Report of the Space Shuttle Management Independent Review Team

The undersigned present the report of the
Space Shuttle Management Independent Review

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PREFACE

The space shuttle is recognized throughout the world's technical community as the consummate vehicle for space transportation. Its performance in placing humans and payloads in orbit and returning products and satellites to Earth is unmatched. Since the vehicle was declared operational in the mid-1980s, however, it has been severely criticized for the high cost of operation. In addition, many of the promises made for the shuttle have never been realized for a number of reasons. For example: 1) the number of flights per year that were forecast never materialized; 2) the Challenger accident temporarily cast doubt on shuttle reliability; 3) the number of payloads by other U.S. Government agencies (particularly the Department of Defense) was overestimated, with many transferred to other launch vehicles; 4) policy (e.g., National Space Policy) and statutory changes were made to discourage the use of the shuttle as a launch vehicle except for missions that require human presence or other unique shuttle capabilities; 5) NASA continued to operate the shuttle in a quasi-research and development mode; this was exacerbated by the Challenger accident.

The NASA Administrator has attempted by various means, and with reasonable success, to reduce the total cost of operating the shuttle. In recent years, NASA has reduced the shuttle's direct operating costs by approximately 25 percent—a valiant effort considering the scrutiny the shuttle receives by the government and the press. As more budget pressures are brought to bear and NASA searches for funds to use in pursuit of future programs, however, it became obvious to the Administrator that he should seek possible changes in the shuttle management structure. As a result of discussions with a number of advisors in the government, the aerospace industry, and former NASA leaders, the Administrator decided to form a team composed of some of these people to review the present shuttle operation management and to propose innovative approaches to significantly decrease total operating costs while maintaining systems safety.

If NASA is successful in bringing about a new approach to spaceflight operations, it will add to NASA's credibility as an agency on the forefront of reinventing government and provide a model for the management of future programs and their transition to the private sector.

ACKNOWLEDGMENTS

The team chairman wishes to acknowledge the work of the official team members, the advisors, and the NASA team members. The team members all served in the best interest of the country's space program and those who read this report must recognize that the team did its utmost to provide candid and useful inputs to the future conduct of spaceflight.

The team wishes to compliment the people both in NASA and the aerospace industry for their lucid and frank presentations and discussions on the many facets of the Space Shuttle Program. As is the usual case, many of the ideas presented herein came from these dedicated and competent people.

Jeff Bantle and Cliff Farmer provided a great deal of effort to bring the written word to paper and are typical of the fine young people that reside in NASA. They are all anxious to continue a productive and exciting space program, which will provoke new knowledge and technology.

Christopher C. Kraft

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EXECUTIVE SUMMARY

At the request of the NASA Administrator a team was formed to review the Space Shuttle Program and propose a new management system that could significantly reduce operating costs. Composed of a group of people with broad and extensive experience in spaceflight and related areas, the team received briefings from the NASA organizations and most of the supporting contractors involved in the Shuttle Program. In addition, a number of chief executives from the supporting contractors provided advice and suggestions.

The team found that the present management system has functioned reasonably well despite its diffuse structure. The team also determined that the shuttle has become a mature and reliable system, and—in terms of a manned rocket-propelled space launch system—is about as safe as today's technology will provide. In addition, NASA has reduced shuttle operating costs by about 25 percent over the past 3 years.

The program, however, remains in a quasi-development mode and yearly costs remain higher than required. Given the current NASA-contractor structure and incentives, it is difficult to establish cost reduction as a primary goal and implement changes to achieve efficiencies. As a result, the team sought to create a management structure and associated environment that enables and motivates the Program to further reduce operational costs.

Accordingly, the review team concluded that the NASA Space Shuttle Program should

(1) Establish a clear set of program goals, placing a greater emphasis on cost-efficient operations and user-friendly payload integration.
(2) Redefine the management structure, separating development and operations and disengaging NASA from the daily operation of the space shuttle.
(3) Provide the necessary environment and conditions within the program to pursue these goals.

With over 65 successful launches, operations have become quite reliable. At this stage in the Shuttle Program, cost-efficient operations and user-friendly payload integration should be pursued along with safe and successful flights. If the Program is to meet the challenge of reducing costs and streamlining payload integration, it will require a major change in how the Program operates.

Given the maturity of the vehicle, a change to a new mode of management with considerably less NASA oversight is possible at this time. In addition, the bureaucracy that has developed over the program's lifetime—and particularly since the Challenger accident—will be difficult to overcome and the optimum operational effectiveness of the system will be difficult to achieve unless a new management system is provided.

The team considered a number of new management approaches. These included to

(1) Stay with the present system and continue to decrease costs in the incremental fashion used to date.
(2) Implement a multi-node system, consolidating contracts in each of the major geographical areas (i.e., the Kennedy Space Center in Florida, Marshall Space Flight Center in Alabama, and Johnson Space Center in Texas), each managed by a prime contractor with continued NASA program management.
(3) Consolidate operations under a single-business entity.

The team concluded that consolidating operations under a single-business entity was the most advantageous. This single-business approach is a change from the present one of government control with industry response to that of government direction with industry operation.

The multi-node approach possesses some of the same features that cause the present system to be cumbersome and expensive. Both options (1 and 2) do not provide the centralization of control necessary to eliminate duplication, the disengaging of NASA from day-to-day direction necessary to reduce requirements, and the incentives necessary to motivate cost reduction. One of the critical deficiencies in today's program management, and one that the multi-node approach also suffers from, is the lack of a single responsible agent among all of the contractors supporting the program. As a result, no one entity feels the total responsibility for the shuttle operation; therefore, no advocate exists for overall cost reduction. This deficiency is the major fault with both the current program structure and the multi-node concept.

Several different single-business approaches were discussed with the prime contractor option considered the most achievable and practical. Other concepts, including a business consortium, joint venture, and government owned-contractor operated (GOCO) arrangement, involve complexities that are difficult to overcome in any reasonable period of time. In addition, selecting a prime contractor from among the current contractors, as opposed to an open competition, could accomplish all of the objectives in a less disruptive and more expeditious manner, realizing potential cost reductions more quickly.

The proposed single-business management system will require a steadfast commitment from both NASA and the aerospace industry to ensure success. NASA must be willing to define clear shuttle operating requirements with limited oversight. The prime contractor must be willing to assume responsibility for safe and productive operations. This requires the assignment of competent and experienced people at all levels and the direct attention of top management. For its commitment, the contractor must be rewarded with appropriate incentive fees. The government in-turn must provide similar talent in program management and a guarantee that the contractor will not be encumbered with burdensome and unnecessary oversight.

The new management approach will require the following immediate actions:

(1) Freeze the current vehicle configuration, minimizing future modifications, with such modifications delivered in bloc updates. Future bloc updates should implement modifications required to make the vehicle more re-usable and operational.
(2) Perform a requirements review, top down, with the goal of significantly reducing checkout and other requirements based upon operations experience.
(3) Consolidate and reduce program and project elements, limiting NASA involvement in operations and minimizing NASA-contractor interfaces.
(4) Restructure and reduce the overall Safety Reliability and Quality Assurance (SR&QA) elements—without reducing safety.
(5) Streamline payload processing and integration, minimizing costs and reducing the length of time required to integrate a payload aboard the space shuttle.
(6) Structure operational contracts to provide real incentive to reduce costs while accomplishing safe and successful missions.
(7) Allow the hiring of NASA personnel by the prime and subcontractors to ensure proper expertise and talents exist to continue with safe and successful operations.

One of the major stipulations to achieve cost reduction is to freeze the present shuttle configuration and perform only those changes required to carry out the individual flights. Currently, change and update are continual and pervasive at all levels of the program and seize a significant amount of attention, focus, and resources. To become an operational program, the shuttle configuration must be more stable. To aid in the transition process, the present NASA management system would complete the development of presently approved changes and then be phased out.

Additionally, turnaround, launch, and mission requirements should be diminished based on operational experience. Currently, for the orbiter alone, approximately 150 hardware package changeouts are performed between each flight; yet an average of only 10 in-flight anomalies, most of which are inconsequential, occur during each mission. Maturation of the vehicle checkout requirements has, clearly, not kept pace with the vehicle hardware, and redundant subsystems are not being used to provide operational flexibility.

Once the new management structure is in place, efficiencies can be realized through the consolidation, reduction, and elimination of functions. This will be a challenging task considering the diffuse state of the current NASA-contractor structure. Duplication and overlap have developed throughout the program.

One of the most apparent examples in this regard is the area of SR&QA. As a result of the Challenger incident, a “safety shield” philosophy has evolved creating a difficult management situation. Managers, engineers, and business people are reluctant to make decisions that involve risk because of the fear of persecution. As a result, a parallel and independent SR&QA element has grown to large proportions. This is not only significant with respect to direct costs, but has an even greater impact when supporting efforts are included. Restructuring and streamlining SR&QA throughout the Shuttle Program, maintaining only the necessary checks and balances, must be accomplished to achieve significant cost reduction.

As the Shuttle Program transitions to an operational program, payload processing must be streamlined, with an associated reduction in cost and length of time required to integrate a payload. As this takes place, payload operations must change from “defensive” to more customer-oriented. Toward this end, payload operations would become an integral part of mission and launch operations with attendant streamlining of organizations, people, and procedures.

To assume greater operational responsibility and risk, it will be necessary to provide the contractor with the opportunity to realize a profit. Proper contract incentives will be needed to ensure the contractor team performs the necessary steps to reduce cost. Greater and longer term sharing of cost savings, along with appropriate penalties for marginal performance, will be required to provide the contractor with the motivation to significantly reduce costs while maintaining safe and successful operations.

Finally, ensuring the NASA-contractor team has the expertise required to operate the shuttle is of significant concern. In the present aerospace industry, it may be difficult to assemble all of the necessary talent and resources to assume the responsibility for shuttle operations. Therefore, initially, this will require private industry to hire NASA personnel and/or utilize specific government engineering organizations with critical skills until these skills can be developed from within. It is also important when constructing the contractor team to recognize current expertise that has already been developed. An example of this is in the areas of orbiter obsolescence and sustaining engineering where specific expertise and experience is necessary to continue to operate the vehicle. Building the NASA-contractor team will require special attention to these types of issues.

The transition process will entail the development of a program office by the selected prime contractor. The present NASA program and project offices would be used to aid the prime contractor through the initial development of this new operating concept. As the contractors' skills mature, they would continually assume greater responsibility. The team believes this transition should be expedited with the overall transition time dependent on the specific shuttle element, the techniques employed by NASA to rearrange the contractual responsibility, and the commitment by all parties to bring about these significant changes.

INTRODUCTION

Charter

In November 1994, the NASA Administrator asked Dr. Christopher C. Kraft to form a team of individuals external to the agency to evaluate the resources being expended on the Space Shuttle Program. The team was chartered to appraise the current set of processes used in performing shuttle operations at the Johnson, Kennedy, Marshall, and Stennis space centers, and to recommend alternative operational concepts that could significantly reduce operating costs. Additionally, the team was asked to develop an approach that would aid in the transition of agency functions to any new organizational and/or management structures proposed.

The Shuttle Management Review Team formed by Dr. Kraft comprised aerospace executives, business leaders, and former NASA officials. They were:

Dr. Christopher Kraft, Team Chairman,
Former Director of the Johnson Space Center

Col. Frank Borman,
Former Eastern Airlines chief executive officer and retired astronaut

George Jeffs,
Former president of Rockwell International's North American Aerospace Operations

Robert Lindstrom,
Former senior vice president and general manager for Space Operations at Thiokol Corporation and retired manager of the Space Shuttle Projects Office at Marshall Space Flight Center

Thomas Maultsby,
Vice president of General Research Corporation and former senior Department of Defense representative to NASA Headquarters

Isom Rigell,
Former vice president, Florida Operations for United Space Boosters, Inc., and retired director, shuttle payloads and former director, launch vehicle operations at the Kennedy Space Center

Objectives, Scope, and Methodology

The focus of the team was to

(1) Determine how the shuttle operations budget is being utilized.
(2) Determine the major cost drivers to the principal functions within the Shuttle Program.
(3) Develop a new model or concept for shuttle operations with the potential for significantly reducing operating costs.
(4) Define a transition approach to move the agency to the new operations concept.

The team limited its scope to the Shuttle Program, considering the International Space Station Program only when it was driving shuttle requirements.

To meet the stated objectives, the team

(1) Held reviews with each of the organizations performing a major function within the Shuttle Program at Johnson, Kennedy, and Marshall space centers.
(2) Talked with NASA and contractor personnel directly involved in performing or managing shuttle operations.
(3) Met with the chief executive officer, or his representative, of each of the major Shuttle Program contractors to discuss ideas for the new shuttle operations concept.
(4) Reviewed a summary of the findings of the Space Shuttle Functional Workforce Review, Johnson Space Center Teams for Level II/Orbiter/Mission Operations Directorate/Engineering Directorate.

The team's detailed activities and proceedings are included as Appendix B.

OBSERVATIONS

Throughout the review, the Space Shuttle Program was found to be successful, operating a mature and reliable vehicle. The Shuttle Program has performed more than 65 successful flights, delivering its varied complement of payloads to orbit and accomplishing nearly all of its mission objectives. The performance of the machine as a space transportation system has been remarkable given the difficult operating conditions and management environment. The preflight operational parts of the program are excellent in delivering, preparing, assembling, and readying the vehicle for flight. Optimal flight designs and plans are developed and executed for diverse and complex payload operations. Crew and flight controller readiness for both nominal and contingency operations are unmatched. Over the last several years, while performing seven to eight flights per year, the Shuttle Program has continued its successful performance while incrementally reducing operating costs by approximately 25 percent.

Yet, with all of its accomplishments, the program remains in a quasi-development mode with the associated overhead and expenses. It continues to operate with large program and support functions supported by a bevy of contractors. Large maintenance and operations efforts are required to support the processing and operations facilities at the various centers. The continuous review process used to bring about reductions in operating costs has had a material effect on morale and caused management frustrations because of a lack of an overall plan, clearly defined goals, and risk taking flexibility delegated to managers. Significant resources are expended on managing and coordinating many elements and their associated contracts, each being driven and influenced by diverse factors.

The current structure makes it difficult to implement changes to achieve the potential operational efficiency and minimum cost of the system. This has resulted in over-extensive requirements, overlapping engineering support, and complex payload processing. Further problems are evident in the safety environment, contract management culture, and NASA-contractor structure.

Requirements Driven System

The large number of vehicle processing and turnaround requirements remains driven by the philosophy, structure, and focus typical of a development organization. While numerous efficiencies have been realized, processing requirements and labor hours remain quite high. In the past 5 years, operational maintenance requirements and specifications have decreased from approximately 11,000 to 8,000, while labor hours per vehicle processing have decreased from about 1,000,000 to 750,000. Both advancements are significant. The program, however, remains encumbered by this cyclical process of requirement stipulation and execution. At the core of this large number of requirements exists the inherent developmental requirements philosophy of the program, the continual testing and analysis requirements, and the ever-changing vehicle hardware and software.

The systems redundancy and turnaround requirements philosophy for operating the shuttle has changed little since the beginning of the program. The shuttle was designed with two, three, and sometimes even four levels of subsystem redundancy. <u>While in the early stages of the program this redundancy was used for safety, it was intended that as operational experience was attained that subsystem redundancy would also be used for operational flexibility</u>. It is clear this progression has not occurred since launch constraints still require that the shuttle launch with very few anomalies and ground testing is routinely performed on much of the hardware, even if it performed flawlessly on its previous mission. As a result, each redundant element continues to be verified every time a vehicle is prepared for flight, resulting in a large and invasive set of turnaround requirements. In addition, the current practice of adding non-mandatory checkout requirements by piggy-backing on other work further burdens and complicates the turnaround process and subjects the hardware to additional and unnecessary operation. As a result of this process approximately 150 hardware package changeouts are performed each time the orbiter is prepared for another flight; yet an average of only 10 in-flight anomalies, most of which are inconsequential, occur each mission. <u>Clearly, the program's requirements-based philosophy has not matured with the vehicle hardware and the majority of hardware lifetime is unnecessarily being expended on ground testing and checkout.</u>

Additionally, the baseline checkout requirements are supplemented by numerous testing and analysis requested by the large engineering presence in the system. Rather than being dealt with in a return-to-print fashion, too many discrepancies result in detailed analysis and testing throughout the program and by the vendor. While this is appropriate for developmental hardware, a demonstrated hardware capability requires this type of testing and analysis much less frequently. Yet with the over-abundance of engineers distributed throughout the program, there is a tendency for their function to become self-fulfilling, routinely creating an inordinate amount of analysis, testing, replacement, and tear-down requirements.

Finally, many requirements result from a frequently changing vehicle configuration, both hardware and software. Vehicle hardware changes are being implemented in a continuous and piecemeal fashion with software changes delivered in the form of yearly operational increments. As an example, more than 20 different vehicle modifications are currently in work to gain 13,000 lb. of additional performance to support space station missions. Many of these performance enhancements have associated modifications to both hardware and software. Hardware and software changes have a cascading impact on the entire program, including turnaround requirements, operating procedures, support documentation, crew training, and ground system changes. Change and update are continual and pervasive at all levels of the program and require significant attention, focus, and resources.

All of these conditions are typical of a research and development program with an immature vehicle configuration. Yet after 65 successful launches and over a year of in-flight time, most shuttle systems have demonstrated outstanding performance, certainly worthy of reducing the abundance of routine requirements. A significant reduction in operational cost cannot occur without addressing the numerous requirements and the many factions which drive them.

Contract Proliferation and Overlap

There are a vast number of support, engineering, processing, and production contracts of varying sizes and complexities within the Shuttle Program. Tables listing some of the larger contracts and their associated contractors and costs across the program is presented in Appendix C. These tables demonstrate the scope of what must be dealt with in consolidating and reducing the total number of contractors. Many of the larger contracts have team members as well as prime contractors, and some of the production contracts have numerous major subcontractors and directed subcontractors. Consolidation or elimination of overlapping contracts and functions across contracts must be considered if NASA is to further reduce costs.

From this complex contractor structure, multiple and overlapping engineering analysis organizations have evolved. These organizations exist at the three major centers as well as within the program and project offices. For example, the Johnson Space Center has a large engineering, test, and analysis contract within the Engineering Directorate that supports cargo integration; payload safety engineering; flight-to-flight guidance, navigation, and control; and analysis of integrated flight systems and performance upgrades to the vehicle. Likewise, the support contractor to the Systems and Cargo Engineering Office in the Shuttle Program Office is responsible for managing the payload and integrated systems safety process and the integrated vehicle ascent design criteria and defining and managing the integration of new capabilities and performance enhancement development to support the Space Station.

At the Kennedy Space Center, numerous organizations perform engineering analysis on the orbiter, external tank, solid rocket booster, solid rocket motor, and main engines. The project offices contain groups of engineering efforts that track the progress of their respective elements through the processing flow and monitor the integration effort of the shuttle processing contract. Problems that arise during processing or a mission on any one of the shuttle elements brings an inordinate amount of attention from the engineering factions within the project office, Shuttle Processing Contract and design center organizations.

Payload Processing

Although the shuttle is attractive to potential customers because of its reliability and mission success record, NASA's philosophy regarding payload processing can be described as nearly an aversion to carrying payloads. As a result, the Shuttle Program has developed a philosophy of compliance versus one of advocation—a philosophy that is not customer oriented. Because of this philosophy, a myriad of safety requirements is levied on customers in the areas of electrical, pyros, propellants, data systems, vibrations, acoustical, structural, thermal, EMI, contamination, etc. These extensive and inflexible requirements have a significant impact on the design and integration of onboard payloads, including the associated development, testing, and analysis.

Additionally, payloads are currently required to be introduced into the flow well over a year prior to launch. While this is a significant improvement over several years ago, the integration template remains diffuse and complex with many interdependencies between the functions of cargo engineering, flight design, simulation development, and safety evaluation. Continuing to simplify, compact, and tailor the integration template will be required to make the program more efficient in processing payloads and more attractive to customers.

Relationship Between Program and Center Management

Program management in NASA has undergone a number of changes over the past 25 years—changes that have evolved into isolation from center management. Early in the Mercury Program, the number of NASA people was relatively small and the designation of responsibility was easy and straightforward. As the programs grew, however, the addition of larger organizations, functional groups, diverse responsibilities, and multiple program support were required.

The centers involved adopted the traditional matrix management style prevalent in the aerospace industry. This allowed both NASA and its contractors to function together with a complete understanding of each other's way of doing business, and in particular, the decision-making process. NASA Headquarters established a working relationship with the centers based on this organizational style, and it functioned extremely well throughout the Apollo and early Space Shuttle Programs.

The post-Challenger organization modified this, and the advent of the Space Station resulted in further changes that have generated confusion within and among NASA Headquarters, the centers, and the contractors as to responsibility and decision making. It is now increasingly difficult for center management to provide the classical technical inputs to program management and to provide the customary checks and balances that were essential in previous programs. In addition, the lack of a strong and effective interface between program and center management can lead to duplication of resources, since the program may develop a capability or technical expertise that already exists within the center.

Fortunately, the pre-Challenger traditions of the Shuttle Program Office have continued to allow reasonable center inputs and rational decision making; however, the close working relationships of the past between center and program management are in decline and need rebuilding. Of greatest concern in this area is the Space Station Program. While the team did not look at this program in any depth, the situation described, almost universally by the engineering staff, was that the management style and structure of the Space Station Program was creating problems and frustration. Specifically, they found it difficult to provide engineering inputs and to make suggestions relative to design, operations, cost savings, or lessons learned. This trend toward isolation of program management from center management is of concern to the review team. Recently, the NASA Administrator has taken some steps to rectify this situation, but the results of the management style followed in the last 10 years will take time to change and the programmatic effects have to be resolved.

Safety Environment

The Challenger incident created a safety environment in NASA that is duplicative and expensive. After the accident in 1986, significant growth of the SR&QA element took place. A corresponding increase in oversight throughout the entire program followed. Recent studies have shown that the number of people associated with the SR&QA effort may be as great as 4000 and cost in excess of $350 million.

The “safety shield” that has been built has created a difficult management situation. Managers, engineers, and business people are reluctant to make decisions that involve risk because of the fear of persecution. Safety is one of those terms that can be used to hide behind and prevent necessary change and innovation.

This is not to say that safety and reliability are to be ignored. Human spaceflight is an inherently risky business; yet these risks can be managed effectively. The Shuttle Program has been successful because the lives of the astronauts are in the mind of every worker in the program. The environment created by this attitude is what has produced the marvelous hardware and software systems that fly in space today. This success is not the result of an inordinate amount of oversight nor a paper world that has been set up to provide an illusory sense of security. Indeed, the system used today may make the vehicle less safe because of the lack of individual responsibility it brings about.

The management changes proposed in this report will most certainly be criticized by the status quo as a threat to safety. Many people who are accustomed to the present cumbersome techniques that have developed in the shuttle era will hide behind the “safety shield.” <u>The challenge lies in requiring NASA and its contractors to totally revamp these expensive habits and still operate a safe and reliable vehicle.</u>

Contract Management Culture

The heritage of NASA by way of NACA is based on technical competence, invention and know-how. There is no airplane flying or space vehicle orbiting that does not possess some quality or form that was provided by the ingenuity of NACA/NASA. The early days of aviation, like the early days of spaceflight, benefited immeasurably by the unerring research and development capabilities of an organization dedicated to excellence.

Former Senator Proxmire, in a speech on the Senate floor, once said that even though he didn't agree with spending the taxpayers' money on some things that NASA wanted to do, he recognized that NASA was the best run agency in the government. The reputation and integrity of an institution such as NASA is a commodity that should be preserved.

When NASA was established by government charter in 1958, NACA was the nucleus around which the new space agency was built. NASA's new assignments at that time required hiring a large number of new people. Because of the demand for experienced engineers and scientists, NASA found it necessary to contract for some of these people from the aerospace industry. The NASA-industry team that resulted was responsible for building the new hardware and producing the vehicles necessary to begin the exploration of space. As in any maturing organization, the use of this contract process as an expedient has flourished and become a part of the normal way of doing business at NASA, even at the so called research centers.

With the passing of 30-plus years, NASA has become more and more a contract management agency and less and less an agency whose people are noted for their technical prowess. This statement is not a new revelation and has been spoken and written by a number of past NASA Administrators and leaders. One highly regarded NASA scientist recently put it this way: "People used to come to NASA for information, now they come for a contract." This is pointed out not to lambaste NASA, but to emphasize the need to restore that internal technical expertise, continuing the traditions NASA has been recognized for and allowing the aerospace industry to do the same.

NASA-Contractor Structure

Many inefficiencies and difficulties in the current Shuttle Program can be attributed to the diffuse and fragmented NASA and contractor structure. Numerous contractors exist supporting various program elements, resulting in ambiguous lines of communication and diffused responsibility. This type of fragmented structure and contract management provides little promise for significant cost reductions. As a result, budget reductions tend to be directed from above instead of cost savings identified from below.

In such an organization, neither NASA nor the contractors are provided the environment or motivation to make significant changes to reduce cost. On the contrary, NASA and its contractors are both internally driven to increase responsibilities, create new functions, and acquire larger budgets. This lends itself to the creation of overlapping tasks and the development of redundant capabilities. The Shuttle Program must devote a significant amount of time and resources to contract management and contractor integration, arbitration, and conciliation. Coordinating between the NASA organizations and contractors just to accomplish daily operations becomes a significant task. Introducing change to eliminate inefficiencies tends to be frustrating and rejected by many parties.

Even though many of the contracts are structured with award fees, most contracts fail to motivate the contractor to significantly reduce costs. Base and award fees tend to be relatively high with little investment made or risk taken by the contractor. While cost reductions might assure a one-time award fee, they reduce the contract base on which the fee for all future years is determined. This is different from private industry where profit and cost directly motivate the process, with cost savings rewarded every year they are realized.

To make significant reductions in cost, the expertise of identifying and implementing specific ideas must come from NASA and the contractor. Instead of making detailed specific cost saving recommendations, the review team provides in the remainder of this report a NASA-contractor program structure and associated environment that will enable and motivate the Shuttle Program to apply its expertise and identify and implement such efficiencies.

RECOMMENDATIONS

Given the current structure and condition of the Space Shuttle Program, it is the conclusion of this independent review team that significant additional reductions in cost will be difficult without a new and innovative approach. This new approach must transition the current program to a more operational program and introduce cost-effective operations as a primary goal. To achieve this goal, a new NASA and contractor management structure will be required. This new structure must provide greater contractor responsibility for standard and daily operations, enabling NASA to pursue new opportunities in space exploration. In addition, a number of conditions will be required to enable this new structure to overcome many of the impediments of the current program and realize numerous efficiencies.

Therefore, it is the conclusion of this independent review team that the Shuttle Program should

(1) Establish a clear set of program goals, placing a greater emphasis on efficient operations and payload integration.
(2) Redefine the management structure, separating development and operations, and disengaging NASA from the routine operation of the space shuttle.
(3) Provide the necessary environment and conditions within the program to pursue these goals.

Based upon the maturity of the shuttle system, now is an opportune time for a change in management structure. The review team has found a stable, high performing work force, including the contractor base. Contractor performance ratings indicate their proficiency at performing the required tasks. The shuttle has flown over 65 flights in the last 13 years accumulating more than a year of flight time while establishing a large database and reducing hardware problems. Flight anomalies have declined to a near insignificant level. Test and processing procedures have stabilized. As a result of these favorable conditions, the opportunity to significantly reduce costs by transitioning to an operational program with reduced NASA involvement can and should be exercised at this time.

Space Shuttle Program Goals

Recommendation 1: Establish a more balanced set of goals for the Shuttle Program, with a greater emphasis on reducing operational costs and making payload integration more user friendly. The following goals provide a better balance between operations and safety, and address the overall NASA objective of reducing the cost of access to space.

(1) Perform safe space shuttle operations while accomplishing mission objectives.
(2) Reduce the cost of space shuttle operations.
(3) Provide user-friendly payload integration.

The Shuttle Program has successfully maintained flight safety while accomplishing mission objectives; however, streamlined spacecraft operations and user-friendly payload integration needs to be pursued more vigorously. A more balanced approach in pursuing the above goals will require the program to make cost/risk evaluations. Careful consideration will need to be given to all changes and their downstream ramifications to overall operation of the shuttle. Future changes to the shuttle should not only be made to enhance operations, but also, as required, to test future technologies. All levels of the program need to pursue cost-efficient operations and user-friendly payload integration with the same vigor as safe and successful flights.

Space Shuttle Program Management Structure

Recommendation 2: Modify the program's management structure, separating development from operations and relinquish the majority of the operational responsibility to a prime contractor.

To best meet the program goals, a new innovative management structure, separating development from operations, and transitioning the majority of operations responsibility to industry must be made. NASA interfaces on the daily repetitive operations of the space shuttle can be minimized and the contractor, given the proper incentive, will have the opportunity to eliminate non-essential effort.

Management Structure Options Considered

A number of NASA-contractor management concepts, including the current structure, were examined.

- Option 1: Maintain the current program structure continuing the incremental reduction emphasis.
- Option 2: Implement a multi-node system that breaks the program into several (two or three) parts, each managed by a prime contractor with continued NASA program management.
- Option 3: Consolidate operations under a single-business entity.

The review team identified the single-business entity approach as the most advantageous.

Option 1 would allow NASA to continue to pursue consolidation and elimination of functions and thereby decrease the many NASA-to-contractor interfaces. NASA would need to significantly reduce the excessive safety element. This would be followed by reducing requirements based on the vehicle's reliable and redundant capabilities for operational flexibility.

The review team determined that while conceptually this approach may be possible, in practical terms the motivational and management difficulties could not be fully resolved. With this type of structure, the combined NASA-contractor organization is not uniformly or directly motivated to substantially reduce costs. Cost reductions will become increasingly more difficult to accomplish within the civil service since further cost efficiencies will primarily come from human resources, and people are generally not motivated to eliminate their own jobs. Similarly, contractors have superficial incentive to reduce costs, in that it is more to their advantage to maintain as large a base as possible rather than making significant cuts to realize a short-lived award fee. This type of overall structure, which promotes numerous interfaces between NASA and the contractor, requires significant overhead. Identification and elimination of overlapping and unnecessary functions becomes controversial and difficult for NASA to resolve.

Finally, the review team believes that an underlying goal of NASA's should be one of technology development followed by the transfer of this technology to private industry. This allows NASA to move on to future technology development and other space exploration ventures. Given such a charter, and the current maturity of the vehicle, the approach for the Shuttle Program should be to permit disengagement of NASA from daily operations.

Option 2 would create two or three distinct primary contractors. Several different multi-node approaches were considered, including a division similar to the Marshall, Kennedy, and Johnson functions of today. In a dual-node approach, one contractor node would be responsible for launch operations, including receiving, assembling and preparing all hardware. The other node would be responsible for mission and crew operations, along with payload integration.

One of the critical deficiencies in today's program management, and one that the multi-node approach also suffers from, is the lack of a single responsible agent among all of the contractors supporting the program. As a result, no one entity feels the total responsibility for the shuttle operation; therefore, no advocate exists for overall cost reduction. This deficiency is the major fault with the two node concept. That is, this concept requires NASA to maintain the costly interface management at all levels of the program and precludes the large cost savings the team believes will be achieved by integrating the myriad of activities that span all of the support contracts.

While NASA-to-contractor interfaces could be reduced in this approach and cost efficiencies realized within each node, NASA would still be required to perform a significant integration and mediation function between the nodes. This would make it difficult to realize efficiencies across the nodes—a key area where overlap exists today and is likely to endure. In addition, this option would foster an adversarial relationship between centers and their respective contractor organizations.

Attempting to use this concept as an intermediate step to a single-business approach would elongate the transition time, providing a greater potential for not achieving the final result and unnecessarily delaying many cost reductions.

Option 3 consolidates all program operations under a single-business entity, such as a prime contractor. This option lays the groundwork for increasing the contractors role and responsibility in the Shuttle Program, allows the contractor to focus on shuttle operations, and provides for a more direct introduction of profit motive and cost reduction. While this approach is the greatest departure from the present system, if properly structured and staffed, it holds the greatest potential for cutting costs by consolidating, minimizing government-contractor interfaces, and giving the contractor the incentive and authority to realize efficiencies. In addition, this approach supplies the advantage of providing a single strong industry advocate for the Shuttle Program.

The challenges of this option lie in continuing safe and successful operations during the transition period and the initial stages of delegating much of the responsibilities to the single-business entity. The fundamental premises of this option are

(1) Separation of the operations functions from the development activities within the program.
(2) Elevation of the NASA-contractor interface to the program level to disengage NASA from daily operations activities and empower the contractor to assume this responsibility.
(3) Development of a contract structure to incentivize the contractor to reduce operations cost while maintaining safety of flight and mission success.

Several different single-business approaches were considered with the prime contractor option considered most attractive. Other concepts included a business consortium, joint venture, and government owned-contractor operated (GOCO) arrangement. It became evident that the construction of a joint venture or business consortium would be difficult to achieve in any reasonable length of time, if it could be achieved at all.

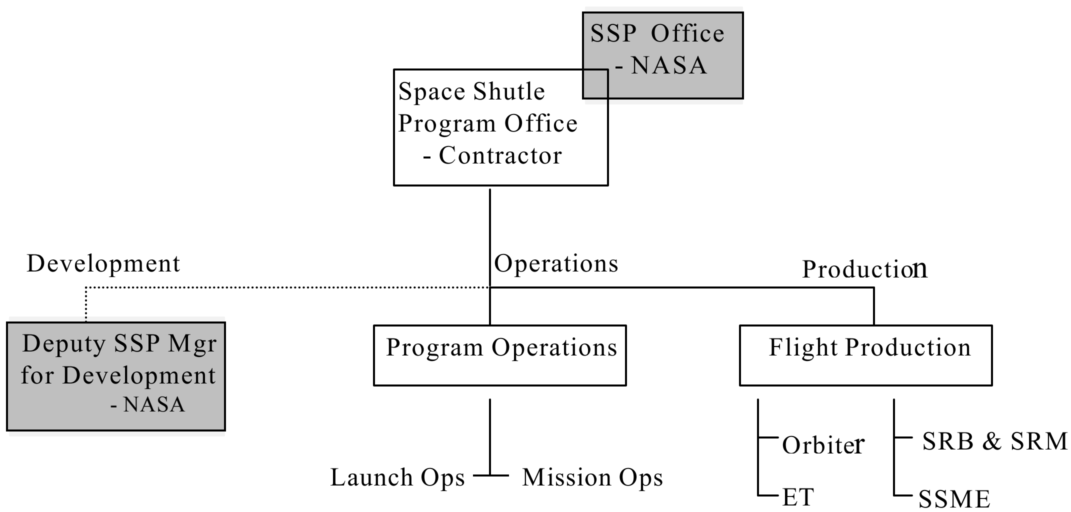
Because the prime contractor approach does not suffer from these detriments, the team concluded that it was the most achievable and practical approach. In addition, selecting a prime contractor from among the current contractors, as opposed to an open competition, could accomplish all of the objectives in a less disruptive and more expeditious manner, realizing potential cost reductions earlier.

Prime Contractor Concept

The basic feature of this new program structure separates development from operations and ultimately has most of the NASA-to-contractor interface at the program office level. Most of the operations will be the responsibility of the prime contractor with minimal NASA involvement and interface.

Current hardware and software development would continue to be a NASA function with future developmental modifications considered and evaluated to improve operations, provide additional capabilities as needed, or test and develop new technologies to be integrated into the program. The deputy program manager will utilize center resources, including small project offices and center Engineering and Development, to perform and manage the bloc updates to the shuttle. As NASA completes the currently planned developmental modifications to increase shuttle performance, further change must be minimized. At some future point, it is envisioned that NASA might even be phased out of shuttle development and any further modifications, if required, would then be identified and implemented by the prime contractor.

To facilitate an understanding of the effects of this option, the review team developed the following conceptual diagram showing what this organization might look like after implementation. This diagram is useful in understanding the concept, but is not intended to provide definitive detail. The review team believes that the details of the organizational structure should be left to NASA.



Space Shuttle Program Conceptual

A downsized and centralized NASA program office and a contractor program office must be given the proper authority and top-level NASA support for this structure to be successful. Both program managers will need to be advocates of this approach and have experience in program management. The NASA Program Manager must be empowered with budget, procurement, and decision-making authority and focus on approving reductions in operational requirements, developing regulations, and monitoring modifications to the vehicle hardware and software. The contractor Program Manager should report to the Chief Executive Officer and will focus on program operations and flight hardware production. The associated support staffs must be knowledgeable of space shuttle operations and multi-talented to facilitate changes which improve efficiency while maintaining safe and reliable missions.

The operations and production branches were primarily viewed as contractor functions. Flight production comprises the manufacturing of the hardware elements that make up the Shuttle vehicle. Program operations were defined as the activities associated with the vehicle and payload preparation, launch operations, mission operations, and landing operations. The flight production organization would provide the orbiter, external tanks, Solid Rocket Motor/Solid Rocket Booster (SRM/SRB), and Space Shuttle Main Engine (SSME) to the Program Operations organization for processing. Vehicle and payload processing necessary to deliver an integrated vehicle to the pad will be performed under the Program Operations organization. The logistics and sustaining engineering functions reside within Program Operations as well.

The production branch of the organization would supply flight hardware to the operation branch for launch processing. This interface must be contractually structured to allow the prime contractor to implement efficiencies in processing the hardware while precluding the unnecessary stacking of fees. The SSME will require special consideration in the production branch due to its criticality and continued developmental nature. NASA involvement in the SSME project will probably be necessary for a period of time until modifications are implemented that make it more reusable and operational. It is also recognized that expertise may need to be enhanced within the contractor organization prior to NASA withdrawing from the SSME project.

This concept calls for minimal NASA involvement below the program office level on the operations side. However, it is recognized that, at least initially, maintaining some key NASA functions critical to the future of the agency may be appropriate. As a result, mission and crew operations are viewed as NASA institutional capabilities, supporting multiple programs. Maintaining these capabilities within NASA is important for the development of expertise, experience and leadership for future NASA programs. Support to these institutional functions in the areas of flight software, facilities support, flight design, mission products, and training will be provided by the contractor. Similarly, it may be beneficial for NASA to retain some key launch operations functions as well. In establishing NASA functions on the operations side, however, it must be recognized that a key element in reducing overall cost is severely limiting the number of NASA-to-contractor interfaces.

Conditions Required to Pursue Goals Within New Management Structure

A number of conditions will be required to ensure the pursuit of cost-effective operations. They can be grouped into the areas of minimizing vehicle modifications; consolidating, reducing, and streamlining NASA oversight and involvement; streamlining payload processing; and establishing proper contract incentives and flexibility.

Minimize Vehicle Modifications

Recommendation 3: Minimize vehicle modifications. Freeze the current vehicle hardware and software configuration. Implement future modifications using a bloc update concept. These bloc updates should be justified and only made to improve safety, reduce operating costs, make the vehicle more reusable, or test new technologies.

The continuous hardware and software modifications typical of a developmental program are costly to implement. Changes permeate the entire program including vehicle checkout and testing, operational procedures, and crew training. Associated facility changes, including processing facilities and simulators, to support configuration updates tend to be costly. Freezing the current vehicle configuration, hardware and software, will stabilize the program and allow reductions in cost. Vehicle testing and turnaround requirements will diminish, facility and simulator configurations will stabilize, and few updates to crew procedures and training will be required. This frozen configuration could be labeled the bloc I configuration, and all associated operations would stabilize with additional cost efficiencies realized.

Future changes should be minimized and concentrate on making the vehicle more reusable and operational. A goal to fly the vehicle some number of times (for example, five) with minimal testing and checkout should be established and pursued. A budget for operational improvements should be established with changes implemented through the bloc update concept. Modifications to further increase payload performance should be carefully scrutinized and accomplished only when absolutely required. It is important to maintain this development activity separate from the operations, allowing the proper focus on effective and efficient operations, and delivering these future changes as bloc updates. This change in culture must be adhered to in order to achieve the goals prescribed.

Recommendation 4: Initiate a requirements review, top level down, with the goal of significantly reducing requirements based on operations experience. This type of review could significantly reduce vehicle turnaround and checkout requirements based upon hardware reliability, criticality, and redundancy.

The Shuttle Program is burdened with requirements typical of a developmental vehicle. As changes to the hardware and software configuration are minimized and the vehicle is transitioned to an operational vehicle, an adjustment in the requirements, taking advantage of acquired operational experience, is appropriate. The vehicle was designed with a significant amount of redundancy which could be utilized not only for safety, but also for operational flexibility. With an unchanging vehicle configuration, the ability to reduce vehicle turnaround and checkout requirements is further enhanced. Most anomalies could be handled in a return-to-print fashion. Overall operations will become more routine and be more conducive to greater contractor responsibility. Such a stable configuration will help to ensure continued safe operation during further transition.

Recommendation 5: Ensure future performance upgrades to support International Space Station Alpha (ISSA) or other payloads are established through a systems engineering process to determine the most advantageous and cost-effective approach.

A large number of performance upgrades are in work in the Shuttle Program resulting from payload lift requirements levied by the ISSA. These performance upgrades, which include modifications to the SRB, External Tank, and SSME, have a goal of obtaining approximately 13,000 lb. of additional performance margin and result in the certification of 5 different vehicle configurations over the next 3 years.

The review committee is especially concerned with the modifications to reduce the weight of the SRB by approximately 12,000 lb. to obtain 1200 lb. additional performance. Additionally, the committee is concerned with the Super Light Weight Tank (SLWT) and SSME improvements. Specifically, the new alloy, aluminum-lithium, being used in the SLWT to reduce its weight by 8000 lb. has the potential for problems during development and manufacturing. In addition, the committee expressed concern over the potential of utilizing the SSME improvements for increased thrust capability instead of increased operational margin. Given the criticality and magnitude of changes to the shuttle elements involved, these modifications were met with concern by the review team. In the future, all other alternatives should be pursued prior to changes of this impact and magnitude. This would include, in the case of the ISSA performance upgrades, to evaluate alternative options, such as adjusting packaging and assembly, modifying payload support equipment, reducing the number of crew members, and lowering orbit inclination.

Consolidation and Reduction of NASA Involvement and Oversight

Recommendation 6: Reduce NASA involvement and oversight in the operation of the space shuttle, transferring responsibility of daily operations to the contractor. Space Shuttle Program and Project elements should be consolidated and reduced with NASA-contractor interfaces minimized.

With the transition to an operational program and a more stable vehicle hardware and software configuration, the need for extensive NASA involvement in operations would no longer be required. As the vehicle configuration becomes increasingly more stable and operations streamlined, increasing reliance can be placed on the contractor. NASA should then remove itself from day-to-day operations, allowing the prime contractor to meet the requirements in the most efficient manner.

Also, it follows that NASA Space Shuttle Program and Project elements can be consolidated and reduced. NASA personnel can be transferred to center/line organizations to maintain and utilize their expertise across NASA programs. NASA involvement in the Shuttle Program can be concentrated in developing and integrating the bloc updates, developing the overall operational requirements, and monitoring and evaluating contractor performance. Consolidation of the NASA elements will enable corresponding consolidation of contractor elements, minimize NASA-contractor interfaces, and reduce operating costs.

Recommendation 7: Restructure and reduce the overall SR&QA element.

A large and complex SR&QA element does not necessarily insure the total safety of the shuttle. Indeed, such numerous layers of checks and balances tend to dilute responsibility and generate unnecessary work. Spaceflight remains an inherently risky venture; yet these risks can be managed effectively. When operating a stable and proven vehicle configuration with associated reduced turnaround and testing procedures, the need for an over-abundance of NASA oversight in the SR&QA area is greatly diminished.

Restructuring SR&QA to minimize parallelism and delegate greater responsibility to the contractor will help to establish clear lines of responsibility with only the necessary checks and balances in place. While the Challenger accident was a terrible tragedy, it is not justification to ignore the total space shuttle flight experience nor conclude that the program cannot be made more productive and less costly to operate while still maintaining the necessary checks and balances of a safe program. Restructuring and streamlining the SR&QA element presents a tremendous challenge to NASA and its contractors, but must occur if significant progress in cost reduction is to be achieved.

Payload Processing

Recommendation 8: Streamline Payload processing and integration, minimizing costs and reducing the length of time required to integrate a payload aboard the space shuttle.

The design and execution of space shuttle mission objectives remains successful and the time required to process and integrate payloads has been reduced in the last several years; yet the payload integration template remains complex and still requires payload assignment well over a year prior to flight. Payload and cargo integration was found to be a long, tedious and complex operation involving many organizations. Consolidation of the organizations with clearly defined responsibilities will be required to simplify this operation.

At the root of this complex operation exists the basic philosophy of compliance versus one of advocacy. The organization should continuously look for creative ways to reduce the requirements levied on the customer and simplify the overall integration template. Alternative standards and methods for integration need to be pursued. Payload design guidelines should be provided to potential customers that reduce testing and analysis. Until the payload processing organization is provided the motivation to become an advocate for payload integration, the system will remain one of compliance.

Contract and Related Conditions

Recommendation 9: Structure operational contracts to provide real incentive to accomplish safe and successful missions.

The contractor must be allowed to make a profit with contracts structured to provide incentives to reduce costs and at the same time maintain safe and successful flight operations. This would include long-term savings sharing and appropriate rewards and penalties based upon schedule and in-flight performance. Additionally, the prime contractor's financial arrangements with subcontractors must be structured so that they preclude costly fee stacking including general and administrative costs and material processing control costs.

Recommendation 10: NASA must pursue innovative approaches in assembling and supporting the prime contractor team. This could include the hiring of NASA civil servants by the contractor and initially allowing the contractor to use specific government capabilities.

It is recognized that the contractor(s) may not currently possess all of the necessary personnel with the talent, expertise, or experience to assume responsibility for daily shuttle operations. One resource for obtaining those personnel is within NASA. Therefore, it is vital that NASA and the contractors pursue the necessary steps to not only allow, but encourage, the transfer of personnel to assume key roles and responsibilities in the proposed new contractor organization. Similarly, it may be advantageous to allow the prime and/or its subcontractors to initially utilize, by some means of understanding , specific government organizational elements with critical skills that cannot be obtained elsewhere (e.g. a cooperative agreement). Integration and downsizing of the NASA organization would occur gradually over time as the contractor organization developed its own in-house skill base or the task was completed or phased out.

Likewise, it will be necessary to realize that, in some cases, specific expertise exists only in particular contractors. For example, in the area of orbiter obsolescence and sustaining engineering a specific expertise will be required to assure the continued operation of the vehicle. Attention to these specialized skills will be required as the NASA-contractor team is constructed.

Future Considerations

Recommendation 11: All artificial barriers which preclude the shuttle from carrying certain types of payloads should be removed. This would require policy and statutory changes which currently discourage the shuttle from carrying commercial payloads.

It is possible that a significant reduction in space shuttle operations costs may stimulate the space economy. In order to maximize the potential economic base for the space shuttle, artificial barriers including policy (e.g. National Space Policy) and statutory requirements, limiting the types of payloads which may be carried should be removed. This will maximize the possibility of generating revenues in the future.

Recommendation 12: As the prime contractor management approach develops and matures, NASA should consider further industry involvement and progression toward the privatization of the space shuttle.

Increasing industry involvement in the operation of the space shuttle can be viewed as one of the first steps toward the commercialization of space flight. Assuming industry were willing to invest capital and accept financial risks of selling flight services, privatization of the shuttle may become feasible. The proposed consolidation of operations under a single prime contractor offers an opportunity to test this concept. Future launch systems could be envisioned as following this pattern and, thereby, encourage capital investment by the space entrepreneurs of the next century.

NASA promotion and encouragement of progression toward greater industry participation is both appropriate and vital for it to succeed. In the space shuttle, NASA possesses the only reusable vehicle capable of flying humans to and from space. Other than paper designs, no other vehicle approaches the capability, reliability, or proven success of the space shuttle. The future challenge of the Space Shuttle Program is to progress to operational status and then determine the economic viability and contribution capacity of its space technology. This is a necessary step in the progression to commercial space flight and will allow NASA and private industry to make reasonable comparisons in economy between the shuttle and proposed reusable launch vehicles in the future.

TRANSITION PLAN

The review team recognizes that the transition from the current Space Shuttle Program structure to that recommended could be somewhat disruptive to current operations, could cause concern among the NASA and contractor communities, and cannot be completed overnight. However, completing the transition as soon as possible will be in the best interest of the Shuttle Program and the agency. Further, the team determined that they did not possess the detailed knowledge or time required to develop a step-by-step transition plan for NASA. Instead, the team outlined an approach and recognized that the detailed transition plan must be developed by the implementing team.

The transition was envisioned to occur in three major steps:

(1) Selection of a prime contractor.
(2) Implementation of the organizational structure within NASA and the prime contractor.
(3) Transfer of activities and functions to the prime and sub-contractors.

The details of the transition should be developed by the agency and its contractors to minimize the perturbations to ongoing operations. Above all, the team acknowledged that the key to a successful transition is staunch support from senior-level NASA management and the empowerment of NASA and contractor shuttle managers.

A competition based on a NASA Request for Proposal would result in lost savings during the time required to conduct such a competition and possibly unacceptable disruption to the NASA flight schedule. To avoid these difficulties, a prime contractor could be selected by the agency from the present contractors.

NASA and the prime contractor would begin implementation of the new program structure by establishing the NASA Shuttle Program Office along with the prime contractor Program Office. Concurrently, the agency would begin the development of the basic scope for the prime contract, as well as the definition of the responsibility, accountability, budget and procurement authority each Program Office will hold. Activities and tasks would transition in a step-by-step process from the NASA Program Office to the contractor Program Office. As these functions and personnel are transitioned, all offices established to manage this activity would be dissolved. NASA would continue its management of the current performance enhancement development activities allowing the contractor to focus on the mission and launch operations. This process would allow for a proper transition of the industry team and a transition of the NASA personnel to other programs and projects at the appropriate time.

During this time, serious attention should also be given to consolidation and integration of the multitude of support contracts that exist at Johnson, Kennedy, and Marshall. Reliance on many government facilities for products and processing will necessitate the negotiation of memorandums of agreement or other similar arrangements.

Those functions that are to remain institutional and which will be performed by NASA must be identified by the agency. Functions such as mission operations and flight crew operations were recognized by the team as being in this category, but others may exist in the area of launch operations.

The specific timing of transitioning the day-to-day operation from NASA to the contractor will of course vary because of many factors. As an example, it is recognized that the SSME will remain the most critical of all the hardware pieces for a considerable time. The continued development of pumps, engine structure, throat modifications, etc. will require NASA to remain involved with the engine contractor. Also, the team realizes that much of the engine knowledge resides at Marshall and should be given special consideration.

To make this transition as expeditiously as possible, a strong commitment to the approach from NASA and the present contractors is required. Opposition to the changes proposed in this report will come from within and outside NASA, but these must be overcome if the goals of this report are to be met.

Finally, to ensure the rapid progress of the transition, the administrator may choose to establish an oversight panel to periodically monitor the progress of the agency and contractor base in moving to the proposed Shuttle Program structure.

APPENDIX A - SUMMARY OF RECOMMENDATIONS

Recommendation 1: Establish a more balanced set of goals for the Shuttle Program, with a greater emphasis on reducing operational costs and making payload integration more user friendly. The following goals provide a better balance between operations and safety, and address the overall NASA objective of reducing the cost of access to space.

(1) Perform safe space shuttle operations while accomplishing mission objectives.
(2) Reduce the cost of space shuttle operations.
(3) Provide user-friendly payload integration.

Recommendation 2: Modify the program's management structure, separating development from operations and relinquish the majority of the operational responsibility to a prime contractor.

Recommendation 3: Minimize vehicle modifications. Freeze the current vehicle hardware and software configuration. Implement future modifications using a bloc update concept. These bloc updates should be justified and only made to improve safety, reduce operating costs, make the vehicle more reusable, or test new technologies.

Recommendation 4: Initiate a requirements review, top level down, with the goal of significantly reducing requirements based on operations experience. This type of review could significantly reduce vehicle turnaround and checkout requirements based upon hardware reliability, criticality, and redundancy.

Recommendation 5: Ensure future performance upgrades to support International Space Station Alpha (ISSA) or other payloads are established through a systems engineering process to determine the most advantageous and cost-effective approach.

Recommendation 6: Reduce NASA involvement and oversight in the operation of the space shuttle, transferring responsibility of daily operations to the contractor. Space Shuttle Program and Project elements should be consolidated and reduced with NASA-contractor interfaces minimized

Recommendation 7: Restructure and reduce the overall SR&QA element.

Recommendation 8: Streamline Payload processing and integration, minimizing costs and reducing the length of time required to integrate a payload aboard the space shuttle.

Recommendation 9: Structure operational contracts to provide real incentive to accomplish safe and successful missions.

Recommendation 10: NASA must pursue innovative approaches in assembling and supporting the prime contractor team. This could include the hiring of NASA civil servants by the contractor and initially allowing the contractor to use specific government capabilities.

Recommendation 11: All artificial barriers which preclude the shuttle from carrying certain types of payloads should be removed. This would require policy and statutory changes which currently discourage the shuttle from carrying commercial payloads.

Recommendation 12: As the prime contractor management approach develops and matures, NASA should consider further industry involvement and progression toward the privatization of the space shuttle.

APPENDIX B - TEAM ACTIVITIES

Kennedy Space Center Review

The team convened at KSC on December 5 and 6, 1994, to review the KSC civil servant and contractor organizations which support ground operations, vehicle, and payload processing for the Shuttle Program. The reviews were held in the KSC Headquarters Building, Center Director's Conference Room.

<u>December 5, 1994</u>

Shuttle Management and Operations	Jay F. Honeycutt, Director Robert B. Sieck, Dep. Director
Space Shuttle Program Office Space	Brewster H. Shaw, Director, Shuttle Operations David C. Schultz, Management Integration James B. Costello, Business
Manager	
Shuttle Logistics Project Management	Roger D. Enlow, Manager
Installation Management and Operations	Marvin L. Jones, Director
Payload Management and Operations	John T. Conway, Director

<u>December 6, 1994</u>

Shuttle Processing Contract	Gerry T. Oppliger, President, Lockheed Space Operations Company
Base Operations Contract	J. R. Dubay, Project Manager, EG&G Florida, Inc.
Orbiter Logistics Operations Contract Systems	Lee D. Solid, VP-GM, Florida Operations, Rockwell Space Division

Payload Ground Operations Contract	George Faenza, VP-GM McDonnell Douglas Space & Defense Systems, KSC Division

Marshall Space Flight Center Review

The team convened at JSC on December 14, 1994, to review the MSFC civil servant and contractor organizations which support the Main Engine, External Tank, Solid Rocket Motor and Solid Rocket Booster Projects for the Shuttle Program. The review was held in Building 1, conference room 966.

December 14, 1994

MSFC Overview	Alex A. McCool, Manager, Space Shuttle Projects Office
Space Shuttle Main Engine Project	Gerry C. Ladner, Manager
Solid Rocket Booster Project	Cary H. Rutland, Manager
Redesigned Solid Rocket Motor Project	V. Keith Henson, Manager
External Tank Project	Parker V. Counts, Manager
SSME Prime Contractor Manager,	Al L. Hallden, VP-Program SSME Program, Rocketdyne
SRB Prime Contractor	Donald K. Reed, Senior Vice President, SRB Programs, USBI
Co.	
RSRM Prime Contractor	Joe A. Lombardo, VP & GM Thiokol Space Operations,
Thiokol	
ET Contractor	Jon A. Dutton, VP-ET Project, Manned Space Systems, Martin Marietta

Johnson Space Center Review

The team convened at JSC on December 15 and 16, 1994, to review the JSC civil servant and contractor organizations which support the Orbiter and EVA Projects, sustaining engineering, and mission operations for the Shuttle Program. The reviews were held in Building 1, conference room 966.

<u>December 15, 1994</u>

JSC Projects Office	Lawrence S. Bourgeois, Acting Manager
EVA and Crew Equipment Office	Clay E. McCullough, Manager
Orbiter Project Office	Daniel M. Germany, Manager
Space Shuttle Systems and Operations	Lawrence G. Williams, Manager Integration Office
Engineering Directorate	Leonard S. Nicholson, Acting Director
Safety, Reliability and Quality Assurance Office	Charles S. Harlan, Director
Space and Life Sciences Directorate Director	Donald E. Robbins, Acting
Mission Operations Directorate Director	John W. O’Neill, Director Brock R. Stone, Assistant for Operations

JSC Review

<u>December 16, 1994</u>

Rockwell Overview Division	Robert G. Minor, President, Rockwell Space Systems
System and Payload Integration Integration	Marty Cioffoletti, VP-Program Director, Space Systems & Cargo
Orbiter Production Orbiter	Jim Eyman, Vice President, Operations
Space Operations Contract Director, Houston	Harold Draughon, Program STS Operations Glynn S. Lunney, VP-GM Operations
Space Shuttle Avionics Software Coordination, Comm.Operation	Ted W. Keller, Project Loral Avionics &
Safety, Reliability, and Quality SRM&QA Assurance Contract	Sam A. Boyd, Director, Operation, Loral
Mission Systems Contract Mission	LeRoy Hall, Vice President, Systems Operation, Loral Space Information Systems
Engineering, Test and Analysis Contract Engineering &	M. M. Miller, VP-PM, Engineering, Test and Analysis Program, Lockheed Sciences Company
Flight Equipment Processing Contract	G. W. Davis, Program Manager, FEPC, Boeing
Flight Crew Systems Development Contract	W. T. Short, President, Johnson Engineering Corp.

Chief Executive Officer Discussions

The team convened at JSC on January 4-6, 1994, to hold discussions with the Chief Executive Officers, or their named representative, of corporations which play a major role in the operations functions for the Space Shuttle Program. Additionally, a summary of the findings of the Functional Workforce Review Team was presented, and a second session with the Shuttle Program Office was held. The meetings were held in Building 1, conference rooms 945 and 966.

<u>January 4, 1994</u>

Rockwell International	Donald R. Beall, Chairman and
Chief	Executive Officer
	Kent M. Black, Executive VP and
	Chief Operating Officer
	Robert G. Minor, President
Rockwell	Space Systems Division
	Glynn S. Lunney, VP-GM
Rockwell	Houston Operations
Lockheed Corporation	Daniel M. Tellep, Chairman of
the	Board and Chief Executive
Officer	
	Robert B. Young, President,
	Lockheed Technology Services
	Group
	Gerry T. Oppliger, President,
	Lockheed Space Operations
	Company
	James C. Adamson, Executive
VP,	Lockheed Engineering and
Sciences	Company
Thiokol Corporation	James R. Wilson, president and
Chief	Executive Officer
	Joseph A. Lombardo, VP-GM,
Space	Operations
Martin Marietta Corporation	Peter B. Teets, President, Martin
	Marietta Space Group

January 5, 1994

McDonnell Douglas Aerospace & Defense Systems	Charles A. Ordahl, Senior VP,
Space	Defense Systems
	George R. Faenza, VP-GM,
Kennedy	Space Center Division
United Technology Corporation	Joseph P. Zimonis, Executive VP
and	GM, USBI Company
	Charles D. Nelson, Director,
	Program Control, SRB Programs
Functional Workforce Review Team Summary	David Mobley, Team Chairman

January 6, 1994

Space Shuttle Program Office	Brewster H. Shaw, Director,
Space	Shuttle Operations
Loral Space Information Systems	Clint H. Denny, President
	A.A. (Sam) Boyd, VP, SR&QA
	Operation
	LeRoy Hall, Vice President,
Mission	Systems Operation

APPENDIX C - SPACE SHUTTLE PROGRAM MAJOR CONTRACTORS

The tables listed in this appendix are intended to identify the major contracts providing support to the Space Shuttle Program. They are not meant to be an exhaustive or complete listing of the all contracts within the Shuttle Program, but are designed to convey the magnitude of several major contracts, as well as the expanse of the subcontractor domain. All information was taken from material contained in either the NASA or contractor briefings to the review team.

Kennedy Space Center

Contract/Function	Prime	$M	Contractor EP	CS FTE	Team Members/ Subcontractors
Shuttle Processing Contract	Lockheed	533	6309	613*	Grumman, Thiokol, Johnson Controls; TTS, Rocketdyne, Bionetics, Wiltech, USI, EG&G
Orbiter Logistics	Rockwell	199	1340		No major subs, suppliers only
Base Operations	EG&G	38	520	164	Precision Fabrication, Atlantic Technical Services, Sherikon, Wiltech, Unified Services Associates
**Payload Ground Operations Contract	McDonnell Douglas	115	977	350	No major subs

*Includes Launch Operations civil servants that work Orbiter Logistics contract as well.

**PGOC is not funded through the Shuttle Program, all funding shown is through Codes M (utilization), X, or U.

Marshall Space Flight Center

Contract/Function	Prime	$M	Contractor EP	CS FTE	Team Members/ Subcontractors
SSME	Rocketdyne P&W	287 85	2018 334	205	Honeywell, Hydraulic Research, Pratt & Whitney
SRB	USBI	162	1024	115	Sundstrand, Moog, Allied-Signal
RSRM	Thiokol	416	2589	100	North American Rayon, KM, Wecco, Ladish
External Tank	Martin Marietta	370	2635	134	Kaiser Aluminum, Reynolds Metals, GE, Grumman

Johnson Space Center

Contract/Function	Prime	$M	Contractor EP	CS FTE	Team Members/ Subcontractors
Orbiter Production, Ops/Launch Support, Spares (Orbiter Project)	Rockwell	288	1803	292	Honeywell, Hamilton Standard, Sundstrand, Ball Brothers, IFC, Loral (of 20 Directed Subs)
Systems & Ops Integration (Program Office)	Rockwell	151	699	118	No major subs
Space Operations Contract (Mission Operations)	Rockwell	264	2214	371	Unisys, Hernandez Engineering, Allied-Signal, Barrios, SAIC
Flight Software Dev SR&QA Mission Support Contract (MCC Dev)	Loral	35 20 21	280 251 170	 114 43	Syscom Development; Ebasco, GHG; Unisys, Booz-Allen, Cimarron Software, DEC, IBM
Engineering, Test and Analysis Contract	Lockheed	39	490	380*	McDonnell Douglas, Oceaneering, TRW, GB Tech, Hernandez Engr., Syscom Development
Medical Sciences Flight Crew Support	Krug, Kelsey Seybold Johnson Engineering	4 1 12	39 13 120	12 0 29	No major subs
EVA RMS Flight Equipment Processing Contract	Ham Std SPAR Boeing	25 13 35	119 60 333	26	ILC Industries, Airlock, Inc., Caarleton Technologies; BEI Motion Systems, DEVTEC, Novatronics; Ham Std, ILC, David Clark, Pacific Scientific, Martin Marietta

*Includes Engineering Directorate civil servants that work the Flight Software Development contract as well.

APPENDIX D - TECHNICAL ADVISORS AND SUPPORT STAFF

Jay F. Honeycutt,
Director, Shuttle Management and Operations, Kennedy Space Center.

David C. Leestma,
Director, Flight Crew Operations, Johnson Space Center.

Bill Mackey,
Independant Consultant; former Chairman of the Board, Lifemark Corporation

John W. O'Neill,
Director, Mission Operations, Johnson Space Center.

George F. Page,
Independant Consultant; former Deputy Center Director and Shuttle Operations Director, Kennedy Space Center

Cary H. Rutland,
Manager, SRB Project, Marshall Space Flight Center.

Robert B. Sieck,
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