

An Evaluation of the U.S. Space Shuttle Program

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Executive Summary

The Space Shuttle, once called “the most complex machine ever built,” is a technological marvel that has helped put the United States at the forefront of space research and exploration for decades. Still, the Space Shuttle program faces intense scrutiny from evaluators. Using the Program Assessment and Rating Tool (PART), the Bush Administration has concluded that the program’s performance is merely “adequate,” and the program should be terminated. Other evaluators, most notably the Columbia Accident Investigation Board and the Return to Flight Task Group, believe the Shuttle program has made great strides towards improvement. President Bush has cut funding for the Space Shuttle by almost 20 percent in two years, although the PART evaluation does not necessarily support this action.

About the U.S. Space Shuttle Program

In 1958, the year after the Soviet Union launched Earth’s first artificial satellite, President Eisenhower signed the National Aeronautics and Space Act. This law created a single federal space agency – NASA – and set out the country’s goals for space exploration. Among others, these goals included the expansion of human knowledge, the improvement of techniques for space flight and travel, the advancement of international cooperation, and the preservation of America’s role as a leader in space. Despite the Act’s declaration of policy that “activities in space should be devoted to peaceful purposes for the benefit of all mankind,” the law also directed NASA to share discoveries of military value with the Department of Defense.¹

NASA had a relatively successful early career – in fact to some observers, its success was judged entirely on beating the Soviet Union to a manned moon landing in 1969. However, the

continued use of expendable spacecraft became extremely expensive, both in terms of time and money. NASA concluded that starting each mission from scratch was like “throwing away a railroad locomotive after every train trip.”²

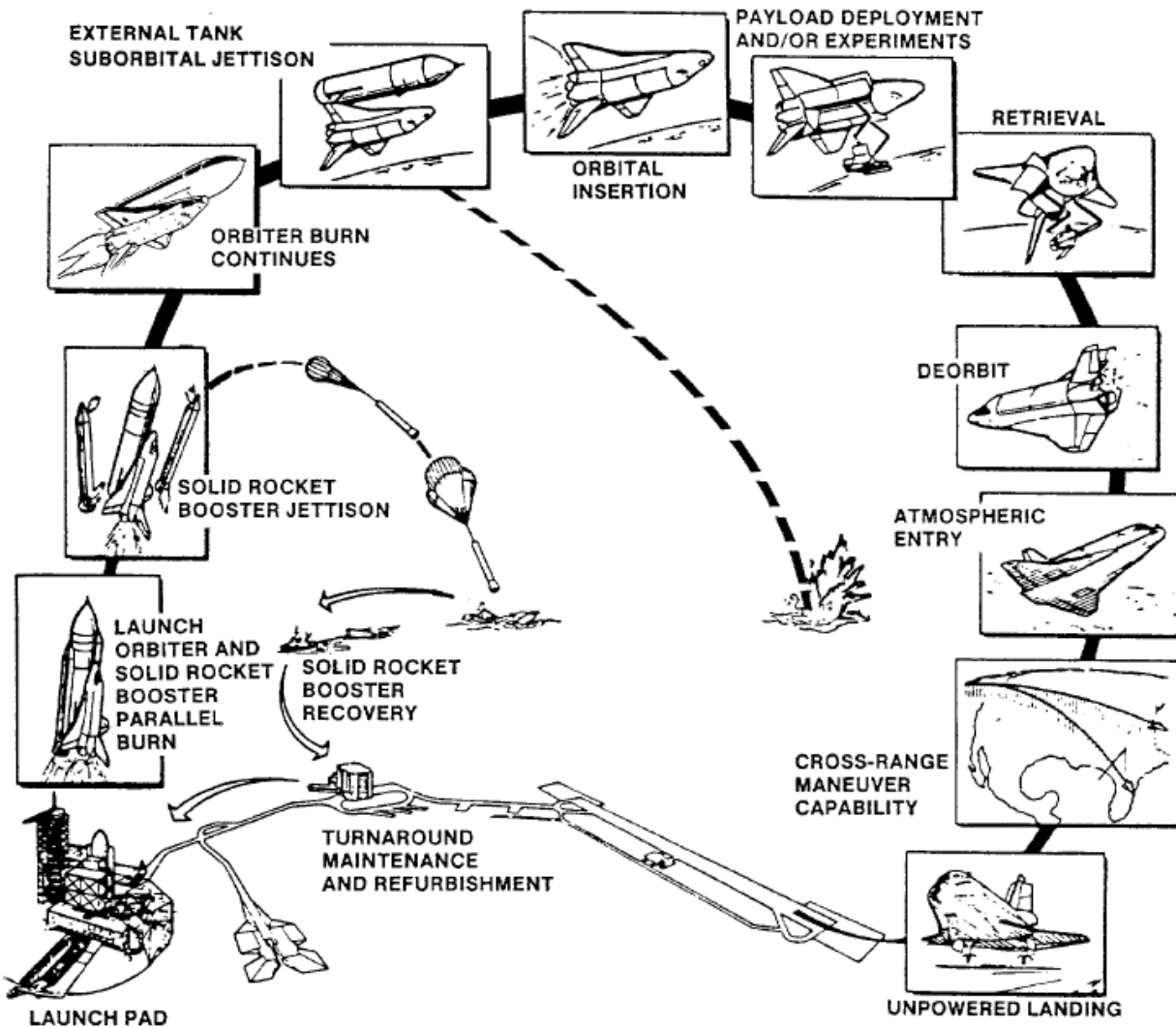
In the 1970’s, NASA began the Space Shuttle program to create the first reusable spacecraft, and the first spacecraft able to deliver cargo to space and retrieve later for return to Earth. In fall 1977, the prototype “Space Transportation System” (STS) *Enterprise* made five test flights, each lasting just five minutes or less. The first production vehicle, *Columbia*, roared into space in 1981. NASA calls the Space Shuttle “the most complex machine ever built.”³ Indeed, *Columbia* and her sister ships *Atlantis*, *Challenger*, *Discovery*, and *Endeavour*, have achieved significant accomplishments, carrying more than 600 humans and three million pounds of cargo into space.⁴

The heart of the Space Shuttle is the Orbiter, a vehicle of approximately the size, weight, and form of a commercial airliner. Mounted to the Orbiter are a large External Tank and two smaller Solid Rocket Boosters. The Solid Rocket Boosters provide extra thrust during liftoff, and separate from the Orbiter after about two minutes. They fall into the ocean, and are recovered for future use. The External Tank is filled with liquid hydrogen and oxygen, which are used by the Orbiter’s engines to propel the entire system towards space for approximately eight minutes. When the engines finish firing, the External Tank falls away from the Orbiter and disintegrates in the atmosphere.

Shuttle missions usually last five to seven days, although they have lasted up to two weeks. When the mission is complete, the Orbiter uses its on-board engines to maneuver back into Earth’s atmosphere. It then glides to an unpowered landing, much like a conventional

airplane, on a runway. Barring unusual circumstances, the Shuttle takes off from and lands at NASA's Kennedy Space Center at Cape Canaveral, Florida.

Figure 1: Typical Phases of a Space Shuttle Mission⁵



There have been tragic setbacks for the Space Shuttle program. *Challenger* exploded on liftoff in 1986, and *Columbia* exploded in 2003 while re-entering Earth's atmosphere on the shuttle program's 113th mission. Each disaster claimed the lives of seven astronauts. Shuttle missions, which during the 1990s had become so routine as to attract little media or public

attention, have now come under intense scrutiny. There are concerns, both within NASA and beyond, over the program's cost, safety, effectiveness, and long-term viability.

Each accident also brings with it a renewed emphasis on the unique single-focus nature of this program, and the enormous stakes. After the *Challenger* disaster, one evaluator observed that the program was cast in a new light because the Space Shuttle “was a manned system, it was the only available one, and it was the backbone of the U.S. space program.”⁶ On the other hand, in the words of another evaluator, “the Space Shuttle is the most reliable human spacecraft ever built; reports of it being inherently unsafe do not fully take into account the physics or technology involved in boosting a payload off the surface of the Earth.”⁷

Evaluation Challenges

The primary purpose of the Space Shuttle today is to assist in the construction and maintenance of the International Space Station. However, an evaluator of the program must keep in mind that some potential improvements to the program for this mission – or for the Shuttle's inherent safety and efficiency – may not be reasonable given President Bush's announcement in 2004 that NASA should return to the moon and eventually visit Mars. This announcement included the order that the Space Shuttle be retired by 2010.⁸

NASA has 15 additional missions planned, through 2010, before the Space Shuttle program – at least as represented by *Atlantis*, *Discovery*, and *Endeavour* – is terminated. The successor to today's Space Shuttles is *Orion*, which is scheduled to be in use by 2014. NASA also plans to use *Orion* by 2020 for the first visit by humans to the moon since 1972.⁹

Another evaluation challenge is that the Space Shuttle program is not likely to ever perform perfectly, and this is actually part of its purpose. An evaluator points out that “the Space

Shuttle is not now, has never been, nor will ever be, an ‘operational’ vehicle. Instead, it is a developmental vehicle performing a dangerous mission in a known high-risk environment.”¹⁰

Another evaluator put it as succinctly as possible: “Building rockets is hard.”¹¹

Of course, many federal programs are charged with difficult tasks, and the Space Shuttle program should be held to as high a standard as any considering the human lives and taxpayer dollars at stake. It is still important to note, however, that this particular program is already beating the odds by its very continued existence, and for more than 20 years it has reaped huge benefits for the nation.

The Program Assessment Rating Tool (PART)

The Program Assessment Rating Tool (PART) is a system used by the U.S. Office of Management and Budget (OMB) to rate the performance of federal programs on an annual basis. To date, approximately 80 percent of federal programs have been evaluated under PART.¹² PART consists mainly of a questionnaire with 25 questions about program purpose and design, strategic planning, program management, and program results and accountability. PART also includes information on the program’s budget, performance measures, and improvement plans.

Each question on PART receives a numeric score, and the total score band¹³ determines the program’s overall rating. Under PART, a program will be classified as either “Performing” or “Not Performing.” Programs that are “Performing” will receive one of three ratings. “Effective” (three-star) programs “set ambitious goals, achieve results, are well-managed and improve efficiency.” So far, 15 percent of programs have received this rating. “Moderately Effective” (two-star) programs have also set ambitious goals and are well-managed, but “likely need to improve their efficiency or address other problems in the programs’ design or

management in order to achieve better results.” Twenty-nine percent of programs have received this rating. An “Adequate” (one-star) program “needs to set more ambitious goals, achieve better results, improve accountability or strengthen its management practices.”¹⁴ Twenty-eight percent of programs have received this rating.

Programs that are “Not Performing” will be rated in one of two ways. Four percent of programs have been rated “Ineffective” because they “have been unable to achieve results due to a lack of clarity regarding the program's purpose or goals, poor management, or some other significant weakness.” OMB warns that “Ineffective” programs “are not using your tax dollars effectively.” A rating of “Results Not Demonstrated” means that a program “has not been able to develop acceptable performance goals or collect data to determine whether it is performing.” Twenty-four percent of programs have received this rating.

PART Evaluation of the Space Shuttle Program

Under PART, OMB has determined that the performance of the national Space Shuttle program is “adequate.”¹⁵ This is the lowest rating a program can receive and still be considered to be “Performing.” Among the major factors leading towards this low rating, OMB included the three-year delay in returning to space flight since the *Columbia* disaster, and the cost overruns associated with the program’s resumption.

Program Purpose and Design

The Space Shuttle program received full credit under the Program Purpose and Design section of PART questions.¹⁶ OMB found that the program’s purpose was clear, in that the mission of the Space Shuttle is well-defined, and the Space Shuttle actually does what its mission

describes. The program addresses a specific problem, interest, or need, because national space policy directs the United States to participate in building the International Space Station, and the Space Shuttle is currently the only way for NASA to do that. The program is not redundant or duplicative, for the same reason as above and because the Space Shuttle will be retired soon to make way for a more modern space vehicle. The program is free of major design flaws, particularly since the thorough review it received following the *Columbia* disaster in 2003. The program design effectively targets intended beneficiaries, and NASA has cancelled planned program upgrades that were determined not to do so.

Strategic Planning

The Space Shuttle program received full credit for eight of nine questions in the Strategic Planning section.¹⁷ The program has a limited number of specific, meaningful, outcome-oriented, purpose-driven, long-term performance measures, and these measures have ambitious targets and timeframes. OMB calls NASA's goals in this area "challenging, realistic, and quantifiable." In addition, NASA has set five annual measures that can demonstrate regular progress toward these goals. However, OMB found that not all of these annual measures have ambitious targets. Specifically, "the goal for the average number of in-flight anomalies is not ambitious, based on past experience," and the program's efficiency measure had not yet been completed. This meant that the program received no credit on one question.

For the remaining questions in this section, OMB gave full credit, finding that partners such as contractors and other agencies are committed to the program and closely monitored, independent evaluations are performed (as will be discussed in a later section of this report), budget requests are goal-oriented and transparent, strategic planning deficiencies are corrected

when identified, and NASA has conducted a meaningful analysis of potential alternatives to the Space Shuttle (to the point that the program is being retired and replaced with such an alternative).

Program Management

The Space Shuttle program received credit for only half of the questions under the Program Management section of PART.¹⁸ OMB found that partners are held accountable for cost and performance results, funds are allocated and spent as intended, the program collaborates effectively, and NASA has taken meaningful steps to address management deficiencies.

However, NASA does not regularly collect information that can be used to manage the Space Shuttle program and improve performance, although progress is being made in this area. The program also lacks specific procedures to measure efficiencies in program execution, because it lacks the efficiency measures in the first place. Independent audits and Government Accountability Office (GAO) reports of NASA's financial management practices found several material weaknesses that had not been corrected from previous findings. Finally, the Space Shuttle program's timelines and schedules for deliverables and mission launches were found to be unrealistic. As a result of these problems, the program received no credit for four of eight questions in this section.

Program Results and Accountability

The Space Shuttle program did not receive full credit for any of the five applicable questions under the Program Results and Accountability section.¹⁹ OMB gave partial credit for the Space Shuttle program and its partners achieving progress towards its performance goals as

indicated by independent evaluations, and for achieving results on-time and on-budget. The program received no credit for the question dealing with increasing efficiencies and cost effectiveness. OMB explained that this is because, in the wake of the *Columbia* disaster, NASA focused on reducing risk rather than increasing efficiency or cost savings at the possible expense of safety. All told, the Space Shuttle program received only 33 percent of credit under this section.

Performance Measures

OMB cited several annual and long-term performance measures for the Space Shuttle program.²⁰ The Space Shuttle delivered 100 percent of its operating time to its program mission, in excess of the 90 percent goal for this measure. The program has had no major mishaps (accident resulting in death, hospitalization or permanent disability of three or more people, or more than \$250,000 in property damage) since resuming flight after *Columbia*, but had two such incidents in 2003. The program's record for recent mission success has been inconsistent, ranging from 65 percent in the year of the *Columbia* accident (2003) to 0 percent in 2004 when no missions were launched, to 100 percent in 2005 after flights resumed.

Two additional targets are still being determined: a reduction in program costs and facilities through the time the Shuttle is retired, and the date of the last Shuttle flight (currently 2010).

Program Improvement Plans

OMB found that NASA has five major plans in place to improve the Space Shuttle program.²¹ NASA returned the Space Shuttle to flight after the *Columbia* disaster, developed

outcome-oriented performance measures for the Shuttle program itself, and developed measures for the transition between NASA focusing on the Shuttle versus focusing on space exploration after the Shuttle is retired. An ongoing plan involves improving NASA's financial management system to comply with federal law and respond to the troubling financial management audits the agencies has received.

The fifth plan to “improve” the Space Shuttle is essentially to terminate the program in 2010, when the Space Shuttle’s role in building the International Space Station is complete. NASA will continue work on the successor space vehicle, and increase its focus on space exploration rather than Shuttle missions.

Other Evaluations

There have been a number of significant evaluations of the Space Shuttle Program over its history, ranging from journal articles to lengthy government and advisory reports. Somewhat unique to this program, however, is that the current PART evaluation – and really all evaluations in the last three years – have been made in the context of the *Columbia* disaster in 2003.

Early that year, after an otherwise successful mission, *Columbia* exploded while re-entering the Earth’s atmosphere. NASA immediately appointed the Columbia Accident Investigation Board (CAIB) to determine what happened and make related recommendations. The immediate physical cause of the disaster was determined to be damage to the Space Shuttle’s wing from foam debris that had separated from the external fuel tank during liftoff. CAIB went further than this conclusion, though, since “[i]t was obvious to the board very early on that there was an underlying problem with leadership, management, and culture at NASA, and specifically within the Space Shuttle Program. Ultimately, the CAIB placed as much weight

on these causal factors as on the more easily understood and correctable physical cause of the accident.”²²

As a result, CAIB became in many respects a general program evaluator for the Space Shuttle, and all previous program evaluations were rendered “of another era” at best, and moot at worst. Since the entire Space Shuttle program revolves around the launch of one vehicle system, all physical, financial, and managerial issues related to the vehicle have an effect on the program’s outcomes. It is unusual for a program to have such a defining moment in its evaluation history, but the *Columbia* disaster, however tragic, provided a much-needed opportunity for comprehensive review and analysis.

CAIB made 29 recommendations for changes to the Space Shuttle Program and to NASA itself, including 15 recommendations that it felt should be implemented before the Space Shuttle returned to flight. “Some of these recommendations were relatively easy, most were straightforward, a few bordered on the impossible, and others were largely overcome by events, particularly the decision by the President to retire the Space Shuttle by 2010.”²³

The Stafford Task Force on International Space Station Operational Readiness appointed a Return to Flight Task Group to review the status of those 15 return-to-flight recommendations. This review was made independently of the NASA administration. The Task Group’s finding began with the overall conclusion that while it is not possible to eliminate all risk from the Space Shuttle, neither is the program inherently unsafe. As of its July 2005 report, the Task Group found that NASA had met or exceeded 12 of the 15 return-to-flight recommendations, and that, while NASA had made great progress towards the remaining three recommendations, they were too challenging to ever be realistically met.²⁴

Most of the recommendations dealt with very specific physical issues concerning various parts of the Space Shuttle system, or with methods to provide photographic or video images of the Shuttle in flight to catch potential problems. Several of the remaining recommendations dealt with management issues.

CAIB was concerned that the program was becoming a slave to promised schedules, and that this trend could jeopardize safety and effectiveness. The Board recognized the legitimate need for schedules, but recommended that they be justified independently of political promises or the separate schedules for completion of the International Space Station. For example, if the Space Shuttle is due to be retired in 2010 and the International Space Station has not been completed by then, the continuation of the Space Shuttle program should be reviewed without regard to other projects. NASA has also embraced improvements to training for Shuttle's mission management teams, and certain changes to the agency's organization structure.

Conclusions

It is very difficult to make a meaningful direct comparison between the PART evaluation of the Space Shuttle program and other evaluations. First, PART is focused largely on program issues that other evaluators would not care to undertake, because the overwhelming emphasis for this particular program has been on whether the program can and should continue to exist after the *Columbia* incident. The PART evaluation somewhat misses this point. The program often gets full credit for essentially being unique; for example, it does not duplicate other programs because there essentially cannot practically be another federal program like it. At the same time, it loses credit when its unique nature is not recognized; for example, even a deadly accident may mean mission failure, but not program failure, when the program is by its nature experimental.

Second, the program must be evaluated in the context of President Bush's political decision to retire the Space Shuttle in 2010. This provides the program with a defense of some deficiencies that would otherwise appear irresponsible, given that it doesn't make sense to institute costly changes that won't last more than a few years. In FY2005, the Space Shuttle program spent \$5 billion. In FY2006, just under \$4.8 billion was allocated for the program's use. For FY2007, the President has request just over \$4 billion – a 20 percent reduction in just two years. Clearly, the President does not want to spend any more new money than necessary on a program he has decided to phase out. Although the PART rating is largely fair, its flaws as applied to the Space Shuttle program mean that it can hardly be relied on to justify slashing the program's budget so significantly. In any event, the logic of relying on PART for budget decisions is circular – funding would then be based on a rating based mostly on the program ending, but the decision to end the program had already been made by the funder. Finally, the PART evaluation seems to miss a crucial question: Will the unmet needs left by the Space Shuttle's retirement be acceptable, given that its replacement is still many years away?

Meanwhile, the CAIB and Return to Flight Task Group evaluations, while often bluntly critical of NASA and the program, heap praise on the agency and program managers for facing up to program flaws in the wake of *Columbia* and making enormous progress towards improvements. Surely, this type of action should result in a higher rating than "Adequate."

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