NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

MBA PROFESSIONAL REPORT

A QUALITATIVE ANALYSIS OF NASA'S HUMAN COMPUTER INTERACTION GROUP EXAMINING THE ROOT CAUSES OF FOCUSING ON DERIVATIVE SYSTEM IMPROVEMENTS VERSUS CORE USER NEEDS

December 2017

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REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** December 2017	**3. REPORT TYPE AND DATES COVERED** MBA professional report

4. TITLE AND SUBTITLE
A QUALITATIVE ANALYSIS OF NASA'S HUMAN COMPUTER INTERACTION GROUP EXAMINING THE ROOT CAUSES OF FOCUSING ON DERIVATIVE SYSTEM IMPROVEMENTS VERSUS CORE USER NEEDS

5. FUNDING NUMBERS

6. AUTHOR(S) Matthew D. Sharpe

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB number ____N/A____.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release. Distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (maximum 200 words)

The National Aeronautics and Space Administration's (NASA) Human Computer Interaction (HCI) group was examined through the use of SWOT (strengths, weaknesses, opportunities, threats) analysis and the development of a Congruence Model of Organizational Behavior. As work of the organization has increased over the last decade, the HCI group has trended toward exploitation of existing routines and derivative software improvements over understanding core user needs and double-loop learning. As a member of the group for more than 10 years, group lead for three years, and assistant division chief in a supervisory capacity of the group for two years, I drew on past subjective experience to create this qualitative analysis. The diagnosis and understanding of the root causes of these symptoms will create the foundation for strategic recommendations for the HCI group moving forward, including organizational structure, process improvements, and training needs as the group prepares to support the retirement of the International Space Station in the 2020s and Mars exploration in the 2030s.

14. SUBJECT TERMS
organizational learning, innovation, SWOT analysis, congruence model of organizational behavior, strategy

15. NUMBER OF PAGES
83

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UU

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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
December 2017

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ABSTRACT

The National Aeronautics and Space Administration's (NASA) Human Computer Interaction (HCI) group was examined through the use of SWOT (strengths, weaknesses, opportunities, threats) analysis and the development of a Congruence Model of Organizational Behavior. As work of the organization has increased over the last decade, the HCI group has trended toward exploitation of existing routines and derivative software improvements over understanding core user needs and double-loop learning. As a member of the group for more than 10 years, group lead for three years, and assistant division chief in a supervisory capacity of the group for two years, I drew on past subjective experience to create this qualitative analysis. The diagnosis and understanding of the root causes of these symptoms will create the foundation for strategic recommendations for the HCI group moving forward, including organizational structure, process improvements, and training needs as the group prepares to support the retirement of the International Space Station in the 2020s and Mars exploration in the 2030s.

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LIST OF ACRONYMS AND ABBREVIATIONS

CAIB	Columbia Accident Investigation Board
CMU	Carnegie Mellon University
EM-1	Exploration Mission 1
ESD	Exploration Systems Directorate
HCI	Human Computer Interaction
HEO	Human Exploration and Operations
HRO	High Reliability Organizations
ISS	International Space Station
IT	Information Technology
MAS	Mission Assurance Systems
NASA	National Aeronautics and Space Administration
ORR	Operational Readiness Review
QA	Quality Assurance
R&D	Research and Development
SJSU	San Jose State University
SRI	Stanford Research Institute
SR&QA	Safety, Reliability, and Quality Assurance
STS	Space Transportation System
SWOT	Strengths, Weaknesses, Opportunities, Threats

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I. INTRODUCTION

The National Aeronautics and Space Administration's (NASA) Human Computer Interaction (HCI) group is examined through the use of SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis and the development of a Congruence Model of Organizational Behavior. The HCI group is an enterprise software development group providing mission engineering data systems and integrations for NASA's human spaceflight programs. Since 2006 the HCI group has developed and deployed a software platform called Mission Assurance Systems (MAS) that now encompasses more than 25 production systems and integrations, 11,000 active users, and more than 300,000 engineering records and analyses. As the MAS platform matured over the last decade, the HCI group faces a common question: how do you continue to innovate while maintaining an existing product base? While NASA has been extensively studied by organizational and strategy scholars (Boin & Schulman, 2008; Casler, 2013; Cannon & Edmondson, 2005; Levine, 1992; McCurdy, 1991; McCurdy, 1994; Starbuck & Milliken, 1988; Vaughn, 1996) this analysis considers a part of the organization that had not previously been studied in order to guide future strategic planning.

The trend toward exploiting existing routines to deliver derivative product improvements over exploring new opportunities within mature organizations is not new (Levinthal & March 1993; March, 1991). Over time the HCI group optimized their processes to deliver smaller, feature-level improvements, what Thornberry calls "derivative opportunities," to the established platform (Thornberry, 2006, p. 76). The HCI group optimized organically as it matured, guided by the needs of the work and without careful consideration. A study of the HCI group is particularly timely as NASA's human spaceflight programs, and by extension the HCI group, need to become paradoxically more innovative to support deep space exploration and efficient in operations at the same time (National Aeronautics and Space Administration [NASA], 2017; Prouty, 2014). The HCI group supports the Exploration Systems Directorate (ESD) toward Exploration Mission 1 (EM-1) in 2019 and following missions culminating in a manned Mars mission by 2033 (National Aeronautics and Space Administration

Transition Authorization Act, 2017). The HCI group supports engineering operations toward the eventual decommissioning of the International Space Station (ISS) sometime during or after 2024 (Holdren & Bolden, 2014).

Understanding the HCI group both through its environment within NASA as well as its underlying software development processes provides insight into how the group can maintain its reputation as an innovative, user-centered software team. The research also provides insight into the cultural and organizational changes that the HCI group might consider to achieve both greater efficiency and innovation. This is particularly timely as they maintain existing software systems and develop new ones as the agency moves toward Mars missions in the 2030s.

Chapters two describes the relevant historical background of NASA and how that environment influenced the HCI group's creation, which is described in more detail in Chapter 3. Chapter 4 describes the HCI group's strategy and organizational components before describing the strengths, weaknesses, opportunities, and threats to achieving its strategic objectives. Chapter 4 concludes with a short assessment of the strategic fit of the organization before Chapter 5 summarizes the findings. Chapter 5 also breaks down the findings into two key areas that need addressing with six specific recommendations.

A. KEY THEMES

While significant literature exists on the expected, predictable symptoms of organizations exploiting established products and routines, less literature exists marrying a diagnosis of the underlying causes to an actionable change strategy. Knowledge based on successful experience can create a source of competitive advantage but it can also create competency traps by relying on where you rely on existing knowledge and expertise to the exclusion of looking for alternatives (Levinthal & March, 1993), thereby exacerbating organizational learning in the long term (Argyris, 1976; March, 1991). Successful competence builds organizational inertia behind established routines resulting in a culture that is "a complex set of beliefs, values, and reinforcing processes, making them both hard to detect and difficult to disentangle" (McGrath & MacMillan, 2000, p. 140). High Reliability Organizations (HRO), such as NASA, are especially susceptible to this type of organizational inertia (Weick & Sutcliffe, 2007; Weick, Sutcliffe, & Obstfeld, 1999).

The appearance of continued success generates a "relative risk aversion" for managers and the organization that can be difficult to overcome (March & Shapira, 1987, p. 1413). This risk aversion to seek opportunities or change reinforces the status quo creating a competency trap where "strengths and capabilities become rigidities that block learning and adaptation" (Barrett, 2012, p. 141). Bluntly put, "too much reliance on learned patterns (habitual or automatic thinking) tends to limit the risk taking necessary for creative growth" (Barrett, 2012, p. 8) or generative learning (Senge, 1990).

What causes these underlying symptoms varies by team and organization. Many of these symptoms existed in the HCI group, but the underlying causes were unknown. MAS was a complicated platform after 10 years of continuous development, and fear existed over changing any significant piece. As Levinthal and Rerup (2006) point out, "tinkering with an established routine, can well be dysfunctional in a complex, interdependent organizational system" (p. 510). On the other hand, as Rumelt (2011) points out, "success leads to laxity and bloat" and ultimately leads to an organization's decline (p. 137). It was unclear at the beginning of this analysis whether tinkering would create dysfunction, whether tinkering was necessary to address what might be a bloated organization, or whether both of these were inevitably true. Successes of the past can lead to complacency (March, 1991; Sitken, 1992) as the arrogance of NASA's history points out with respect to the *Challenger* disaster in 1986 (Boin & Schulman, 2008; Starbuck & Milliken, 1988). In the absence of competition, we expect complacency and less desire for change (Beatty & Ulrich, 1991).

In complex or complicated processes, the difficulty can be in understanding where to start organizational changes. This is the underlying implication for organizational strategy and structure. The symptoms are apparent; the causes are not. The primary point of this analysis was not to document examples of symptoms already present, but to diagnose their underlying causes toward focused change. Diagnosing both the forces *on* an organizational environment (Porter, 1980) and the causes of dysfunction *within* that organization are critical to establishing where to begin actionable change strategy (Rumelt, 2011). This is the primary objective of a study of the HCI group within NASA.

B. RESEARCH QUESTION

Examples from the last two years demonstrate that the HCI group has optimized on derivative feature improvements to the existing MAS platform and is less capable of creating entirely new products. The HCI group experienced an increased emphasis on meeting deliverable dates over a focus on customer service and user experience, a common finding in McGrath and MacMillan's (2000) research with technical teams. The group's competence gradually leaned toward small feature improvements to the existing platform, resulting in a group less able to organize and create new products as expected—and requested—by stakeholders. That is not a surprise to the team. What is causing it, what is preventing change, and how to change it are less clear.

Understanding the underlying causes of the symptoms that have appeared in the HCI group over the last decade is of primary interest in this analysis. Some of these symptoms include:

- sources of organizational inertia toward derivative improvements
- risk aversion
- exploitation of status quo processes
- reliance on existing software platforms
- lack of organizational structure and clear roles.

Many of these symptoms correspond to traits that warrant the consideration of a major organizational redesign (Nadler & Tushman, 1997). This analysis provides insight into the cultural and organizational changes that the HCI group might consider to achieve both greater efficiency and innovation as they maintain existing software systems and develop new ones as the agency moves toward Mars missions in the 2030s.

C. PRIMARY ANALYSIS FRAMEWORKS

Two primary frameworks have been selected for this research: SWOT and the Congruence Model of Organizational Behavior. Together, these frameworks marry two fundamental aspects of organizational strategy, structure, and change by tying together both a high-level strategic understanding of the organization (HCI group) in its environment (NASA), as well as the organization's operational capabilities, activities, and problem root causes. Together these provide an analysis framework through which to consider potential future states and specific factors that need to change during an organizational transition. While I draw on the scholarly traditions of the Carnegie School on Organizational Learning and the High-Reliability Theory originating at UC Berkeley, the goal is to apply this research to a practical strategy application. As Nadler and Tushman (1997) put it, "No amount of organization design can prop up an ill-conceived strategy. By the same token, no strategy, no matter how dazzling it looks on paper, can succeed unless it's consistent with the structural and cultural capabilities of the organization" (p. 30). These two go hand-in-hand, as strategy is a critical input into the Congruence Model of Organizational Behavior. Together they operate like a doctor diagnosing the symptoms of a patient toward the strategy of getting well.

The SWOT framework of analysis is historically a stand-alone tool used in strategic management. It was originally developed in the 1960s and 1970s at the Stanford Research Institute (SRI) (Humphrey, 2005). By considering both internal factors (strengths and weaknesses) of a group and external factors (opportunities and threats) of the environment SWOT provides an opportunity to consider the evaluation or creation of an organizational strategy within the context of the HCI group and its environment.

The Congruence Model of Organizational Behavior was created by David Nadler and Mark Tushman and is a framework for diagnosing "fit" between organizational components as shown in Figure 1 (Nadler & Tushman, 1997, p. 28).

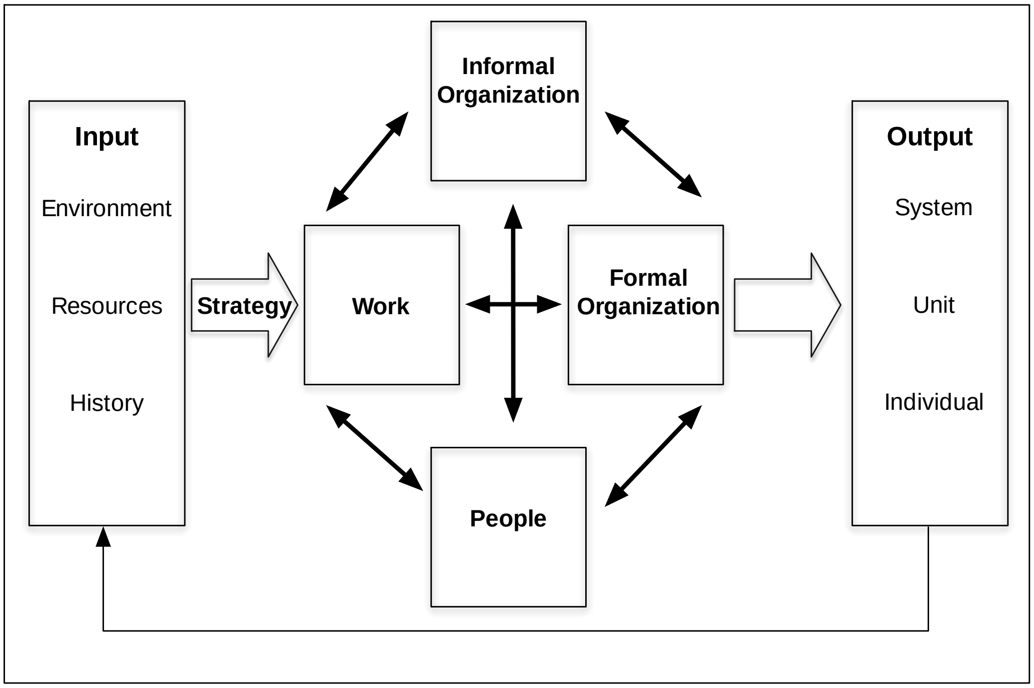

Figure 1. The Congruence Model of Organizational Behavior.
Adapted from Nadler and Tushman (1997).

Thus, the important connection to SWOT is that the congruence model takes as an input the desired strategy, and the underlying analysis helps evaluate the strategic fit of the organization. A key element underlying the Congruence Model "is that diagnosing organizational problems requires describing the system, identifying problems, and determining the sources of poor fit" (Nadler & Tushman, 1997, p. 35).

D. ASSUMPTIONS AND LIMITATIONS

As a member of the HCI group for more than 10 years, group lead for three years, and Assistant Division Chief in a supervisory capacity of the group for two years, I drew on past, subjective experience to create this qualitative analysis. The diagnosis and understanding of the root causes of these symptoms enabled strategic recommendations for the HCI group moving forward including organizational structure, process improvements, and training needs.

The HCI group as a whole provides a variety of software services to NASA for manned and unmanned missions. In addition to requirements gathering and software development, the HCI group operated as a consulting arm to NASA from a mission centric information technology (IT) perspective. The group had a variety of software projects including support for the Mars Rovers' planning software and mobile applications, and research in autonomy that were outside the scope of this analysis as they make up a proportionally small part of the HCI group and funding. MAS is the focus of this analysis as it makes up the bulk of the HCI group organization, work, and funding and where organizational improvements were sought.

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II. NASA FAILURE: NOT AN OPTION, REQUIRED, OR INEVITABLE

Constructing an implementable forward strategy for the HCI group must consider the environmental and organizational context of NASA's culture and history. NASA's history is steeped in monumental successes and failures that pervade its every day activities. From an organizational change perspective, Karl Weick and Robert Quinn (1999) point out, "to understand organizational change one must first understand organizational inertia, its content, its tenacity, its interdependencies" (p. 382). This analysis attempts to do that both from the environmental context of NASA as well as the work within the HCI group. In the context of the congruence model, "the environment makes demands on the organization" by both enforcing constraints and providing opportunities that are difficult to change in the short term (Nadler & Tushman, 1997, p. 29). The environmental context of NASA serves as the first input to the analysis.

A. NASA HUMAN SPACE FLIGHT EARLY HISTORY

In 2017, NASA was divided into four Mission Directorates: Aeronautics Research, Human Exploration and Operations (HEO), Science, and Space Technology (NASA, 2017b). The main focus of my analysis was HEO since the vast majority of the HCI group's work falls under this Mission Directorate. HEO contains both of the large programs that MAS supports: ISS and the integrated vehicle replacing the Space Shuttle Program underneath ESD. Historically, HEO's lineage dates back to the Space Shuttle Program and the Apollo program.

Although the Apollo program had strong central authority, NASA from its inception was a decentralized conglomerate with disparate specialties (Levine, 1992). Apollo was a "crash project" (Levine, 1992, p. 199; McCurdy, 1994, p. 166) more "grafted" onto this disconnected structure (Levin, 1992, p. 199) that blossomed with its strategically focused goal and strong public and presidential support (Lambright, 1992).

Much of the HEO basic structure and culture remains from the Apollo program. The 1990 Augustine committee highlighted the "characteristic management style" of

NASA that formed during its first decade: complement in-house work with detailed specifications and strong oversight of contractors (NASA, 1990). NASA's decentralized organization resulted in a matrix-managed organizational structure where expertise was lent to programs as needed (Carroll, Gormley, Bilardo, Burton, & Woodman, 2006; Levine, 1992). Even the offices of Safety, Reliability and Quality Assurance (SR&QA) were decentralized and removed as a formal organization structure for this task removed by 1963 (NASA, 1990). The underlying Apollo credo for open communication in engineering regarding anomalies laid the foundation of the safety and reliability community for their inherently risky missions (NASA, 1990). Apollo and its predecessor programs (Mercury, Gemini) were able to manage the relative safety of their programs while attending to the relentless schedule pressure to reach the moon by 1969. These may be structural and organizational artifacts, but they are just as much the values and assumptions about the core work that continued in NASA's environment and culture. From this era we get NASA's lofty goals, basic decentralized structure, management-style, engineering processes, and relentless schedule pressure.

B. SHIFT FROM APOLLO TO SPACE SHUTTLE

The post-Apollo transition to the Space Shuttle program provided one of the first large-scale environmental shocks to the still young organization. The 1970s were different for NASA in an era of budgetary constraints in a suffering economy. The Space Shuttle that was designed in the 1970s first flew in 1981. For comparison to Apollo, by 1982 the Space Shuttle program's budget was "two-fifths of what it had been (in 1982 constant dollars) during the peak Apollo years" (McCurdy, 1991, p. 209). While the Apollo budget was high partly due to the strategic national security implications and may not have been reasonably maintainable, NASA in the 1970s was learning to survive on a new budgetary landscape.

In the spirit of significant budget cuts post Apollo (and across government in the 1970s), NASA oversold Space Shuttle as routine and reliable. "NASA pitched Columbia as 'a 747 that you could simply land and turn around and operate again'" according to Sheila Widnall who was both a Secretary of the Air Force and a member of the Columbia

Accident Investigation Board (CAIB) (Roberto, Bohmer, & Edmondson, 2006, para. 18). This marked a transition from an experimental model to a routine one (Roberto et al., 2006; Senor & Singer, 2009). Part of this confidence stems potentially from the resilient response to overhauling Apollo after the Apollo 1 fire and the refocusing on astronaut safety at that time. This "transformation from the *Apollo* culture of exploration to the *Columbia* culture of rigid standardization began in the 1970s, when the space agency requested congressional funding for the new shuttle program" (Senor & Singer, 2009, p. 92). During the transition period, NASA's Skylab space station (1973-1979) utilized left over Apollo hardware but progressed in the areas of long-term space flight habitability, standardization of on-orbit processes, and accessibility. The implication here is the pendulum swinging from flexibility and adaptability of the Apollo era to one underscoring standardized processes and routine documented in the Space Shuttle program.

There is an "uneasy tension between bureaucratic accountability, political accountability, and the original technical culture at NASA" wrote Diane Vaughn (1996) in summarizing the lessons for the decision to launch Space Shuttle *Challenger* (p. 419). As they mature, public agencies have to manage risk since outcomes can be "both highly visible and highly consequential" thereby reducing public confidence in government's overall effectiveness (Casler, 2013, p. 231). The underlying meaning is that NASA needed to cater to politics in order to survive (Lambright, 1992), and in the late 1970s Space Shuttle era this means understanding that congress wanted to believe in easy, cheap, reliable space flight (Greene & Miesing, 1984).

The environmental shock to NASA in the 1970s resulted in an Agency that shifted from its exploratory crash program roots to political desires stressing routine and safe efficiency. It proved too early to label inherently risky spaceflight routine and "firms get into trouble when they apply the wrong mind-set to an organization" (Roberto et al., 2006, para. 18). Nonetheless it scarred NASA's culture.

C. CHALLENGER AND COLUMBIA ACCIDENTS

The Space Shuttle *Challenger* accident of 1986 (referred to by its flight number STS-51L) and the *Columbia* accident of 2003 (flight number STS-107) shared certain traits that either existed at NASA during this analysis or lead to the existing culture. Relying on historical success created a culture of arrogance (Starbuck & Milliken, 1988), complacency, and hubris that occurred in both accidents (Boin & Shulman, 2008). The Rogers Commission investigating the Space Shuttle *Challenger* accident cited the deficient decision-making processes in deciding to launch (Vaughn, 1996). In both accidents the flawed philosophy was the same: using past success to justify flight risk (Boin & Schulman, 2008; NASA, 2003). This was driven in part by what CAIB highlights as the premium placed on meeting schedules and cutting budgets at the expense of NASA's safety and quality processes (NASA, 2003). Unfortunately, this was not new in 2003 as it is eerily similar to the contributing factors highlighted by Diane Vaughn's (1996) monumental analysis of the *Challenger* disaster (p. 107).

The ensuing investigations provided additional environmental shocks to the Agency. STS-51L came at a time when the Agency was supposed to be safe and routine. STS-107 came at a time when NASA was supposed to be preparing to sunset Space Shuttle and design a new vehicle. The Rogers Commission investigating STS-51L highlighted that NASA overpromised. W. Henry Lambright's (1992) research concluded that the Rogers commission "dug deeply, visibly—probably hurting the technical core of the agency significantly" (p. 193). Lambright contrasts this investigation to the stronger NASA that emerged following the Apollo 1 fire and attributes this to the understanding and acceptance of risk during that era.

Sim Sitkin's research, describes the necessary balance between successes and failures to create organizational resiliency (Sitkin, 1992). This parallels the similar balance in the literature in exploitation of existing routines versus exploration (Levinthal & March, 1993; March, 1991). Continued success leads to persistence but too much success (i.e., over exploiting) can lead to an avoidance of new options, risk aversion, complacency, organizational inertia, perpetuation of the status quo (Sitkin, 1992), myopia (Levinthal & March, 1993), overconfidence (March & Shapira, 1987), and "suboptimal stable equilibria" (March, 1991). On the other hand, failure questions the status quo leading to an expanded search of alternatives (March & Simon, 1993), and can create more effective organizational learning, flexibility, and adaptation (Sitkin, 1992). But failure (over exploring) can lead to seeking increased risks (Kahneman & Tversky, 1979), inefficiency, and doubt that leads to "analysis paralysis" and fear (Vogus et al., 2014, p. 594). The general point here is that NASA, driven by the political back drop struggled to find a balance between these two points on the spectrum, and the large accidents of *Columbia* and *Challenger* likely made the agency more risk-adverse.

The Apollo 1 fire was preceded by the enormous success of Mercury and Gemini in a culture still accepting of risk. STS-51L occurred against the backdrop of an agency still attempting to demonstrate its new goal of routine reliability. Sitkin's (1992) theory is that small failures, those exemplified by deliberate experimentation (Cannon & Edmondson, 2005), combined with small wins are necessary to produce organizational resilience. At the same time, in the face of large failures, "organizational responses are more likely to be protective than exploratory" (Sitkin, 1992, p. 238). The implication is clear: in the face of large scale disasters such as STS-51L and STS-107 NASA was more likely to become rigid and protective, escalating commitment to existing routines. Rigidity is amplified if those large failures challenge the chief value by which an organization is measured—in this case NASA's label of routine.

For maturing organizations, the end result is inevitably more conservative, protective, and risk-adverse over time (Downs, 1964). This is particularly apparent for NASA's large-scale programs, particularly in HEO. More broadly speaking, that organizational conservatism is partly due to the desire to avoid accidents "not only for societal safety and security, but also for continued acceptance and possibly survival in the unforgiving political and regulatory 'niche'" (Boin & Schulman, 2008, p. 1053; Downs, 1964). Howard McCurdy (1991) analyzing his 1988 survey of NASA employees wrote that "at the management level, NASA is dominated by people who are cautious and inclined to avoid risks" (p. 313).

While true of NASA's human space flight programs, there have been other notable failures in NASA's history as documented in the Hubble Space Telescope mirror flaw (Capers, 1994) and the losses of both the Mars Climate Orbiter and Mars Polar Lander in the 1990s (Roberts, Bea, & Bartles, 2001). The primary compounding factor is that the complexity of the technology and other pressures (e.g., budget, schedule) means that design flaws are likely to be introduced years before they manifest themselves as catastrophic or mission critical events, what Roberts, Bea, and Bartles (2001) call "organizational catastrophes" (p. 71). O-rings (STS-51L) and Foam strikes (STS-107) are two Shuttle-specific examples. These accidents and their subsequent investigations furthered NASA's direction toward reliability and safety and a drive toward modeling itself after High-Reliability Organizations (HRO). From this era we add to the Apollo culture an emphasis on routine, and a desire to be a reliable HRO, delivering on an aggressive schedule and budget.

D. HIGH-RELIABILITY ORGANIZATIONS AND LEARNING

In the 1990s, a debate ensued between two management theories on safety, reliability and accidents in high-risk environments. These are relevant in that they have been historically grafted onto NASA, especially during the ensuing accident investigations. High-Reliability Theory (HRT) contends that continuous, safe operations are attainable while Normal Accident Theory (NAT) believes that accidents are inevitable in tightly-coupled complex environments. The theory later morphed into mindfulness, where constant vigilance and rapid response to potential failures is a hallmark (Levinthal & Rerup, 2006). Considering these theories holistically provides a lens through which to consider how NASA and other reliability-seeking endeavors approach organizational learning.

Two of the primary researchers of HRT, Todd La Porte and Paula Consolini (1991), describe HRO systems as those that are complex with "tightly-coupled interdependence" whereby a failure in one element may quickly cascade catastrophically (p. 22). At the same time, these organizations attain continuous reliability and are notable for stable processes and horizontal coordination amongst elements (LaPorte & Consolini, 1991). HROs are categorized by a "strategy of redundancy," decentralized decision-making, conceptual slack, and an accomplishment of "their extremely reliable performances only after a long, trying, costly and sometimes, lethal trial-and-error learning process" (Rijpma, 1997, p. 17). Here organizational slack closely mirrors the idea of "buffers" in organizational literature (Levinthal & March, 1993; Thompson, 2004). Slack provides the opportunity to digest information, hold multiple theories at once, and determine the best course of action. HROs "consistently navigate complex, dynamic, and time pressured conditions in an error free manner" (Vogus, Rothman, Sutcliffe, & Weick, 2014, p. 592). In HROs, "safety is the chief value against which all decisions, practices, incentives and ideas are assessed—and remains so under all circumstances" (Boin & Schulman, 2008, p. 1052). Although HROs tend toward a central, bureaucratic authority they allow for decentralized decision-making and action deferring to local expertise especially in periods of crisis (Rijpma, 1997; Weick, 1987). This implies that HROs move fluidly between sequential and reciprocal interdependencies as task urgency requires (LaPorte & Consolini, 1991; Thompson, 2004). HROs studied include continuous operations such as air traffic control (LaPorte & Consolini, 1991; Schulman, 1993); aircraft carrier flight decks (LaPorte & Consolini, 1991; Weick & Roberts, 1993), and nuclear power (Schulman, 1993).

NAT was expounded in Charles Perrow's 1984 seminal work *Normal Accidents: Living with High-Risk Technologies*, where the premise is that tight-coupled and complex systems inevitably create accidents (Perrow, 1999). The more "complex and tight-coupled" (Rijpma, 1997, p. 16) or "complex and interdependent" (Roberts et al., 2001, p. 70) the systems are "the more complex the interdependencies, the tougher it is to catch everything" (Roberts et al., 2001, p. 71). NAT cautions that "organizational interventions (such as centralization or adding redundancy) are likely to escalate the risks inherent" in these systems since additional layers of process or bureaucracy are implied (Boin & Schulman, 2008, p. 1053). This can adversely affect efficiency in responding or cloud roles and responsibilities. Over time, other pressures, such as schedules and budget, replace safety as the primary goal (Perrow, 1994). In NAT, reliability is illusory.

NASA has been labeled historically as an HRO, but there has been debate here as well. At the same time HRT and NAT were created and debated NASA experienced the *Challenger* Explosion in 1986 (two years after Perrow's initial publication of NAT) and then the *Columbia* disaster in 2003. Looking back at the *Challenger* explosion, Howard McCurdy (1994) in his book *Inside NASA*, implied NASA was an HRO (p. 163). NASA's "Faster, Better, Cheaper" management philosophy of the 1990s shared many HRO characteristics (Casler, 2013). The CAIB went further by holding HRO up as the necessary standard by which to evaluate NASA and its future aspirations (NASA, 2003). Since then, the labeling of NASA an HRO has come into question. HROs operate continuously and trial and error is removed as a possibility (Weick, 1987), but "nothing about NASA's human spaceflight program has been repetitive or routine" (Boin & Schulman, 2008, p. 1054). Each of the 135 Space Shuttle flights over thirty years were anything but routine despite its mostly stable processes. Contrast Space Shuttle's 135 flights to the example of a nuclear carrier with 10,000 landings in one, six-month deployment (LaPorte & Consolini, 1991). James Casler's (2013) work proposes a framework of 10 dimensions to measure HROs—NASA meets one. At the same time, Casler's broad, agency-level view of NASA likely misses the subtleties of specific programs (namely ISS which is nearing 19 *continuous* years in human space flight). NASA, regardless of the debate, is held toward the standard of an HRO.

The HRT/NAT debate is irrelevant for the purposes of this analysis as the end result is an emphasis on safety and risk analysis that permeates all NASA activities. NASA in the 1970s labeled itself routine and safe to survive post Apollo. The agency was bruised by *Challenger* and refocused on Safety. Then CAIB explicitly held HRO as a model to pursue (NASA, 2003). In the end, NASA cannot publicly declare that accidents are a normal part of risky space flight (Casler, 2013). Whether NASA, and specifically the human spaceflight programs, qualifies as an HRO or whether or not that is even a viable goal, the end result is a culture that emanates safety, reliability and risk analysis.

E. ENVIRONMENTAL IMPACT TO THE HCI GROUP

All of this combines into a 2017 environment where the goals, structure, and management style of Apollo blend with the budget and schedule pressures expanded during the 1970s, the scars of the Space Shuttle era, and the resulting aspiration to be an HRO. NASA is at in interesting crossroads. In designing its first heavy-lift rocket since

Space Shuttle in the 1970s toward a mission to Mars, there is the acknowledgement of unknown risk. At the same time a long-duration two to five year mission to Mars in the 2030s will require continuous, safe operations similar to ISS to be successful. Mars exploration has the interesting paradox of safe, long-term risky exploration. It must marry the risk of a manned Mars mission with the HRO culture ascribed to Space Shuttle, but exemplified in ISS.

Given that the MAS work was founded in no small part directly as a result of the CAIB findings, this environmental context cannot be overlooked. The cultural environment shapes the software development approach of the HCI group since it is where the majority of the MAS systems support and reside. As James March (1991) foresaw, where time is of critical importance, the primary role of IT is to increase reliability. MAS was created to help HEO be more safe and reliable by increasing the consistency and integrity of the underlying engineering data as well as the speed in which the data could be retrieved. The environmental implication is that the HCI group, as a natural extension to this culture, is expected to function like a continuously operating HRO. Usability, thus, becomes secondary and naturally over a decade of development there is a risk aversion to breaking what has become its own complex, tightly-coupled system.

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III. HCI GROUP OVERVIEW

A. GROUP ORIGINS

One of the HCI group's first significant research opportunities grew out of the Columbia Accident Investigation Board (CAIB) findings. The 2003 report highlighted information systems that were "extremely cumbersome and difficult to use in decision-making at any level" (NASA, 2003, p. 189). The report went on to say that these systems contained a "wealth of data tucked away in multiple databases without a convenient way to integrate and use the data for management, engineering, or safety decisions" (NASA, 2003, p. 193). The HCI group was initially tasked by the Constellation Program to write requirements for a new problem reporting system to address these issues. After more than six months interviewing and conducting research in analogous domains such as submarine safety systems as part of the requirements analysis, the group created a temporary solution based on readily available open-source technology. The temporary solution was meant to house initial problem reporting data collected in Constellation while determining a final solution through the standard acquisition process and writing additional requirements for other safety and reliability systems.

The HCI approach generally allows usability and user-centered design to lead technology selection and solution, as was the case with the initial problem reporting research. HCI combines design, psychology, and computer science to create highly usable software. While related to aesthetics and graphic design, HCI is more rooted in deeply understanding why and what people are trying to accomplish and how people might use the resulting technology. In this way, understanding the core needs (including NASA requirements for engineering processes), specific areas of current issues, and usability and design drives software development. In an area with deep engineering domain expertise such as NASA, designers effectively become apprentices of these processes working closely together with the engineering teams to weigh potential process tradeoffs with their technical implementation. This guiding principle that understanding user needs before determining a potentially suitable technology was one of the primary reasons the HCI group was asked to help generate the problem reporting requirements.

The success of the initial problem reporting solution and its features were quickly leveraged for related safety and reliability systems. A problem report at its simplest is a form documenting the problem, how to fix it, and routing it through the approval process. Other safety analyses are similar at this most basic level. A safety analysis might be a study of a piece of hardware, what might cause it to fail, how the design mitigates that failure, and routing it through the approval process. The very nature of open-source software enabled NASA essentially to own the underlying code and build a layer of modification on top to meet necessary requirements for different data sets and processes. The notion of a temporary solution enabled the HCI group time to scale up to production hosting infrastructure with failover and build out new features as they were identified or needed. What began as a temporary problem reporting system for Constellation in January 2007, was quickly adopted to support other processes, picked up by the International Space Station (ISS) Program in 2008, and continued beyond the cancellation of the Constellation Program in 2010.

B. MAS AND DATA INTEGRATION

What was created out of the initial open-source solution was something low cost and highly flexible. As the number of applications deployed grew, the name MAS was applied to distinguish the broad set of capabilities from a single tailored instantiation such as problem reporting. A custom MAS configuration provided engineering teams a single, centralized data set with powerful search and reporting to manage highly structured datasets. It provided a highly modifiable system for processes that evolved over time especially with respect to the data collected and workflow. An HCI team member acted effectively as an MAS system administrator configuring the engineering process, data collected, and workflow with few modifications to the underlying code. This enabled rapid response for quick changes without the need to recertify NASA security or hosting requirements. Working across platforms (e.g. Microsoft Windows, Apple) and across browsers (e.g. Firefox, Chrome) it enabled remote access for simultaneous users to collaborate with change logs and visibility permissions supporting data integrity. Much of this functionality was already available with the open-source software. The HCI group effectively leveraged a proven enterprise level architecture and technology, augmented it as needed to support increasing complexity in datasets and processes, and built out a hosting infrastructure to support 24/7 operations.

CAIB and the HCI group's initial research also pointed to the inadequate means of data integration. Building on the example above, problem reporting is one component of a much larger, integrated systems problem. As a practical example, say a safety analysis is in Microsoft Word and is related to a light bulb. Any reference to the specific light bulb name and part number is simply a text entry copied and pasted from a different part system. Over time a new vendor might provide the part resulting in a slightly altered part name and number. That same safety analysis might also be related to historical problems that occurred, mathematical models, verifications or inspections that occur during vehicle processing or on the launch pad, etc. In Microsoft Word all of these references might need to be kept in sync and updated depending upon the process decided by the engineering team. Many times people did not go back and update these references as they changed (except in new document revisions), but in some cases the processes did not allow for such modification. Institutional knowledge and human memory were sometimes the only reason someone knew something related had previously occurred. In Microsoft Word it is very difficult to determine whether there is an increasing trend line of problems with light bulbs that point to either a problem with the specific part or vendor or potentially some larger engineering issues such as the light bulb housing or electrical system. Almost as soon as the HCI group created an initial problem reporting system the team was asked to add integrations to increase the data integrity and search benefits across data sets.

By 2017 there were almost 25 MAS systems and just as many integrations. Over ten years of augmenting and re-architecting the original open-source platform, MAS had become an enterprise solution for engineering data sets. Many of those systems and integrations support ESD, the program who's primary directive is a mission to Mars by 2033. The HCI group's focus is now on understanding how to best visualize and utilize this integrated information across the enterprise for better trend analysis and reporting.

C. TEAM ORGANIZATION

In 2007, at the time the first MAS system was deployed, the MAS portion of the HCI group was approximately ten people including all aspects of research and design, development, and quality assurance. Aside from the two quality assurance (QA) testers, the other eight members had advanced degrees and these were almost exclusively in HCI from Carnegie Mellon University (CMU). Four had attended CMU together the same year.

The team adopted a stable open-source technology, but from the outset had to create all of the processes to augment it. Ignoring the different software development methodologies, the team created hosting and patching processes, failover constraints and processes, documentation for creating new feature designs, testing processes and documentation for software bugs while maintaining configuration management, training procedures and help documentation, certification of NASA requirements (which can be tailored), and communication with stakeholders among other things. All of these were created, not by adopting something from an outside team, but by the team selecting what worked best for each other. The team did not rigidly follow any specific software development process, opting instead to allow the software features identified and the development time required to drive the schedule.

While there was a group lead and leadership, the team's organization was flat and non-hierarchical. With the exception of technical software development, everyone performed the other functions. These functions included conducting user training in a classroom setting, writing documentation, testing, verifying bugs, answering help desk tickets, etc. There was a significant amount of autonomy with the expectation that there were experts within the team for a specific domain (e.g., problem reporting) and a lot of sharing and combining of use cases across different systems. Individuals and the team built credibility by the depth of understanding for the engineering processes. All job titles were effectively the same. Empowerment and responsibility were high; structure was not. Team members either worked for NASA or for San Jose State University in a cooperative agreement with NASA. All but the two QA members converted to NASA Civil Servants within a year after the first system in 2007. All team members had individual offices once becoming a Civil Servant and the team had exclusive use of a conference room collaborative space.

By 2017, the MAS portion of the HCI group had grown to 25 people including design, development, and QA. While additional support was provided for hosting and infrastructure by another organization, these 25 people supported just as many systems and integrations and all of the task functions originally created in 2007. Of the 25 people, 12 had an advanced degree in HCI from CMU and all 12 were considered designers or project managers. If you consider the HCI group a software development team, 50% of employees focused on user research and design is higher than the industry average, even for companies well regarded for user-centered design. The MAS team has continued to focus on understanding core-engineering processes and that expertise takes time to create. This deep domain expertise in a given engineering process also means that designers are expected to take more of a project management role since they should know more than anyone else what is most important to that user community. This means they are responsible for guiding the schedule, effort, and direction for a project. Designers also handle all help requests and training. Five members of the design team are Civil Servants while the rest work for San Jose State University under the cooperative agreement. The five civil servants have individual offices on the same hall while the remaining designers are co-located in a large room around the corner.

The development team was nine people in 2017, with one Civil Servant. The QA team was made up of the remaining four people. These 13 developers and QA members sit in two rooms across the hall from one another. The QA team members are divided evenly between the two rooms, as are the developers. These two rooms are between the design room and the row of offices for the Civil Servants. There are two conference rooms shared exclusively by the MAS team in the middle of the offices with a row of cubicles in an adjoining room designated as a quiet working space.

The HCI group's processes inherently underscore the value of understanding user needs in determining future software development efforts. Designers are expected to understand the goals of a given feature or implementation and are thus expected to control the implementation of the project including stakeholder management. These are things not typically included in formal HCI education. At the same time these roles were not explicitly written down potentially growing out of the collaborative, shared responsibilities approach from 2007. While examples of artifacts from prior software development deployments are plentiful (e.g., cost estimates, schedules, research analysis results, feature documentation and storyboards, testing cycles, etc.), no explicit process is followed to allow tailoring to the scope or complexity of a given feature or system. Tailoring processes and assigning of tasks underneath each role is essentially determined by consensus based on the historical institutional knowledge of team members. Without a central technical authority in 2017, the distributed nature of the decision-making across domains has made small, incremental platform changes the safest solution.

D. TEAM PHILOSOPHY AND VISION

The basic underlying philosophy of the MAS group is to build the most usable and integrated mission engineering data systems at NASA. At the same time, a specific team philosophy in the form of a traditional vision or mission statement did not exist. The original HCI Group Lead established the team's mantra, "Do Good Work." The expectation was to hire talented people, expect them to understand the needs of users better than anyone else, and help engineering teams do more engineering and less data management. The team followed a basic project management principle to under promise and over deliver. As successes continued, the relied on positive word of mouth experiences from existing engineering teams to lend the software team credibility in an intensely hardware engineering organization and effectively provide all team marketing. Engineers trust other engineers more than software developers.

While the HCI group develops and maintains the MAS platform, the message conveyed is that the engineering teams own the individual system configurations, data, and processes. For example, the problem reporting team is responsible for managing the process and data collected to meet their requirements. The HCI group provides the mechanism to accomplish those processes and is stewards of that engineering team's collective knowledge. The basic principle is simple: the engineering team should decide and own their process not the software team. At the same time, the two work together closely to align best practices from both engineering and software to improve processes, data integrity, and efficiency. This is not the traditional software requirements development process, but was much closer to 2017 industry best practice.

From this situational awareness of both the broader NASA environment as well as the HCI group's history, we can now create a strategy that considers how they may impact the overall group's ability to adapt and change. In the next section a strategy is considered and the overall strategic fit is considered in the context of the congruence model.

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IV. HCI GROUP STRATEGY AND STRATEGIC FIT

The next input to the congruence model is a strategy, which is necessary in order to diagnose or evaluate the strategic fit. In the following sections, the strategy of the HCI group is discussed as well as the four key organizational components: the work, the people, and the formal and informal work structures. Finally, a SWOT analysis of the HCI group is documented utilizing this strategy and organizational components.

A. STRATEGY

Strategy has been defined in a number of ways in the literature. Nadler and Tushman (1997) describe it as the "explicit choices about markets, offerings, technology, and distinctive competence" (p. 30). Distinctive competence is similar to Richard Rumelt's (2011) idea that good strategy uses "precious functional knowledge that is proprietary," to create a hypothesis and implementation plan (p. 241).

A strategy focuses the direction of an organization both on the objectives as well as the appropriate targets, and in doing so, succinctly describes what things are not important to the organization. Michael Porter (1980), in his book *Competitive Strategy*, introduced the idea of "focus," describing it as an enabling mechanism for better meeting the core needs of a specific user community, decreasing costs, or doing both simultaneously (p. 38). The entrepreneurial perspective implies that focus likely enables a more successful down select of opportunities to pursue (McGrath & MacMillan, 2000; Thornberry, 2006). Rumelt (2011) bluntly states that bad strategy is one that lacks focus, because inherently this results in poor decision-making regarding actions and resources. The implication is that the right strategy focuses the actions of the organization in such a way that it threads the needle through what the environment can absorb and what the team's core competence can accomplish.

What all of this literature has in common, is that strategy flows from understanding the strengths, weaknesses, opportunities, and threats (SWOT) to an organization. It must balance all of these aspects coherently, and also be implementable. This is partly the reason why the SWOT framework was selected to combine with the congruence model as a mode of analysis. Though much of the strategy literature points to similar techniques, Rumelt's (2011) "kernel of good strategy" is a simple distillation that describes strategy as the following three elements: 1) a diagnosis of the core problems, 2) a guiding policy to address these challenges and 3) a set of coherent actions (p. 77). At the end of the day, the goal is an implementable strategy that can be tested and evolved.

An interesting realization in performing this analysis was that the HCI group did not have a coherent vision or strategy focusing its efforts. While Rumelt's kernel principle does away with the notion of needing to label and differentiate vision, strategy, mission and other nomenclature, there is an important distinction between vision and strategy for the purposes of this analysis. If the intent of a strategy is to be implementable, then the vision is one level higher. The vision is an initial determination of what services a group will provide and "what kind of organization it wants to be" (Nadler & Tushman, 1997, 29). From that vision comes the choices that create a strategy. At the same time, it is important not to get wrapped around the axle, since inherently these both rely on a balanced perspective of the SWOT of a particular organization.

For the purposes of this analysis, a vision and mission statement were encapsulated here as an input to the congruence model. It was clear that MAS provided a key source of the HCI group's power as it provided a desirable mechanism for engineering teams to create and maintain their vehicle analyses. Earlier in the HCI group's history, the goal was to replace everywhere spreadsheets or documents were used to manage data. That still rang true. The HCI group's vision for MAS was probably closer to creating "the most usable data curation, integration, and visualization." More specifically, the goal was to leverage MAS to enable better data curation, then use that structured data to integrate between systems, and finally visualization between all of the integrated data sets. The focus is on core, hardware engineering data relied on during design or operations with a particular emphasis on human space flight, as these tend to be the most long-term, data and process intensive, and large programs.

Note again, that the definition of strategy used in this analysis is one that results in specific, implementable action. While the vision and mission are generic, the following sections outline the four key components of the organization and assess strategic fit along the lines of congruence utilizing the SWOT framework. First, assessing strategic fit helps diagnose the existing problems, which is the primary step in creating implementable strategy. Second, the assessment underscores the methods currently used to accomplish the vision (i.e., the currently implemented strategy).

B. ORGANIZATIONAL COMPONENTS

In the following sections the organizational components of the HCI group are described. These include the work, the people, and the formal and informal work structures. Together these create a picture of the pieces that come together to accomplish a given strategy and through which we can assess the SWOT of the organization and misalignments of strategic fit.

1. The Work

In the context of the congruence model, the work is a description of the activities, tasks and workflow that must be performed in order to meet the intent of the strategy (Nadler & Tushman, 1997). The core competency and success of an organization depends upon the performance of these particular activities. The other key components of the transformation process considered in the congruence model (people, formal and informal organization and arrangements) all take cues from the core work that must be performed by the organization.

Since the HCI group was an applied software development group, the work activities and workflow represented all stages of the software development life cycle process. From an overly simplistic point of view, the work included the research, design, development, testing, maintenance and hosting of a particular configuration of MAS and its integrations. Initial research included observation and documentation of existing work within an engineering domain to produce key focus areas or pain points that need to be addressed. This research was documented in various ways depending upon the complexity of the problem or scope of the project but historically included examples (in order of formality) such as requirements documents, white papers, process models, artifact evaluation, presentations, and storyboards. Storyboards were utilized to a great extent to bridge the gap between research and design. Storyboards are screenshot mockups of what the new system or configuration will look like and created a hub of understanding between life cycle participants. Storyboards were valuable in that they 1) demonstrated an understanding and summary of the core issue(s) to be fixed 2) succinctly communicated the requirements or scope of work for agreement and 3) created a single, visual place for communication to all participants from stakeholders through to final quality assurance testers. In parallel the necessary development features (represented in the storyboard or not) were tracked in a Google Sheet and included cost estimates based on input from design, development and QA. The Google Sheet was only created if the scope was deemed too large or complicated for a storyboard or if budget did not exist for that work already. Based on the existing MAS system and integrations, the trend has moved from formal documents for each configuration to informal storyboards as the main means of communication and documentation. The storyboard and the Google Sheet together communicated a bare bones skeleton encompassing the core problem, scope and requirements, and expected feature and configuration costs and assumptions. Formal schedules were created from the Google Sheet if requested by the stakeholder or if deemed necessary because of the overall complexity or if a deployment was date driven.

Storyboards helped transition out of the research and requirements phase, but in some regards storyboards were a final output of the design stage. The design phase might include documentation of engineering team permissions, record visibility structures, workflow processes, and data field layout. This was performed extensively in Google Sheets and Docs for their quick adaptability, reuse, easy sharing and collaboration. Sketches on paper, whiteboard, or through a digital means created initial discussion and buy in from development and quality assurance members of the HCI group. The culmination of this work was a storyboard that was presented to stakeholders for agreement. At that point, full feature specifications were formalized including the finer details not included in a storyboard including such nuance as edge case behavior, color, font, and spacing for the development team to implement. A feature “bug” was then added to the team’s bug tracker by the design team, which referenced the full design specification to be implemented, developer assignment, and associated deployment milestone. The Google Sheet documenting cost, scope and assumptions referenced this same feature bug number to meet NASA software development tracking requirements and provide high-level estimates of estimated time allotted.

The feature bugs and their assignment trigger the development process, though in reality developers began the initial implementation before the full specification was documented if there was slack time. During the design and development phase the QA team would overview the new configuration and features to determine specific test cases that needed to be performed. Since testing time was an input to the Google Sheet documenting features and scope, the QA and design team might begin documenting specific test cases that need to be performed very early. Once developers complete development on a feature, the feature bug is closed. Formal testing occurred in "rounds" sometimes based on developers completing individual features, and sometimes waiting for all features to be completed if there was not QA resources available or if a given feature was deemed risky in that it touched a significant amount of underlying functionality (i.e., visibility permissions). Rounds of testing were also tracked in Google Docs with problems found documented in bugs that were reassigned to developers.

A deployment wrapped up with any additional help documentation, user or help desk training or demonstrations that needed to occur. "Smoke testing" occurred for major updates where system functionality would be tested without the modification of the underlying data (e.g., loading records and printing reports). Developers also performed system maintenance including security and vulnerability patches, triaged servers, and coordinated deployments with the hosting organization in the NASA Super Computing Division. A retrospective meeting occurred open to all team members approximately every month to create lessons learned that were rolled back into the process.

The workflow described in this manner appears linear, but in reality it was not. Testers or developers may be engaged very early to talk through (and potentially test or prototype) alternatives to determine level of effort. Developers may hit issues that require further search or design input to understand tradeoffs to primary user goals. Some items began as soon as practical and evolved throughout the life cycle process such as test cases or help documentation. The workflow was incredibly informal based on evolving institutional knowledge of the team members over thousands of system configurations, bugs, features, test cases, patches, deployments, trainings, and retrospectives over ten years. While informal, that workflow was also incredibly complex leading to a reluctance of designers to try an alternative approach once they finally understood how it was “supposed” to work. The end goal was to find the best solution that solves the primary issue of the users in a timely and cost effective fashion.

2. The People

The people are an obvious critical part to all organizations as they perform the work and enable a core competency. Within the context of the congruence model, “that means looking at the workforce in terms of skills, knowledge, experience, expectations, behavior patterns and demographics” to understand their ability to meet the core work tasks and strategic fit (Nadler & Tushman, 1997, p. 32). For the HCI group there is the expectation that the work was design driven from the standpoint that meeting the engineering teams’ processes and intents was the first priority.

As discussed previously, fully half the team came from a usability and design background, all from CMU with few historical exceptions. All designers were 35 years of age and under at the time of writing. The CMU connection is partially because from its inception the HCI group has sponsored an eight-month Master’s Thesis project containing four to five students. The projects, in addition to their overall value, acted as an evaluation mechanism for potential new hires and as an introduction into the HCI group’s work. Thus, new design hires were normally fresh out of graduate school with some moving into their second job. They were drawn to the group for many reasons, but one of the primary factors was that they were able to gain experience in all aspects of the software development process (including project management) as opposed to a single one (e.g., one type of user research or graphic design) at larger Silicon Valley firms. The core competency of the design team tended toward qualitative analysis methods where they excelled at user research and workflow process analysis consistent with their formal training, rather than technical software development. As expected, the design team was less skilled initially at project management or understanding formal NASA requirements or engineering processes. They all quickly grasp the open, honest informal culture and utilization of technology to accomplish their tasks, but are less adept at the complicated nature of MAS, its integration technologies, or its underlying software development languages.

The development team was a mix of age and experience, from new graduates to those with significant, decadal Silicon Valley experience at large firms. With MAS based on aging open-source technology, developers recognized that cutting-edge technological breakthroughs were not the goal, rather augmenting and refactoring it to meet user needs. Indeed, many of them were hired due to their particular experience in underlying MAS development languages, databases, or web integration technologies. Their experience was in open source web technologies over mobile applications or operating system development. Developers were hired to contribute directly to development—not lead. Indeed, significant previous discussion had occurred around the notion that no development lead, a standard industry role, existed within the HCI group to coordinate development resources. This is not to say that the developers were not incredibly talented or submissive, rather that the design-lead culture permeated this aspect of the development team.

The QA team was made up of driven, detail-oriented people who performed complicated manual test cases to ensure system integrity. Their specific background or education was less relevant than their ability to think critically, and methodically through testing a user interface. Two examples were a QA person with a nursing background and another with an English Literature background. Automated testing was not a priority or competency for a variety of technological and historical reasons. The QA team was dispersed throughout the development team and was both the informal social glue of the organization as well as key integrators between the design and development processes.

3. Formal Organizational Arrangements

The formal organizational arrangements refer to the structures in place to meet the demands of the work like functional groupings, coordination processes, work environment, and reward structures. The formal arrangements are the "explicit structures, processes, systems, and procedures developed to organize work and to guide the activity of individuals in their performance of activities consistent with the strategy" (Nadler & Tushman, 1997, p. 32). In the study of the HCI group, there were surprisingly few. The mantra of the organization, established by its founder, was "Do Good Work" and that established the tone and tenor of the formal structures.

One of the most perceptible ways in which this mantra applied was to the selection of IT systems used to the support the organization's activities. With the exception of the HCI group abiding by the business colloquialism to "eat your own dog food" and use MAS as its own bug tracker, IT solutions-selection was not mandated. Confluence for storage of important documents such as test cases or project-specific documentation was one of the few original team implementations that still survived in 2017. Even in this case the team hosted their own Confluence instead of using a NASA provided one in order to have more flexibility and control. Google Docs, mentioned previously and used extensively, came about organically because it solved the age-old dilemma of emailing versioned documents and presentations back and forth. The HCI group started using Google Docs before other cloud-based collaboration was supported, or a NASA-approved Google Drive existed. When NASA's formal screen sharing solution continued to not work consistently, the HCI group used an approved alternative. Trello and Slack were used for informal communication and coordination amongst team members when email and traditional instant messaging became outdated. Design tools, text editors, and development environments are continuously tinkered with based on the task. The HCI group is recognized as a software development group and as such all members have full administrative privileges on their government issued laptops to perform testing and evaluation of alternative tools. The goal was always to be as flexible as possible to evolving needs and to stay current with business practices.

As mentioned in the overview of the HCI group, the design team was segregated from the development and QA teams who were mixed together. Front end and backend developers were mostly grouped together with few exceptions. A formal "Priorities Meeting," organized by the HCI Group Lead, is held Mondays but otherwise meetings were mostly scheduled ad hoc and organically on a project or issue basis. Designers who were primarily acting as project managers mainly attended the Priorities Meeting. While the Priorities Meeting was open, there was minimal to no developer representation but strong QA representation. Major project deadlines or issues were reviewed with loose roles, responsibilities, next steps or assignments discussed.

Formal performance review standards and reward structures tended to observe the original “Do Good Work” mantra. The performance review standards for the five civil servants followed the NASA specific and measurable standards. The specific evaluations generally listed the expected deliveries of major features, integrations, or systems configurations. The general expectation, or explicitly written, was that an excellent rating could be accomplished either through delivering more than listed, bringing in significant new work, or receiving team or individual awards. Awards were generally received from stakeholders for accomplishing a significant improvement or written by the HCI group management to reward specific individual accomplishments. The latter generally rewarded heroic efforts and was true for both civil servants and SJSU members of the team. The twenty SJSU members of the MAS team also received on the spot financial rewards that mainly emphasized significant effort to accomplish a given milestone. Civil servant members of the HCI group did not review SJSU performance reviews or goals, but civil servant feedback was requested during the annual SJSU performance review cycle. Several SJSU designers held monthly one-on-one meetings with NASA HCI management, but these took on more of an informal mentoring or personal growth relationship as opposed to setting performance standards.

4. Informal Organization

The informal organization is where the “unwritten guidelines that exert a powerful influence on the behavior of groups and individuals” exists (Nadler & Tushman, 1997, p. 32). The culture of organization, including politics, exists here and manifests itself in the behaviors, beliefs, and values that are exemplified in how daily works gets performed. It also corresponds to the informal rules, power, and communication paths utilized to coordinate activity.

In the case of the HCI group there are a few historical items that have been mentioned previously that influence the group significantly remunerated here with additional context. First is the user-centered, or design driven environment. This means that informal power rests with the designers because they are the closest to the users and have the most qualitative knowledge about how a feature or product will be used. It also means that there is the expectation that designers will provide the precise, key insights and data that will drives the products' success. "Stick to the facts" and "what does the data say" were common sayings and reinforced honesty across the various group structures. Understanding the data and attempting to differentiate on facts was exemplified all the way to a culture of acknowledging problems, not hiding them, throughout the development life cycle. In the design phase, the expectation was that you could not deliver something better without understanding the existing problems. In the post-deployment phase, improvement can only come from evaluation as the team performed in retrospectives. It should be noted that even though they occurred roughly monthly, retrospectives were organically scheduled, non-mandated meetings although two designers initially created these to be performed after each deployment.

The overall informal culture was one where everyone was expected to be problem solvers who share information and jump in to help one another. Mistakes were treated as learning opportunities. The informal friendliness from graduate school of the original members potentially helped create this atmosphere. There was still an almost familial feeling, where motivation came from not wanting to let your friend down which has eroded but still existed. The informal, friendly relationships where mistakes were tolerated and learned from also helped create the culture where being responsive to user requests and finding innovative solutions thrived. A 24-hour rule for investigating and responding to help desk requests was instituted and still existed. "Duct taping" initial solutions to receive rapid user feedback was encouraged and helped reinforce a solution-oriented culture where pushing the boundary of rules and ignoring formal protocol was expected if it made sense for the user. Overtime, "duct taping" solutions became more frowned upon as MAS became more established and replaced with one where stability of the platform across configurations was emphasized. Nonetheless, a solution-oriented culture focused on the needs of the user still existed.

The culture of everyone helping one another and solving problems potentially reinforces the notion of shared roles and responsibilities without formal titles. There were multiple benefits to the group historically performing user research in pairs, including the ability to better share information, problem solve, and exchange roles quickly. At the same time, in a formal organizational structure devoid of hierarchy, an informal one ultimately forms. Personal tasks or resources, with the exception of project manager responsibilities, could wholly be swapped or exchanged as team members saw fit. There may not be formal acknowledgement of some decisions, but ones based on shopping the idea around team members to determine the best approach and create consensus so as not to create massive disruption. While power rests with designers who, with the most detailed knowledge of the problem, act as project managers, senior members of the team or civil servant leadership act as gatekeepers with a type of informal veto power. It was not used as a formal veto power, but more as a redirection toward exploring other options based on existing constraints (e.g., resources or schedule) that are not always clear or known. In this way the unwritten rule was that questions of schedule or financial resources were to be deferred to a civil servant within the HCI group and new features or system configurations could not be committed without their prior knowledge (and informal approval). The informal approval process was then as follows: designers with the most knowledge shop solutions and get consensus, then those solutions are brought one level further and shopped with management for informal approval. It should be noted that the formal "Priorities Meeting" evolved into one of the formal mechanisms to request resources because the informal mechanisms were no longer practical as the team grew.

C. HCI GROUP SWOT

A summary of the SWOT analysis performed on the HCI group for this thesis is in Figure 2. A detailed SWOT for the six relationships between the four organizational components can be found in the Appendix.

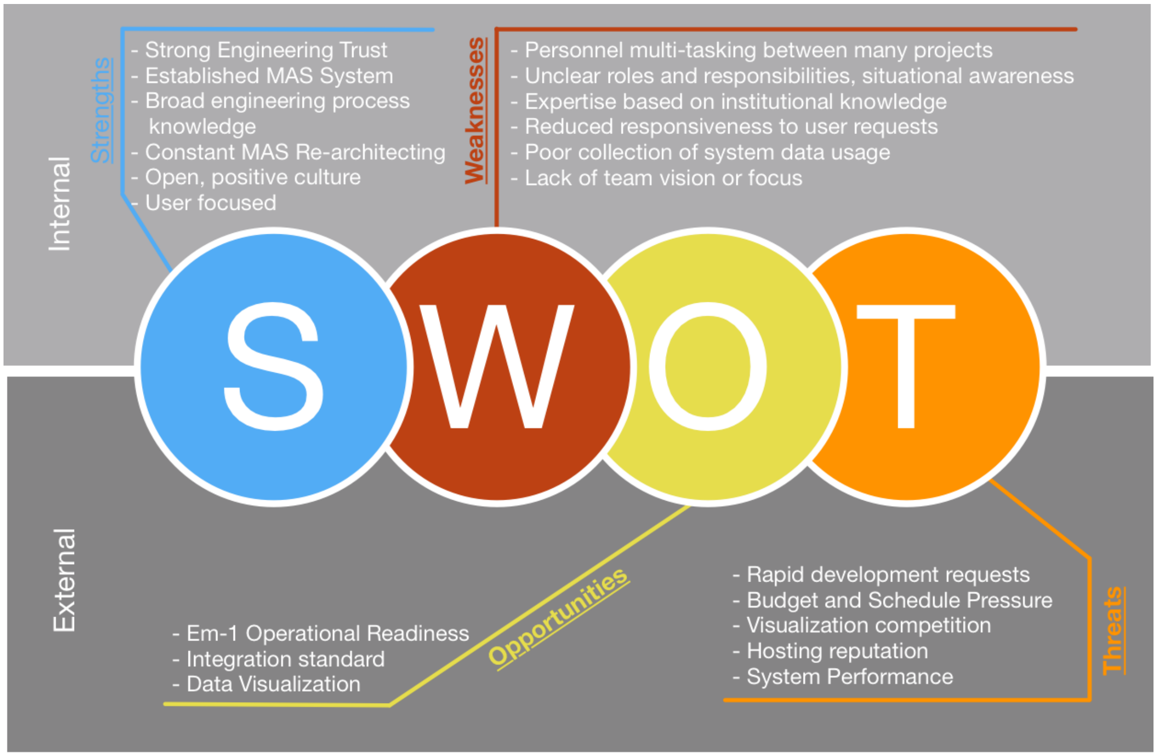

Figure 2. A Summary of the HCI Group SWOT

1. HCI Group Strengths

Another way to consider these combined "strengths" at the group level is to think about these as a core competence that are desirable to keep in future strategy or actions. The idea of a core competency, introduced by C. K. Prahalad and Gary Hamel (1990), meets three primary tests: 1) it provides wide market access 2) significantly contributes to perceived customer benefits and 3) combines a complexity of technologies and individual skills in such a way that is difficult to imitate. In the case of MAS this means that the strong engineering trust provides continued market opportunities, the speed of data retrieval and data integrity contributes to customer benefit, and the user-focused, positive culture combines in such a way that on the whole is difficult to imitate. In addition to MAS core capabilities such as data curation and search, the established integration capabilities with other systems reinforce the group's core competence. Rumelt (2001) defines a strategic resource as "a kind of property that is fairly long lasting that has been constructed, developed over time, designed, or discovered by a company and that competitors cannot duplicate without suffering a net economic loss" (p. 135). By this definition, MAS is the clear strategic resource to the HCI group. It is relevant to also point out that engineering trust was won with open, honest communication, understanding their core needs, and MAS and the team repeatedly delivering what was agreed.

The HCI group's solution-oriented, open culture was a noted strength. The helpfulness of members and lack of structure created an environment where there was quick access to institutional knowledge and collaboration to find solutions. The culture was supportive where sharing and reuse of previous knowledge or solutions was encouraged and new team members were easily assimilated. The user-focused culture reinforced the underlying goal to create the best system available to the engineering teams and this was bolstered by the HCI group's ownership of the entire software development life cycle process including hosting. The full ownership of every aspect except the data and process creates a flexibility and adaptability that matches the goals of creating the most usable system possible.

The group culture promoted timely, direct, informal constructive feedback whether positive or negative. Borrowing from the objective design critique process, the group prided itself on openly accepting feedback for improvement. At the same time, as the number of team members expanded without everyone working in close proximity for long durations, there was social reluctance to provide feedback while at the same time a desire to receive it.

2. HCI Group Weaknesses

A number of significant internal weaknesses were found in the analysis. The continuation of a "flat" hierarchical structure from the team's inception resulted in unclear roles and responsibilities that continually shift. Unclear responsibilities lead to poor situational awareness of other team members' time or priorities and the eventual diffusion of responsibility. As stated previously, developers did not want to question the direction of designers, but the designers did not have clear picture of the developer time constraints or development complexity until much later in development cycles. Poor situational awareness creates an environment where it is difficult to gather the necessary resources to respond quickly to user requests. With so many configurations it was difficult to understand through consensus whether a change might negatively impact another MAS configuration or functionality. The lack of a development lead role or centralized technical authority to help means that decision making was slowed and that small modifications to MAS became the preferred solution. Small modifications were both quicker and safer – though not necessarily the desired outcome.

The group's historical culture also mandated that designers perform duties supporting the help desk and testing new software releases in addition to user research and project management. On the one hand this was purposeful. Answering user questions creates new ideas for future development and reinforces a close relationship with the engineering team. Testing new software releases was meant to keep designers informed of new features to be utilized in future system configurations, to describe expected functionality to users, and to recognize areas of poor usability for future improvement. With a few systems this may be possible. With 25 systems and just as many integrations it became considerably more difficult to expect every designer to maintain the full breadth of potential in their heads. In computer science terms, this much task switching is called thrashing.

Combining these together creates one potential picture of why the team seemingly contributes to small, derivative improvements to MAS. For example, as user requests come in unpredictably, they require task switching and coordination of resources. The solution-oriented, supportive collaborative culture described above as a strength supports this. With so many tasks, the inevitable result is responding directly to the request (adaptive learning) as opposed to seeking deeper knowledge (generative learning). Thus, individual expertise was based on their own institutional knowledge and augmented by working closely with other team members or asking open questions, the latter further adding task interruptions. This notion is reinforced by the literature on market orientation where Stanley Slater and John Narver conclude that a focus on responding to existing customer needs prevents the deeper organizational learning necessary to pursue other innovative opportunities in latent needs (Slater & Narver, 1995). Information does not equal understanding.

Finally, no specific unifying vision organized the HCI group’s work, with the exception of the informal (but strong) user-centered approach to development. Although a unifying vision existed in pockets of work (e.g., how the ESD systems and integrations combine to inform certification of flight readiness or operations), no such vision or mission existed for the overall MAS work. “Guiding ideas” are a requisite precursor to enabling a unifying organizational focus (Senge, 1990, p. 326). Within the HCI group, no such guiding ideas formally existed in such a way to guide daily activities or priorities.

3. HCI Group Opportunities

Opportunities are relevant to this analysis, not only because it is a part of the SWOT framework, but specifically because cultural change can potentially occur more efficiently when an organization is aligned behind a specific, easily visualized market opportunity (Thornberry, 2006). The HCI group has a number of broad opportunities to investigate that may lead to such a specific, concrete goal that would accelerate organizational change. While MAS has become an engineering standard for creating data analyses, no such unifying standard exists for either the integrations or subsequent data visualization across integrated systems. Both of these areas were emerging.

A number of recent downtimes put into question the group’s ability to host and maintain a fully redundant operation. As the Exploration Systems Directorate moves toward a first launch in 2019, a number of other engineering groups will perform Operational Readiness Reviews (ORRs). The HCI group may have an opportunity, under its ESD work, to place an emphasis on its overall operational hosting capabilities to shore up this capability and protect its reputation. The ORR would help engineering teams feel comfortable by formally validating systems ahead of the mission and highlight gaps in processes to create specific targets to fix prior to the first flight.

These specific opportunities may help create change in some of the smaller, structural opportunities that were found as well as supporting the different sets of daily activities. The first is a clarification of mandatory process level constraints and circumstances. Storyboards were highlighted as a core part of the work process above and this may be relevant for all but security patches or emergency bug fixes but it was unclear. Storyboards are one of multiple examples. Basic constraints create opportunities for quicker learning for new members and better efficiency through clear expectations.

Second, an overall team-level restructuring may be applicable. The team was organized sequentially with informal structures creating reciprocal exchanges as necessary. There may be efficiencies that can be gained by organizing teams around new products, research and development, functions (e.g., maintenance releases), or support as opposed to the informal mechanisms used today. To highlight a specific example, while qualitative observation has been used historically, little quantitative analysis of the behavior of MAS' 11,000 users has occurred which could be an area of research and development. The quantitative data might augment on-going deployments based on qualitative feedback.

4. HCI Group Threats

A noted threat to the group was its ability to rapidly respond to user requests as engineering teams had come to expect historically. This was evidenced with respect to direct MAS user requests as well as with new work. The first way diminished rapid response was exemplified was in responses to direct MAS customer requests. In several cases, it was unclear when MAS user requests could be accomplished either due to bureaucratic reasons (e.g., was there budget or schedule slack) or due to weaknesses described above (e.g., poor situational awareness). It should be noted that too much structure or too little can create similar problems where "due and delivery dates become all consuming" and without coordination of action or situational awareness people "either feel too constrained to take creative action or, when they do, discover too late that they have caused massive problems for others" (Barrett, 2012, p. 76). When the weaknesses described above result in a fear of action, the end result is an overall threat to the group's core competency, specifically an erosion of engineering trust. At the same time, emphasizing and rewarding responsiveness may under incentivize usability or user research resulting in short cuts. This leaves the team vulnerable.

That vulnerability was exemplified in increased competition for new visualization work. In several recent cases, initial prototypes were established on top of the integration work performed by the HCI group before the team could respond. From an overall NASA perspective it should be noted that this is not necessarily considered negatively. The question for the HCI group is why did this occur? One potential hypothesis is that the group relies on its MAS perspective. While MAS would not satisfy the needs for data visualization, MAS sets the tone for HCI members' expectations of work. MAS needs everything for a full configuration (e.g., workflow, permissions, data structures, etc.) whereas an initial visualization capability might not. There is potentially an aversion to prototyping systems of this nature because the designers feel that they lack the core user needs necessary to do so or the quick commitment of focused, open-ended resources to find a production-worthy solution that still ensures high-quality data.

Finally, it should be noted that budget and schedule pressure are omnipresent. The specific threat to the organization, however, is that while the number of systems and integrations has increased, the overall budget for MAS has only increased incrementally. The original team of 10 people supported around six systems, whereas in 2017, 25 people support 50 systems and integrations. The funding ratio has not kept pace, but nor have the HCI processes evolved to more efficiently support this operations-centric problem. This affects the overall team's ability to sustain current operations and grow new work at the same quality level expected.

5. Assessing Strategic Fit

Using Rumelt's simple terms of diagnosis and hypothesis, the SWOT reveals several considerations when taken into the context of the environmental history. When the HCI group formed, all team members regardless of function (i.e., design, development or quality assurance) were all co-mingled with loose, organic roles and responsibilities. This made the team responsive and flexible, but at the same time the team had the advantage of working on a few, targeted system configurations. Essentially, the team was organized in a way that created reciprocal interdependency where everyone contributed at the same time to increase speed and information flow.

As the team grew with more systems to support, the basic organic organizational structure and informal hierarchy persisted, but with an evolution toward sequential interdependence. The basic hypothesis was that this organic organization with informal hierarchy combined with a need to support 25 systems created many of the underlying symptoms and weaknesses documented. Most alarmingly was perhaps the combination of flat hierarchical structure without a specific vision driving the HCI group. On its own, "an organic structure could provide only inefficiency and disarray" (Slater & Narver, 1995, p. 71). Without "non-negotiable constraints" there cannot be a balance between order and chaos (Barrett, 2012, p. 68). Minimal constraints create directed learning. This led to a shift in thinking in writing this analysis: hierarchy is not equivalent to minimal constraints and an aversion to it is potentially unwarranted. All of this leads to the possible conclusion, that while the open (and potentially innovative) culture of the HCI group existed, it did so in a non-directed way that limited the realization of its full potential. There was a need to transition to being more aligned with the inherent maintenance role and consider creating more structured routines to support this effort to create efficiency. The idea was that a more efficient operations focus would enable more dedicated time to focus on core user needs.

This is counterintuitive and opposite of the original expectation. In truth, the idea that the team needed to be better managed seems anticlimactic and overly simplistic. Rumelt stresses however that there is a "general tendency of unmanaged human structures to become less ordered, less focused, and more blurred around the edges" (Rumelt, 2011, p. 218). At the same time, the underlying rationale is that by defining roles and responsibilities and building constraining routines that have previously not existed (including those that may combat environmental pressures such as budget and schedule), more innovative, experimental behavior can be found in this more targeted direction. There was a general realization in performing the SWOT that the team already stressed innovation and entrepreneurial thinking in their approach to the work and processes. Part of the problem was that this energy was not directed in a clear and concise way throughout the entire team.

V. FINDINGS AND RECOMMENDATIONS

There are a number of high-level conclusions from the analysis that influence the recommendations moving forward. First, the HCI group maintained an innovative culture but lacked a managed vision and focus. Second, the deeply user-focused culture and subsequent loose organizational structure was preventing the economies of scale necessary to efficiently manage the number of systems and integrations. There were competing priorities between a team attempting to sequentially organize software maintenance and deployments while maintaining the responsive flexibility inherent in their original, reciprocally organized team. In the following sections, these two conclusions are described more deeply and followed by some potential next steps for the HCI group to consider. In completing the full congruence model, the final part of this chapter addresses future considerations in measuring the output produced by strategy.

A. HCI GROUP VISION AND FOCUS

As the analysis underscored, one of the primary weaknesses of the HCI group was an overall lack of team vision. While much has been written about vision, and while acknowledging that one is not a valid substitute for actionable strategy, vision is what channels a group's energy. A user-focused, market-orientation alone without a focused vision more likely results in too narrow a focus resulting in adaptive learning (Slater & Narver, 1991). This user-driven focus partly underscores why there is a seeming focus on smaller, derivative improvements to the existing MAS platform as the group responds to user requests. At the same time, without a specific guiding vision it also makes the group susceptible to environmental pressures (e.g., budget and schedule). That narrowly focused, adaptive response to expressed user requests and environmental pressures results in a "learning boundary" constraining the organization towards incremental improvements within the scope of what the organization knows it can accomplish (Slater & Narver, 1995, p. 64). In other words, lacking a focus constrains the organization when existing systems are established, leaving a team to innovative internally without interrupting what it perceives as accomplishable. The HCI group was culturally innovative, as documented as in strengths, and the innovations observed were consistent with this premise. The group's creativity was mainly constrained towards internal system re-architecting, process learning and improvements, and reinforcing the open culture.

The conclusion is that a lack of focus on the HCI group's core competency has blocked more innovation to the core products. This effect is amplified by the perception that there is no significant, direct competition against the HCI group. Contrary to the initial thinking, by focusing and grounding the team's efforts, the team will become more innovative, not less. The following are a few specific recommendations for this finding.

1. Recommendation 1: Establish an HCI Group Vision and Focus

Relying on the historical group mantra to "Do Good Work," ill equips the team to address the current challenges. The first step is for the HCI group to establish the vision and focus of the organization and then reinforce it. Senge's (1990) notion to focus less on the specific words and more on "using the words to engage people" and motivate the organization is apt (p. 327). Any strategic shift requires the adaptation and implementation of all levels of the organization. A vision helps create balance between the tension of exploration and exploitation (Senge, 1990; Slater & Narver, 1991). The HCI group suffered from James March's (1991) description that "adaptive systems that engage in exploration to the exclusion of exploitation are likely to find that they suffer the costs of experimentation without gaining many of its benefits" (p. 71). While a starting vision was outlined in this document, it should be vetted with senior leadership and communicated consistently throughout the organization and used to direct all efforts.

2. Recommendation 2: Identify a Specific Opportunity

There are three primary areas of work including data curation, data integration, and data visualization within the MAS group. One of the most commonly discussed mistakes in strategy is making one that contains too many objectives (Luecke, 1994; Rumelt, 2011; Senge, 1990). Opportunities are specific and focused and are thus "easy to visualize and rationalize" enabling cultural and organizational change to occur more quickly (Thornberry, 2006, p. 197). While the HCI group must maintain the existing systems and integrations, there are potentially specific opportunities that can be identified that can unify these work areas more efficiently or support the type of structural redesign that may be necessary. This may result in a specific opportunity targeted at the emerging data visualization trend or a specific opportunity that results in clear restructuring that enables the accomplishment of that objective through a more defined, efficient workflow.

3. Recommendation 3: Refactor Established Performance Reviews

The established performance reviews as described previously lack the specificity to reinforce a directional shift in the organization or to protect against the symptoms described previously. There is the management proverb that "what gets measured, gets managed." While there are more tactical metrics that may be managed, there are also those at an individual performance level. These might include:

- The attendance of learning opportunities outside of NASA as a basic requirement with demonstrating their use in advancing group process or products as a goal for superior rating.
- Conducting internal group training on areas of process or lessons learned to increase institutional awareness and learning.
- Implementing and documenting changes to the process that result directly in positive usability or efficiency results.

These could be tailored to specific roles and responsibilities based upon the reorganization that results as part of the recommendations in the next section. Currently, performance reviews are generically written across individuals with small modifications. While that does result in consistent expectations, performance reviews may need to be tailored both to specific individual roles and more specific objectives.

4. Recommendation 4: Transformational Management

With a lack of direction and organic structure, one of the by products was that the team needed to be better managed. A discussion of strategy and organizational change would not be complete without addressing aspects of group leadership. Specifically, there was a need for a transformational, internally focused manager of the group's vision, process, and focus. A transformational leader is needed when the organizational change is significant with their goal to “make the situation conform to their vision of the desired state” (Thornberry, 2006, p. 22). Slater and Narver (1995) call this type of leader facilitative as opposed to transformational, but the intent is identical.

Transformational leaders often stubbornly focus on the anchored vision (Thornberry, 2006) while being adept at inspiring and motivating change and learning (Slater & Narver, 1995). These leaders must be the first to recognize and unlearn the defensive routines that have previously defined an organization. Stubborn does not imply negativity. On the contrary, maintaining psychological safety is paramount to success. Psychological safety refers to reducing the fear of negative repercussions for the moderate levels of risk taking necessary in change efforts (Schein & Bennis, 1965). In their book, *Crucial Conversations,* Patterson et al. predicted with 90% accuracy whether projects would fail based on groups’ ability to have crucial conversations of which psychological safety is a large enabler (Patterson, Grenny, McMillan, & Switzler, 2012). No amount of pressure can force change unless there is a feeling of safety in uncertainty (Schein, 1980). So transformational management is required to drive change towards a new vision while maintaining the psychological safety inherent in innovative endeavors.

Here the word “management” is used specifically, as opposed to leadership. Either word has some loaded meaning and intention. While they may be approximate synonyms the word management implies a more internal view of the organization. Historical leadership within the organization has been outwardly focused, whereas the recommendation here is an internal focus on managing the people and the change process.

B. HCI GROUP ORGANIZATIONAL STRUCTURE

The second primary conclusion was that the deeply user-focused culture and subsequent loose organizational structure was preventing the economies of scale necessary to efficiently manage the number of systems and integrations. The inability to create efficient economies of scale is an inherent weakness of user-focused organizations since their resources are specialized around products or users (Nadler & Tushman, 1997).

The HCI group's organizational structure has always been user-centric with designers attempting to attain specific engineering knowledge to produce the custom MAS configurations needed to support those domains. The user-centered approach was a strength, but it was also an overall weakness with respect to the number of systems needing maintenance and support. It was reasonably clear that this structure was no longer satisfying user expectations regarding support, nor team member expectations regarding their ability to focus on specific tasks. The formally flat organizational structure led to an informally rigid one. Many of the symptoms that imply the need for an organizational restructuring were present (Nadler & Tushman, 1997). There was a significant amount of daily work that revolved around the need to maintain the 25 different MAS configurations, but the team was not organized to do so efficiently. What follows are a few specific recommendations to address this conclusion.

1. Recommendation 5: HCI Group Reorganization

The HCI group needed to transition to an alignment more focused around the efficient maintenance of 25 production systems. While there are many potential solutions, one possible solution is an explicit organization around maintenance, operations, and user support of existing systems. The new organization would include designated design, development, and QA resources and require additional documentation of the system configuration on the part of the design team.

The primary resistance to this will be in the form of holding onto the user-centered approach. This resistance is not without justification and not to be taken lightly. The user-centered approach was a core competency of the organization and the custom MAS configurations are dictated by the NASA engineering process requirements. The maintenance organization would include members from all three disciplines to support the user-centered culture and help proactively respond to unforeseen issues. It would also require additional effort on the maintenance team to maintain the core competency of user-centered design, without necessarily learning deeply about any specific engineering domain. This may be accomplished by requiring data mining of the existing user data, calling users who may be having issues for more in depth user research, or other means.

Efficiencies might need to be created in this area to make it cost-effective. The challenges of designing and implementing new features across the platform while maintaining custom configurations would need to be addressed. It would also have to find ways to incentivize designers to work on the existing product base as opposed to entirely new systems or system configurations. The benefits, however, would be that a maintenance specific organization could stabilize processes and routines to enable more efficient operations, planning, and potentially design implementation.

A formal operations organization implies a separate structure focused on the development of new products or MAS configurations. Recommendation two suggested the identification of a specific opportunity to focus the group. An opportunity such as creating data visualization techniques to navigate through the integrated engineering data, implies the ability to do so while maintaining the existing user base and system configurations. The specific team focused on new products or MAS configurations would likely be a relatively small contingent of the team, thus enabling the reciprocal interdependency necessary for quick responsiveness.

The goal of separating the two teams would be to create the quick interplay of research, design, and development (exploration) while balancing the needs of maintaining existing systems (exploitation). Some tasks are episodic, while others are continuous and a mixture of strategic initiatives to support both are necessary (Weick & Quinn, 1999). By separating a new product team it also separates the uncertainty of research and design activities around new engineering teams from the stability of ongoing maintenance (March, 1991). An overall maintenance and support organization enables a focus on the parts of the work that are meant to be high-reliability and stable. This can enable better detection of small early failures through creating data collection procedures to identify and address qualitative and quantitative issues, while experimenting in a more controlled, isolated context (Cannon & Edmondson, 2005).

A reorganized HCI group might contain four functional groups with specific leads around the following:

1. Operations. Operations might oversee the response to help desk calls, server monitoring, automating tasks such as user provisioning, responding

to outages, and coordinating cross-center infrastructure. The mantra might be “Everything online, always.”

2. Maintenance. Maintenance might be responsible for MAS as a platform including integrations, continually building new features gleaned from usage metrics, re-architecture efforts, and software updates. The mantra might be “Evolving the cutting edge.”

3. Research and Development (R&D). R&D might be responsible for new MAS projects and customers, significant new augmentations (e.g., visualization), and budgeting new projects. The mantra might be “Never stagnant.”

4. Organization. The Organizational lead might be responsible for people (including hiring, identifying missing skillsets and salaries), structure, roles and responsibilities, feedback, career growth and awards. “Engaging the Team.”

The HCI group’s support of MAS, and part of its strength has been the vertical integration and ownership of the entire product and its life cycle. The HCI group is beholden to no external vendor or organization for its technology. A reorganization of this type would address the weak formal structures and organization and more appropriately pool task resources around the group’s current functions.

2. Recommendation 6: HCI Group Workflow Improvements

While high-level refactoring of performance reviews were described in the first conclusion, there are two additional areas for improvement at the tactical, workflow level. The first is a set of roles and responsibilities based upon the direction of the reorganization chosen such as the one outlined above. These need to be created both to create a formal hierarchy to replace the informal one and to reestablish decentralized decision making underneath those roles and responsibilities. For example, it may be necessary to create a team lead for the operations team and at the same time creating a role to document and manage the routinization of those processes. The goal is not to create unnecessary hierarchy, but to create roles in such a way that decision-making is driven down to individual team members. There should be clear responsibilities documented in the management of the workflow. Better systems need to be created such that clear expectations and gates in the workflow enable faster situational awareness and adaptation among team members to the tasks being performed. This speaks to the cultural strength of the organizations members to support each other through shared responsibility and should be considered in both the more routine operations team and the new product team and how and when products are handed off between these.

Second, but related, are defining the minimum, mandatory workflow requirements that are necessary throughout the software development process. The basic workflow process and tasks were understood within the organization, but greater specificity can be established to guide and constrain the work. In the most successful technology organizations clear project and managerial priorities are observed while at the same time operating with processes that are “highly flexible, improvisational, and continuously changing” (Weick & Quinn, 1999, p. 371). The mandatory minimum requirements were not documented, nor did the HCI group provide structured training for new (or existing) members around its processes or technologies. Training is an essential ingredient to creating the agency and ownership of high performing teams (Weick & Quinn, 1999). Earlier, training was considered at the individual performance level for attaining new skillsets to remain current with industry, whereas here the intent is to create internal group training.

The word ‘minimum’ is chosen specifically to describe necessary requirements, but this does not imply simple to determine what those are. The question moving forward for the team is what those minimal requirements should be. The requirement of an internally reviewed storyboard and project team walkthrough prior to any new feature regardless of where the proposal originated might help to maintain the user-centered core-competence and information sharing, and combat the documented organizational inertia of budget and schedule. The storyboard might be augmented to include the specific usability problem being solved, the data supporting the design and implementation direction and other key insights. Augmenting and requiring review of the storyboard would continue to reinforce the core strategy of usability and help create organizational learning. Connecting the workflow artifacts (e.g., full design specification to feature and testing bugs) should be explicitly documented and self audited. To enable organizational learning a formal release notes for each deployment might be created to highlight significant changes or enhancements, major issues addressed, and performance metrics defined at the team level. The team needs to agree to these minimal constraints and should consider posting them prominently.

It is important to note that these constraints may slow the process down; that is intentional by design. Slowing the process can reinforce strategic goals and combat organizational and environmental inertia but specifically because it enhances learning and performance through the consideration of a wider variety of potential solutions (Herriott, Levinthal, & March, 1985; Levinthal & March, 1981; Levitt & March, 1988; March & Shapira, 1987; Sitkin, 1992). By slowing the team's pace of learning and better defining the minimal processes and structures the team will be better able to continue with the self-managed and decentralized decision making that is consistent with the existing culture.

C. ORGANIZATIONAL PERFORMANCE

The strategy and recommendations described above imply that changes will be made to the HCI group. The final element of the congruence model is the output produced by the organization. As with any change effort, the results need to be considered and then flowed back as input as part of continuous evaluation. Nadler and Tushman (1997) specify three criteria to consider that are beyond the minutiae of performance metrics and can be considered at the system, unit and individual levels of the organization:

1. Did the organization meet its expressed strategic objectives?
2. Did it better utilize available resources or create new ones?
3. How well did the organization accomplish new opportunities or fend off environmental threats?

For the purposes of this analysis, these questions are beyond the scope of evaluation but help sharpen the focus on how to measure any large changes within the organization. For example, an organizational change of the HCI group's structure into operations and new product units would result in large changes. These questions help consider whether those changes made a positive impact. These questions also help evaluate the strategy that was input against the metrics that were implemented so that a more quantitative evaluation might be created than the one herein described.

VI. CONCLUSION

A. HCI GROUP CONCLUSION AND NEXT STEPS

The primary goal of this paper was to understand the broader context and diagnose the organizational issues facing the Human Computer Interaction group towards the development of an implementable strategy. The group suffers from common ailments that growing organizations experience. In this case, the HCI group, as a user focused design organization, created a strong core competency through the Mission Assurance Systems platform, but requires a transitional focus on operations and maintenance to achieve the necessary economies of scale required to maintain the number of MAS configurations while continuing to make significant improvements or develop new products. The informal organizational structure that organically occurred over the last decade cannot efficiently support the number of applications and systems that exist. A change to the organizational structure is warranted including formal roles and responsibilities and measurable deliverables, as is the creation of minimal process constraints to guide the various areas of the software development process. The utilization of the SWOT framework and the Congruence Model of Organizational Behavior were helpful in providing clarity both to the underlying causes of the observed symptoms as well as highlighting potential areas of challenge in the future.

By itself, this analysis is only a starting place towards actionable next steps. Further work with the entire group should be considered to help collect relevant feedback and input from all members to confirm these findings and help build consensus on the path forwards. This might take the form of cultural, deftness or leadership surveys outlined in Rita McGrath and Ian MacMillan’s (2000) book, *The Entrepreneurial Mindset*. Other quantitative metrics of group performance may also be considered both as data to support the necessary change, and as the targeted, specific strategic objectives to evaluate in the future. Depending on the organizational structures or mechanisms put into place, more quantitative metrics should be developed as the desired output of the congruence model to measure individual and team progress in addition to the high-level questions suggested to assess overall success. These metrics and questions suggest the final step, which is to revaluate the success of the changes and observe the new unexpected symptoms or problems that inevitably result from change efforts.

The larger NASA organizational issues moving forwards were not addressed in this analysis but are relevant for future consideration. International Space Station as an example of a High-Reliability Organization has not been formally considered in the literature and may provide additional insights into strategies and techniques crucial to Mars Exploration and long-duration missions. The existing literature on HROs is based on the evaluation of existing operational systems (e.g., nuclear power plants) or the transition of existing systems to more HRO-based principles, but little by way of how to *build* or *design* those systems anew as NASA is currently doing in the Exploration Systems Directorate. There may be distinct differences to consider between ESD (in the design phase) and ISS (in continuous operation). Distinguishing the phase of an HRO may provide insight into how to further best practices in safety and reliability. Historical human spaceflight accidents were partially influenced by the budget and schedule pressures present – pressures that still exist today. ISS is an aging piece of infrastructure currently refocusing on more efficient operations to increase scientific output heading into retirement. At the same time, ESD is moving towards building a tightly-budgeted new vehicle and deep space gateway that will rely heavily on the operations insight and expertise from ISS. A proactive analysis of historical accidents as compared to the current NASA environment may be timely.

B. FURTHERING STRATEGY

The consideration of strengths and weaknesses of an organization towards the development of a strategy is not new. The utilization of the SWOT framework as an analysis tool for assessing the strategic fit of a strategy is relatively unique. Strategy is more than visions and mission statements. Organizational design is more than structures. If SWOT provides breadth of analysis, then the congruence model of organizational behavior provides depth. The interplay of the two frameworks enables insight into the multiple dimensions and interdependencies of an organization towards both diagnosing organizational issues and creating an implementable strategy absorbable by culture.

It was noted that with the HCI group, further quantitative research through the use of surveys might be necessary. These would provide additional insight to determine how closely the qualitative analysis documented here matched the data provided by the organization. The point is that this would provide additional insight into whether the combining of the frameworks provided a reasonably accurate assessment or additional value over using them independently as is supposed. Regardless, the two frameworks provided valuable context of the organizational environment and issues facing the HCI group but not necessarily a clear direction forwards. Therein lies the challenge of strategy and the need for leadership.

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APPENDIX. DETAILED SWOT ANALYSES

The appendix documents the individual lines of congruence with the SWOT analysis performed. Each of the six lines were evaluated utilizing Nadler and Tushman's (1997) definition of fits.

A. INDIVIDUAL TO FORMAL ORGANIZATION

Evaluating strategic fit between the individual and the formal organization is performed with the following two questions, as stated in Nadler and Tushman (1997):

1. How are individual needs met by the organizational arrangements?

2. Do individuals hold clear perceptions of organizational structures (p. 35)?

The following detailed SWOT analysis answers these questions.

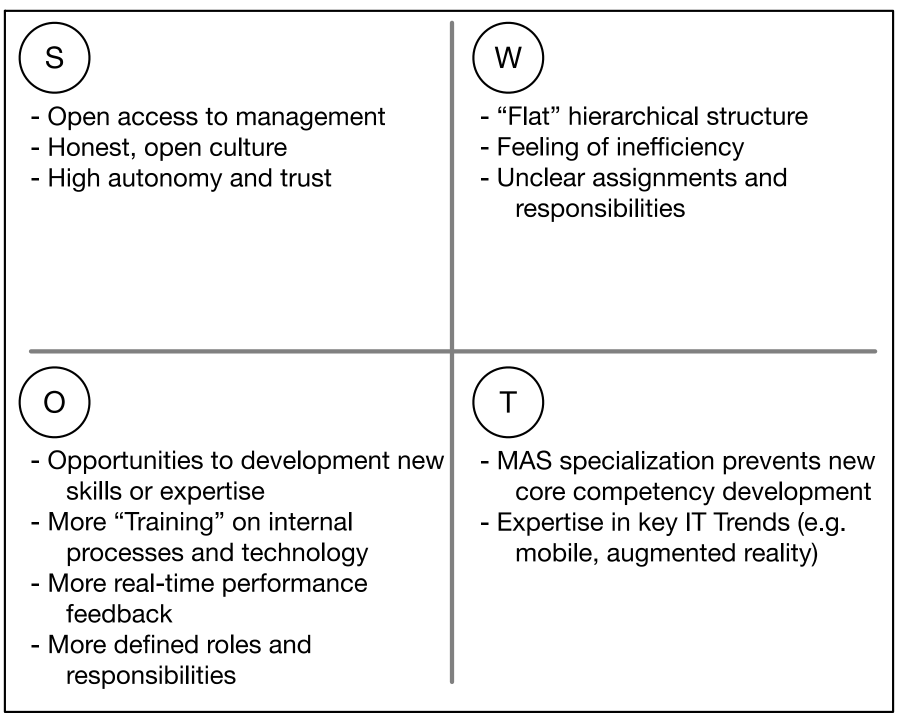

Figure 3. A SWOT Analysis Evaluating the Strategic Fit Between the Individual and the Formal HCI Group Organization.

B. INDIVIDUAL TO WORK

Evaluating strategic fit between the individual and the work is performed with the following two questions, as stated in Nadler and Tushman (1997):

1. How are individual needs met by the work?

2. Do individuals have skills and abilities to meet work demands (p. 35)?

The following detailed SWOT analysis answers these questions.

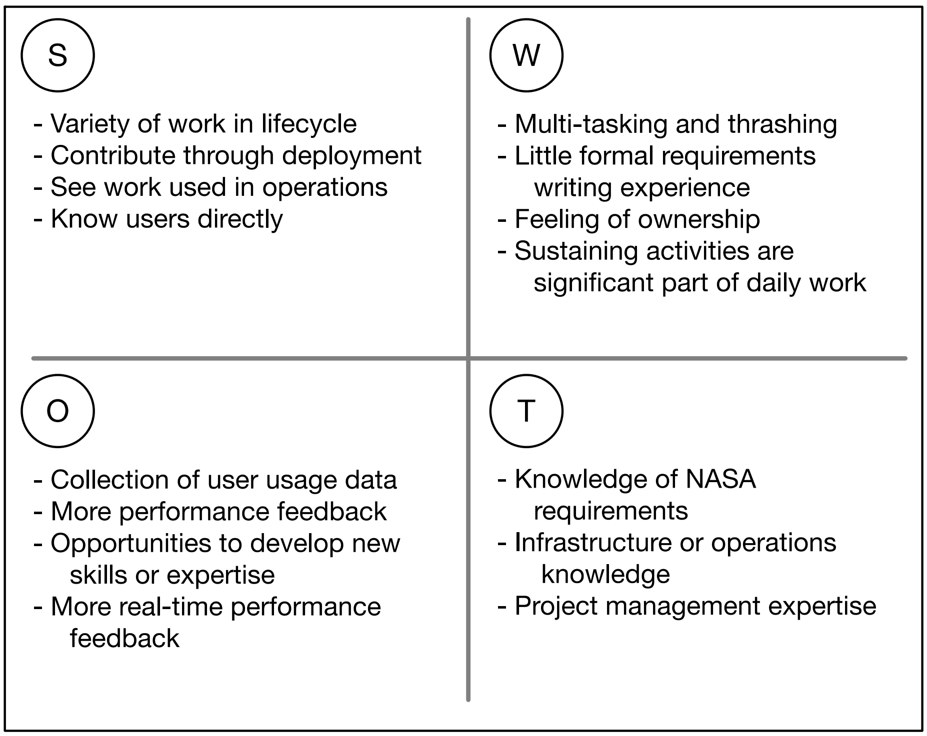

Figure 4. A SWOT Analysis Evaluating the Strategic Fit Between the Individual and the HCI Group Work.

C. INDIVIDUAL TO INFORMAL ORGANIZATION

Evaluating strategic fit between the individual and the informal work is performed with the following two questions, as stated in Nadler and Tushman (1997):

1. How are individual needs met by the informal organization?

2. How does the informal organization make use of individual resources consistent with informal goals (p. 35)?

The following detailed SWOT analysis answers these questions.

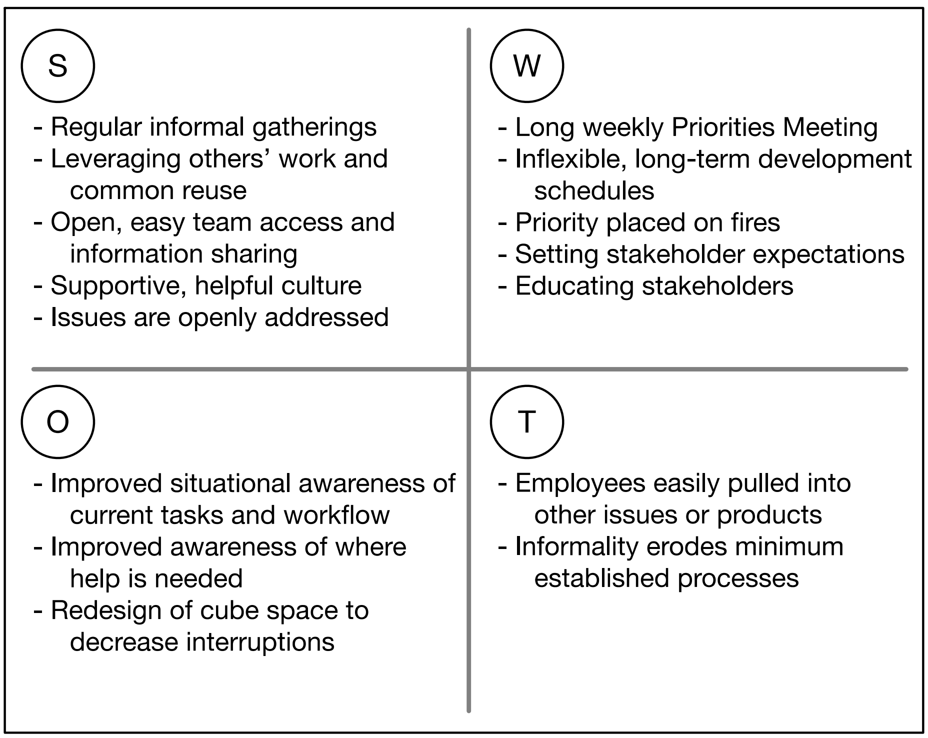

Figure 5. A SWOT Analysis Evaluating the Strategic Fit Between the Individual and the Informal HCI Group Organization.

D. WORK TO FORMAL ORGANIZATION

Evaluating strategic fit between the HCI group work and the formal organization is performed with the following two questions, as stated in Nadler and Tushman (1997):

1. Are organizational arrangements adequate to meet the demands of the work?

2. Do organizational arrangements motivate behavior that is consistent with work demands (p. 35)?

The following detailed SWOT analysis answers these questions.

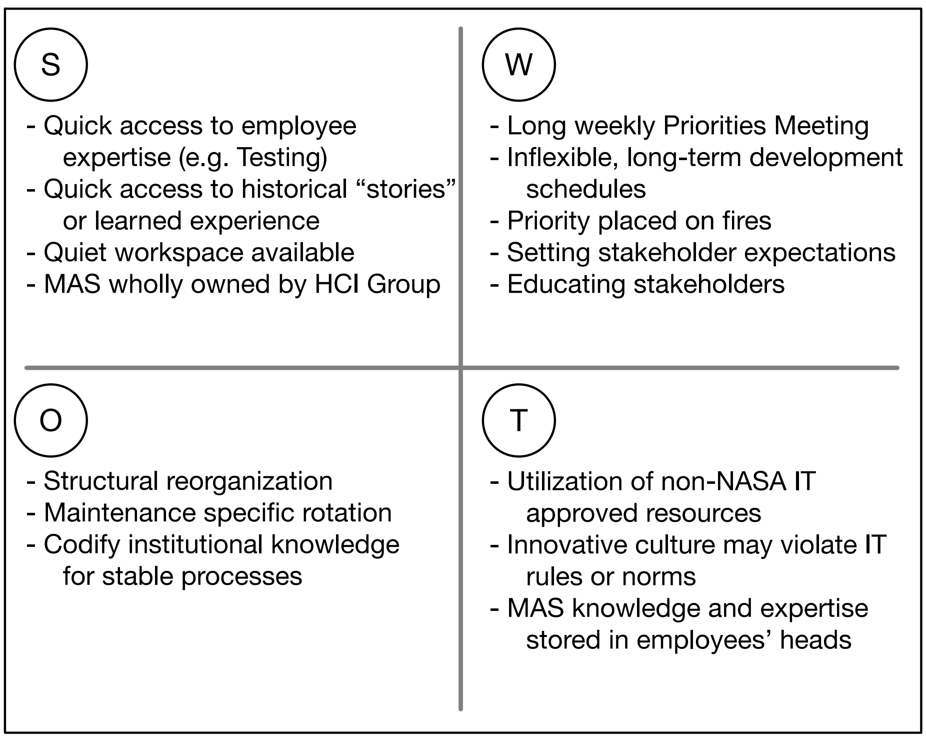

Figure 6. A SWOT Analysis Evaluating the Strategic Fit Between the HCI Group Work and the Formal HCI Group Organization.

E. WORK TO INFORMAL ORGANIZATION

Evaluating strategic fit between the HCI group work and the informal organization is performed with the following two questions, as stated in Nadler and Tushman (1997):

1. Does the informal organization structure facilitate work performance?

2. Does it help meet the demands of the work (p. 35)?

The following detailed SWOT analysis answers these questions.

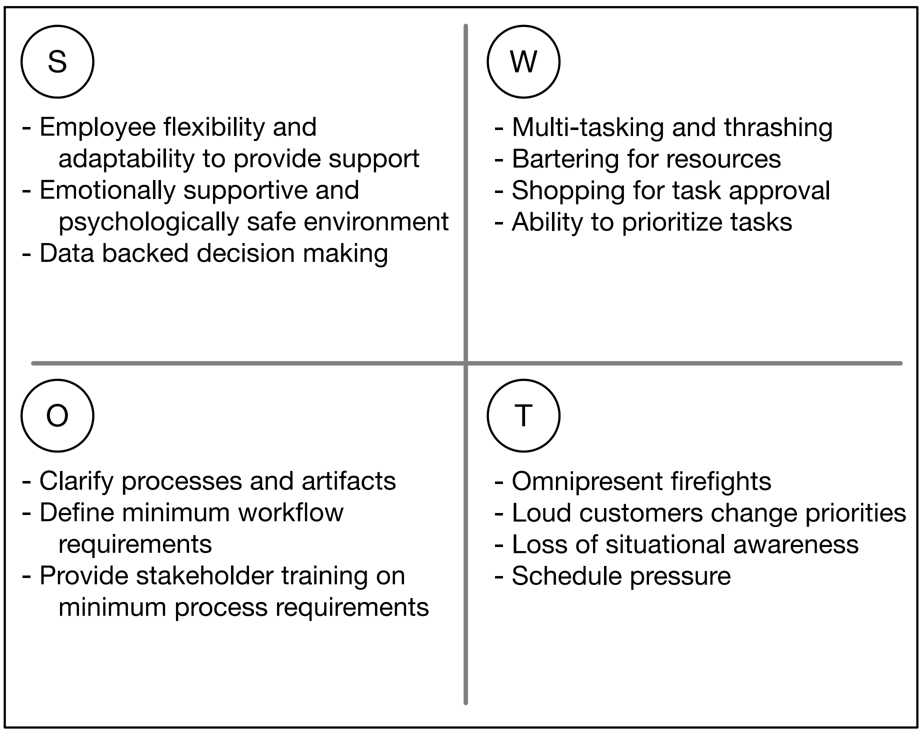

Figure 7. A SWOT Analysis Evaluating the Strategic Fit Between the HCI Group Work and the Informal HCI Group Organization.

F. FORMAL ORGANIZATION TO INFORMAL ORGANIZATION

Evaluating strategic fit between the HCI group's formal and informal organization is performed with the following question, as stated in Nadler and Tushman (1997):

1. "Are the goals, rewards, and structures of the informal organization consistent with those of the formal organization (p. 35)?

The following detailed SWOT analysis answers this question.

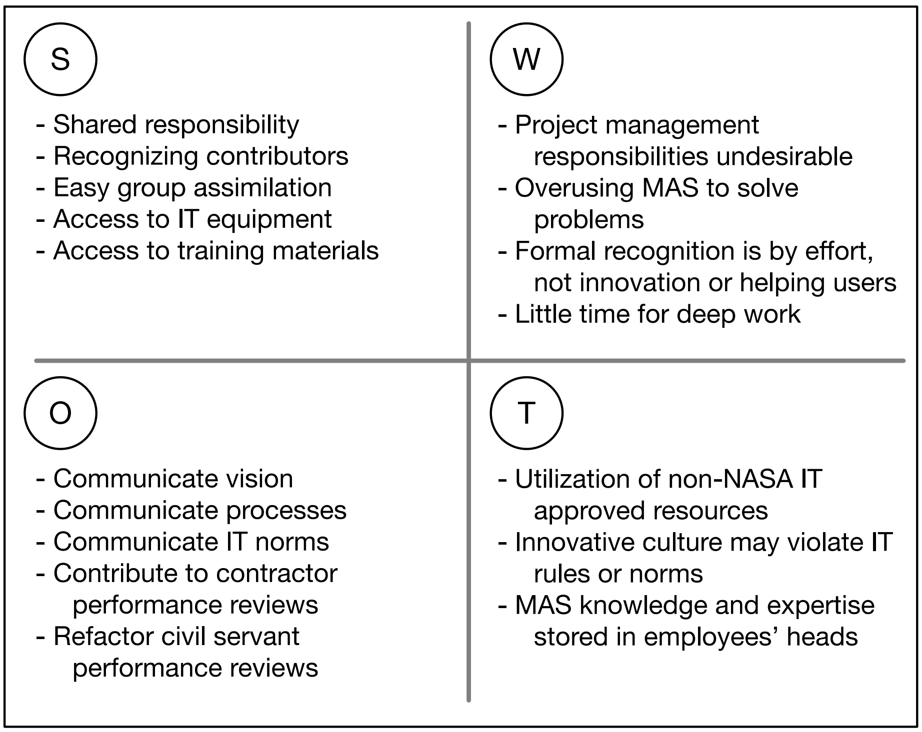

Figure 8. A SWOT Analysis Evaluating the Strategic Fit Between the HCI Group's Formal and Informal Organization.

LIST OF REFERENCES

Argyris, C. (1976). Single-loop and double-loop models in research and decision making. *Administrative Science Quarterly*, *21*(3), 363–375. doi: 10.2307/2391848

Barrett, F. (2012). *Yes to the mess: Surprising leadership lessons from jazz*. Boston, MA: Harvard Business School Press.

Beatty, R.W., & Ulrich, D. O. (1991). Re-energizing the mature organization. *Organizational Dynamics*, *20*(1), 16–30. doi: 10.1016/0090-2616(91)90080-S

Boin, A., & Shulman, P. (2008). Assessing NASA's safety culture: The limits and possibilities of high-reliability theory. *Public Administration Review*, November/ December, 1050–1062. doi: 10.1111/j.1540-6210.2008.00954.x

Cannon, M. D., & Edmondson, A. C. (2005). Failing to learn and learning to fail (intelligently): How great organizations put failure to work to innovate and improve. *Long Range Planning*, *35*, 299–319.

Capers, R. S. (1994). NASA post Hubble: Too little, too late? *The Academy of Management Executive*, *8*(2), 68–72.

Carroll, T. N, Gormley, T. J., Bilardo, V. J., Burton, R. M., & Woodman, K. L. (2006). Designing a new organization at NASA: An organization design process using simulation. *Organizational Science*, *17*(2), 202–214.

Casler, J. (2013). Revisiting NASA as a high reliability organization. *Public Organization Review*, 229–244. doi: 10.1007/s111115-012-0216-5

Downs, A. (1964). *Inside bureaucracy.* RAND Corporation. Retrieved from https://www.rand.org/content/dam/rand/pubs/papers/2008/P2963.pdf

Greene, C. S., & Miesing, P. (1984). Public policy, technology, and ethics: Marketing decisions for NASA's space shuttle. *Journal of Marketing*, *48*(Summer), 56–67.

Holdren, J. P., & Bolden, C. (2014, January 8). Obama administration extends International Space Station until at least 2024 [Blog post]. Retrieved from https://obamawhitehouse.archives.gov/blog/2014/01/08/obama-administration-extends-international-space-station-until-least-2024

Humphrey, Albert S. (December 2005). SWOT analysis for management consulting. *SRI Alumni Association Newsletter*, 7–8. Retrieved from https://www.sri.com/sites/default/files/brochures/dec-05.pdf

Kahneman, D., & Tversky, A. (1979). Prospect Theory: An analysis of decision under risk. *Econometrica*, *47*(2), 263–292.

Lambright, W. H. (1992). The Augustine report, NASA, and the leadership problem. *Public Administration Review*, *52*(2), 192–195.

LaPorte, T. R., & Consolini, P. M. (1991). Working in practice but not in theory: Theoretical challenges of "High Reliability Organizations." *Journal of Public Administration Research and Theory*, *1*(1), 19–48.

Levine, A. L. (1992). NASA's organizational structure: The price of decentralization. *Public Administration Review*, *52*(2), 198–203.

Levinthal, D., & March, J. (1993). The myopia of learning. *Strategic Management Journal*, *14*, 95–112.

Levinthal, D., Rerup, C. (2006). Cross an apparent chasm: Bridging mindful and less-mindful perspectives on organizational learning. *Organization Science*, *17*(4), 502–513.

March, James G. (1991). Exploration and exploitation in organizational learning. *Organizational Science*, *2*(1), 71–87.

March, J. G., & Shapira, Z. (1987). Managerial perspectives on risk and risk taking. *Management Science*, *33*, 1404–1418.

March. J. G., & Simon, H. (1993) *Organizations* (2nd ed.). Cambridge, MA: Blackwell.

McCurdy, H. E. (1991). Organizational decline: NASA and the life cycle of bureaus. *Public Administration Review*, *51*(4), 308–315.

McCurdy, H. E. (1994). *Inside NASA: High technology and organizational change in the U.S. space program*. Baltimore, MD: The John Hopkins University Press.

McGrath, R., & MacMillan, I. (2000). *The entrepreneurial mindset: Strategies for continuously creating opportunity in an age of uncertainty*. Boston, MA: Harvard Business School Press.

Nadler, D.A., & Tushman, M. L. (1997). *Competing by design: The power of organizational architecture*. New York: Oxford University Press.

National Aeronautics and Space Administration. (1990). *Report of the advisory committee on the future of the U.S. space program*. Washington, DC: NASA History Division. Retrieved from https://history.nasa.gov/augustine/racfup1.htm

National Aeronautics and Space Administration. (2003). *Columbia Accident Investigation Board*. Washington, DC: Government Printing Office. Retrieved from https://www.nasa.gov/columbia/home/CAIB_Vol1.html

National Aeronautics and Space Administration. (2017a, August 3). Journey to mars overview. Retrieved September 12, 2017, from https://www.nasa.gov/content/journey-to-mars-overview

National Aeronautics and Space Administration. (2017b, October 2). Organization. Retrieved October 16, 2017, from https://www.nasa.gov/about/org_index.html

National Aeronautics and Space Administration Transition Authorization Act of 2017, Pub. L. No. 115–10 (2017). Retrieved from https://www.congress.gov/bill/115th-congress/senate-bill/442/text

Perrow, C. (1999). *Normal accidents: Living with high-risk technologies* (2nd Ed). Princeton: Princeton University Press.

Porter, M.E. (1980). *Competitive strategy*. New York: Free Press.

Prahalad, C. K., & Hamel, G. (1990, May-June) The core competence of the corporation. *Harvard Business Review*. Retrieved October 12, 2017, from https://hbr.org/1990/05/the-core-competence-of-the-corporation

Prouty, R. (2014, November 13). Doing space station differently, we can RISE to a new future. *JSC Features*. Retrieved September 12, 2017, from https://jscfeatures.jsc.nasa.gov/pages.ashx/159/Doing%20space%20station%20differently%20we%20can%20RISE%20to%20a%20new%20future

Roberto, M., Bohmer, R. M. J, Edmondson, A. C. (2006, November). Facing ambiguous threats. *Harvard Business Review*. Retrieved October 12, 2017, from https://hbr.org/2006/11/facing-ambiguous-threats

Roberts, K.H., Bea, R., & Bartles, D.L. (2001). Must accidents happen? Lessons from high-reliability organizations [and executive commentary]. *The Academy of Management Executive*, *15*(3), 70–79.

Rumelt, R. (2011) *Good strategy bad strategy: The difference and why it matters*. New York: Crown Business.

Schulman, P.R. (1993). The negotiated order of organizational reliability. *Administration & Society, 25*(3), 353–372.

Senge, P.M. (1990). *The fifth discipline*. New York: Doubleday.

Senor, D., & Singer, S. (2009). *Start-up nation*. New York: Hatchett Book Group.

Sitkin, S. B. (1992). Learning through failure: The strategy of small losses. In B. M. Staw and L.L. Cummings (Eds), *Research in Organizational Behavior, 14*, 231–266.

Slater, S. F., & Narver, J. C. (1995) Market orientation and the learning organization. *Journal of Marketing*, *59*(3), 63–74.

Starbuck, W. H., & Milliken, F. J. (1988). *Challenger*: Fine-tuning the odds until something breaks. *Journal of Management Studies*, *25*, 319–340.

Thompson, J. D . (2004). *Organizations in action: Social science bases of administrative theory* (2nd Ed). New York: Transaction.

Thornberry, N. (2006). *Lead like an entrepreneur*. New York: McGraw-Hill.

Vaughn, D. (1996). *The Challenger launch decision: Risky technology, culture, and deviance at NASA*. Chicago: The University of Chicago Press.

Vogus, T. J., Rothman, N. B, Sutcliffe, K. M., & Weick, K. E. (2014). The affective foundations of high-reliability organizing. *Journal of Organizational Behavior*, *35*, 592–596. doi: 10.1002/job.1922

Weick, K. (1987). Organizational culture as a source of high reliability. *California Management Review*, *29*(2), 112–127.

Weick, K., Quinn, R. (1999). Organizational change and development. *Annual Review of Psychology, 50*, 361–86.

Weick, K., Sutcliffe, K. (2007). *Managing the unexpected: resilient performance in an age of uncertainty* (2nd ed.). San Francisco: Jossey-Bass.

Weick, K., Sutcliffe, K., & Obstfeld, D. (1999). Organizing for high reliability: Processes of collective mindfulness. In R.S. Sutton and B.M. Straw (Eds.) *Research in Organizational Behavior*, *1*, 81–123.

Weick, K. E., & Roberts, K. H. (1993). Collective mind in organizations: Heedful interrelating on flight decks. *Administrative Science Quarterly*, *38*(3), 357–381.

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