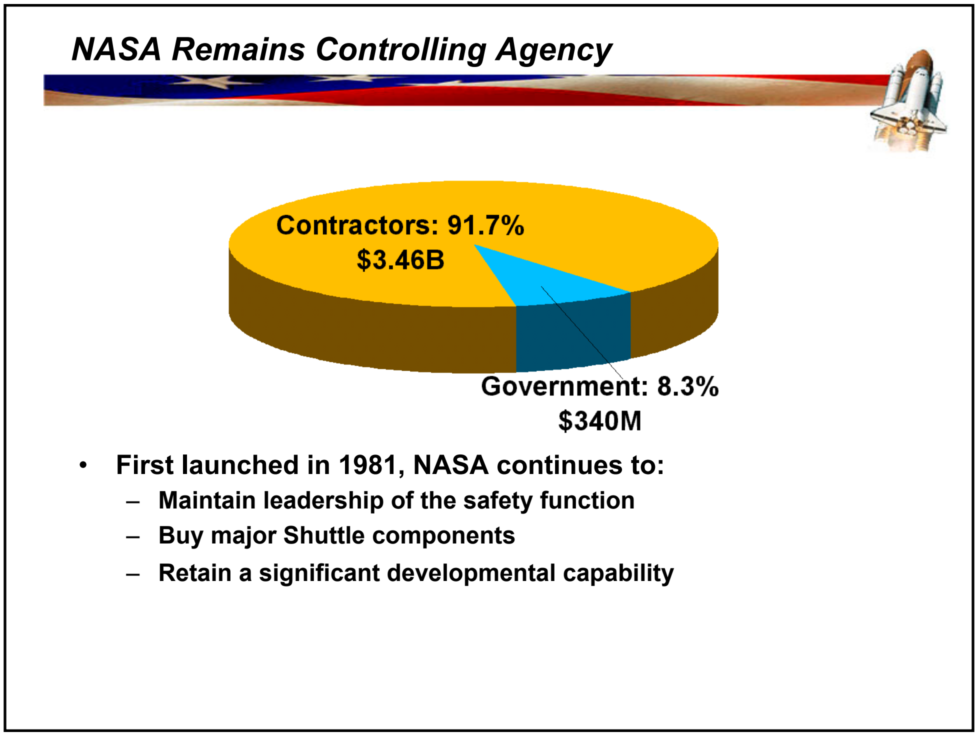
The Shuttle program encompasses a great deal of activity and is expensive to operate. Spaceflight itself is an expensive endeavor, human spaceflight more so.

"Shuttle, Inc." Is a Balanced Enterprise

- **Actions can be taken to reduce the "cost of goods sold," but SSP maintains acceptable indirect costs**



This view of the annual Shuttle costs presents a business-focused assessment of cost. Indirect cost consists of overhead and general and administrative (G&A) costs. *Overhead* is predominantly the general computer services charge to the program, while *G&A* is that share of cost which is not assignable to specific end items. *Direct Labor* is the cost of NASA personnel assigned to the program. Having isolated these cost elements, the remainder is termed *Cost of Goods Sold*, a business accounting item that represents the "finished goods" delivered through the year. The pie chart above shows that the indirect cost of the SSP is 12.5 percent. This is noteworthy because it represents a very acceptable value for a program of this size and complexity. While efforts can be made to reduce the overall cost of the SSP, it is unlikely that significant savings can be generated through reductions of indirect costs.

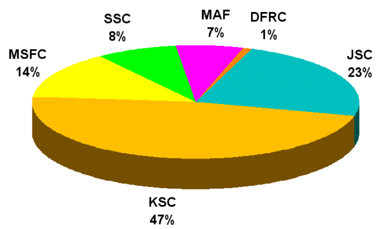


The great majority of the $3.8 billion full-cost SSP budget is outsourced. Yet, the government retains control and maintains the capability to develop the system. As mentioned earlier, NASA retains leadership of the safety function as well as control of out-of-family concerns. In a broad sense, sustaining engineering (activities designed to maintain, improve, and modify Shuttle components) is dominated by NASA. NASA also manages the procurement of main propulsion elements, namely the ET, RSRM, and SSME components. It is through SFOC that NASA has relinquished the most control of the Shuttle program. So, while heavily outsourced, the SSP continues to be a program solidly controlled by NASA.

SSP Is Carrying Over $400M BMAR

- *BMAR represents a significant investment and the estimates provided below are likely to be low*

NASA Center Summary

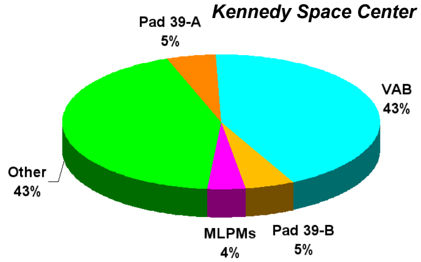


Center		Total		Shuttle	% Shuttle
JSC	$	185,890,437.02	$	65,462,175.50	35%
KSC	$	377,342,156.26	$	280,548,502.78	74%
MSFC	$	108,449,587.00	$	9,468,503.00	9%
SSC	$	62,071,897.00	$	11,623,902.55	19%
MAF	$	53,460,000.00	$	52,390,800.00	98%
DFRC	$	7,200,000.00	$	746,476.60	10%
Totals	$	794,414,077.29	$	420,240,360.43	53%

NOTE: This value is likely to be low, not included are:

- Only JSC and KSC provided future BMAR estimates
- If the ratio of current/future BMAR holds, the estimate could increase to ~$800M

Kennedy Space Center



Facility		BMAR
VAB	$	163,515,711.21
Pad 39B	$	20,221,476.81
Pad 39A	$	16,998,514.21
MLPs	$	13,591,583.04
Other	$	163,014,870.99
Totals	$	377,342,156.26

Next, the Task Force looked at Shuttle infrastructure. During recent years, due to inadequate levels of funding for facility maintenance, NASA has amassed a sizable backlog in maintenance and repair. Based on data obtained from the major Shuttle field centers, the Task Force found that the Shuttle program is carrying over $400 million of unbudgeted backlog of maintenance and repair (BMAR), which accounts for over half of all BMAR at those centers. Because only the Johnson Space Center (JSC) and the Kennedy Space Center (KSC) provided the Task Force with both current and future maintenance requirements, however, the overall BMAR figure could actually be substantially higher (applying the ratio of current to future requirements at KSC to other centers suggests the number could increase to approximately $800 million).[35]

Based on the data currently available, nearly half of the identified BMAR is at KSC. Of that number, the VAB accounts for over $163 million—a large proportion of that needed to repair the building's roof. An additional 14 percent of the BMAR requirements are accounted for by the Shuttle Launch Pads (39-A and 39-B) and the Mobile Launcher Platforms

[35] "SSP Facilities Inventory" (Appendix F), Office of Management Systems, Facilities Engineering Division, *NASA Real Property Inventory/Facility Utilization Database*, Washington, DC: NASA.

(MLPs), meaning that the three largest systems account for over half of the $377 million in BMAR at KSC. This requirement for facility repairs represents a significant future investment for the SSP.

NASA policy regarding the management of facilities maintenance (and commonly used industry heuristics) suggest that 2–4 percent of CRV should be budgeted annually for plant maintenance and revitalization. Utilizing the low end of that spectrum as a basis, the Task Force found that the minimal investment for maintenance and revitalization of SSP ground infrastructure should be approximately $90 million per year. Because NASA is currently funding far less than this amount, the unbudgeted BMAR increases by tens of millions of dollars each year.[36]

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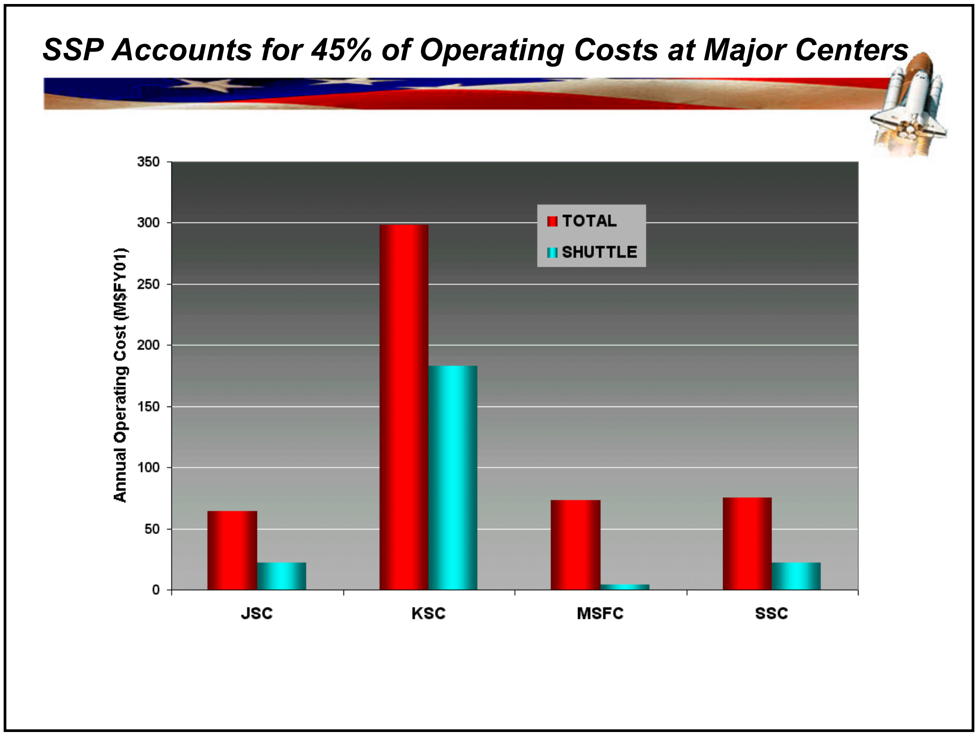
[36]National Aeronautics and Space Administration, *NPD 8831.1C, Management of Facilities Maintenance*, May 29, 2002.



Based on an analysis of base maintenance and operations contracts awarded by NASA, the Task Force found that the SSP accounts for nearly half of the combined operating costs at the four largest Shuttle field centers—JSC, KSC, Marshall Space Flight Center (MSFC), and Stennis Space Center (SSC). Operating costs were calculated by summing all of the base maintenance and operations contracts awarded at each field center, then apportioning the total figure among the specific center's facilities as a function of its size—determined by assessing the percentage of current replacement value (CRV) accounted for by that facility. This analysis revealed not only that the Shuttle program funds a large proportion of the operating costs at many of these centers, but that each of these centers is very expensive to operate on an annual basis. KSC, for example, costs the agency nearly $300 million annually—61 percent of that amount can be attributed to the SSP. JSC, MSFC, and SSC all cost between $60 million and $75 million annually—with the SSP accounting for between 6 percent (MSFC) and 34 percent (JSC) of those totals. Center operational costs are ultimately paid by the programs that they serve. Competitive sourcing options could significantly affect how "taxes" are collected to pay for field center services as well as the proportions being paid by the SSP.[37]

[37]National Aeronautics and Space Administration, Office of Procurement, *NASA Financial and Contractual Status (FACS) System*, 2001.

Top 25 SSP Buildings Account for Nearly $800M in Annual Costs

SITE	NAME	SHUTTLE CIVIL SERVANTS	SHUTTLE ON-SITE CONTRACTORS	SHUTTLE FACILITY COST	SHUTTLE ANNUAL COST#
KSC	OPERATIONS SUPPORT BUILDING	201	1,049	$ 2,335,335	$149,521,335
KSC	VEHICLE ASSEMBLY BUILDING	45	499	$ 36,373,347	$101,023,347
KSC	ORBITER PROCESSING FACILITY	68	556	$ 5,923,233	$79,851,233
KSC	LAUNCH CONTROL CENTER	73	541	$ 4,720,424	$77,378,424
KSC	MANUFACTURING BUILDING	12	424	$ 1,138,772	$53,290,772
KSC	ORBITER PROCESSING FACILITY HIGH BAY 3	23	381	$ 2,026,848	$50,184,848
KSC	PROCESSING CONTROL CENTER	126	266	$ 971,426	$46,247,426
KSC	LAUNCH PAD 39A	-	38	$ 20,658,025	$25,218,025
CAPE	SRB RECOVERY BUILDING - HANGAR AF	2	167	$ 1,002,994	$21,254,994
KSC	LAUNCH PAD 39B	-	31	$ 17,970,790	$21,690,790
JSC	JAKE GARN SIMULATOR & TRAINING FACILITY	1	121	$ 1,160,915	$15,786,915
EAF	MAINTENANCE HANGAR	9	112	$ 421,212	$14,815,212
KSC	VAB MODULAR OFFICE BUILDING	17	103	$ 34,585	$14,196,585
SSC	TEST STAND A-2	8	61	$ 6,204,483	$14,372,483
KSC	VAB MODULAR OFFICE BUILDING	-	103	$ 27,591	$12,387,591
KSC	VAB MODULAR OFFICE BUILDING	-	98	$ 31,380	$11,791,380
KSC	VAB MODULAR OFFICE BUILDING	-	97	$ 29,804	$11,669,804
EAF	MAINTENANCE HANGAR	33	62	$ 432,167	$11,370,167
KSC	VAB MODULAR OFFICE BUILDING	-	69	$ 22,640	$8,302,640
KSC	VAB MODULAR OFFICE BUILDING	-	66	$ 36,244	$7,956,244
EAF	HANGAR, MAINTENANCE	19	44	$ 404,386	$7,698,386
SSC	TEST STAND A-1	-	17	$ 5,617,557	$7,657,557
KSC	TEMPORARY BUILDING NO. 31 (15B)	-	57	$ 36,732	$6,876,732
KSC	VAB MODULAR OFFICE BUILDING	-	53	$ 34,242	$6,394,242
SSC	PROPULSION ENGINE ASSEMBLY BUILDING	6	41	$ 755,229	$6,311,229
	TOTAL	**643**	**5,056**	**$108,370,362**	**$783,248,362**

Annual Cost = CS Cost ($106K per annum) + Contractor Cost ($120K) + Operating Costs

Based on an analysis of personnel costs and operating costs, the Task Force found that the largest 25 SSP buildings (displayed in the table above) account for nearly $800 million in annual costs at the four largest Shuttle field centers—JSC, KSC, MSFC, and SSC. Annual costs were calculated by summing the cost of civil servant labor (the number of civil servants working in a building multiplied by the average SSP fully burdened labor rate of $106,000), the cost of contractor labor (the number of contractors working in a building multiplied by an assumed fully burdened labor rate of $120,000), and operating costs at each building. This analysis revealed that the largest SSP building costs between $6 million and $150 million to operate annually. If it were determined that the Shuttle could continue to operate safely and meet the manifest, mothballing or abandoning some of these buildings could open up a considerable cost wedge.[38] This analysis reveals that it costs a great deal to operate Shuttle ground infrastructure. Therefore, the utility of these facilities should be accurately ascertained before implementing competitive sourcing options to ensure they are required.

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[38]National Aeronautics and Space Administration, Office of Procurement, *NASA Financial and Contractual Status (FACS) System*, 2001.

Replacement of Shuttle Facilities Valued at >$4.5B

Field Center	Sites	#	BV	CRV	CS FTE	CON. FTE
JSC	5	561	$ 585,662,672.00	$ 1,472,757,258.00	3068	7315
Shuttle	**3**	**93**	**$ 177,291,531.91**	**$ 517,374,798.50**	**969**	**2934**
KSC	3	885	$ 1,577,611,472.00	$ 4,228,340,774.00	2142	11672
Shuttle	**3**	**310**	**$ 918,312,463.86**	**$ 2,593,011,572.02**	**1298**	**7226**
MSFC	3	437	$ 414,778,461.00	$ 1,228,704,791.00	2593	4276
Shuttle	**2**	**20**	**$ 20,757,279.83**	**$ 70,803,341.37**	**195**	**831**
SSC	2	228	$ 487,781,468.00	$ 1,640,013,928.00	663	1510
Shuttle	**1**	**47**	**$ 109,844,218.55**	**$ 489,424,882.10**	**106**	**315**
MAF	1	181	$ 276,179,484.00	$ 1,053,170,857.00	21	1944
Shuttle	**1**	**181**	**$ 221,884,964.42**	**$ 753,242,551.04**	**21**	**1905**
DFRC	1	213	$ 152,571,865.00	$ 262,861,079.00	658	944
Shuttle	**1**	**21**	**$ 16,587,805.00**	**$ 27,252,728.50**	**43**	**116**
WSTF	4	205	$ 113,265,315.00	$ 267,981,959.00	71	881
Shuttle	**4**	**63**	**$ 26,741,177.58**	**$ 79,344,541.67**	**26**	**277**
NASA TOTAL	**19**	**2710**	**$ 3,607,850,737.00**	**$ 10,153,830,646.00**	**11,734**	**40,872**
SHUTTLE TOTAL	**15**	**735**	**$ 1,491,419,441.15**	**$ 4,530,454,415.20**	**2,658**	**13,603**
% SHUTTLE	***79%***	***27%***	***41%***	***45%***	***23%***	***33%***

NASA owns land and facilities with an estimated CRV of approximately $20 billion (~$10 billion at the major Shuttle field centers). Facilities and land utilized by the SSP represents nearly one-quarter of that total number—$4.5 billion. The Shuttle program uses 735 different facilities at 15 different sites.[39]

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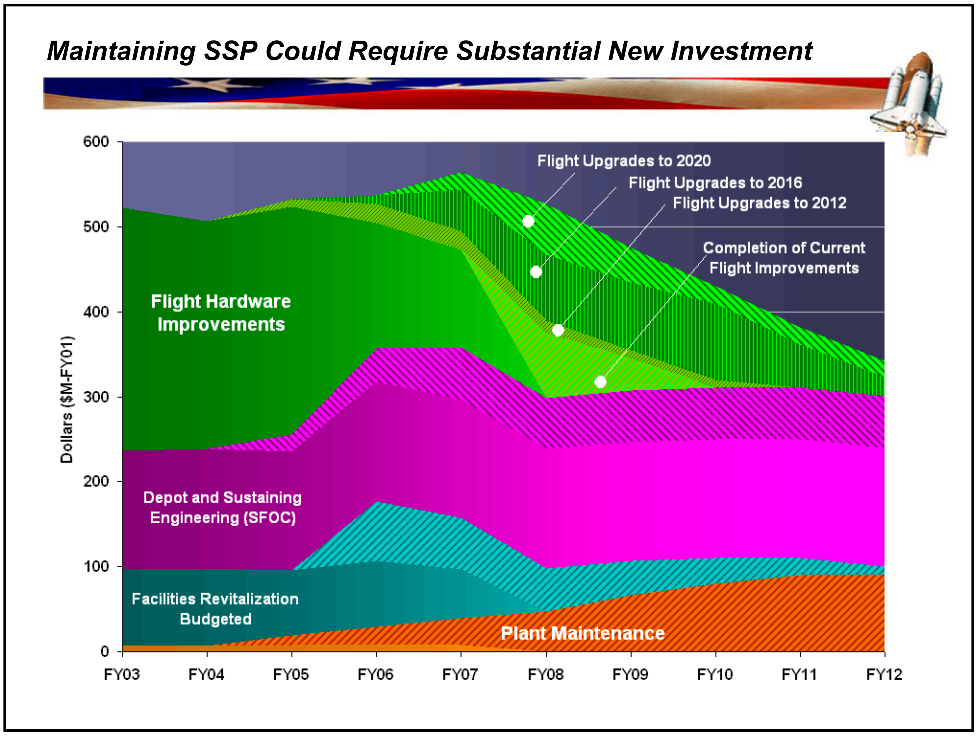
[39]National Aeronautics and Space Administration, Office of Procurement, *NASA Financial and Contractual Status (FACS) System*, 2001.



Current budgeted funds for sustaining the SSP are likely to be inadequate. The projection of these costs is the result of a bottom-up accounting of sustainability costs for program elements. The stack of cost curves presented in the chart begins with actual costs based on the SSP budget and embedded costs in the SFOC. Solid areas represent budgeted items; hatched areas represent projected future costs. The costs fall into two general categories: ground infrastructure and flight hardware. Ground infrastructure refers to the buildings, roads, launchpads and other facilities that the SSP uses to perform its functions. Flight hardware refers to those items more commonly associated with the SSP, such as the orbiters, the SRBs, the ET, and training and test equipment. The chart demonstrates that continued operation of the SSP will require a sustained investment of approximately $300 million per year. This is important because system upgrades will likely require a deeper commitment than currently envisioned and also because future operational costs will likely be higher.

Sources that contribute to the projected costs depicted in the chart are the current budget, which allocates funds through 2007, NASA's estimate of BMAR related to the Shuttle, recommendations from NASA management regarding the costs of future facilities maintenance, and sustaining engineering estimates from USA.

The Task Force assumed that the Shuttle will fly four to six flights per year. At this flight rate, system upgrades designed to ease maintenance and improve the efficiency of system processing are unlikely to pay for themselves.[40] Related to the benefits of system improvements are "safety" upgrades. Indeed, most system changes are related to the safe operation of the system, but given the length of time to incorporate many of the changes and the low flight rate, the effect that the "safety" upgrades will have for significantly reducing the probability of catastrophic events is debatable.

The Task Force analyzed three dates for possible termination of the SSP. The first is 2012, which is the original date that NASA proposed for the availability of a replacement system. The long-term date for phaseout of SSP is 2020, which could also include system continuation. The midterm date of 2016 represents a compromise between the two alternatives. Each scenario assumes the availability of a replacement system. Though some of the costs in our analysis assume particular end dates, not included are cost-saving efficiencies that are possible as the program nears termination.

In the chart, the bottom cost wedge entitled Plant Maintenance grows from zero to $80 million. It reflects the need for continued plant maintenance at a certain percentage of the replacement value; in the past, the authority over plant maintenance was shared among the centers and the program, resulting in a considerable backlog of maintenance.

The Shuttle ground infrastructure is in need of repair. The current Space Shuttle budget calls for an annual allocation of $6 million to $10 million of maintenance on infrastructure valued at $4.5 billion.[41] As mentioned previously, some infrastructure maintenance is part of the budget of the controlling NASA field center. According to a NASA memorandum, and as noted in the previous chart, a reasonable estimate for the maintenance of ground infrastructure is 2–4 percent of the replacement value per year.[42] Two percent of the replacement value of SSP-specific facilities is $90 million; a figure of $80 million is plotted to account for periodic maintenance by USA under SFOC.[43] Through 2007, $394 million is allocated to the revitalization of much of the ground infrastructure as part

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[40]Boeing Company, Space Shuttle Office, telephone interview, July 16, 2002.

[41]"SSP Facilities Inventory" (Appendix F), Office of Management Systems, Facilities Engineering Division, *NASA Real Property Inventory/Facility Utilization Database*, Washington, DC: NASA.

[42]National Aeronautics and Space Administration, NASA Policy Directive 8831.1C, May 29, 2002.

[43]Halligan, Ann, Director of Financial Control, USA Inc., telephone interview, July 2002.

of $420 million in improvements;[44] $26 million is included in the chart to complete this set of repairs. Additionally, James Costello, SSP Business Office Director, reported to the Office of Space Flight that the actual maintenance backlog was $703 million.[45] The hatched line on the chart reflects these costs spread over seven years.

The "sustaining engineering" category refers to activities related to the maintenance of aging systems. These activities include the development and certification of parts and subsystems that are no longer manufactured by the original vendor. These obsolescence mitigation activities typically deliver replacement components, which are newly manufactured or refurbished components that conform to the specifications of the original. USA maintains a depot in which it rebuilds and certifies electronics and ground support equipment for the STS. USA currently allocates $140 million annually to these efforts and predicts that as the system continues to age the costs will rise to $200 million per year.

Current flight hardware improvements cover a broad range of subsystems of the Shuttle. In anticipation of program sunset, the Task Force assumed that all major system upgrades are phased out by 2012, allowing for sustaining engineering to maintain the system until it closes. The FY2003 budget includes $285 million in flight hardware and training aircraft upgrades. These upgrades continue through FY2007 and include annual expenditures for the checkout launch and control system ($25 million to $50 million), flight operations ($2 million), friction stir welding ($1.5 million), SSME upgrades ($3 million), orbiter and orbiter supportability ($80 million to $100 million), and other flight hardware ($85 million to $120 million). Also included are $10 million to $20 million for the T-38 trainers and Shuttle training aircraft and $12 million for improved program integration. The Task Force assumed these programs to be completed by FY2010.

Future Shuttle improvements are a cottage industry for NASA's engineering staff and contractor base. The SSP Development Office lists, without cost, over a dozen upgrades designed primarily to maintain the Shuttle. These upgrades include a Block III upgrade for the SSME and engineering studies of a five-segment SRB.[46] The result of these upgrades

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[44] Office of Management Systems, Facilities Engineering Division, *NASA Real Property Inventory/Facility Utilization Database*, Washington, DC: NASA.

[45] Costello, James, "Space Shuttle Program, POP 2002," presentation to the Office of Space Flight, June 14, 2002.

[46] Henderson, Mac, *Shuttle Upgrade Plan: Executive Summary*, Space Shuttle Program Development Office, 22 May 2002.

is incremental improvements to Shuttle safety and performance, measured in on-orbit-time, lift capability, and ascent and mission risk. The Boeing Company, the manufacturer of the Shuttle, has a functional view of the system upgrades. Its set of upgrades, entitled in aggregate "Future Shuttle," have been selected according to each upgrade's effect on safety and reliability, supportability, operational efficiency, performance, and implementation risk, operational efficiency being the primary weighting factor.[47] "Future Shuttle" relies upon strong assumptions regarding Shuttle operations; in particular, it assumes a flight rate of six flights per year until 2012 and 10 or more flights per year thereafter.[48] A flight rate of four to six flights per year justifies no investment beyond sustaining engineering.[49]

The hatched lines that top the chart represent flight upgrades beyond those that are budgeted. They represent what the Task Force believes to be reasonable system improvements based upon the expected life of the system. Additional upgrades for the 2012 system end date total $90 million through FY2010 and include full funding of industrial engineering for safety and the environmental control and life support system. If it is decided to maintain the Shuttle through 2016, upgrades in addition to those cited above total $280 million through FY2012, and include payload processing and integration, and Ku and S-Band communications system upgrades. The final upgrades are those that would be implemented if the Shuttle operated through 2020. These upgrades total $600 million through FY2012 and include Phase 2B of the SSME advanced health monitoring system and a new electronic power distribution and control system. Regardless of the of the Shuttle retirement date, or the particular set of upgrades that is chosen, fixed costs with respect to facilities, sustaining engineering and current upgrades dictate that sustaining the Shuttle will require $500 million annually in the near term and approximately $300 million annually in the long term.

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[47]Boeing Company, *Space Shuttle 2020 Investment Strategy Recommendations Overview*, June 18, 2002.

[48]Boeing Company, Space Shuttle Office, telephone interview, July 16, 2002.

[49]Boeing Company, Space Shuttle Office, telephone interview, July 16, 2002.

Competitive Sourcing Will Likely Affect Shuttle Staff

- **Disposition of NASA Shuttle:**
  - **For the program it means:**
    - **Termination of some activities**
    - **Transfer of work functions to contractors**
    - **Workload reduction**
  - **For NASA Civil Service employees it means:**
    - **Reassignment to other projects**
    - **Possible transfer to contractor workforce**
    - **Potential A-76/"best-value" competitions in very limited number of areas**
    - **Buyouts/earlyouts for a limited number of personnel**
    - **Staff reduction through attrition (unlikely through RIF)**

Competitive sourcing of the Space Shuttle Program will affect the program itself and the civil service employees who work in it. The Task Force found that while the impact on the civil service workforce could be significant, it is unlikely that competitive sourcing would lead to a reduction in force (RIF).

Obviously, competitive sourcing will mean that some functions currently performed by NASA may be transferred to a contractor. Less obviously, the process of competitive sourcing may reveal aspects of the program that are less efficient than they could be. For example, during a formal A-76 competition to determine if a commercial activity should be accomplished by the government or be contracted out, the government proposal for doing the work requires a detailed plan for a "most effective organization" (MEO) that will be efficient and cost-effective.[50] Improving the efficiency of functions that remain with NASA could mean the termination of some activities that are no longer needed and a reduction in workload for personnel who remain with NASA.

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[50]Office of Management and Budget, *Performance of Commercial Activities*, Circular No. A-76, Revised Supplemental Handbook, March 1996 (updated through transmittal memorandum, June 20, 1999).

NASA civil servants could be affected in several ways. Personnel with skills in areas that are transferred to the contractor may, with the proper incentives, leave government service and hire on with the contractor. Personnel who do not want to leave the government even though their SSP work will move to the private sector may have to be reassigned to other positions in NASA. NASA may, as part of its program changes, authorize buyouts or early retirements to encourage some of these personnel to leave. While an RIF is unlikely, a major reorganization with a large reduction in workforce could make one necessary if voluntary departures could not be induced.[51] Even if NASA MEOs eventually won specific A-76 competitions, the process would be time-consuming, costly, and disruptive to workers.[52]

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[51]One of the reasons NASA wanted to use buyouts rather than RIFs when it was necessary to reduce personnel in 1994 was that the negative “residual effects” of RIFs done in the mid-1970s could still be felt 10–15 years later.

[52]See Robbert, Albert A., Susan M. Gates, and Marc N. Elliot, *Outsourcing of DoD Commercial Activities: Impacts on Civil Service Employees*, Santa Monica, Calif.: RAND, MR-866-OSD, 1997. These authors found, for example, that discovering new positions for displaced workers sometimes took precedence over efficient use of the workforce.

Task Force Developed Simple Way to Count FTEs

- **Collected personnel data for HQ, JSC, KSC, MSFC, and SSC:**
  - **Estimated DFRC, WSTF, and GSFC**
- **Categorized organizations as full-time Shuttle, part-time Shuttle, G&A, overhead**
- **Determined percentage of work that is Shuttle related:**
  - **Obvious Shuttle offices were counted as 100%**
  - **Facilities overhead: percentage of facilities devoted to shuttle**
  - **Other overhead: percentage of center budget devoted to Shuttle**
  - **Indirect office percentages determined by Task Force expert opinion**
- **"Direct" counts personnel in offices designated "full-time Shuttle"**
- **Other counts are FTEs**

To assess the implications of competitive sourcing for the Shuttle work force, it was necessary to count the number of full-time equivalent (FTE) personnel working on the Shuttle program. The Task Force developed a straightforward counting approach to do this.

The Task Force obtained three types of data from the Management Systems Division, Code FM, at NASA Headquarters:

1. FY01 and older historical data available on a public NASA website maintained by the Division: these data provide general demographic information for the various centers, but only break the information down at the directorate level. These data were used to look at trends, such as changes in age distributions over time.[53]

2. Code FM data from a restricted website: this site has more detailed personnel data that allow analysis of demographic information at smaller institutional levels. These data are also updated more frequently.[54]

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[53]Data were from the NASA Personnel/Payroll System (NPPS) and were compiled by NASA Headquarters' Management Systems Division (Code FM).

[54]These data are also from the NPPS.

3. A “sanitized” list (stripped of personal identifying information) of all personnel at JSC, KSC, MSFC, and SSC. This list included the office symbol, job title, Office of Personnel Management (OPM) job code, NASA job code, grade, years of service, age, retirement plan, retirement eligibility, and pay for each individual. This information was used to develop detailed personnel distributions and to study characteristics of personnel approaching retirement.[55]

To analyze the data, the Task Force first established nine administrative “groups”:

- Institutional: this includes activities such as facilities management and security.
- International Space Station–Direct: this includes offices that work only on the ISSP.
- Space Shuttle–Direct: this includes full-time Shuttle activities.
- Other Direct Program: programs such as the Advanced Space Transportation Projects office at KSC.
- SSP/ISSP Program Direct Split: this includes offices that work both on the Space Shuttle and the ISSP.
- Shuttle Program Indirect: this includes organizations such as the safety and mission assurance office that obviously do Shuttle-related work, but are also required for other functions.
- R&D/Technology Development: non–Shuttle related R&D.
- Overhead: organizations such as the human resources office that are required for NASA operations in general.
- General and Administrative: administrative offices, such as procurement offices.

Every office at the four major centers for Shuttle operations (JSC, KSC, MSFC, and SSC) was assigned to an administrative group.

Second, each office was assigned a percentage value for the proportion of its work that is devoted to the SSP. These percentages were estimated in four ways:

1. For offices designated as “institutional” (F), the percentage is estimated to be the percentage of facilities used for Shuttle

[55] This data set was extracted in May 2002 by the Management Systems Division.

operations. The values used were: JSC, 34 percent; KSC, 62 percent; MSFC, 61 percent; SSC, 32 percent.

2. For offices designated G (General and Administrative), O (Overhead) or N (Indirect), the percentage is estimated to be the percent of the center's budget that is devoted to Shuttle operations. The values used were: JSC, 51.6 percent; KSC, 22.2 percent; MSFC, 35.5 percent; and SSC, 25.3 percent.
3. Obvious Shuttle-only offices were assigned 100 percent; SSP/ISS offices were assigned 50 percent.
4. All other offices were assigned percentages based on expert opinion of members of the project Task Force in consultation with NASA.

In addition to the administrative groupings, offices were assigned to one of 44 functional categories in order to develop a master budget.

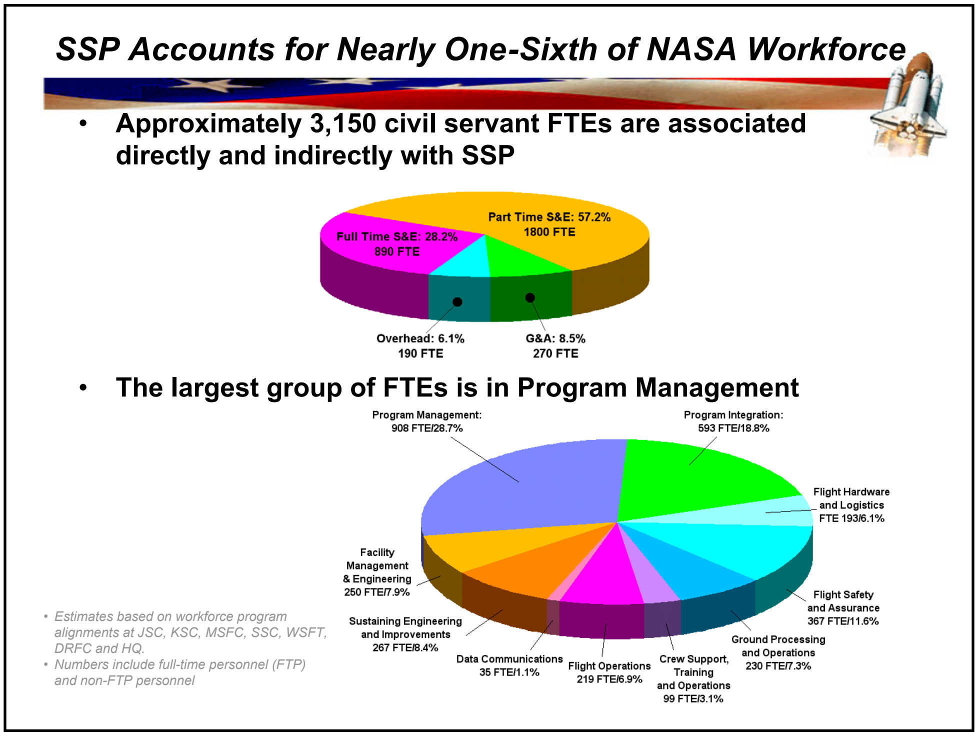
For JSC, KSC, MSFC, and SSC, the detailed personnel data and the organizational categories were used to estimate the number of personnel involved with Shuttle operations. For example, the Center Operations Directorate at MSFC was categorized as a G&A function, which, using these calculations, means that 36 percent of its effort is estimated to be devoted to Shuttle operations. Each individual in the personnel file who is in this office is counted as 0.36 FTE working for the Shuttle. At the same time, this office is counted in the "Senior Leadership" budget category, so 36 percent of the cost of this human resource is included in this category.

Staff working in offices designated as 100 percent Shuttle, such as the Shuttle Assurance Office (QS20) at MSFC, are included in the count of "full time" Shuttle personnel. Some "full time" personnel work in offices that are not in the "Shuttle direct" administrative category. For this reason, the counts of "direct" Shuttle personnel and "full time" Shuttle personnel in the figures that follow are slightly different.

Detailed personnel data were not available for Headquarters, Dryden Flight Research Center (DFRC), Goddard Space Flight Center (GSFC), and White Sands Test Facility (WSTF), so we used a different counting approach. Aggregate data for HQ were obtained from NASA, and individual offices were assigned a functional category for the budget and a percentage of SSP work by the experts in the Task Force working group. Detailed assignments of budget categories were not made for DFRC, but the working group estimated that 88 personnel there are involved with the alternate Shuttle landing facility and other Shuttle-related work. These people were included in the "Ground Processing and Operations" budget category and as part-time SSP personnel. Ten FTEs from GSFC are counted as part-time SSP personnel and included in the "Data Communications" budget category.

The structure of the data files makes it easy to modify the assignments of administrative categories, budget categories, and percentage of work devoted to the SSP, and to analyze the effects of these changes on personnel counts.

The Task Force recognized that this accounting method would generate values that exceed the personnel counts estimated by the SSP. These methods are, however, rigorous in that they fully allocate NASA personnel to enterprises and programs. Under full-cost accounting rules, it is ultimately NASA's enterprises that must absorb the personnel allocations and the associated human resource costs.



The counting procedure described above was used to develop the charts in this figure. NASA has more than 18,000 personnel, and the Task Force's count shows that about one-sixth of NASA's FTEs are associated directly or indirectly with the SSP.[56] Our count shows that of these 3,150 FTEs, 57 percent work for the Shuttle program only part of the time, 28 percent work full time, and about 15 percent are devoted to overhead and G&A functions.

In the budget categories, the largest number of FTEs (28.7 percent) is devoted to program management.

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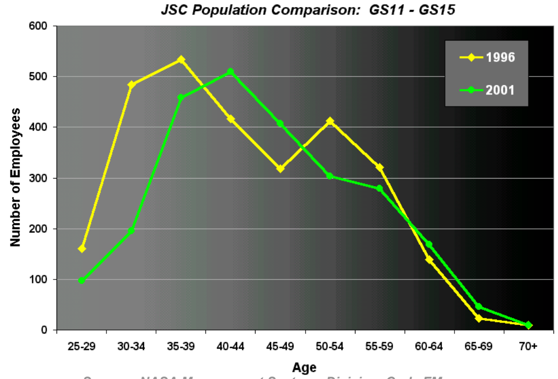
[56]Thus, 888 people at JSC, KSC, MSFC, and SSC are, according to our data, in offices that are labeled "Shuttle direct" (and are 100 percent Shuttle). The number of remaining FTEs will vary with the assumptions made about how much time offices devote to the SSP.

Aging Population Not Necessarily a Problem

- **Average age for GS11–GS15 at JSC has increased from 43.6 to 45.2, but is the result of an earlier hiring freeze:**
  - **Similar trends at other centers**
  - **Skill mix and training—not simply aging—are the issues**
  - **Workforce planning currently under way is critical to meet future needs**

JSC Population Comparison: GS11 - GS15



Source: NASA Management Systems Division, Code FM

During field visits conducted as part of this study, we were told that the "aging population" of NASA Shuttle workers might be problematic because experienced personnel were reaching retirement and younger workers were not being hired to replace them. Age data do not clearly validate this concern. Data from NASA's Management Systems Division show that at JSC (for example), the average age of GS11–GS15 personnel has increased from 43.6 to 45.2 from 1996 to 2001. However, this is largely the result of a hiring freeze that was in effect from 1993 until 2000.[57] This is clear from the above graph, which shows that the 2001 distribution of ages is essentially the 1996 graph shifted to the right (for example, the 1996 peak in the 35–39 year age group has shifted, five years later, to the 40–45 year age group). The "hump" in the 50–54 year age group of 1996 has disappeared in the 2001 graph, but the 2001 graph as a whole shows a gradual loss of personnel as the population ages.[58] The relatively low number of personnel in the 25–34 year age groups also is not necessarily a

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[57] Halvorson, Todd, "Help Wanted: NASA Lifts Seven-Year Hiring Freeze," *Space.com*, February 4, 2000.

[58] Data for this graph come from NPPS data compiled by NASA'S Management Systems Division. Age distribution graphs from KSC and MSFC show similar shifts.

problem, as NASA has recently concentrated on hiring experienced engineers in the 35–39 year age group.[59]

Ensuring that the appropriate skill mix is available in the future is more important than the overall age distribution of the NASA workforce. Workplace planning efforts are currently under way at NASA to ensure that this is the case.

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[59]Interview with Craig Conlin at NASA HQ Code FM, approximately April 10, 2002.

Retirement Benefits Are Portable for Most Employees

SSP FTEs

Retirement Plan	Early Out Eligible	Regular Eligible	Not Eligible
CSRS	351	305	263
FERS	46	36	1691
Other	37	9	29
TOTAL	434	350	1983

SSP Full-Time Personnel

Retirement Plan	Early Out Eligible	Regular Eligible	Not Eligible
CSRS	123	118	78
FERS	11	9	549
Other	7	3	10
TOTAL	141	130	637

- **At JSC, KSC, MSFC, and SSC, 28% of SSP FTEs are eligible for regular or early-out retirement (29% of SSP FT personnel)**
- **Of the remaining SSP FTEs ineligible for retirement, 85% have portable retirement benefits through FERS (82% of SSP FT personnel)**
- **Senior CSRS personnel ineligible for retirement will not be inclined to leave NASA, and might need special incentives to move to a commercial firm**
- **Personnel targeted for incentives will depend on NASA's desired skill mix**

NOTE: Table excludes HQ, DFRC, WSTF, and GSFC personnel. Six FTEs at the centers reviewed have no federal coverage. SSP full time is 909 (vice 888 in earlier slide) because our categories place some full-time Shuttle personnel in offices that are not labeled "Shuttle direct"

One concern expressed in other studies of commercialization of the Shuttle is the potential loss of benefits for civil service personnel whose Shuttle positions are transferred to the private sector.[60] While this might be an issue for some senior personnel who are under the old Civil Service Retirement System (CSRS) and cannot yet collect an immediate annuity, the majority of Shuttle workers have relatively portable retirement benefits under the Federal Employees Retirement System (FERS).[61]

The left-hand table in this figure shows the Shuttle FTEs by retirement plan and retirement eligibility. At the four major centers, 28 percent of these personnel are eligible for regular retirement or early outs (which can be authorized when an agency decreases its workforce or undergoes significant restructuring). If their *government* positions were eliminated, these personnel would still receive immediate retirement benefits. Of

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[60]See, for example, *Concept of Privatization of the Space Shuttle Program*, report of a study conducted by Ronald D. Dittemore, Manager, Space Shuttle Program, September 28, 2001.

[61]Regardless of their years of service, employees under CSRS do not receive any immediate benefits if they leave government service before retirement eligibility (age 55 for regular retirement, age 50 for early retirement). However, they are eligible for benefits that begin at age 62.

those who are not eligible for regular or early retirement, 85 percent have the portable retirement benefits of the FERS program through the Thrift Savings Plan (TSP) and Social Security coverage.[62]

Senior personnel ineligible for regular or early retirement who are under CSRS will not be inclined to leave government service and might require special incentives to move to a commercial firm if their jobs are eliminated. In the event of the elimination of their jobs, however, they might also be able to take advantage of "bump" or "retreat" protections if RIF procedures are invoked, thereby typically replacing younger employees who may well possess skills that NASA prefers not to lose.[63]

The decision on how to deal with these personnel will depend on the desired skill mix for the positions that remain with NASA as well as the desired skills in the new commercial organization.

Note: the right-hand table in this figure presents the same information as the left-hand table, but for personnel that work in the SSP 100 percent of the time. This table, then, counts people, not FTEs.

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[62]The TSP is essentially a 401(k) to which an individual can contribute with partial matching funds from the government.

[63]See Robbert et al. for a discussion of bump and retreat options. These are rules that allow individuals whose government jobs have been eliminated to take the jobs of other personnel under prescribed circumstances.

Current "Buyout" Amounts Might Be Too Small…

- *…for staff that are not yet fully eligible*
- **Consider a Shuttle Engineer who would be fully eligible for early retirement …**

Age	50	55
Years of Service	20	25
Annual Salary	$98,428	$102,750
Full Retirement	$35,680	$47,522
Adjusted*	$32,112	N/A
Difference	$3,568	$0
NPV of 30-year annuity to make up difference (5% interest rate)	$57,591	N/A

- **Even a $35,000 buyout is probably too low an incentive when compared with a conservative value placed on the NPV of the loss of retirement value**

** Early retirement penalty at 50 years of age is 10% of the basis, which in the example case is 36.25% of high-three average pay*

While the structure of monetary incentives to keep personnel in NASA or encourage them to transfer to the new commercial organization cannot be determined until the appropriate skill mixes are described, current "buyout" amounts for government personnel are typically insufficient to encourage people to leave NASA unless they are already eligible for an immediate annuity.

This chart compares the retirement benefits of typical 50- and 55-year-old civil servants with 20 and 25 years of service respectively. The CSRS retirement benefit is based on the number of years of service and the average salary received in the highest three consecutive earning years. The multiplier for the pension calculation is 1.5 percent per year for the first five years of service, 1.75 percent per year for the next five years of service, and 2 percent per year for years beyond ten years of service. Thus, for the 55-year-old in this table with 25 years of service, the pension is 46.25 percent of his "high-three" average pay. For the 50-year-old with 20 years of service, the pension is 36.25 percent of the "high-three average" pay. However, the pension amount is reduced 2 percent per year for each year that a person retires before age 55.[64]

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[64]Information on the retirement system and buyout practices is taken from the OPM documents listed in the Bibliography.

Thus, in this example, the 50 year old loses $3,568 per year (10 percent of his pension amount) because of the penalty incurred by retiring before age 55. If we assume the individual will live until age 80 and that inflation is 5 percent, the present value of this loss over 30 years is $57,591.[65]

When government buyouts were first offered at NASA in 1994, their maximum value of $25,000 (before taxes) was meant to offset the losses incurred from an early retirement penalty.[66] However, as this example shows, even if the buyout amount were increased to as much as $35,000, it would not make up for the present value of benefits lost from the early retirement penalty.

Obviously, alternative employment opportunities will have an effect: for example, if the salary at a new position more than makes up for the loss in retirement benefits, current buyout levels might be sufficient. For those senior personnel whose jobs are eliminated with no possibility of transfer to the new commercial organization, the current buyout level will be insufficient to induce them to retire.

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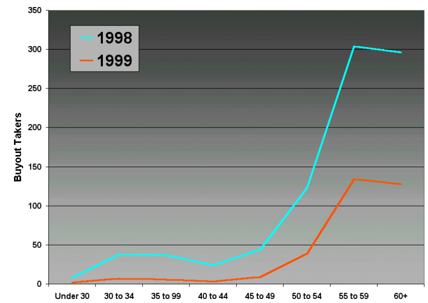
[65]Using the summation formula $S_n = P\sum_{m=1}^{n} r^{m-1} = P\frac{1-r^n}{1-r}$ with n = 30, P = 3,568, and r = (1/(1+.05)).

[66]See "NASA Employee Buyouts in 1994 and 1995."

Buyouts Are Likely to Be of Limited Utility

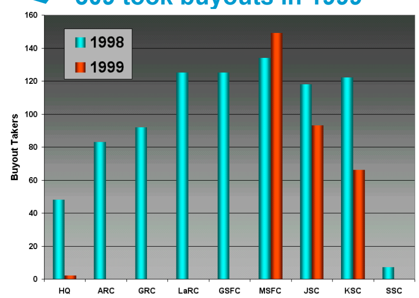
- **At main FCs, 154 SSP full-time personnel (17%) in buyout age groups**

Full-Time SSP Personnel		
Center/Age	55 to 59	60+
JSC	25	29
KSC	42	18
MSFC	11	28
SSC	0	1



80% were 55 or older

309 took buyouts in 1999



Source of graphs: NASA Management Systems Division, Code FM data available on NASA's public website.

The recent history of buyouts and takers also shows that buyouts would probably be of limited utility in "shaping" the NASA workforce in the event of Shuttle commercialization.

In 1999, 309 people at JSC, KSC, and MSFC took buyouts, and 80 percent of them were 55 years old or older. If we look at full-time Shuttle personnel at the major centers who are likely candidates for buyouts (that is, those eligible for retirement or early retirement), only 154 of them (17 percent) are age 55 or older. Estimates of the number of personnel that would need to be transferred from NASA to a commercial Shuttle organization range from approximately 600 to over 900;[67] current buyout options would not induce such a large movement.[68]

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[67]The 600 estimate came from a private company; the 900 estimate is found in Dittemore, 2001.

[68]This is evident from the percentage of eligible personnel who have accepted buyouts recently. NASA Headquarters' Management Systems Division provided information on eligibility and acceptance of buyouts in 1999 at MSFC, KSC, and JSC. MSFC had the least restrictive offer (all permanent civil service employees were eligible, if otherwise eligible under law), and 21 percent of those technically eligible separated under the buyout program. This is not to say the buyout wasn't considered successful—MSFC planned to accept up to 147 applications, and 145 employees separated—but there is no indication that more people wanted to take the buyout.

Transfer of CS Personnel Has Limited Viability

- **A shift to competitive sourcing is likely to drive a need to transfer many personnel out of NASA:**
  - **The majority of personnel that work on SSP are part time—needed by NASA on other programs**
  - **Many senior technical and management personnel are in CSRS and will not be inclined to leave NASA**
  - **Buyouts are not viable for most people—most eligible have taken them and the incentives are inadequate**
  - **Transfer of government benefits is not a viable option—it has been proposed before and rejected by OPM and OMB**
- **Key personnel transfer will require exceptional incentives**

As noted earlier, about one-sixth of NASA's FTEs are devoted to the Shuttle program. Any change in NASA structure as a result of competitive sourcing of the SSP will likely require changes in the workforce through transfer of personnel with Shuttle skills to private firms, reassignment of personnel still needed by NASA, or incentives to leave government service.

Inducing the transfers necessary for a new Shuttle structure might require exceptional incentives for three reasons. First, senior personnel under CSRS who are not yet eligible for regular or early retirement will not be inclined to transfer to commercial positions because of the loss of benefits. Allowing the retention of government benefits for those who leave NASA is not a viable option; a similar idea was suggested in the FY1997 authorization bill when NASA considered a plan to "privatize" some of its science programs by tying them to universities and not-for-profit organizations.[69] This idea was not viewed favorably by OMB and OPM because of its expense and the precedent it would set.

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[69]See U.S. General Accounting Office, *NASA Personnel: Challenges to Achieving Workforce Reductions*, GAO/NSIAD-96-176, August 2, 1996.

Second, the currently authorized buyout amount of $25,000 is not sufficient to make up for the loss in present value of benefits even for those who are eligible for early retirement. While some personnel who are eligible for early retirement may accept the buyout because they have new employment options that are sufficiently lucrative to make up for the loss, those without such new employment options will not.

Finally, the majority of personnel who work on the Shuttle do so part-time; and have skills that NASA needs for other programs. This will present a challenge for both NASA and any private firms involved in competitive sourcing. Competition may develop for some of these workers, which will complicate the development of appropriate hiring (or retention) incentives for each side.

Outline

SHUTTLE OPERATIONS IN A COMPETITIVE SOURCING ENVIRONMENT

Regarding competitive sourcing options, NASA should consider the fact that private firms exercising increased leadership of the Shuttle program may result in changes in operation strategies. Driven by different motivations, a private firm might not select the same operational alternatives that NASA might select under similar circumstance. While the Task Force found that private firms could accept an increased role while maintaining safety, it was also concluded that they might make different choices. Such choices may be driven by the desire to increase operational efficiency and reduce costs. In this chapter the Task Force notionally explores some of the possible ways that commercial Shuttle operations may differ from current NASA practices. The Task Force concluded that many of the options described in this chapter may be available to NASA management independent of competitive sourcing.

It is important to note that the Task Force believes that while competitive sourcing could help NASA find additional opportunities to streamline and reduce operating costs, significant net cost reduction in the SSP is unlikely. This is because any savings found will be needed for investment in the continuing operation of an aging Shuttle system.

"Right-Sizing" Supports Competitive Sourcing

- "Right-sizing" means matching resources to SSP requirements:
  - Facilities, personnel, BMAR, flight rate, schedule, etc.
- Continued Shuttle operations will require significant investments to maintain safe operations:
  - These investments can be quite large if long-term operations are contemplated
  - Obsolescence and BMAR have been seen to be major long-term cost drivers
- Finding new ways of operating the Shuttle should be considered mandatory in order to:
  - Achieve improved levels of safety
  - Stay within the planned budget
  - Take advantage of commercial best practices
  - Support transition to the safest, most cost effective competitive sourcing option.
- Goals of this section are to identify:
  - Current operational characteristics that drive SSP operations
  - Right-sizing opportunities that could enable a wedge to apply against growing obsolescence and BMAR costs
  - Commercial management approaches that would enable a safer, more commercial, and cost effective means for SSP operations.

The Task Force's analysis of alternative operational strategies took advantage of findings presented earlier, namely that

- Commercial companies can operate programs like the Shuttle program safely.
- There is a significant backlog of Shuttle facility maintenance and repair that is required; likewise the continued cost of mitigating system obsolescence is likely to be high.
- Vehicle obsolescence costs could be substantial if the Shuttle remains in operation.
- It is unlikely that any new program demand or commercial requirement will result in a need for more than four to six flights per year.

If competitive sourcing of the Shuttle program results in the transfer of significantly more responsibility to a private entity, then NASA must recognize that a private entity would likely run the Shuttle program differently than NASA does today. Depending on several factors, including the length of continued operation, transitional complexity, and customer base beyond NASA, a private entity would likely seek to restructure the Shuttle program. Though this restructuring would have many facets, one characteristic would be the transfer of direct control and authority over program assets to the PM. Such a management approach would likely be common to any of the competitive sourcing options considered by the Task Force.

The future operational characteristics of the Shuttle should drive any contemplated restructuring. The Task Force determined that the following characteristics will influence any viable restructuring:

- ISS is the primary customer and drives the need for the launch schedule, payload requirements definition, and payload manifesting.
- The operational lifetime of the Shuttle will be determined by near-term NASA decisions on future launch systems and ISS research necessities.
- Facility investments and obsolescence costs are dependent on projected program duration.

Program restructuring, of the type implied by competitive sourcing, is risky. The principal argument in favor of program restructuring is that it will realign NASA with its original R&D charter and allow the private sector to more efficiently operate the Shuttle program. However, restructuring requires that NASA make significant decisions today regarding the organization and management of many interrelated programs across many field centers and the likely outcome is irreversible. Restructuring based upon current projections of demand for Shuttle services and the availability of replacement systems assumes that the current market projections presented to the Task Force will be upheld for the operational lifetime of the Shuttle program. Should new commercial or government—DoD heavy-lift requirements for example—markets develop, the contemplated restructuring would likely preclude a capability to support both the existing and new requirements.

The Task Force sought to determine the factors that led to the current Shuttle program operational practices. Given this understanding, the Task Force was then able to suggest opportunities that NASA has to prepare for a competitively sourced Shuttle program. A result of this effort was a list of initiatives that could lead to program resource reallocation opportunities.

As the Task Force interpreted the meaning of competitive sourcing, an implication of such an approach is that the resources, management, and operations of the Shuttle program should be aligned with the projected market requirements. The Task Force defined such an alignment as "right-sizing." Historically, Shuttle program requirements often exceeded the actual services that the system had delivered. In fact, during its planning phase, it was expected that the Shuttle would fly much more.[70] Given that the resulting infrastructure and the current planned flight rates are not consistent, opportunities exist to right-size the SSP to meet actual system demand and perhaps to provide for more efficient and cost effective operations.

"Right-sizing"[71] is a term chosen to represent an alignment of Shuttle operations and facilities with the actual mission profile and the realities of operating a space system that is three decades old. We found that it is possible to maintain or potentially achieve increased levels of safety through competitive sourcing. Here, we broadened our focus to include facilities maintenance, budgetary concerns, the transition to the next generation system, and the transformation of NASA to a more focused R&D organization that operates within the best practices of the private sector.

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[70]Logsdon, John M., "The Space Shuttle Program: A Policy Failure?" *Science,* Vol. 232, May 1986, pp. 1099–1105.

[71]The term "right-sizing" describes the process of restructuring the Shuttle program—as well as matching the scope of the program to the expected marketing base.

Private Firms Will Seek to Operate SSP Differently

- **Competitive sourcing involves shifting more authority to the private sector**
  - **It is likely, that when given this authority, a private firm, using different decision criteria, will reshape the Shuttle program**

	NASA Practice	Commercial Practice
Acquisition	Available budget is dominant	Life-cycle costing is dominant
	Rigid process designed to ensure fairness in procurement with limited ability to evaulate prior performance	Flexible procurement environment with trusted vendors
	Mandate to foster and preserve competition	Strategy to eliminate competition and create high market entry costs for competitors
	NASA is the source of advanced technology that is needed to meet requirements	Prime and/or vendor supply chain is the source of advanced technology
	Short-term relationship with producers and limited ability to evaluate prior performance	Long-term relationship with trusted vendors and constant quality monitoring
	Threat and opportunity based assessments, often overlooking end-user integraton	Market-base and competitive assessment in terms of cost, performance, and reliability focused on customer
	Funding usually allocated each year through political system with limited forward basis	Funding is identified and available throughout the development cycle
	Buyer preference specified through need statements (RFQ/RFI/AO)	Customer preferences determined by survey, testing, and focus groups
	Open competition with predefined evaluation criteria and the ability to protest	Limited competition and subjective selection process free from protest
Operations	Rigid hiring and workforce stabilization regulations	Flexible team-building with rapid hire/fire authority
	Traditional use of complex custom designs to meet unprecedented mission requirements	Use of COTS wherever it is cost effective
	Upgrade driven by desire for risk reduction, improved performance, and R&D goals	Upgrades driven by customer demand, desire to reduce operating cost, and risk reduction
	Requirements controlled by operator	Requirements determined by customer
	Systems may operate in unknown environment and may be called upon to fulfill roles other than originally intended	Systems are built to withstand known environments and fixed missions
	Established practices that determined order of work	Streamlined workflow management and elimination of cumbersome work practices
Facility Management	Capital management plan but maintenance often deferred by limitations of by budget	Tax-based capital asset planning sets facility investment at levels established to assure no production/service interruption
	Maintenance of facilities and functions as part of balancing agency workforce and need to maintain constituent support	Unfront investment to reduce downstream maintenance as a result of focus on LCC
	Facilities can be held and maintained as national assets to meet future needs and past economic viability	Facilities are built and maintained to meet product/service requirements and are replaced through a fixed calculus
	Consolidation possible as part of cost avoidance strategy after political support is achieved	Consolidation whenever possible - redundancy only when required to ensure production

Many of the competitive sourcing options resulting from the Task Force study would transfer management and programmatic responsibilities to a private entity or multiple private entities. The options also establish the potential for more accountable lines of program authority. NASA should recognize that different levels of authority, accountability, and responsibility could result from the different competitive sourcing options. A private company or entity will likely establish programmatic management changes that will affect operations, acquisition, and management organizations and processes. These practices, sometimes termed "best of breed" or "best commercial practices" imply that the private entity will manage the Shuttle program according to a different set of criteria than NASA. The fundamental operational question for program managers is what the program must do to operate the Shuttle to meet actual requirements in a safe and efficient fashion. The Task Force would expect that facilities, functions, and processes that do not contribute directly to safe and economic operation of the vehicle would be modified or eliminated.

Although the private entity, or entities, will likely be encumbered by the lingering political climate, they may strive to reduce the levels of constraints artificially placed by the space center heritage; government contracting practices; government budgetary practices that separate research, development, operations and maintenance, and cost of facilities; and decisionmaking (as identified in previous sections) that has prevented operational authority from transitioning away from the government. Typically these practices strive to reduce the transactional costs of the business process, which may result in an operationally focused enterprise and a general reduction in developmental activities.

The Task Force expects the multiplicity of functions will likely be reduced and investment will be measured against life cycle cost (LCC) criteria that are based on a more accurate estimate of program longevity. Certain options will have the opportunity to address the longevity of the Shuttle program in the context of evolving programs such as the ISS and other STS options that supplement Shuttle services.

In keeping with a transition of authority and the added corporate risk (since much of the accountability and economic risk will transition from the government), contract management and profitability may also change. Whereas NASA may be willing to allow facilities to have unbudgeted maintenance and accept risk and liability associated with facility and infrastructure degradation, a private entity may elect to minimize liability and make these strategic investments. Similarly a private entity may remove from program responsibility facilities that NASA would otherwise continue to maintain.[72] A private entity may also address investment to help attract additional business opportunities that can take advantage of available capacity, program or functional similarities, or other tangible intellectual property derived from this business base. The private entity, as previously mentioned, will not, through corporate avarice, trade safety for profitability: it is not in its self-interest to do so. Rather the private entity will make strategic business decisions in the context of real customer and performance requirements.

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[72]NASA may have long-term strategic reasons for keeping facilities that reach beyond the Shuttle program open. A shift to competitive sourcing must include an ability to factor such strategic needs into private-sector decisions.

SSP Retains Features of a Development Program

- **R&D programs are not focused on taking advantage of operational management practices and cost savings opportunities**

Feature	Organizational Characteristics		SSP Feature
	R&D	Operations	
Organizational Alignment	"Centers of Excellence"	Functionally Focused	Duplicated Functions at Multiple Sites ***(Mixed)***
Facilities Management	Significant Capacity and Flexibility for Test	Capacity Optimized and Maintained for Process and LCC	Overcapacity for Flight Rate Requirements with Large Retention of Heritage Test Facilities ***(Development)***
Systems Engineering and Development	Focused on New Technologies	Focused on Process Improvement for LCC Reduction	Technologies for Safety and Obsolescence but Limited LCC/Payback Analysis ***(Mixed)***
Supply Chain	Short-Term Planning and Contracting Horizon	Life Cycle Planning, Acquisition, and Storage/Sparing	Short-Term Acquisition; Vehicle Obsolescence and Major Facility Maintenance Backlog ***(Development)***
Mission Standardization	Constantly Changing Activities	Maximally Standardized and Largely Fixed	All SSP Flights Have Different Payloads, Software, Large Degree of Astronaut Training and Retraining ***(Development)***
Process Stabilization	Few Standardized Processes, Little Training	Fixed Processes, Minimal Changes, High Level of Operator Training	Launch Vehicle Processing and Safety Process Stable; Effective Training ***(Operational)***

One of the major encumbrances to competitively sourcing the Shuttle program is the current management structure. Many operational government programs, including some found in the military, have distinguishing organizational characteristics that are also shared with successful and safe commercial industries. These organizations conduct highly routine (and often dangerous) activities accompanied by a management philosophy of efficiency. Developmental programs, in contrast, have a different set of organizational characteristics that support research and testing. The SSP has arguably passed its developmental phase, but retains many characteristics of a developmental program. In the opinion of the Task Force, this is one of the first areas that a private entity would address to achieve the efficiencies of a streamlined, safe, and cost effective SSP.

Examples of concurrent operational management and R&D coexist in the SSP. KSC processes are typical of an operational program; processes are clearly established, staff-to-management ratios are high, and there is little engineering and development activity beyond process and safety improvement. However, the dominant contract management function occurs at MSFC in Huntsville, Alabama, and is emblematic of an R&D organization. These contracts continue to maintain substantial development functions to enhance performance. Additionally, the production element contract durations more often than not resemble shorter development contracts, the external tank and reusable solid rocket motor being examples. These types of programs, in the operational sense, could take advantage of their sole-source and unique nature through long-term purchases and process stabilization. As a result, supply-chain and acquisition strategies do not appear to be based on LCC, which is a characteristic of operational systems.

The organizational structure and historically center-focused nature at NASA have been a source of much of the SSP organizational inertia. Although NASA has moved away from this nomenclature, the centers still retain the character of "Centers of Excellence." As such, each center retains a broad range of skills to support full research, test, and development activities. It is arguable that this is the approach that NASA should take in its overall organization, but the structure that it imposes upon the Shuttle program, as the Task Force discovered, adds costs through artifacts of NASA's heritage rather than operational necessity. A more commercial approach to Shuttle operations would be motivated to maintain only that infrastructure that is necessary for safe and efficient operation of the program relative to the existing market requirements. Some of the proposed new technologies to be incorporated as upgrades to the fleet would not necessarily be required to maintain an operational stance into the future.[73] The distribution of authority across the NASA centers with R&D charters has produced a system that introduces conflicting development requirements above and beyond efficient and safe operations.

Competitive sourcing could result in Shuttle program management structure that streamlines operations to maintain a focus on safety while meeting the system performance requirements, rather than a program that seeks continued system modifications.

A private entity may also better address facilities management. NASA often resists facility closures lest they are needed in the future for another purpose. Centers also have a vested interest in their infrastructure regardless of program needs. The center-based management structure, with its emphasis on R&D, limits program control over facilities even though the programs provide the funding. A private company, especially one that is provided with a clear vision for the time frame for Shuttle closeout, will likely look to consolidate, or transition to another program owner, unneeded facilities, reducing its revitalization costs.

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[73]Henderson, Mac, *Shuttle Upgrade Plan: Executive Summary*, Space Shuttle Program Development Office, May 22, 2002.

In summary, right-sizing is a notion consistent with competitive sourcing. Even prior to a commitment to competitive sourcing, NASA may take steps to address the most effective transition to such an operational infrastructure. Doing so would likely have little impact on any decisions related to anticipated follow-on systems as they do not appear to require many of the facilities currently "on the books" of the SSP for their successful development and operation.

Restructuring Is a Prelude to Competitive Sourcing

- **Center heritage, policies, and political forces have resulted in functional alignments and program structure management practices that limit operational efficiencies**

Center/Site	Primary Role	SSP Managed Dollars ($FY 01M)	Onsite NASA Personnel	Onsite Contractor Personnel	Selected Functions: Program Management	Contract Management	Systems Engineering	Propulsion Refurb and Test	Crew Operations	Recovery Operations	ET Production	Space Communications	Mission Operations	Launch Operations
JSC	Program Mgmt, Mission Ops, Crew Ops	1,802.76	1,191	2,934	•	•	•		•				•	
KSC	Launch/ Recovery Ops	153.04	874	7,226		•	•	•		•		•		•
MSFC	Systems Engineering	992.41	613	221		•	•	•						
SSC	Propulsion Test	36.38	75	315		•		•						
MAF	ET Manufacture	None	21	1,905							•			
DRFC	STS Recovery	4.18	88	116						•		•		
WSTF	Space Communications	None	20	277				•				•		
GSFC	Space Communications	3.27	10	n/a								•		
HQ	Leadership	0.95	3,158	n/a										
Other Field Centers/ Nonrecorded	Various	225.50	negligible					•				•		
Total		3,218.49	2,658	12,994										

- **Transitioning now will embed existing structures and practices:**
  - **SSP operations infrastructure should be "right-sized" to the flight rate before the transition**
  - **Organizations should be realigned for management effectiveness**
  - **Acquisition strategies should be readdressed for more-effective management, integration, and risk mitigation**

NOTE: Onsite personnel in table refers to FTEs.

NASA's heritage and other factors, including political allocation of funds for infrastructure development, have resulted in a geographically and functionally distributed program. Many technical functions are replicated across the centers, as is management responsibility including contract and transaction management.

Competitive sourcing could be preceded by a restructuring of the program to enable management and financial stewardship and accountability, cost effective program realignment, and effective use of facility and infrastructure resources. Transition to a competitive sourcing option without internal reorganization runs the risk of embedding too many of these existing structures and practices, perhaps making a private solution an unattractive option.

Right now, one of the inefficiencies in the SSP is that resources, authority, and performance responsibility are not collocated within the existing program management. This results in layers of management, complicated communications, and redundant personnel and facilities. The current program management structure not only inhibits, but in some cases precludes, the program management from being accountable for personnel utilization, facilities management, allocation of BMAR funds, supply chain, and so on. Full-cost accounting implies a different structure, one in which the program has control over its resources.

Flight Rates Provide Options for Right-Sizing Critical Infrastructure

- **Unequal flight spacing largely driven by ISS manifest:**
  - **Drives workweek and facility utilization**
  - **Consideration should be given to more equally spaced flights now and in the post-assembly period to facilitate safer, cost effective operations**

		Annual Flight Rate		
		5 Days /Week	6 Days/Week	7 Days/Week
Orbiters	3 (2 + 1 OMDP)	4.9	5.6	6.3
	4 (3 + 1 OMDP)	7.3	8.4	9.6
OPF	1 Bay	2.4	2.7	3
	2 Bays	5.9	6.8	7.7
	3 Bays	9.3	10.9	12.5
VAB	1 Cell	5.3	6.3	7.3
	2 Cells	10.6	12.6	14.6
MLP	1 Platform	3.1	3.7	4.3
	2 Platforms	6.2	7.4	8.6
	3 Platforms	9.3	11.1	12.9
Pad	1 Pad	9.2	11	12.7
	2 Pads	18.4	22	25.5
Assumptions	*Equally Spaced Flights (Major Safety Enhancement)*		*No Fixed Launch Dates (Major Safety Enhancement)*	
	Standard Flows, Benign Payloads		*No Major Facility Modifications*	

SOURCE: NASA, Volume II, "Schedule Status and Summary Enhancement Analysis, KSC Processing Summary Data," March 27, 2002.

Some elements of ground infrastructure provide examples of potential right-sizing opportunities. As the chart above shows, NASA has already studied such options.

The opportunity to right-size SSP operations starts with the KSC processing infrastructure. A flight rate of four to six missions per year allows for changes in the operation and maintenance of the processing infrastructure. The analysis presented in the chart suggests that the infrastructure initially developed to support higher flight rates can be reduced.

The choice of reducing infrastructure as outlined in the chart carries risk: for example, if a need for Shuttle services emerges after infrastructure has been eliminated from program control, the restructured SSP may not be able to provide the desired services. In addition, the transition costs associated with a more streamlined program would have to be weighed against the benefits. Closing, decommissioning, or demolishing elements of the current infrastructure may also seriously reduce or eliminate the ability of the program to respond to future contingencies. For example, if a launchpad is lost in an accident, a second launchpad may not be available if it is retired for cost advantages.

In keeping with the notion of right-sizing elements of ground infrastructure, a more stable, equally spaced launch rate could both improve safety and permit more streamlined operations. Equally spaced flights (as opposed to concentrated activities to launch to get ISS elements on orbit) and elimination of fixed launch dates, provide relief to the crews, contribute to safe operations, and help to reduce the cost by not instigating personnel overtime.

NASA should also consider how program longevity will drive these decisions. For example, the analysis of follow-on systems for SLI and third-generation launch vehicles does not appear to require most of the current Shuttle program processing and launch infrastructure. As a result, the assessment that follows considers that closing a facility would be feasible in the context of flying the orbiter *to* a specific date instead of *through* that specific date. "To" implies that the program requirements end at that date; "through" implies that the end date is indeterminate and the infrastructure may be required to fly to that date and then to an unspecified date beyond that. That level of uncertainty requires a different set of assumptions.

Right-Sizing KSC Facilities Could Lead to Significant Savings

- **Assumptions:**
  - **KSC BMAR to 2011 and includes new VAB roof**
  - **Out years estimated BMAR savings at 2%CRV annually (Code J guidance)**
    - **Major facility BMAR required regardless of facility utilization**
    - **Assume completion of work to 2011 and no more BMAR subsequently to either 2016 or 2020**
  - **Assume $106K per civil servant, $120K per contractor full up in annual staffing Savings**
    - **Assumes facility closure in 2004**
    - **Facility personnel prorated across facility**
  - **Facility operations costs prorated with exception of VAB**
- ***Additional savings would also result from ceasing refurbishment toward program end***

	Potential Operations Savings Through 2012 (02$M)			Potential Operations Savings Through 2016 (02$M)			Potential Operations Savings Through 2020 (02$M)		
	BMAR	Facility	Staffing	BMAR	Facility	Staffing	BMAR	Facilities	Staffing
OPF	2	4	197	8	12	296	15	20	394
VAB	10	0	259	52	0	388	93	0	517
MLP	14	83	0	50	125	0	86	167	0
Pads	28	165	36	72	248	55	115	331	73
Totals	54	253	492	181	385	738	309	517	984
	799			1,304			1,810		

Assumes decertification of facilities that may not be desirable in terms of operational effectiveness

KSC is the center responsible for maintenance, launch, and recovery of the STS. As such, Shuttle facilities were designed to support a larger flight rate. Since the anticipated flight rate for the foreseeable future is an order of magnitude less, it might be possible to reduce the number of facilities at KSC to realize significant savings. This example of facility right-sizing provides a template for similar activities across other infrastructure elements.

Data for this analysis were provided from the facilities and staffing databases that addressed BMAR to 2011, facilities operations cost estimates, and facility staffing. NASA Code J planning factors were used, in particular the 2-percent annual allocation of CRV to BMAR after the current planned BMAR activities.[74]

Three program durations were assessed consistent with the obsolescence target dates to maintain a flight capability to 2012, 2016, and 2020. The following assumptions were included in this analysis:

- Current BMAR is performed through 2011 and its annual rate is the average facility BMAR rate.

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[74]National Aeronautics and Space Administration, NASA Policy Directive 9931.1C, May 29, 2002.

- After 2011, no BMAR is planned or budgeted owing to the limited programmatic facilities requirement. The savings to the program are estimated using the Code J planning factor of 2 percent of the CRV for annual budgeting, even though the program does not follow this guidance in the projections of BMAR through 2011.
- The VAB facility operations costs are not impacted owing to the unlikely ability to allocate heat and other services to a portion of the VAB.
- OPF, pad, and MLP excess capacity result in excess facility closure.
- No cost savings are estimated from a reduced Shuttle fleet.
- Personnel are prorated across the facility so a fractional staff reduction results from the fractional facility closure. This does not reflect the fact that some of the personnel may be matrixed and cannot necessarily be excised. (As potential personnel savings are the dominant savings in each of the scenarios, this assumption may seriously limit the analysis.)

This is not a comprehensive analysis of potential infrastructure savings at KSC; program termination could also eliminate component refurbishment and reuse. This would further enable savings to the infrastructure as this function could be destaffed and facilities reallocated from the SSP.

Accelerated Acquisition Can Take Advantage of Lower Unit Costs

- **Production facilities designed for significantly higher flight rates**
  - **Demonstrated for more than 12 per year**
- **Relatively short-term buys result in higher unit costs and reduced commitments to supply chain providers**
  - **Sole source nature provides opportunities for longer contractual commitments**
- **Marginal costing provides opportunities for savings**
- **Data provided by manufacturers**
  - **ET's $11 million marginal cost per tank**
  - **RSRMs in the following table**

Number of RSRM Flight Sets Per Year	Cost Per Flight Set (02$M)	Total Annual Cost (02$M)
4	92	368
5	74	370
6	62	372
7	56	392
8	51	408

Another example of savings that can result from a decision on Shuttle program longevity and its follow-on program comes from supply chain management, in particular for the ET and RSRM programs. These are provided through relatively short-term contracts to sole source providers.

Though the Shuttle relies on several sole source contracts for the supply-chain, the terms of these contracts remain short. Initially the program sized both the ET and RSRM production for substantially higher annual flight rates than were demonstrated in the last decade. Current contracting practices ignore the minimum cost of operations and do not appear to lead to long-term contracts that could provide for more cost effective pricing.

Site visits and data from both ATK and LM indicated that the marginal cost of both the ET and RSRMs were small compared to the fixed costs required to maintain the production capacity. Lockheed Martin claims that the marginal cost for an ET is $11 million. ATK claims the marginal cost of a fifth or sixth set of RSRMs is $2 million, the marginal cost of a seventh set is $20 million, and the marginal cost of an eighth set is $16 million. The unit cost declines from $92 million to $51 million when the production is doubled to eight flight sets per year. These costs remain to be independently verified or substantiated. However, even if the marginal cost were doubled or tripled, the marginal cost of several additional flight sets per year can dramatically reduce the unit cost of both the ET and the

RSRMs. This implies that a more proactive supply chain that performs an acquisition strategy based on the total programmatic fly out rather than matched to an annual flight rate could provide significant life cycle cost savings.

Transition Decisions Can Further Result in Supply Chain Alternatives

- **Example: 15/20 year transition (60–80 flights)**
  - **ET—No R&D and retooling; accelerate production and store; mothball near program end**
  - **RSRM—No R&D, accelerate production and store; mothball near program end; plan for no recovery upon program transition**
  - **Supports more effective management of critical supplier stockpiles, logistics, vanishing vendor requirements**

Feature	Current Annual Cost (Production + Facility) (02$)	Annual Marginal Production Cost (50% Production Increase) (02$)	LCC Savings Estimate (15 Years, Including Storage, 02$M)	LCC Savings Estimate (20 Years, Including Storage, 02$)
ET Surge and Store	$272 M	$22 M	$0.9 B	$1.3 B
RSRM Surge and Store	$368 M	$4 M	$1.6 B	$2.2 B
Basis of Estimates and Assumptions	ET storage based on prior flight rate storage capability and MAF ET Briefing.	RSRM storage based on prior flight rate production, demonstrated storage, ATK Thiokol Briefing, and an estimate of $35M/year storage costs. No LCC reductions were estimated for the elimination of refurbishment nearing program end.		

- **Other program elements could take advantage of similar approach**
  - **Example: flight software stabilization (cost to NASA at $100 million per year)**

This figure represents the notional case of bounded procurement of ETs and RSRMs. This would be the likely result of the Space Shuttle Program specifying a transition date to the follow-on launch vehicle and the phasing out of the Shuttle Program.

This model is based on the premise that if a program end is specified, the number of ET and RSRM units is bounded by the number of remaining flights. The Task Force observed that the ET and RSRM production facilities demonstrated a production rate of 10–12 flight sets per year in the mid-1980s. Right now, the production rate of 4–6 flights per year is running well below facility capacity. The Task Force further observed that NASA could develop a long-term strategy that takes advantage of this excess capacity for end-of-program cost savings that could reduce the transition costs to the follow-on launch system.

The Task Force noted that the concept of right-sizing may be applied to the ET and RSRM supply chain since discussions with both ATK and Lockheed Martin indicated that the baseline costs to maintain the production capability dominate the current costs of production; data presented by the contractors indicated that the incremental cost of one or two additional flight sets comes before the “knee in the curve” after which the unit cost of each additional flight set increases because of additional labor and other factors beyond the current facilities’ capacities. If NASA identifies a transition date to the new system (an end date for SSP operations), then the program could "back up from that point" and determine whether utilization of this excess capacity could allow for savings from the accelerated production, surge, and early retirement for the assembly plant.

In this notional analysis, the Task Force estimated the potential near-term costs and downstream benefits by using the marginal cost data provided by the ET and RSRM contractors (it is important to note that these marginal costs do not include the cost for integration to the flight system, and in the case of the RSRMs, integration into the stacked SRB with the forward cone and aft skirt assemblies). This analysis identifies the potential that the up-front costs of surging the production capability and storing for future use can lead to a reduction in the end-of-program costs. This analysis is bounded by the storage capacity for ETs and RSRMs and the number of RSRM casings; however, in 1986 the manifest projected annual flight rates of 12 flights per year and a two-year inventory of systems in the pipeline.

It is important to recognize that this analysis is based on many assumptions and, as a result, warrants further analysis by the program office. These assumptions include:

- Marginal cost data was provided by the contractors and no detailed verification analysis was performed by the Task Force.
- The cost of long-term storage for the ETs was based on the current O&M component of the GOCO contract at Michoud, which was approximately $35 million per year. During the surge and store phase, there was no additional cost calculated for facility management; however, this $35 million cost would continue after the production line was closed.
- Storage of RSRM segments was estimated to be $35 million per year based on similar requirements for storage as the ET case after closure of the RSRM production line.
- Long-term storability of RSRMs was not determined; storability was assumed based on demonstrated capabilities at NASA and other ballistic missile systems.
- Cessation of refurbishment costs at the program end is not estimated.
- No estimates were made for additional labor handling activities for stored systems.

In this analysis, for a 15-year flight duration, the production capability ceases after 10 years; for a 20-year flight duration, the production capability ceases after 13 1/3 years, assuming a flight rate of four flights per year. Additional costs are required during the surge and store period, with an accrual of savings upon the program's twilight—the implication of this is fundamental to the strategy because a program end date must be set and managed to; otherwise the transitional savings could disappear.

This analysis highlights an opportunity that NASA could address in right-sizing the supply chain to the flight rate and program duration because the potential out-year savings could offset transition costs for the follow-on system. If NASA elects to pursue such a strategy, a more comprehensive analysis must be performed with detailed costing by the contractors.

Such a supply chain operational concept could enable several reforms:

1. Further standardization of the ET and RSRM production and elimination of ongoing R&D activities and site retooling.
2. Longer-term contractual commitments and reduction in risk of loss of critical supply chain providers.
3. Eventual termination of reuse and refurbishment.

Other supply chain economies may also be available in such areas as SSP software (MCC and orbiter). NASA currently expends $100 million annually on this function. Regularly spaced flight schedules and the description of standardized versus custom service capabilities may allow reductions in these costs, although the Task Force did not estimate the possible magnitude of such savings.

This supply chain analysis provides an opportunity for NASA and a competitive sourced alternative to take advantage of best-business practices for operations if a transition to a new system is clearly identified

Facility Consolidation May Result in Net Savings

- ***Example:*** **Consolidation and restructuring R&D and propulsion refurb/test functions across MSFC, SSC, WSTF to SSC:**
  - **This is a modest effort that would reduce redundancy and streamline operations**
  - **Are cost savings sufficient to motivate NASA or Commercial Entity to move hypergolic facilities to SSC and tackle regulatory issues?**

Center	# of Facilities (STS/Mixed Programs)	(On Site Civil Servants/ Contractor)	Potential BMAR Savings (SSP Facilities) (02$M)		Potential BMAR Savings (Mixed Program Facilities) (02$M)		Potential Annual Operations Savings Estimate (02$M)
			Backlog	Future (Est.)	Backlog	Future (Est.)	
MSFC	2/11	82/152	0.1	0.5	4.9	26	3.5
WSTF	19/36	25/250	No Data	No Data	No Data	No Data	2.1
Current SSC	38/8	106/315	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Consolidate To SSC	>38/8	<213/<717	> 0.1	> 0.5	> 4.9	> 26	5.6 Annually

NOTE:
- *A 10% Reduction In Staffing ($11M) + >$3M/Year in BMAR + >$5.6M in Facilities Savings Results in Potential for approximately >$20M in Annual Savings*
- *Facility Operations Costs for WSTF estimated using average cost per square foot at MSFC for relinquished space—approx $16/sq ft. Facility data are underestimated because database was incomplete.*

Consolidations like this and the reduction of excess capacity currently in the system are important to avoiding cost growth and to enabling competitive sourcing

Restructuring particular field center facilities and their supply-chain components to a reduced flight rate is a possible action of private-sector-oriented program management. Additional opportunities also exist to consolidate functions across geographically distributed centers. If program R&D could be largely eliminated, significant savings could be achieved through realignment of certain functional activities.

In this notional case, consolidation of propulsion activities at SSC is considered.[75] Other sites that have propulsion responsibilities for the SSP include MSFC, WSTF, and KSC. The KSC facilities are for Shuttle refurbishment and were excluded from this example, as was GRC's Plumbrook facility. WSTF's propulsion research focuses on hypergolic (self-igniting fuels) system refurbishment and testing. The key issue associated with relocating this function is the requirement for certifying the new facility for handling hypergolic propellants, with its associated environmental and public safety processes. A new management structure might pursue a cost versus benefit analysis of consolidation options with

[75]SSC was chosen because of its current propulsion test facilities and its dramatic success at lowering the unit service costs to tenants through its successful expansion to a broader customer base.

respect to safe operations, focused requirements for BMAR, facilities, and personnel.

The Task Force's notional assessment focused on bounding the potential savings. Critical parameters, such as BMAR for WSTF were not provided and could not be estimated. Nevertheless, the potential cost savings could be significant. From a programmatic point of view, facilities reductions reduce the program costs on a full-cost basis; however, if those facilities are not further consolidated, closed, or occupied by other tenants, NASA retains exposure for maintenance external from the SSP.

Approaching Shuttle operations in this way has the potential to save costs across other functional areas as well. Continued assessment of consolidation opportunities should not be ignored prior to a competitive sourcing decision. This would better posture the program for continued safe operations and make eventual termination and transition to a new system easier.

There Are Many Other Right-Sizing Opportunities

- **Consolidated and reduced astronaut training infrastructure:**
  - **Reduced SSP flight rate could result in decreased Corps and reductions in T-38 and mission training infrastructure**
  - **More effective consolidation and integration of training functions and materials could result in programmatic savings**
- **Consolidated range operations:**
  - **Commonality of launch range and orbital communications offers opportunities for reductions to range operations costs through interoperability with the Air Force 45th and 50th Space Wings**
- **Integration of contract and Center-centric communications to NASA enterprise-wide communications could offer significant annual savings:**
  - **Service level agreement-based architecture**
  - **Many architectural opportunities including mission voice, WAN services, integrated LAN services**
  - **Significant opportunities to consolidate with other identical functional architectures including the 45th SW (Patrick Range ops) and the 50th SW (Air Force Satellite Control Network)**

Other restructuring opportunities exist. Examples include:

- *Astronaut Corps and training*. The current astronaut corps is large relative to the flight rate requirements and the training infrastructure is commensurate with the size of the corps. Many astronauts are not on flight status and maintain other jobs including engineering management and support. On average, NASA spends over $1 million on basic training per astronaut, and training costs for pilot astronauts who train on the Shuttle Training Aircraft or T-38 jets are more expensive than for mission specialists in general. Reducing both the astronaut corps size and resizing the supporting infrastructure could provide savings in the range of tens of millions of dollars per year. Such a move should be viewed as consonant with safety concerns since crewmembers would fly more frequently and retain proficiency.

- *Consolidating range operations*. Potential savings might exist through the consolidation of requirements across NASA, Air Force, and commercial users at KSC. The Air Force's 50th and 45th Space Wings both have major operations at the Cape with almost identical functions and infrastructure as NASA.

- *More effective integration across NASA contracts*. Commercial companies are generally interested in service-level agreements and often prefer to sign up to performance measures (the basis for awarding a contract or task order). The incentive for increased performance and greater profitability generally results in advantages to the government. The Task Force noted that service-level agreements are not widely used within the SSP currently.

NASA Can Begin to Right-Size Now

- **Rational cross programmatic integration of requirements could reduce infrastructure needs and operations processes**
- **Consolidation of functions both geographically and, in the interim contractually, could prepare for more effective transitions:**
  - **Realignment of contracts and durations can enable competitive sourcing options and reduce supply chain interruptions and costs.**
  - **Reassessment of sole source provider contract durations could reduce long-term costs (ET and RSRM)**
- **Eliminating "system tweaking" could reduce R&D expenditures and facilities requirements**
- **Potential additional opportunities could result from fleet reduction and alternative sparing strategies**

If NASA cannot overcome political and bureaucratic resistance to right-sizing, the annual cost of SSP will likely rise

Competitive sourcing could provide NASA with opportunities for enhanced cost and operational performance, but NASA can start the process today in anticipation of any of the potential options. Right-sizing the infrastructure to the operational requirements could not only support more cost-effective operations in the selected option, but NASA could define a more efficient infrastructure for the contractors to bid against and reap benefits today rather than hoping that the future contractors will perform this activity for NASA tomorrow.

Cross-programmatic integration of requirements between the SSP, ISS, and SLI programs has been a recurring theme in this briefing. The analysis of the opportunities for operational and programmatic right-sizing key on decisions being made in an integrated manner; the result could be, for example, that ISS supports a more evenly spaced flight rate to reduce processing challenges and staffing, and that the SLI program establishes a firm date for first flight so that more effective facility management and SSP obsolescence decisions can occur.

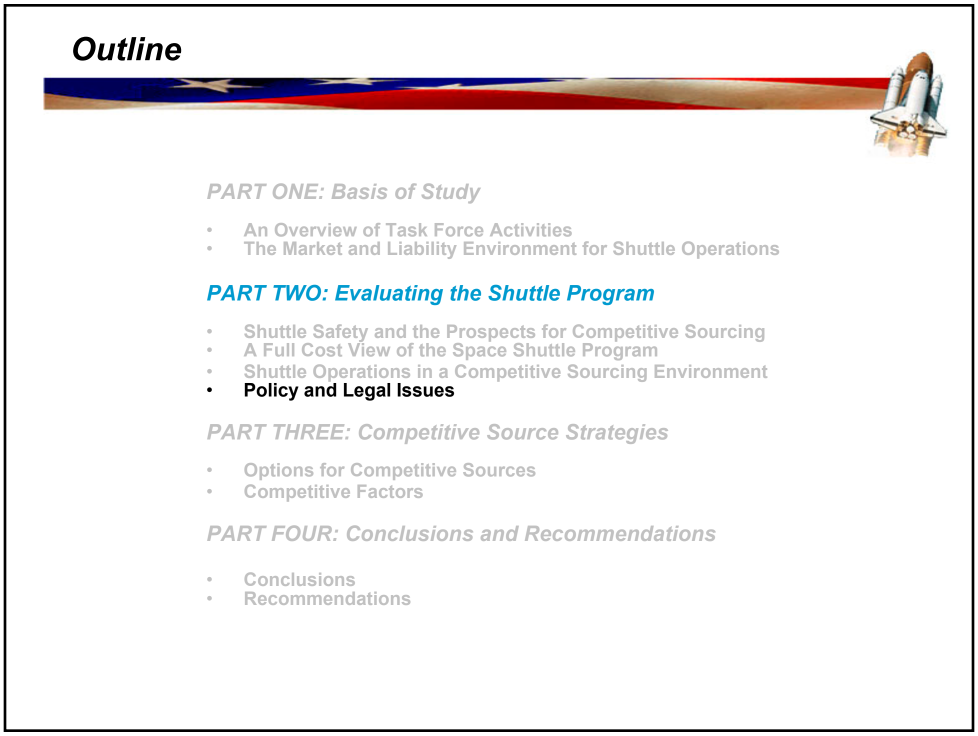
The concept of more effective integration can be extended to both geographic and contractual consolidation of functions for more effective transition to the selected option. NASA should consider the potential savings and both personnel and facilities efficiencies that can result through geographic and/or functional consolidations across sites, centers, and contracts. These consolidations could further support cross-programmatic integration of requirements between the various programs by supporting functional and geographical focus and streamlining supporting infrastructure for the eventual transition to a follow-on launch capability and architecture. Functional consolidation across existing contracts could also provide efficiencies that further support transition effectiveness; an example of this is MCC consolidation to a single contractor rather than both flight operations and maintenance pieces that carry redundant staffing, overhead, G&A, and integration costs.

Other contract efficiencies could lead to safer long-term operations; specifically, the sole source nature of the RSRM and ET contracts could provide for more effective supply chain management. Rather than continuing with short procurements, a long-term contract commitment could provide RSRM and ET suppliers, many of them small "mom and pop" shops that are single critical subcontractors, with a reasonable business base for continuing services. Failing that, many of these companies will likely exit from the supply chain owing to the poor business case or retirement, and that will require finding and certifying a new vendor, if even possible. This feature, coupled with more firm commitment by NASA, could also lead to a price break from a more certain business backlog.

The Task Force also observed that the "operational" SSP was still being "tweaked" as a developmental vehicle. If the cross-programmatic integration results in a clear understanding of the future mission requirements, including planned life for the SSP, then NASA may decide to cease potentially costly R&D activities that will not lead to appreciable increases in system safety or performance but would lead to up-front implementation and certification costs. One such example is the ET friction stir welding process that has the potential to increase some payload capacity through modest weight savings and also system safety through modest increases in ET reliability. Friction stir welding is a very interesting procedure, but it was neither developed by NASA nor patented by its contractors and there is substantial R&D development elsewhere by the current patent holders. Friction stir welding has been partially implemented, but complete ET implementation on the ogive segments will be very expensive from a tooling standpoint, so the question remains: Is it necessary for a system that is being planned for transition to the next generation vehicle within the next two decades?

Several areas of right-sizing have been examined. Other activities were identified that should be further addressed by NASA, and even more exist that should be cited for their potential benefits to the program and agency. For example, in the study performed by NASA on the KSC facilities and infrastructure, it was noted that three, not four, orbiters were needed for the projected flight rates. Furthermore, for the ISS mission, *Columbia* cannot provide substantial support and is not considered required for the ISS program. The concept of fleet reduction should be addressed in concert with vehicle supply chain and sparing analyses, as should the size of the astronaut corps. These, once again, are some of the many opportunities available to NASA *today* that can be addressed prior to the selection of a competitive sourcing option.

Right-sizing appears to make eminent sense; however, there remain two major implementation obstacles—political and bureaucratic resistance. If NASA cannot overcome both from a center, function, and contractor basis, then the annual cost of the SSP will likely rise. More importantly, the future transition to a cost-effective follow-on system will be strongly challenged without a willingness on the part of NASA, contractors, and politicians to right-size and streamline the infrastructure. Otherwise, parochialism will continue to maintain inefficiencies and costly facilities that, under full cost accounting, will continue to require BMAR, obsolescence, and personnel (both government and contractor) costs.



POLICY AND LEGAL ISSUES

Any decision about revising Shuttle sourcing will need to address potential changes in the policy and legal regime in which the Shuttle operates. This section discusses the policy and legal ramifications of Shuttle competitive sourcing, including potential avenues for addressing contracting and liability issues.

NASA's Contracting Authority Provides Flexibility

- **The 5-year FAR limitation (basic plus option periods) applies to all NASA contracts regardless of type, except when the time needed to complete system development or hardware production is greater than five years**
  - The Associate Administrator for Procurement can approve deviations from the 5-year limitation policy based on evidence that the extended years can be reasonably priced
- **National Aeronautics and Space Act of 1958 grants NASA broad discretion in performance of its mission (Space Act Agreements/Other Transaction Authority) (OTA)**
  - NASA "authorized to enter into and perform such contracts, leases, cooperative agreements, or other transactions as may be necessary in the conduct of its work and on such terms as it may deem appropriate, with…"
    - Federal Agencies, State Governments, or Territorial Governments
    - Persons, Firms, Associations, Corporations, or Educational Institutions
    - Foreign Governments and Organizations
  - NASA generally utilizes OTA only for small, cutting-edge research projects
- **NASA's subsequent classification as a "defense agency" makes it subject to all of the rules of the Competition in Contracting Act**

Awarding long-term contracts for different competitive sourcing options is theoretically possible—calculating reasonable price projections is the primary impediment to implementing long-term contracts

The Task Force found that the space agency has contracting authority that provides flexibility when implementing competitive sourcing options. In 1958, the Space Act provided NASA with extraordinary "other transaction authority" that gave the agency broad procurement authority. However, the subsequent reclassification of NASA as a "defense agency" reduced the applicability of its "other transactional authority—currently, it is only utilized through "Space Act Agreements" for small, cutting-edge research projects and cannot be used for large procurements.[76]

Even though NASA does not have full procurement flexibility, which means the agency is subject to the five-year Federal Acquisition Regulation (FAR) limitation for procurement contracts, the NASA FAR Supplement provides the Associate Administrator for Procurement with the authority to approve deviations from that five-year rule. The major requirement for gaining approval to deviate from the five-year rule is providing solid evidence that such a long-term contract can be reasonably priced. Regardless, NASA appears to have some flexibility to approve

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[76]Public Law 98-369, Competition in Contracting Act of 1984; U.S.C. § 2473 (c), 42 U.S.C. § 2475, Sections 203 (c), 205, and 305 (i) of the National Aeronautics and Space Act of 1958, as amended; National Aeronautics and Space Administration, NPG 1050.1, Space Act Agreements, December 30, 1998.

long-term contracts that would extend 10 to 20 years (five-year base period with a series of five-year options). That authority could prove critical when implementing competitive sourcing options that necessitate a long-term commitment from the government to close the business case for a private company bidding on specific Shuttle operations.[77]

[77]National Aeronautics and Space Administration, Office of Procurement, *NASA FAR Supplement*, *Part 1217*, January 25, 2002.

Competitive Sourcing May Require Revised Shuttle Use Policy

	EXAMPLES	NATIONAL POLICY	POLICY DETAILS	POLICY REQUIREMENTS & ISSUES
Non-NASA Government Payloads	USAF Payloads NRO PayloadsNOAA Payloads	Shuttle Use Policy (42 USC 2465a)	R&D payloads requiring human presence, shuttle-unique capabilities, or other compelling circumstances Secondary payloads exempted	To launch non-Shuttle unique government payloads would require revision of the Shuttle use policy Lack of interest from non-NASA govt. customers makes a change in the Shuttle use policy
Commercial Payloads	Communications Satellites Remote Sensing Satellites	Shuttle Use Policy (42 USC 2465a)	R&D payloads requiring human presence, shuttle-unique capabilities, or other compelling circumstances Secondary payloads exempted	To launch non-Shuttle unique commercial payloads would require revision of the Shuttle use policy Large EELV investment make it unlikely the govt. would allow Shuttle to compete against those vehicles
Foreign Payloads	Commercial Payloads Government Payloads	Shuttle Use Policy (42 USC 2465a) NASA Space Flight (14 CFR 1214.2)	R&D payloads requiring human presence, shuttle-unique capabilities, or other compelling circumstances No conflicts with foreign policy and technology transfer policy	To launch non-Shuttle unique foreign payloads would require revision of the Shuttle use policy Allowing Shuttle to aggressively compete for foreign payloads, while exempting domestic markets, would have negative foreign policy consequences
Launch Prioritization	DoD Precedence NASA Precedence	Commercial Space Launch Activities Act of 1995 (49 USC 70109)	In event of imperative national need, NASA and DoD launches preempt commercial ELV launches	Allowing non-NASA payloads to fly on Shuttle requires concise national policy that delineates prioritization processes for NASA, non-NASA government, commercial, and foreign payloads
Tourism	Dennis Tito Mark Shuttleworth	NASA Space Flight (14 CFR 1214.3)	"Space Participants" approved as contributors to NASA's objectives may fly on the Shuttle - policy provides an objective selection process	Informal NASA policy has opposed space tourism primarily based on safety concerns
Commercial Products	Spaceflight Memorabilia "Been-in-space" Items	NASA Space Flight (14 CFR 1214.6)	On a space-available basis, such items are flown as a free courtesy to astronauts and certain organizations Economic gain from products that have "been in space" is prohibited	Allowing the sale of space memorabilia or "been in space" products would require revisions in national policy
Advertising Rights	Corporate Trademarks Logos Official Sponsorship	NASA Policy Directive 1383.2	NASA does not allow advertising on the Space Shuttle because of an agency policy against endorsement of commercial products	Selling advertising rights for the Shuttle program would require a revised policy with clear guidelines for usage and pricing of those rights

The table above describes the policy details, requirements, and issues relating to seven different Shuttle-use categories: non-NASA government payloads, commercial payloads, foreign payloads, launch prioritization, space tourism, commercial products, and advertising rights. Each of the policies (formal and informal) that address these Shuttle-use categories provides restrictions on the utilization of Shuttle for many government and commercial activities.[78]

The SSP, as originally envisioned, was intended to have a significant commercial component. The Shuttle was designed to launch a wide variety of government and commercial payloads and conduct a wide range of missions (e.g., human transport, reconnaissance, satellite deployment, satellite repair, satellite recovery). After the Shuttle *Challenger* disaster in 1986, however, national policy was amended to allow commercial and foreign activities on the Shuttle only when a mission had a defined requirement for human presence, Shuttle-unique capabilities, or

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[78]Source: Space Shuttle Use Policy (42 U.S.C. 2465a); NASA Space Flight (14 CFR 1214); Commercial Space Launch Activities Act of 1995 (49 U.S.C. 70109); NASA Assistance to Non-Government, Entertainment-Oriented Motion Picture, Television, Video and Multimedia Productions/Enterprises, and Advertising (NPD 1383.2).

compelling circumstances necessitated the use of Shuttle (secondary payloads were exempted). During the past 15 years, NASA policy and culture have remained averse to commercial activities on the Shuttle. During that same time period other government agencies have moved away from using the Shuttle and almost exclusively utilized ELVs to get payloads into orbit.[79]

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[79] 42 U.S.C. 2465a, Space Shuttle Use Policy; 14 CFR 1214, NASA Space Flight; 49 U.S.C. 70109, Commercial Space Launch Activities Act of 1995; National Aeronautics and Space Administration, NPD 1383.2, NASA Assistance to Non-Government, Entertainment-Oriented Motion Picture, Television, Video and Multimedia Productions/Enterprises, and Advertising, October 7, 1999.

The Current Licensing Regime May Apply to a Commercial Shuttle

- **Under the auspices of the National Aeronautics and Space Act of 1958 (NAS Act), NASA has no regulatory authority**
  - **Therefore, without amending the NAS Act, licensing/certification of a commercial Shuttle would be conducted by a separate regulatory agency (e.g. FAA)**
- **The Commercial Space Launch Activities Act of 1995 (CSLAA) grants the FAA (through the Secretary of Transportation) the authority to license the launch and reentry of commercial RLVs**
  - **A licensee is responsible for ensuring the safe conduct of an RLV mission and for protecting public health and safety and the safety of property during the conduct of the mission**
  - **Types of licenses**
    - **Mission-specific license: for a single launch/reentry mission**
    - **Operator license: for a launch/reentry operator, valid for two years**
- **While the CSLAA was not intended as an instrument for licensing a commercially-operated Shuttle, there appear to be few impediments to using the regime for launching commercial payloads**
  - **A national policy statement, either from Congress or the White House, would be desirable to clarify the applicability of the CSLAA to launching passengers-for-hire aboard RLVs (and specifically aboard a commercially-operated Shuttle)**
  - **To obtain safety approval, the Shuttle-operator would have to demonstrate safe operations that do not exceed an expected average number of 0.00003 casualties to the collective members of the public per flight**

Based on an analysis of relevant legal instruments, the Task Force found that the current licensing regime may apply to a commercially owned Shuttle. While NASA has no regulatory authority under the Space Act, the Commercial Space Launch Activities Act of 1995 (CSLAA) granted the FAA the authority to license the launch and reentry of commercial RLVs. While not a fully reusable launch vehicle, a commercially owned Shuttle conducting commercial missions could theoretically be licensed under this regime. Any option that allows Shuttle assets to remain with the government or in which the commercial owner sells services back to the government is exempted from the requirement to obtain a launch license.[80]

There are two major obstacles to utilizing the CSLAA for commercial Shuttle operations. First, the current legislation does not clearly provide licensing authority to the FAA for launching passengers-for-hire aboard a commercial RLV. If an option relied upon revenues from space tourism, the legislation would need to be amended to clarify the applicability of the CSLAA to passengers-for-hire. Second, to obtain safety approval, the Shuttle would have to demonstrate safe operations based on an extremely

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[80] Pub. L. No. 85-568, National Aeronautics and Space Act of 1958 (as amended); 49 USC 70101-70119, Commercial Space Launch Activities Act of 1995 (as amended).

low probability that significant civilian casualties would result from an unsuccessful launch or landing—although since these standards would not apply to crew or passengers, the Shuttle could theoretically obtain a license based on the current FAA standards.[81]

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[81]Pub. L. No. 85-568, National Aeronautics and Space Act of 1958 (as amended); 49 USC 70101-70119, Commercial Space Launch Activities Act of 1995 (as amended).