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Working at the Speed of Innovation: Impedance Mismatch in Rapid and Innovation Projects

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I. Abstract

In this paper we report on the results of an ethnographic study of a rapid design innovation (RDI) experiment in NASA Aeronautics. This work is based on the study of the Aeronautics Autonomy Testbed Capability (AATC) team in the Convergent Aeronautics Solutions (CAS) project. This paper focuses on and summarizes one of the key over-arching findings from the study: there is a significant mismatch in the organizational culture in the rest of the organization compared with that required for RDI. And, if this organizational cultural mismatch is not addressed, the likelihood of any organization being able to advance a new and different type of work (such as RDI) will be jeopardized. We delineate several aspects of the two different cultures identified in order to enable leaders and practitioners to better understand what contributes to the cultural dissonance and the implications of the differences in the cultures. As well, we identify ways in which those differences can be addressed. Research from organization and other social sciences are incorporated to highlight the differences. The implications of the research suggest that the significant cultural differences trigger a strong and resistive response from the dominant culture that may negate leadership's strategy to build the new capacity for RDI.

While the research results noted the pervasive nature of innovation throughout the workplace, the type of innovation envisioned in RDI is a rare type of innovation that requires significantly new methods, work processes, tools, and skills such that approaches used in the dominate culture cannot be adopted by expediting the existing approaches. Examples include: innovation teaming and leadership; the need for adaptive leadership that changes the relationship of a research leader to the other researchers; and, an interdisciplinary teaming approach which shapes team relationships and activities. Each of these aspects requires new teaming, tools, and skills in order to succeed. Thus, when introducing RDI activities where there is a different dominant culture, teams need to be: well trained; protected; recognized and rewarded. And, team leaders must also be trained in the unique types of teaming and innovation tools used in RDI. Both RDI teaming and team leadership must be sanctioned, supported, and rewarded by leadership. Because of the cultural mismatch, in some organizations looking to add RDI to their existing and established organizations, separate organizational entities have been developed to avoid or mitigate the negative impact of the culture mismatch.

II. Introduction

Innovation and the speed to innovate are discriminators of the most well-known innovative institutions today including Google, Apple, and SpaceX. As the pace of technological advancement continues to rise, the need for engineering and scientific organizations to be able to respond rapidly to technological advancements and innovation continues to be an imperative. Dr. Jaiwon Shin, Associate Administrator for NASA's Aeronautics Research Mission Directorate (ARMD), stated: "The challenge in science and engineering is how do you compete in this era of tremendously exciting IT and computer world (of) Google?" (Song 2015). For large, well-established engineering and scientific organizations such as NASA, re-tooling their organizations to respond with greater speed to innovate can be a challenge due to the need to overcome organizational inertia and the associated organizational cultural rate limiting factors.

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Cognizant of these realities, leaders in NASA's Aeronautics Research Mission Directorate (ARMD) launched the Convergent Aeronautics Solutions (CAS) Project in the Transformative Aeronautics Concepts Program (TACP) as one avenue to explore rapid and innovative approaches that capitalize upon another key discriminator of rapid innovation: technological convergence, where technologies from diverse disciplines within and external to aerospace converge to enable new, potentially disruptive capabilities. The CAS project is structured as a place to encapsulate, explore, and enable rapid, innovative, cross-disciplinary, and disruptive research that pushes the boundaries of where ARMD has previously explored. (NASA 2015, 2016, 2017)

Owing to CAS's charge, a recent challenging rapid design innovation experiment was conducted in CAS to focus on understanding how to enable considerably faster cross-disciplinary and convergent innovation. The experiment explored two concepts: 1) using a rapidly formed, interdisciplinary teaming approach with adaptive leadership and 2) using rapid design based upon the design thinking approach to address to a technical challenge in a shorter timeframe and more innovative manner.

The experiment was known as the (team-named) "Aeronautics Autonomy Testbed Capability" (AATC) and was set within the organizational world of NASA, ARMD, TACP, CAS, and NASA's Research Centers but the experiment required the team to function outside of the normal processes of all. It was a counter-cultural experiment in NASA that required the AATC participants to simultaneously and rapidly adopt new skills and work in new ways to innovate. Lessons learned regarding the rapid design portion of the study are documented in reference (LTG Associates, 2018).

The experiment illuminated a clear mismatch between the organizational culture required for the majority of ARMD research (which still has a great deal of innovation) and the organizational culture required for what we will call rapid design innovation, which is the type of work conducted during the AATC experiment. Rapid design innovation was found to be a rare type of innovation as will be discussed subsequently. In the paper we will discuss a few of the findings related to the organizational cultural mismatch identified during the AATC experiment and some of the implications.

Though the AATC experiment serves as an important case study for NASA ARMD, it also serves as an exemplar of the cultural impedance mismatch that many established organizations with a sizable engineering and scientific workforce may experience while striving for rapid design innovation efforts in developing large-scale engineered systems such as aerospace systems. As most aerospace companies understand the importance of rapid design innovation, our objectives in this paper are to bring rigor from organization and social science integrated with empirical data from the NASA AATC study to increase understanding regarding what is required for successful implementation of rapid design innovation efforts in engineering institutions.

We begin this paper with background describing the ethnographic research methodology used in studying the AATC experiment and describing the AATC experiment itself; and defining organizational culture. Next, we discuss our findings and focus on a contrastive analysis of two of the cultures that must coexist in the organization: the culture that shapes and supports central, routine or standard organizational operations and the culture that enables and supports rapid design innovation efforts. We explore two examples of the cultural impedance dynamic: teaming as an expression of organizational culture and the use of the methods, processes, and tools of rapid design innovation. We highlight some of the cultural drivers and dependencies that reinforce the standard culture and mediate against the uptake and utilization of explored kinds of teaming and innovation design approaches. In particular, we will explore leadership, team design and conduct, and rewards and recognition. The final section of the paper will discuss steps that can be taken to address the challenge of enabling rapid design innovation work in the organizational context of large and established engineering and scientific institutions that develop large-scale engineered systems.

III. Background

A. The Ethnographic Research Methodology Used

Ethnography is the systematic account of a particular cultural group. The central purpose of the ethnographic approach used in this study was to understand the AATC rapid team formation and processes within the general cultural context of NASA, the specific cultural context of ARMD and the NASA Aeronautics Research Centers.

The research team was comprised of nine senior anthropologists who used the tools of ethnography to conduct the research. Ethnography has several purposes including "telling a credible, rigorous, and authentic story" (Fetterman 2010), and building "theories of culture – or explanations of how people think, believe, and behave" (LeCompte and Schensul 2010). It is a systematic account of a particular organizational or community culture. Ethnography is not a single method but rather a toolkit of methods developed by anthropologists and other social scientists to document "how things work, what is going on, and the meaning" within a cultural group in a systematic way. Ethnographers often blend quantitative and qualitative methods, choosing fieldwork tools and techniques best suited to particular cultural contexts and research questions. In this case, the team drew from the long tradition of team ethnographic research in anthropology (Erickson and Stull 1998).

Like most anthropological fieldwork, much of our data was collected in person (whether physically proximate or virtual), through semi-structured and informal interviews and observation. For needs assessment or evaluation work, ethnographers often employ rapid methods; they draw on past experience in similar settings and/or on a careful literature review and make short field visits spread over a period of time to speed the ethnographic process (Handwerker 2001). In this case, the ethnographic team was able to be in contact during much of the AATC team's work, observing virtually by reviewing videos and real-time team sessions and conferences, asking follow-up questions on the telephone, reviewing relevant literature and videos, conducting on-site interviews and observations, and conducting video interviews. By focusing on both the AATC and multiple NASA Centers, our methods and analysis are part of the study of present-day dispersed but globally-connected communities through multi-site ethnography (Marcus 1995). Multi-site ethnography presents both practical and theoretical challenges (Berg 2009), some of which are resolved by the type of team approach taken.

The ethnographers studied the AATC team as it conducted its tasks, as well as team contexts, to understand the "emic" (or insider) viewpoints and experiences of the team and administrators and understand themes and patterns within the larger culture. The ethnographic data led to an understanding of the facilitators, barriers, and potential value of this rapid teaming approach as well as ways to enhance its value and likelihood of success for future projects. More than 100 hours of interviews were conducted over the course of the ethnography with over 45 additional hours of guided conversations with NASA employees. And, the team conducted more than 180 hours of observations of both video and in-person events. We used a variety of analysis techniques, most notably content analysis which leads to the identification of key themes and patterns.

Ethnographic work generally starts with anthropologists adopting a kind of methodological and theoretical neutrality, with the primary goal of understanding "what people do" (local practices) and "what people say" (local discourses), to yield the discovery of patterns and themes. Ethnographers listen, ask questions, note informal interactions, observe, and participate, usually in a value-neutral way, always cognizant of the fact that their presence may change the context and content of the situation. The task is not to eliminate bias, but to identify and understand possible inconsistencies or biases in the data by cross checking findings from a particular data source against the body of data collected. Attention is paid to what is said and what is not said, and, what is on view and what is hidden. In team ethnographic research, researchers can check their findings and discover patterns by comparing their findings with the whole team and against findings in the literature in a constant, iterative, analytic process. In this way, ethnographic analysis is broadly comparative, exploring similarities and differences among local and non-local patterns.

B. The AATC Experiment/Case Study

The AATC experiment was a thoughtfully-designed experiment which changed many conditions simultaneously for a team of NASA engineers. While there were many lessons learned from the experiment, some of which are captured in "Working at the Speed of Innovation" (LTG Associates, Inc. 2018) the ethnography was focused specifically on the rapid teaming process and outcomes. ARMD, TACP, and CAS leaders wanted to understand the feasibility of 1) using a rapid teaming process and 2) how that could be utilized to address rapid and innovation tasks. The experiment and the ethnographic study that accompanied it were designed to address the central question: Can a rapidly-formed team made up of the best researchers available at that time (not waiting to design a specific team) rapidly learn and apply new approaches to create innovative conceptual designs? Several embedded questions were also important to NASA leaders: "What are we doing that prevents this from happening more routinely?" "What are the factors that militate for and against rapid innovation?" Additional questions also emerged: what are the potential costs and dangers? and, what will be needed to create and lead teams that are ready and able to use these methods and approaches?

While the AATC study was a deliberate experiment in rapid design innovation in NASA aeronautics, ethnographic analysis of this study revealed several findings that are likely transferrable to other large and established engineering institutions that develop large-scale engineered systems such as aerospace systems. Similar efforts may be found in internal research and development (IRAD) or advanced concept teams in engineering institutions.

Our research confirms what many in these organizations have experienced: the organizational culture required for successful implementation of rapid design innovation is significantly different from that required for successful implementation of more routine organizational operations in a large engineering organization. This paper focuses on this overarching finding: an organizational-culture mismatch exists and must be overcome for successful formation and implementation of rapid and innovation efforts in an established organization. In this paper we will refer to general and rapid design innovation (RDI) teams to demarcate the routine from the unusual.

C. Organizational Culture and its Power to Shape Work Tools and Tasks

Culture is as inescapable as earth gravity and must be managed thoughtfully for objectives to be achieved, whether in space or in a laboratory. And, not recognizing and addressing the organizational culture can result in the culture driving the organization in unintended and potentially counter-productive directions. The standard culture can also resist change and growth for the organization even where there is putative leadership desire for such change. In short, those who deny or ignore the power and persistence of organizational culture lose some ability and opportunity to shape and direct the work and the organization.

In order to affect organizational culture, it is important to be clear about what it is, how it works, and how it shapes the organization. While definitions of organization culture vary in the literature, several key constructs are common among researchers. These constructs include values, assumptions, and behavioural norms that define the way in which an organization conducts its business (Barney 1986; O'Reilly, et al. 1991; Kotter 2008). Anderson (2017) describes organizational culture in this way:

Organizational Culture is its collective mindset. It is the pattern of widely shared (often unconscious) assumptions, beliefs, and values that form the basis of people's ways of being, relating and working, as well as the organization's interaction with its environment and its success in it. Essentially, culture determines "how things are and how things get done around here." It is largely invisible, and very powerful!

While somewhat intangible and hard to address pragmatically for most leaders, culture permeates virtually every aspect of an organization. The norms, work practices, thought patterns, values, and beliefs at play in the organization have direct influence. What decisions are made and how they are made, the way structure, systems, and business processes are designed and executed, and the behavior of leaders and the workforce – all are influenced by the existing culture.

O'Reilly (1991), et al. note that "basic values may be thought of as internalized normative beliefs that can guide behavior." Though members of the organization may change, an organization's culture often persists over time since members tend to teach the culture to new members and reward those that abide by the norms. (Kotter 2008) Though it is common for organizational culture to be referred to in the singular, all organizations have multiple cultures, some of which may be conflicting. (Kotter 2008) The different cultures may be associated with different functional groups or geographic locations. In this paper we delineate two cultures: 1) the standard culture that grounds, sustains, and supports the organization's routine planning and functioning and shapes the majority of the organization and 2) a rarer culture that grounds, sustains, and supports the ability of an organization to take up the teaming practices and tools related to conducting rapid design innovation. An analysis of both cultures was grounded in the literature, ratified through the research using NASA's AATC study, and found to exist in the majority of organizations.

The standard organizational culture is highly adapted to accomplish the work the organization has always accomplished. It drives day-to-day functioning in an organization and shapes the vision, values, forms, and behaviors that are supported and tolerated within the organization. The standard culture therefore will shape the nature of the desired workforce, types and styles of work, and forms of products. Because it sets basic expectations for functioning, those in the organization generally defend the existing standard culture fiercely, though perhaps unconsciously. Changes to the standard culture, even if those changes are discussed as desirable, will generally be guided back to the normative behaviors by the participants. Cultural disruptions and transformation are thus considerably challenging.

The second kind of culture, that required for rapid design innovation, is formed to create both technological disruption and transformation and to do so rapidly. We will call this culture Rapid Design Innovation (RDI), a rare form of innovation as discussed subsequently. Though the focus of RDI is to rapidly create technological disruption and transformation, the methods, processes, and tools to do so are organizationally disruptive to the standard organizational culture -- even when such transformation is desired. While Silicon Valley has made a reputation for embracing this culture, RDI is appropriately a very small part of most large and long-standing organizations as it is at NASA. To be expected, RDI is therefore disquieting to many who primarily work in the organization's standard culture.

In the following sections we will illustrate a few of the differences between the two cultures by focusing on differences in teaming styles, leadership, risks and rewards, and in types of innovation. To reiterate: these differences arise when working in a large, established organization where a sanctioned and supported cultural home for RDI has not yet been created. The differences between the cultures sets the stage for the standard culture to reject the RDI culture which violates established cultural norms. While protection of the standard culture can be productive and necessary, it will generally ensure that RDI will have difficulty taking root.

Adding a new type of work that is very different than what resides in the standard organizational culture, in this case RDI, necessitates methodically expanding the cultural continuum of the organization to create an intentional home that allows the counter-cultural to become culturally acceptable and even appreciated. This requires sanctioning and modeling by leadership and the development of and support for appropriate practices that integrate RDI into a protected organizational space. There should not be an expectation that the standard culture will adapt to a new, dramatically different way of working naturally. Rather, it should be expected that the standard organizational culture

will mark the RDI work as something perhaps less rigorous and orderly and more nonconforming and disrupting – something the standard culture defends itself against in engineering institutions. As the standard organizational culture is pervasive and inherently reinforced daily, enabling a new dramatically different way of working and work products, requires creating, supporting and sustaining a new culture that can be held in the same organization as the standard culture. The following sections will delineate several specific characteristics of Rapid Design Innovation and the cultural impedance mismatch that occurs when the organization is not prepared for its inclusion as was identified in the NASA AATC study.

IV. Findings

“Culture eats strategy for lunch” (attributed to Peter Drucker)

A. Desired but Counter-Culture

Google CEO Eric Schmidt said that company culture and innovation cannot be separated, stating "You have to have the culture (for innovation), and you have to get it right" (2017). Although NASA leaders sought the inclusion of RDI and its associated work culture (the creation of CAS and the launch of the AATC study are two examples of this), the prevailing organizational culture created significant barriers to the AATC’s attempts to work and act in ways consistent with RDI.

1. All Innovation is not the Same

The word innovation is often used as a synonym for both “improved” and “new”, words that define vastly different starting and ending points. So, before going further, we offer some definitions to improve clarity in discussing different types of innovation. For innovation, **defining the expected outcome helps to determine the skills, tools, approaches, and people needed to attain it.** The following are three concepts of the innovation continuum found in the literature. The first concept illustrates three types of innovation and the healthy ratios of each suggested by Kaplan (2017) and shown in Figure 1.

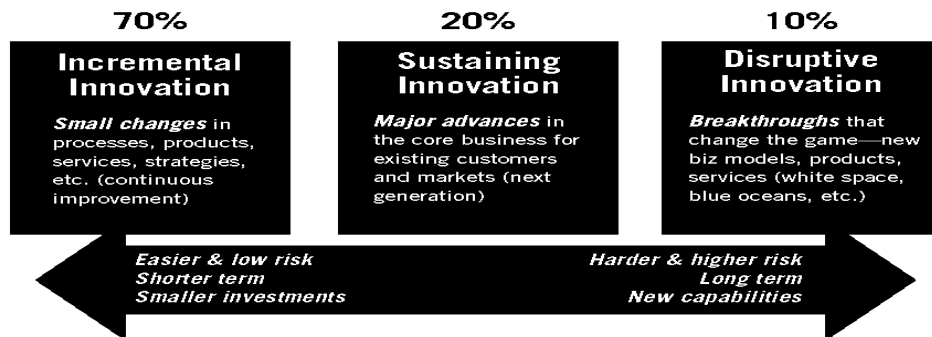


Fig. 1. Kaplan Definitions and Ratios of Innovation

In the second example, four stages of an innovation continuum are envisioned by Grisedale (2012) and depicted in Figure 2.

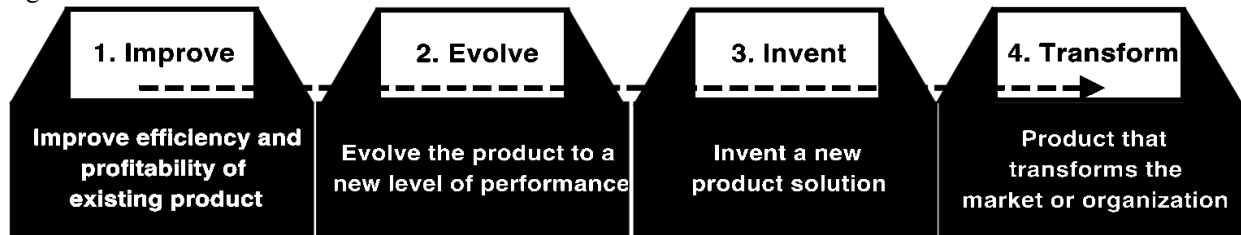


Fig. 2. Grisedale Innovation Stages

Both models illustrate the range of innovation from improvement to transformation. In Kaplan’s diagram, the conditions of innovation – risk, time, and investment as he envisions them are emphasized. And, importantly, Kaplan suggests that the majority of time and effort for an organization are generally focused on incremental innovation, that is, improving a process or product. A third example by Griffin (2013) envisions two innovation processes and simplifies those offered by Kaplan and Grisedale.



Fig. 3. Griffin Primary and Secondary Innovation

Griffin states “Primary, where an organisation creates something new from scratch and Secondary, where they take an existing solution and simply fine tune it to increase its efficiency and effectiveness.” Throughout this paper, we will refer to the concepts of primary – completely new and transformative - and secondary innovation – evolution or improvement. Both are important, but each will demand different methods, tools, and processes to be successful. And, as Kaplan suggests, healthy organizations need to calibrate their innovation work with the majority of time spent in “incremental” innovation, that is improving products or processes. This suggests that organizations can and do create culturally-supported spaces along the continuum that allows these different kinds of innovation to coexist.

Although innovation permeates much of NASA, the type of rapid design innovation conducted during the AATC study is less often undertaken. More frequently, the described incremental, sustaining, or secondary innovation types mark the core work. What is important is that innovation is multifaceted, and all types serve important but different purposes. The AATC experiment challenged the team to work at the far end of innovation which is generally understood to be rarefied and risky territory. Throughout the paper when innovation is discussed, it will be referencing that far end of the innovation continuum. This type of work is sometimes associated with design thinking.

2. Key Features of RDI Teams and Work Process

In this section we will describe some of the key features that distinguish RDI teams. These features are common to yet not exclusive to RDI teams.

Speed

RDI teams often work on much shorter timelines than typical teams. The speed of non-RDI engineering teams allows for longer development cycles, more complex prototyping, and more thorough testing and evaluation of more matured design concepts. For RDI teams, the tasks and tools of design innovation often demand shorter development cycles as well as low-cost and simple prototyping in order to rapidly develop and initially test new ideas to determine what merits further development. For example, the “sacrificial prototypes” of RDI work are not used to assess technical feasibility but rather to better understand the problem domain and assess if the right problem is being solved. Importantly, the pace of iteration and the transformative products sought for RDI teams is such that many of the methods, process, and tools of non-RDI engineering teams cannot simply be adapted for RDI work by executing them more quickly.

Team Form

RDI teams are not always fully populated with subject matter experts (SMEs). In RDI teams, as the need for speed and rapidity of cycles of innovation increase, RDI teams are frequently going to rely on the methods of innovation as much or more than the skills and knowledge of content experts. Rather, RDI teams will quickly connect with SMEs as needed as well as embrace diversity of thought by gaining the perspectives of professionals in different fields. Key features of RDI teams include those shown in Table 1.

| | | |
|--|----------------------|--|
| ▪ Small | ▪ Highly interactive | ▪ Interdisciplinary |
| ▪ Often work without prescribed requirements | ▪ Problem driven | ▪ Roles may be unspecified and members adapt as needed |
| ▪ Ambiguity tolerant | ▪ Design oriented | ▪ Adaptive team leadership (vs. Principal Investigator-centered) |

Table 1. Key RDI Team Features

Many of these features are counter-cultural to the ways in which non-RDI teams are formed and generally function in the prevailing organizational culture. Even for experienced engineering, stepping into RDI culture for the first time may require learning the methods, processes, and tools of design innovation as well as learning new teaming skills. The RDI team’s ability to work together rapidly, in ambiguous areas, with changing roles, and without requirements creates both opportunity and likely tension and demands new skills and behaviors. One of the RDI features that we will explore further in this section is that of innovation and adaptive leadership.

Innovation and Adaptive Leadership

The literature points to leadership and team skills being equally central to the development and conduct of innovation teams. While the innovation literature may suggest to some that there is a team environment devoid of status and position of individual members, this does not suggest that there is no place for leadership or structure. The relationship between leadership and an innovation team must be managed carefully. Microsoft, Apple, and Google have navigated this relationship and have gathered insight into the dynamics of the structure. Microsoft's Bill Gates references Peter Drucker's vision in Wartzman (2013). Drucker states that "It [a team] only has clarity if the team leader creates it". Steve Jobs gave the iPod team "ambitious and clear visions", charging the team with creating "a product that will put 1,000 songs in their pocket" (Fisher, 2010), but, Jobs did not interfere with the team's functioning nor did he give the team detailed requirements. Google re-discovered the importance of leadership when it experimented with a flat organizational structure in 2001; Google found that it was difficult to "communicate vision, handle logistics, and foster career development" (George, 2015). Google also differentiates between leaders of large enterprises, and leaders of innovation, citing the following qualities for leaders of innovation (George, 2015):

- They are "We" leaders, not "I" leaders.
- They align their teams around an inspiring mission and set of values.
- They have high levels of emotional intelligence (EQ) combined with high IQs.
- They possess passion, compassion and courage.
- They are skilled at drawing out the best talents of innovators.
- They inspire, empower, support and protect their innovators and mavericks.
- They focus on bold long-term visions and are not deflected by short-term pressures.
- They are superb collaborators with other teams and other leaders.

Codelitt, a corporate skunkworks-type research and development (R&D) lab, reported that leadership within teams requires leaders who will drive the team forward, pushing them towards innovation (Littlewood, n.d). Littlewood lists common features of skunkworks, innovation, and R&D teams and departments that succeed. The first feature Littlewood offers is the "freedom to fail", noting that a great leader and team will learn from it and move forward. Littlewood states that this freedom should come without consequences from leaders or peers, the benefit of which allows the team time to recognize the failure and to re-adjust and refocus. Littlewood's second feature of a successful innovation team is "Top Down Support from Leadership". Littlewood states that: "There needs to be a direct line of communication to the decision makers and time allotted for engineers to spend time, teach, and develop relationships with execs so they understand what they're supporting." Littlewood also notes that "nothing will kill an R&D team/project/individual quicker than not having a leadership team that isn't driving them forward and moving obstacles out of the way." Third, Littlewood states that the successful innovation or R&D team has a multi-tier map for success. This map may span 1, 3, or 5 years and involves short-term and long-term successes. Littlewood states that if a team does not have short-term successes, morale will suffer and progress will be hard to see. If a team does not have projects that look far into the future, then nothing disruptive will come of it. Lastly, Littlewood emphasizes the importance of both internal and external communication. In this case, internal means within the team, and external means within the larger organization. Littlewood states that it is important to promote what the team is doing externally so the company realizes its importance and does not "attack" the team. Littlewood states that leadership can facilitate and promote this type of communication.

In Google's findings noted above, communication between leadership and the innovation team is critical. The leader must understand the problems the team is tackling and be able to provide the team with proper support (Littlewood, n.d.). However, as noted, this does not mean that the leader should or must be a content contributor or subject matter expert; he or she may well be a good manager/facilitator/supporter to a diverse innovation team.

Adaptive Leadership

Adaptive leadership often runs counter to leadership roles and expectations for the prevailing culture. Adaptive leadership is a form that is consistent with rapid design. The company Acumen is a leading proponent of adaptive leadership. Acumen's Namara (2013) wrote the following about adaptive leadership.

What happens when you are faced with real life challenges that do not have a technical solution or fix, where the problems are adaptive and you have to think through a process to come to the solution? ... Adaptive leadership requires re-organizing our values and norms and looking at the challenges at hand and involving people to push real issues forward. Leadership is an activity – it is not a title, it is the ability to mobilize people to address their own problems... So many of us in our organisations are faced with a lot of adaptive challenges, where there is no easy fix to the problems that need to be solved, and because our teams are built to look up to us for answers, we end up choking at the top because we believe we are supposed to have all the answers.

Namara emphasized that the team is the most valuable asset and using an adaptive leadership approach allows one to: “give the power back to your team, pull the entire process back to the problem and let everybody focus on finding a collective solution...” Finally, she discussed resistance and loss: “Adaptive leadership also means that you will be dealing with loss, because it is a new way of tackling issues people will resist it. Always remember, people do not resist change – people resist being forced to change” (2013).

Raybourn (2005) discussed the particular challenges of operating in a complex world, and the fundamental importance of leadership competence. She cited a variety of specific competencies including adaptive thinking which she defined as: “consisting of competencies such as negotiation and consensus building skills, the ability to communicate effectively, analyze ambiguous situations, be self-aware, and think innovatively and critically.”

While strong leadership is necessary for innovation teams, there are pitfalls that must be avoided. Although leaders must provide a clear organization for a team, they cannot restrict the team's talents and capabilities (Fisher, 2010). Coutu, (2009) gives stern warnings about the role of leadership in team functioning; on one hand, it is critical for leaders to set the direction and team boundaries, on the other hand, such an exercise in authority can leave the team with "angst and ambivalence" and such leaders may encounter resistance. Thus, the relationship between leadership and innovation teams, requires skill to navigate and nurture. The need for leaders to exercise emotional intelligence and nurture collaboration, psychological safety, and autonomy within teams, as mentioned previously, is paramount to proper team functioning.

It is important to note that adaptive leaders do not function like a typical Principal Investigator (PI) to the team where PI's are the centralized node on the team and are expected to have conceptualized a solution to problem at hand such that they are able to guide the rest of the team toward the envisioned solution. RDI teams work in ambiguous arenas such that no one person or leader has the solution, rather the team works interactively to explore the problem domain and the potential solution domains with the adaptive leader proactively coaching, mentoring, and facilitating the process as a co-investigator with the rest of the team. This style of leadership is often associated with interdisciplinary teams.

Interdisciplinarity is the bedrock of rapid design innovation teaming

An important distinction between most non-RDI and many RDI teams is between multidisciplinary and interdisciplinary interactions in the teams. RDI teams work mostly in an interdisciplinary manner. While the differences may seem subtle, for engineers accustomed to a multidisciplinary approach, the egalitarian, highly interactive, frequently divergent, and ambiguity tolerant nature of interdisciplinary interactions can seem quite different and thus add to the cultural dissonance created when RDI teams work in an environment dominated by more multidisciplinary.

For purposes of clarity, we provide further background on multidisciplinary and interdisciplinary teaming. Both approaches seek to overcome disciplinary monism but with different approaches toward that end. (Repko, 2012) The uniqueness of *Multidisciplinary* teams is that each discipline (and associated discipline representative on the team) preserves its/his/her methodologies and assumptions (and understanding) without significant modifications. Other research on multidisciplinary states:

- Klein (2010): “an approach that juxtaposes disciplines. Juxtaposition fosters wider knowledge, information, and methods. Yet, disciplines remain separate, disciplinary elements retain their original identity, any existing structure of knowledge is not questioned.”
- Repko (2012): “More than a single discipline in which each discipline makes a separate contribution” and “multidisciplinary approaches tend to be dominated by the method and theory preferred by the home discipline.”
- Augsburg (2006): The relationship between the disciplines “may be mutual and cumulative but not interactive.”
- Teams work across ARMD and the NASA Aeronautics Research Centers every day with a range of teaming types represented. There was reported to be a dominant team type - which is frequently a PI-driven, hub-and-spoke model in which the members of the team often have little interaction with one another but rather relate to their particular home Centers. As one member of the AATC team described: “We bust up the assignment, tackle separate things, come back together and check in, iteratively.” Thus, “teamwork” generally involves the expertise of specialized scientists and engineers engaged in largely individualized work tasks at their home Centers. ARMD and the Research Center’s form of “teamwork” was described as tapping into multiple Centers; it uses a multidisciplinary approach to get the work done rather than the interdisciplinary or transdisciplinary work approaches found in most innovation settings.

The uniqueness of an *interdisciplinary* approach is the interdependence and interaction of the disciplines such that disciplinary understanding changes and work is often focused on topics between and beyond the existing disciplines. Other research on interdisciplinarity states:

- Lattuca (2001): The problem of interest may “lack a compelling disciplinary basis, and a critique of disciplinary understanding is often implied.”
- Repko (2012): “employing a research process that subsumes the methods of the relevant disciplines, interdisciplinary work does not privilege any particular disciplinary method or theory.”
- McGowan (2014): “Perhaps the most salient discriminator for interdisciplinarity (as compared to multidisciplinary) is that the individual disciplines are transformed during the integrative process and are no longer individually and distinctly distinguishable.”

In a study of cross disciplinary work practices in engineering settings, McGowan and her colleagues (2015) contrast four constructs of working across disciplines in the R&D and early design of large-scaled engineered systems: connection, coordination, collaboration, and collective. Using this terminology, a “collaboration” is more typical of multidisciplinary efforts where sub-systems are “distinct but interwoven.” This relates to the types of PI-centered teams observed with SMEs providing different sub-systems that is common in the standard organizational culture in ARMD and the Research Centers. However, a “collective” is more common for innovation and especially for RDI efforts. In a “collective”, McGowan, et al, state that: “interdisciplinary interactions involve different disciplines striving to achieve a common goal (a new system or innovation) not by focusing on integrating existing technologies as is more common in [more multidisciplinary efforts], but by proactively exploiting and fusing diversity of thought that is resident in the team members. The resulting co-creation of knowledge further enhances the diversity of thought as team members re-think their incoming assumptions.” For those that work in the standard organizational culture and are accustomed to having clearer disciplinary boundaries and individual roles on the team, the blurred team roles, required frequent team interactions, and inherent ambiguity of interdisciplinarity can potentially make RDI teamwork appear somewhat messy with somewhat of a loss of individual status. Thus, to enable RDI in the standard organizational culture, attention must be paid to training and supporting interdisciplinary teamwork.

B. The Need to Expand the Cultural Continuum

Success in implementing RDI in a large, established engineering organization that develops large-scale engineering products and systems lies in understanding the cultural differences with sufficient depth and providing the organizational supports such that both cultures can successfully co-exist and inform and enhance one another. An area that needs particular focus in organizations that want to embrace both standard and rapid design innovation cultures is that of professional risks and rewards.

1. Professional Risks

Engaging on RDI teams and with counter-cultural projects, that is, projects that do not conform to standard norms, may carry a number of potential professional risks, and some researchers may be hesitant to participate on teams at all for a variety of reasons, including:

- Loss of individual status
- Ideas taken by others
- No recognition for original ideas
- Loss of professional status
- Lack of monetary rewards
- Loss of non-monetary benefits such as making an individual impact and pride

All of these professional risks are exasperated with working on the highly interdisciplinary teams associated with RDI. Thus, there may be additional loss associated with RDI teams and may include loss of position, status, and role comfort.

2. Rewards

Reward systems are often optimized for the standard culture and may include recognition for specific achievements such as:

- Number of peer-reviewed publications
- Number of 1st author publications
- Number of projects
- Number of new ideas implemented
- Number of internal collaborations
- Number of external collaborations
- Exceeding financial goals
- Exceeding R&D goals

While some of these items may work for all kinds of teams, as most focus on individual achievement, new means of measuring success that account for both individual and team achievement must be created and must reflect the different processes and products of RDI. Engaging with counter-cultural projects may result in researchers being placed at a competitive disadvantage in relationship to their peers. A carefully designed alternative reward structure that will directly recognize and reward researchers who engage in innovative, non-traditional efforts such as RDI is an important part of effectively expanding the organizational cultural continuum to sanction and support RDI.

V. Discussion

RDI is the kind of innovation work that was envisioned for NASA’s AATC team and is at the far end of the innovation continuum—a place at which many organizations strive to have success. To be successful in implementing RDI, the organizational continuum of ARMD and the NASA Research Centers and the associated responses to teaming and the use of design innovation tools must be extended. Table 1 summarizes the team impedance mismatch encountered while doing RDI work.

Table 2 presents an overview of the reported characteristics of general, PI-centered teams and those expected of an RDI-type innovation team; this table is not intended to represent a definitive view of teaming at ARMD and the NASA Research Centers (RCs). As noted earlier, there are many teams working daily at the NASA RCs which will represent different permutations of teaming and leadership types. This however, is intended to illustrate the potential distance between the two types.

| Characteristics | Team Type | PI-centered Teams | PI Participant |
|------------------------------------|-----------|------------------------|-----------------------|
| | | General Teams (Common) | RDI-Type Teams (Rare) |
| Multidisciplinary | | Yes | No |
| Interdisciplinary | | Not Generally | Yes |
| Egalitarian | | Can Be | Yes |
| Requirements Driven | | Yes | No |
| Problem Driven | | No | Yes |
| Rapid Action | | No | Yes |
| Innovation-Type Methods/Work Style | | Not Generally | Yes |
| Ambiguity Tolerant | | No | Yes |
| Adaptive Leaders | | Not Generally | Yes |
| Commonality of Teaming Type | | High | Rare |
| Centrality to ARMD Work Culture | | High | Low |
| Aligned Institutional Rewards | | Yes | No |
| Associated Potential Career Risk | | Low | High |

Table 2. Team Typology Comparison

This typology illustrates the general range, characteristics, and frequency of teaming types as reported in this research. Those teams that are most likely to be prepared to take on rapid design innovation work were reported to be unusual and counter-cultural in ARMD and at the RCs. And, they rely on skills, methods, and processes that are generally not viewed as central to the work at the Research Centers. As such, they are perceived to carry career risks.

Harnessing and focusing the skills, experience, and synergy among talented professionals is a challenge and an important opportunity for all organizations. When constructed, supported, and managed well, teams are a potent force for productivity and creativity. And, the quality of teaming is directly correlated with the quality of process and outcomes. Poorly designed and managed teams can drain resources and energy and produce *pro forma* results. There is a long, rich history of research on teams and teaming and on leadership for general teams as well as teams working on innovation. The development and management of teams is a science and an art. And, for high-performing teams for RDI to be developed and to succeed, there must be a place on the cultural continuum for them to be recognized and valued. High-performance teaming skills are not innate or intuitive to team leaders or members and their importance to organizations is significant. Further, working effectively at this far end of innovation requires the best innovation teaming and leadership skills and tools. It also requires tolerances for ambiguity such that new tools and individual and team.

A. How to Expand the Cultural Continuum

The why of expanding the cultural continuum is to afford the organization a new means of undertaking critical tasks and establishing and sustaining a leading-edge position. Throughout this paper, we have discussed key differences between the generally encountered standard culture and that of RDI. As discussed earlier, organizational culture tells members of a work culture what they can and cannot do, how they will do it, and what the risks and reward are for work. It also governs who is recruited, hired, and promoted as the organization serves its own understood needs for skills and tools. In order to expand the organizational culture, understanding and acknowledging the key elements of the standard culture is required. There may be multiple cultures at work within an organization and those should be researched and mapped so that decision-makers and strategists have the most complete picture of what is before adding additional elements. Once this cultural assessment and mapping is completed, the organization can determine how to thoughtfully create and test the conditions and form for RDI teams to function and thrive. Remembering the admonition attributed to Peter Drucker, addressing culture is critical or it will “eat your strategy for lunch.” In 2013

in an opinion piece focused on aerospace organizations, one of the recommendations was that aerospace must: "...Commit to innovation and ...embrace technology, process, and business-model innovation as a crucial route 'out of the box' they are in." (Brookings 2013).

Specifically addressing team-type, leadership-type, and reward structure can yield critical foundational steps for enabling RDI culture. For example: adaptive leaders must be nimble, agile, flexible, disruptive, and out-of-the-box and supported within the extended cultural continuum and able to lead high-performing teams using the methods, processes, and tools of design innovation many of which require working with ambiguity, qualitative methodologies, and highly interdisciplinary teams. Further, developing a reward structure that recognizes the process and outputs of rapid design innovation teams will encourage participation and is likely to reduce the professional risks as the organization recognizes the value of these activities.

We highlight Phil McKinney's (n.d.) work in which he described "The 7 Immutable Laws of Innovation" in which he provided advice on establishing a foundation for RDI in an organization, some of which is abstracted here.

- 1) **The Law of Leadership:** Executive level support (Board, CEO and his/her direct reports) is critical for an organization that wants to have innovation at its core. Leadership means talking-the-talk AND walking-the-walk.
- 2) **The Law of Culture:** Establishing and nurturing an innovation culture sets the foundation for the organization. For leaders it means rewarding the right behavior (teamwork, collaboration, honesty, trust) and identifying and eliminating bad behavior (not-invented-here, passive/aggressive, turf battles).
- 3) **The Law of Resources:** Innovation requires a committed level of resources (people, money, time, equipment) over an extended period of time. The level of resourcing is the validation for the importance and commitment the organization devotes to innovation.
- 4) **The Law of Patience:** Innovation takes time. More time than is expected. The organization must take the long view on innovation and avoid the temptation and resist the pressure for short-term adjustments.
- 5) **The Law of Process:** To succeed at innovation, organizations need an innovation process that fits and works within their organization and culture. The process should cover the full innovation chain from idea capture through the last steps of execution.
- 6) **The Law Of BHAG:** A BHAG is "Big Hairy Audacious Goal". It's what leadership lays out as the innovation agenda. The BHAG sets a clear and compelling target, serves as unifying focal point of effort, and acts as a clear catalyst for team spirit. It has a clear finish line, so the organization will know when it has achieved the goal. It does NOT prescribe the how. John F. Kennedy didn't design the rockets that got the U.S. to the moon. He set the BHAG.
- 7) **The Law of Execution:** The ability to execute on both the innovation agenda and the quarterly objectives of the operating business is a key skill that the organization needs to have. Focusing on only one area of execution leaves the other to flounder. Segmenting the execution roles into separate silos works against the Law of Culture.

B. Culture Rules and Eats Strategy for Lunch

Finally, it is critical to remember that culture is ubiquitous, resilient, and remarkably difficult to change. If stretched, it will snap back to its original form and the dominant group and forms will continue to rule. To incorporate something wholly new and create a longer cultural continuum takes a clear understanding of the standard culture and its norms and behaviors and then careful and deliberate planning, as well as through and through commitment to the effort. The new place must be highly incentivized, resources, supported, defended, and celebrated by leadership.

Many organizations attempting to adopt new innovation tools, methods, and practices create a separate organization in order to allow each to thrive separate from the influences and potential distractions of the other. This may help to avoid wasting time and resources attempting to combine what may ultimately be discordant cultures. If separated, they may be able to excel and the skills of each connected under carefully planned and thought out conditions.

VI. Concluding Remarks/Conclusions

This paper focuses on an overarching finding from ethnographic research of a rapid design innovation team at NASA in Aeronautics. The research identified an organizational-culture mismatch that must be overcome for successful formation and implementation of rapid and innovation efforts that we call rapid design innovation (RDI). This kind of innovation work is at the far end of the design innovation continuum and presents several significant differences in work style from the established or standard organizational culture studied. These differences include: work products, methods, processes, and tools; teaming style; approach to team leadership; and, the nature of the cross-disciplinary interactions on the team. As with all organizational culture, the standard organizational culture, which is dominant in all aspects, can view these differences with a negative perspective and work to mitigate the differences and draw the RDI work closer to the standard culture making it difficult for an RDI culture to thrive in the established organization. RDI can appear to be antithetical to the standards in the standard organizational culture and therefore rejected by the standard culture.

Having a thriving RDI culture in an established large engineering institution will require excellent innovation teaming and associated adaptive leadership skills and tools. It also requires learning new methods, process, and tools

and individual and team tolerances for ambiguity and interdisciplinarity. To foster this and address the cultural impedance mismatch, leaders need to provide strategic separation of the RDI groups – otherwise the more dominant and standard culture will naturally impede or fully prevent the progress of the RDI work in the organization. Training in RDI ways of working and strong professional incentives are also crucial to enabling RDI work to thrive. With these foundations well established and supported (training, separation, support, and incentives), it is possible for the significant benefits of RDI to be realized in an existing organization.

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