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Columbia and *Challenger*: Organizational failure at NASA

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A B S T R A C T

The National Aeronautics and Space Administration (NASA)—as the global leader in all areas of spaceflight and space science— is a unique organization in terms of size, mission, constraints, complexity and motivations. NASA's flagship endeavor—human spaceflight—is extremely risky and one of the most complicated tasks undertaken by man. It is well accepted that the tragic destruction of the Space Shuttle *Challenger* on 28 January 1986 was the result of organizational failure. The surprising disintegration of the Space Shuttle *Columbia* in February 2003—nearly 17 years to the day after *Challenger*—was a shocking reminder of how seemingly innocuous details play important roles in risky systems and organizations. NASA as an organization has changed considerably over the 42 years of its existence. If it is serious about minimizing failure and promoting its mission, perhaps the most intense period of organizational change lies in its immediate future. This paper outlines some of the critical features of NASA's organization and organizational change, namely path dependence and "normalization of deviance". Subsequently, it reviews the rationale behind calling the *Challenger* tragedy an organizational failure. Finally, it argues that the recent *Columbia* accident displays characteristics of organizational failure and proposes recommendations for the future.

1. Introduction

"What we find out from [a] comparison between Columbia and Challenger is that NASA as an organization did not learn from its previous mistakes and it did not properly address all of the factors that the presidential commission identified."

—Dr. Diane Vaughan; Columbia Accident Investigation Board testimony, 23 April 2003 [1].

Organizational failure is a fact of organizational life. Failure will happen no matter how elaborate of a system an organization deploys. Nowhere is this more apparent than in high-risk organizations like NASA. NASA has a variety of risk-avoidance systems that all aim to do one thing: ensure that instruments and astronauts sent into space complete their missions safely. NASA has failed in a few instances to fulfill this goal in the realm of human spaceflight.[1] The Space Shuttles *Challenger* and *Columbia* tragedies as well as the Apollo launch pad fire in 1967 are examples of failure at NASA that cost a total of 17 astronaut lives. Where the Apollo accident was a mix of organizational and technical failure,[2] both the Shuttle tragedies are largely organizational failures.

Section 2 acquaints the reader with the unique organizational features of NASA. Section 3 explains the *Challenger* tragedy and the rationale behind calling it an "organizational failure". Section 4 explains the working scenario behind *Columbia*'s disintegration and the parallels with *Challenger*. Finally, Section 5 proposes some possible remedies.

2. Organizational features of NASA

2.1. Overview

The National Aeronautics and Space Administration (NASA) is a

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[1] For the remainder of this paper I will speak specifically about human spaceflight.

[2] The Apollo accident in 1967 was the result of bare wires short-circuiting in the capsule's pure oxygen environment causing an intense fire, toxic gas build-up and pressurization of the spacecraft denying the astronauts egress from the vehicle. It can be argued that this was an organizational failure based on the extremely hazardous conditions of the test capsule. However, Apollo is distinct compared to *Challenger* and *Columbia* considering Apollo took place during NASA's formative years when all vehicles were designated as research and development craft. Notably, the Apollo accident does not display the path dependence (Section 2.2) or normalization of deviance (Section 2.4) characteristic of *Challenger* and *Columbia*.

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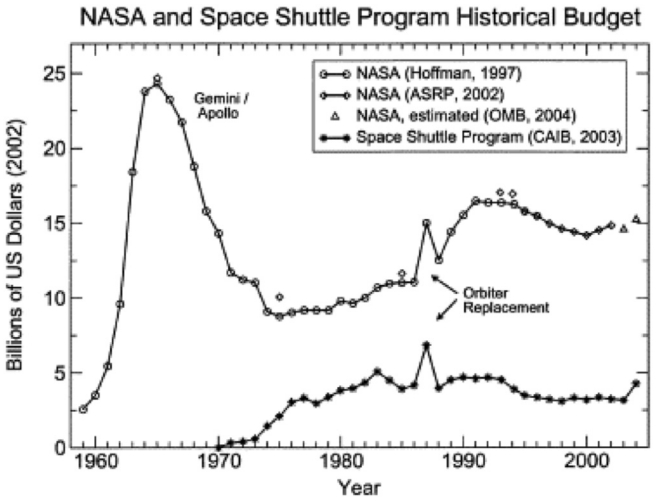

Fig. 1. A plot of the NASA and Space Shuttle Program (SSP) historical budget in billions of US dollars. The figures are constant-dollar amounts based on the year 2002. Note the relatively large amount of funding during NASA's formative years, the spike in 1987 due to replacing the *Challenger* orbiter and the decrease in funding in the past decade. *Source*: Data adapted from Hoffman [24], ASRP [25], OMB [26] and CAIB [27].

unique organization in terms of size, mission, constraints and motivations. Even as one of the smallest of the major federal agencies, NASA is a large organization that directly employs 18,000 people and has an operating budget of approximately US$ 15 billion (out of every US dollar spent in the world on space, roughly 35 cents is spent by NASA [2]). NASA's mission is unique as a leader in all areas of spaceflight and space science. Along with the traditional constraints of a federal agency like annual budget review and organizational complexity, NASA's main endeavor of human spaceflight enjoys no flexibility in terms of risk. Complicating things further, the motivations for NASA's mission have varied from the very specific in the past—winning the US/Soviet space race during the 1960s—to the very abstract today—technology transfer, advancement of scientific knowledge and space development.

2.2. Path dependence

NASA has been described as a heavily "path dependent" organization [3]. Path dependence refers to the tendency for organizations to make decisions based on, and have their present state defined by, their history. A good analogy for this phenomenon is when something—like a cardboard box—is pressed upon and is unable to return to its original form. Organizations are often equally unable to return to their original state given a stimulus.

NASA is very much influenced by its history. The agency was established in 1958 by the National Aeronautics and Space Act of 1958.[3] The aftermath of John F. Kennedy's historic "man on the Moon" speech in 1961 sparked the "space race" between the United States and the Soviet Union as each struggled to prove its technological superiority. Cost concerns were of less importance during this era as nothing could be spared to beat the Soviets to the Moon. However, at the end of the era, NASA experienced substantial budget cuts (see Fig. 1) but retained the organizational structure of the Apollo era. Additionally, human spaceflight was recognized as an important and vital part of the space program's success in the 1960s and as such played a major role in the direction of NASA and human spaceflight. These circumstances led to the NASA of the 1980s: still focused on human spaceflight with a smaller budget and no heavy-lift capability like Apollo's Saturn V.

2.3. The perpetually "developmental" shuttle

It is important to understand that—even today—the Space Shuttle is an experimental vehicle. Much is learned from each Shuttle after returning to Earth and during preparation for the next launch. The Space Shuttles flown today are different from those initially flown in 1981. In fact, the Shuttle's official "developmental" stage was from 1980 to 1982. After this point, it was declared "operational" so as to be available to ferry passengers and cargo to the to-be-completed Space Station and to lend legitimacy to the political selling point that the Shuttle could "pay its way" by launching spacecraft for the global telecommunications market. This operational designation was—and still is—in direct conflict with the experience of Shuttle engineers.[4] The Shuttle is still very much a developmental craft with constantly changing technology and mysterious problems that are not predicted from design.

The "operational" designation also sent the message that Shuttle launches were intended to be a routine, regular part of the space program. As Shuttle launches became routine, the excitement of the Apollo-era Moon race abated and NASA was forced by various administrations to cut costs (see historical budget data in Fig. 1). NASA realized that it could contract out portions of the Shuttle program and take advantage of the private sector's business savvy. Unfortunately, this had the effect of injecting production pressures into what was essentially a research and development operation.

2.4. "Normalization of deviance"

Vaughan [4–6] has developed the concept of "normalization of deviance" to explain how technical flaws can escape the scrutiny of the various safety bodies within NASA[5] over time. In many cases, unanticipated problems continue to occur even though nothing particularly catastrophic happens during a given Shuttle mission. This leads to the very pragmatic notion of "acceptable" deviance. That is, it was often very expensive and time-consuming to root out the cause of a given anomaly with some problems being incorporated into the regular maintenance cycle of the Shuttle without detailed examination. Under the production pressures mentioned above, it was unacceptable to spend significant resources on problems that were not "flight safety" risks—that is, if the problem could cause loss of the vehicle.[6] This provided disincentives for the engineers to track down the source of problems, even though many were not part of the Shuttle's design and, if magnified, *could* pose "flight safety" risks. Frequently, a flight was cleared based on previously successful flights that had completed their missions but still exhibited a given problem. This reasoning led physicist Richard Feynman to comment "When playing Russian roulette the fact that the first shot got off safely is little comfort for the next." [7].

3. The *Challenger* tragedy

3.1. The launch

On 28 January 1986, some 73 s after lift-off, the Space Shuttle *Challenger* exploded. President Reagan appointed William Rogers,

[3] Public Law 85–568, 72 Stat. 426 (as amended).

[4] In fact, Shuttle engineers pray during launch … in light of *Columbia*, they will likely pray during re-entry as well. This is not a cultural feature of an "operational" vehicle.

[5] See Vaughan [4] for an extensive discussion of the safety divisions within NASA.

[6] Loss of vehicle assumes loss of crew as the Shuttle has no crew escape capabilities.