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AN ANALYSIS OF THE ORGANIZATIONAL STRUCTURE OF REDSTONE TEST CENTER'S ENVIRONMENTAL AND COMPONENTS TEST DIRECTORATE WITH REGARD TO INSTRUMENTATION DESIGN CAPABILITIES

September 2016

By: Adam Turnbull

Advisors: Raymond D. Jones
Brett Boren

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This research found that these problems could be corrected through organizational changes, grouping the instrumentation design engineers together. The research also found that creating a leadership position tasked with promoting communication, efficiency, and standardization is also necessary to achieve these goals.

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Adam Turnbull, Civilian, Department of the Army

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Approved by: Raymond D. Jones

Brett Boren
Department of the Army

Brad Naegle
Academic Associate
Graduate School of Business and Public Policy

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LIST OF ACRONYMS AND ABBREVIATIONS

#1RTC	One RTC
ABMA	Army Ballistic Missile Agency
AFTD	Aviation Flight Test Directorate
ATEC	US Army Test and Evaluation Command
ATTC	Aviation Technical Test Center
DAC	Department of the Army Civilian
E3	Electromagnetic and Environmental Effects Test Division
ECC	Climatic Test Division
ECD	Dynamics Test Division
ECL	Components and Surveillance Test Division
ECS	Subsystem Test Division
ECTD	Environmental and Components Test Directorate
MICOM	US Army Missile Command
MRDEC	Missile Research, Development, and Engineering Center
MRTFB	Major Range and Test Facility Bases
MSTD	Missile and Sensor Test Directorate
OPTEC	US Army Operational Test and Evaluation Command
RF	Radio Frequency
RTC	Redstone Test Center
RTTC	Redstone Technical Test Center
SATSA	Signal Aviation Test and Support Activity
T&E	Test and Evaluation
TATSA	Transportation Aircraft Test and Support Activity
TECOM	U.S. Army Test and Evaluation Command

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EXECUTIVE SUMMARY

This research provides an analysis of the organizational structure of the Redstone Test Center's Environment and Components Test Directorate, with specific regard to its instrumentation design and development capabilities, for the purpose of identifying opportunities to improve communication, standardization, and efficiency. Redstone Test Center (RTC) is one of the U.S. Army Test and Evaluation Command's test centers, and is responsible for the system, subsystem, and component testing of a variety of missiles, sensors, and Army aviation platforms. RTC's leadership reports that most of the organization's funding comes not from Congressional appropriation, but directly from customers. In a world where Department of Defense dollars are harder to come by, RTC has to stand out from other test organizations by providing innovative test solutions and competitive value to potential customers. Since RTC's core mission is to test systems and subsystems, it needs to provide testing capabilities that other organizations cannot match.

To accomplish this, it is often necessary to build customized hardware, software, firmware, and mechanical design solutions to command and control the systems under test, to acquire test data, or to fool specific components into believing they are in operation rather than in a lab environment. RTC has a cadre of technically savvy engineers tasked with designing and developing these innovative test solutions. Because of this capability, RTC is known around the test community for its technical expertise and innovative thinking.

However, the instrumentation design and development engineering capabilities are scattered throughout the various organizational groups within RTC. In my eight years in the organization, it has been my experience that communication and collaboration are not common. Inefficiency is rife, with engineers solving problems that might have already been solved by other groups. And standardization of processes and procedures is almost nonexistent. The current RTC Commander has often remarked that he would like for RTC to be both innovative and efficient. He has tasked all of the leaders throughout the organization to come up with ways to promote both of these goals, through organizational change, leadership initiatives, and cultural emphasis.

This research was conducted with the purpose of uncovering the extent to which the various instrumentation design personnel within RTC's Environmental and Components Test Directorate collaborate with each other to produce innovative ideas, and to propose solutions to address any possible deficiencies in communication, standardization, and efficiency. The first part of the research turned to the literature of organizational structures to determine the strengths and weaknesses of various groupings. The study found that the formal network is the actual on-paper organizational chart, and that it usually reflects some particular goal that the leadership wishes to emphasize, such as efficiency, flexibility, openness, and so on. Equally important to the formal structure is the informal network, those relationships of trust between people where ideas are shared, assistance is offered, and real work gets done. The research showed that one of the best ways to form new informal networks is to make changes to the formal structure. Old relationships of trust stay in place (though they fade over time) while the formal structure makes new relationships develop.

Having established the value of reorganizing a formal structure to create new informal networks, the exploration then considered how to get people to be receptive of organizational change. Investigation showed that people become more receptive of change if they can perceive an overwhelming benefit to the change versus the cost of maintaining the status quo. The research looked at how to create that delta between the cost and benefit, and how to dismantle stove pipes of agendas that operate parallel to, or in conflict with, the goals of the overall organization.

Next, the study turned to RTC, and to the divisions within ECTD in particular. Each division was examined to determine what its core capabilities are, who it frequently works with, and what instrumentation design and development talent it possesses. The same analysis was applied to the other test directorates within RTC. This helped create a picture of who does and does not collaborate with whom, and where personnel could be reorganized to promote communication, standardization, and efficiency.

Three possible organizational changes were proposed. One is to create an instrumentation design division within ECTD. A second is to take the instrumentation design personnel from throughout RTC and create an instrumentation design support directorate. The final change is to leave the current formal chart in place, and to create a matrixed, cross-directorate team of instrumentation design engineers from all over RTC. Each of these arrangements have strengths and weaknesses. Regardless, simply reorganizing would not sufficiently address the stated goals of improving communication, standardization, efficiency, and innovation. Additional leadership is needed. Thus, it is important to create a new position tasked with incentivizing communication, developing standards, and identifying inefficiencies. RTC's instrumentation design engineers are innovative, but there are some problems with how they do and do not work together. Research and analysis shows that these problems could be alleviated through changes to the organizational structure and through the creation of a leadership position charged with helping solve these specific problems.

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I. INTRODUCTION

This chapter will provide an introduction to Redstone Test Center (RTC) and to the current organizational model of the engineers who do instrumentation work. It will provide an overview of RTC's history and mission, and will briefly discuss the capabilities and services that the instrumentation engineers provide. After discussing the vision of RTC's commander, this chapter will use the background information provided to illustrate what topic is being addressed and how it is being researched. This chapter will also examine the importance of the topic and how the research will be presented in subsequent chapters.

A. BACKGROUND

1. History and Mission of RTC

Located at Redstone Arsenal in Huntsville, Alabama, Redstone Test Center's roots go back to some of the earliest days of U.S. Army missile and aviation testing. The organization known today as RTC was formed in 2010 through the consolidation of two different test organizations: Redstone Technical Test Center (RTTC) at Redstone Arsenal and the Aviation Technical Test Center (ATTC) at Fort Rucker.

Prior to the formation of RTC, RTTC's genesis goes back to 1956, when the Army Ballistic Missile Agency (ABMA) was established at Redstone Arsenal. It was tasked with developing an intermediate range ballistic missile, which was a first for the Army. Due to the space constraints of testing intermediate range and long range missiles in a populated area like Huntsville, the testing done by the ABMA was largely related to short range flights, and to strapping rocket motors to fixed, static test stands. AMBA constructed several open-air ranges where these test stands were built and short-range flights were conducted, and eventually these ranges grew to occupy more than fourteen thousand acres of NASA and U.S. Army test space. In 1962, the ABMA was folded into the U.S. Army Missile Command, MICOM, which established a Missile Research, Development, and Engineering Center (MRDEC) at Redstone Arsenal. This new MRDEC featured a specific subordinate directorate dedicated entirely to test and evaluation (T&E). The test stands and flight ranges became the basis of the directorate's capabilities, and provided the means to conduct testing on a wide variety of missile components, systems, and subsystems. For the next thirty plus years, MRDEC conducted missile testing at Redstone Arsenal ("RTC history RTTC," 2015).

Meanwhile, in 1956 at Fort Rucker, Alabama, the Transportation Aircraft Test and Support Activity (TATSA) was activated, along with the Signal Aviation Test and Support Activity (SATSA). These groups conducted aviation-related testing under a number of different organizational names for the next forty years. Specifically, these groups conducted flight tests, as well as testing of avionics components and subsystems, and airworthiness qualification testing ("RTC history ATTC," 2015).

In 1990, as part of a major reorganization of the Army's research and development (R&D) and test and evaluation (T&E) capabilities, the missile testing at Redstone Arsenal and the aviation testing at Fort Rucker were designated as RTTC and ATTC, respectively, and came under the authority of the U.S. Army Test and Evaluation Command (TECOM). Another reorganization came in 1999, as the developmental testing functions of TECOM and the operational testing functions of the U.S. Army Operational Test and Evaluation Command (OPTEC) consolidated to form the U.S. Army Test and Evaluation Command (ATEC) that is operating today. RTTC functioned primarily as a test center for missiles and sensors, while ATTC continued primarily as a test center for aviation systems, until the beginning of their consolidation in 2010 as the newly renamed Redstone Test Center. The aviation capabilities from Fort Rucker were relocated to Redstone Arsenal's airfield, and today RTC operates as a cutting-edge center for testing a wide variety of missile, sensor, and aviation systems.

Many of the test centers within ATEC are Major Range and Test Facility Bases (MRTFB). This means that they are funded by Congressional appropriation through the Department of Defense's Test Resource Management Center. They are funded in this way to preserve a test and evaluation infrastructure in support of DOD's acquisition system. Unlike its sister test centers, RTC is not an MRTFB, and is not primarily funded by Congress in order to maintain and improve DOD's test capabilities. More than ninety percent of RTC's funding comes directly from customers. In many ways RTC operates more like a business than a government entity, with all of the advantages that operating in a competitive environment brings. From RTC's website, its mission is to "provide superior technical expertise and state-of-the-art facilities and capabilities to plan, conduct, analyze and report the results of tests on aviation, missile and sensor systems, subsystems and components." RTC provides services "to ensure the safety, performance and reliability of military hardware and embedded software in their operational environment." The fact that RTC must compete for customer funding is evident in its desire to "provide best technical results for our customer's dollar" by optimizing "each test program with the best combination and sequence of testing, modeling and simulation." RTC is driven by customer-focus and, ultimately, by making the warfighter safer, more secure, and more lethal ("The Redstone Test Center," 2015).

2. Organizational Structure of RTC

RTC is made up of more than eleven hundred people, spread across almost fourteen thousand acres and more than 1.4 million square feet of facilities. There are about three hundred fifty Department of the Army Civilians (DACs), seven hundred fifty contractors, and around three dozen active duty military. About two-thirds of the soldiers are test pilots. RTC is commanded by a colonel, while most of the other leadership positions are filled by DACs.

Organizationally, RTC consists of several directorates, all but one headed by a GS-15 civilian. Despite some overlap in duties and responsibilities, these directorates may be generally divided into two major groups. The first group consists of the directorates that conduct testing on missile, aviation, and sensor systems. The Aviation Flight Test Directorate (AFTD) is headed by a Lieutenant Colonel, and conducts testing of cargo and fixed wing aircraft, aviation systems, avionics, and unmanned systems. The Missiles and Sensors Test Directorate (MSTD) is responsible for the live fire of missile systems like TOW and Javelin, as well as testing of missile telemetry systems, sensors, and rocket motors. The Environmental and Component Test Directorate (ECTD) works with both the aviation and missile directorates, but is focused on testing related to environmental and electromagnetic effects, climatic conditions, and subsystem testing of aviation and missile components. Each of these directorates has a Chief Engineer, responsible for the technical capabilities of the directorate, and a Chief of Operations, responsible for the day to day activities of the directorate.

The second group of RTC directorates may be generally categorized as those that directly or indirectly support the groups who conduct the actual tests. These directorates include the Center Support directorate, which performs functions like human resources, information management, security, and contracting. There is also the Test Program Integration Directorate (TPID) whose responsibility is to directly interface with the customer and to make sure that the various test groups spread throughout RTC coordinate and integrate together as needed to support the customers' needs. There is also a separate Safety Office that reports directly to RTC's commander. Finally, the most senior civilian at RTC is the Technical Director, whose responsibility is to coordinate RTC's technical capabilities in the present and to forecast what capabilities RTC's customers will need in the future.

3. Organizational Structure of ECTD

All of RTC's directorates are broken into divisions, grouped by the functions they perform within that directorate, and ECTD is no different. ECTD has five different divisions, with each division headed by a GS-14 civilian. The first ECTD division is the Electromagnetic and Environmental Effects Division. This division tests systems to both detect susceptibilities to the surrounding environment's radio frequencies (RF), as well as to characterize contributions the system under test is making to the ambient RF environment. The Climatic Test Division provides climatic tests, non-destructive tests, and X-ray inspections to customers and to other RTC divisions. A third division within ECTD is the Dynamic Test Division. This division conducts dynamic testing of missile and aviation components, including shock and vibration tests, impact tests, safe and arm fuse test, and pyro-technic shock tests.

The Component and Surveillance Test Division is the fourth of ECTD's divisions. They conduct component level testing, evaluation, and analysis, as well as component level stockpile reliability testing. This division also conducts missile surveillance, as well as materials analysis. Finally, the Subsystem Test Division performs hardware-in-the-loop testing for missile and aviation systems, and designs equipment for recording and analyzing test data for use by various programs across the Center. Subsystem Test also is developing a new capability in support of distributed testing, where test assets that are geographically isolated from each other can be linked via high-speed networking to conduct testing.

4. Instrumentation Electronics and Mechanical Design

In the course of testing various missile and aviation systems and components, it is often necessary to design customized hardware and software to support those tests. In instances where commercially available equipment can be purchased to record data or properly stimulate the systems under test, that is the preferred method. But frequently, the systems are so specialized that no hardware or software exists that adequately covers the needs of the particular test. Thus, RTC has civilian and contractor engineers whose job is to research and develop the electronic and mechanical hardware needed to support customer and test events.

Typically when the phrase “instrumentation” is used, it refers to using equipment to measure parameters or gather information about a system. For example, mechanical instrumentation might include things like strain gauges, which measure the stress to a system during a particular test. Or, electrically, an optical sensor might be used to measure the intensity of the muzzle flash of a weapon being fired. This type of instrumentation is usually passive, in that it simply observes and does not require any sophisticated interaction with the system being tested. However, most modern systems feature some sort of test interface, through which a large volume of diagnostic information can be gathered. Connecting to this test interface requires specialized equipment and capabilities. Additionally, many systems require that their subsystems and components be tested individually before being integrated with the full system, and this type of testing requires the development of special hardware and software to go “in the loop” with the components under test. It is important for a test organization like RTC to have the knowledge and expertise needed to conduct various types of tests and collect manifold types of data.

RTC has instrumentation engineers who are capable of instrumenting systems in both the more traditional sense as well as developing advanced, interactive technologies. These engineers serve a variety of functions. The software engineers work with Windows and Linux, developing applications for data analysis and display. Electronics engineers design specialized circuitry on custom printed circuit boards in support of digital, analog, and RF applications. Firmware engineers work with both software and electronics hardware, creating programmable logic that accomplishes complicated electronics tasks with great speed and precision. And mechanical engineers design enclosures for the test equipment, as well as considering the effects that the ambient environment has on their equipment as well as the system under test. RTC is a test organization, and the end product of each test is data. These engineers design and develop advanced instrumentation equipment for most of the systems RTC tests, providing the specialized expertise necessary to collect and analyze the data needed to create RTC's end product.

Currently, there are instrumentation groups throughout each of RTC's directorates. AFTD has a division whose specific function is to instrument aircraft and aircraft systems. Since many of the avionics systems they are instrumenting are industry standard, AFTD's instrumentation engineers are able to buy a lot of equipment off the shelf, like telemetry recorders. They do design custom equipment and software as necessary though. MSTD's instrumentation engineers do research and development on equipment for collecting data from disparate missile and sensor sources and syncing the data together with global positioning systems and common time standards. Much of the equipment that MSTD designs is used in the rugged environment of open-air test ranges. The instrumentation engineers within ECTD build custom capabilities for specific aviation and missile components. ECTD instrumentation is typically used in the controlled environment of a laboratory. However, because of the significant overlap of capabilities and blurring of responsibilities, the instrumentation engineers often find themselves crossing division and directorate boundaries to support testing as needed.

5. RTC Commander's Vision

The current commander of RTC began his tenure in the summer of 2013. He has put particular emphasis on streamlining many processes across the Center to promote efficiency and communication. The merger between RTTC and ATTC in 2010 has been a bumpy but fruitful transition, and the Colonel is interested in continuing to forge these groups into what he calls "1RTC," a single team dedicated to customer focus, people, value, safety, and integrity. To that end, several reorganizations have occurred to date, and improvements have been made to the way RTC generates cost estimates and how RTC communicates with each customer. The Colonel believes there are still opportunities to be better, and is working on instilling an organizational culture geared towards improvement.

One area the Colonel is giving attention to is in getting the right people in the right roles. Historically, RTC has been lacking in the career path for technically-oriented people like instrumentation development engineers. In the past, moving up the ranks meant moving into management, with very limited opportunities for people who wished to increase their technical expertise. There were opportunities for senior technical people, but the criteria for attaining these positions was confusing and not well-documented. The Colonel is hoping to change that by developing a formalized path for both experimental developers and subject matter experts.

Because of their deep knowledge of and extensive experience with the systems under test, many instrumentation development engineers at RTC are prime candidates to become these subject matter experts and experimental developers. The instrumentation engineers know the ins and outs of each system, often down to the voltage of an electrical signal or torque rating of a particular screw. By providing career paths forward, the Colonel is hoping to build RTC's bench of technical experts, and enhance RTC's position as one of the Army's centers for test excellence. And by getting the right people in the right roles and on the right teams, efficiency and communication will be promoted. This will help RTC's people and benefit RTC's customers.

A final area of emphasis from the Colonel is in improving communication, standardization, and efficiency while maintaining an innovative spirit. This is a challenge, as typically efficiency and innovation are seen as competing goals. However, the Colonel has directed all of the leaders throughout the organization to look for ways to continue innovating while working better together and becoming more efficient. #1RTC is a slogan not only for improving RTC's interface with its customers, but also an internal mantra for making sure everyone is collaborating and innovating together every day.

6. Summary

This chapter detailed the history of RTC, through the inception of its ancestor organizations to its role today as one of ATEC's test centers. The chapter also discussed RTC's mission, and looked at the current organizational structure of the Center as a whole and of the Environmental and Components Test Directorate in particular. Further, the chapter explored the various instrumentation capabilities that are spread across RTC directorates, and detailed how those functions fit in with the overall development strategy as influenced by the current commander. This background information is important in setting the stage for the analysis and conclusions discussed in later chapters.

B. PROBLEM STATEMENT

RTC has instrumentation development engineers on many teams throughout each of its directorates and divisions. Many of these engineers are dedicated to particular customers. In the past this has been beneficial to the customer, because the customer has access to engineers who are intimately familiar with their system and are working on no other projects. However, because the instrumentation engineers are so tightly focused on their customers and their projects, they do not interface with other engineers who perform similar functions as them on a regular basis. This creates a few problems. First, the lack of communication between engineers means that when one group solves a problem, that solution is not disseminated to other groups. Down the line, the next group might need to solve the same problem, and wind up duplicating work that has already been done. This sort of poor communication is bad for RTC, bad for the customer, and bad for the Army as a whole.

A second problem related to having instrumentation capabilities scattered throughout the Center is related to work load. At various times, one group within the Center might be so busy that it is working overtime, while another group is relatively unburdened and draining overhead dollars. It would be beneficial to be able to plug and play software, electronics, or mechanical capabilities as needed, when one customer's work is heavier than another's current needs.

An additional problem relates to standardization. Different groups use different tools to accomplish similar tasks, and have different ways of documenting their projects or archiving their code. This makes collaboration between groups more difficult, and makes the previously mentioned plug and play impossible. Developing common standards and best practices would be particularly beneficial.

Next, RTC wants to position itself to meet the test needs of customers today and tomorrow. This requires innovation, which comes from the instrumentation development engineers working with the experimental developers to push the boundaries of what RTC can do. RTC wants to continue to have a climate of forward-thinking, which means that the advanced instrumentation engineers and subject matter experts must work together with management to prepare RTC for the battlefield of the future. With the experts in their fields not working closely together, innovation that would benefit more than just the single customer the experts are supporting is stifled.

Finally, one problem facing RTC might be termed the inertia of the status quo. Some members of the various divisions and teams are resistant to change. They are quite successful at meeting customer needs and do not see the value of collaboration.

These problems are partially due to the different groups being in different directorates. However, even within ECTD, and sometimes even in the divisions within ECTD, different pockets of capability are not functioning together optimally. Having the groups of technical instrumentation expertise separated into support of distinct customers does have some advantages, but it promotes significant disadvantages in the areas of communication, efficiency, standardization, and innovation. This paper will consider these disadvantages and address these problems, particularly in ECTD. It will also examine the barriers to addressing these problems through organizational change aimed at promoting collaboration, and will look at ways to work around or eliminate these barriers.

C. RESEARCH OBJECTIVES

The primary objective of this research is to determine the best way to promote communication, efficiency, standardization, and innovation among all of the instrumentation engineers within the ECTD directorate. The research will be geared towards identifying the knowledge, skills, and abilities of the different groups, and looking at the positives and negatives of how these groups operate. A better understanding of who the instrumentation and design engineers are, what they do, and how they can work together best is essential to accomplishing RTC's mission. The end goal is to take this understanding and determine what organizational lines should be formal, what should remain informal, and how this structure will help realize the RTC commander's vision.

The secondary objective is to gather data from the other test directorates within RTC, MSTD and AFTD, regarding the organization of their instrumentation and design engineers. Lessons that those directorates have learned might prove beneficial to ECTD, and this research might also provide insights that cross directorate boundaries.

The final objective is to consider barriers to organizational change, and to look at how managers can motivate their team members to embrace rather than resist any proposed changes.

D. RESEARCH QUESTIONS

There will be two aspects to the research. The first set of questions is related to the theory and literature concerning organizational models and organizational change.

Question 1: What are some different types of organizational models, and what are their strengths and weaknesses?

Question 2: What dynamics determine an organizations' ability to change successfully?

The second set of questions will be related to ECTD and RTC personnel.

Question 3: What is the current formal organizational structure of ECTD, and what collaboration with other groups currently exists?

Question 4: What organizational model would be best for achieving the stated goals of improving communication, efficiency, standardization, and innovation?

E. PURPOSE / BENEFIT

RTC is unique as a Department of Defense organization for many reasons. First, in many ways RTC operates like a business rather than as a government entity. Second, many test organizations have a reputation, fairly or unfairly, for being little more than "gear turners." This means that many outside those organizations view them as having little technical engineering expertise, but instead specializing in conducting tests, pushing buttons, collecting data, and writing reports, without ever truly understanding the system being tested. RTC does not fit that reputation, because of the research and development that RTC's experimental developers, instrumentation development engineers, and subject matter experts are doing each day. These things set RTC apart from other test organizations.

However, unlike DOD's acquisition organizations that are specifically chartered to conduct research and development and to design and develop new systems or improvements to existing systems, RTC is ultimately an organization for conducting tests. RTC is not involved in a system's production, and though RTC's test results do have a role in helping determine the design of a system, RTC is not the primary driver for design decisions. In that way, RTC is distinct from R&D organizations and from the various project offices who produce and field missiles and aircraft.

It is best to think of RTC as a test organization, but not only a test organization. RTC's relative uniqueness in this area means that there are those outside of RTC, be they customers or other government entities, who perhaps do not fully understand RTC's capabilities. it is likely some even within RTC do not grasp all of the technical boundaries RTC engineers are advancing. This research will have the primary benefit of suggesting ways for the technology drivers within RTC to communicate better and be more efficient, as well as execute standard processes and continue innovating. But in the bigger picture, a better understanding of its technical knowledge, skills, and abilities could help RTC continue to define its identity, to itself and to others, as an Army leader in testing research and development.

An additional purpose of this research is to identify areas that are lacking in RTC's capabilities. Currently, most of the engineers who work on instrumentation electronics, software, and mechanics are contractor employees. Having this knowledge and experience base external rather than internal to the government presents risks. When contracts change, or contractors pursue other opportunities, often years-worth of hard-earned expertise leaves with them. The wrong person leaving at the wrong time can cripple a project. By identifying not just the roles and duties of each person, but also whether they are government or contractor, this research should reveal ways that RTC can seek to move expertise back to government hands.

This research should shed light on ways for RTC's instrumentation engineers to work better together, and should also help define RTC's identity and illustrate areas where RTC needs to enhance its government workforce. A final benefit of the research is the possibility of lessons learned being applied to other government entities or commercial businesses. While RTC is unique in its role as a test organization with R&D capabilities, it is certainly not the only organization out there with teams of hardware, software, and mechanical engineers dedicated to solving complex problems under tight schedule and cost constraints. By researching literature and industry, lessons might be applicable to RTC's structure. Conversely, lessons learned by this research might also apply to other technical organizations or teams.

F. SCOPE / METHODOLOGY

This project will begin by collecting information about the current organizational structure of ECTD. All of the leadership within ECTD, along with other key instrumentation personnel, will be interviewed to determine electrical and mechanical knowledge, skills, and abilities. Further, this project will analyze the overlaps and unique capabilities in the activities of each ECTD division. Interviews will be conducted with division and directorate leadership in order to get a feel for their vision and goals for the organization.

Next, some alternatives for organization will be considered. A brief survey of organizational structures will be conducted to see which ones might be applicable to RTC's unique way of doing business. Additionally, attention will be given to the dynamics associated with forming and rearranging teams.

Lastly, the organizational culture of RTC in general and ECTD in particular will be considered in light of the best way to meet customer needs. The way that RTC/ECTD conducts business will be explored, and data about ECTD's active projects that involve instrumentation will be collected.

Because of the nature of this project, much of the data will come from internal RTC documentation and from discussions with RTC personnel. The remaining data will be collected from relevant literature concerning organizational models and team dynamics.

G. THESIS STATEMENT

It is theorized that the current organizational model of RTC's Environmental and Component Test Directorate is not ideal when it comes to facilitating communication and standardization while seeking both efficiency and innovation. This study will test that thesis in several ways. First, it will analyze the strengths and weaknesses of RTC/ ECTD's current organizational structure, including the informal relationships that exist outside of the documented organizational chart. It will also consider which alternative models might fit, and evaluate the strengths and weaknesses of those approaches. The study will result in at least one proposed organizational structure. Further analysis will show what, if any, changes or commitments from RTC/ECTD leadership will be required to realize the benefits of this proposal. Lastly, analysis will show how these recommendations support RTC's desire to continue as an Army center of technical test excellence.

H. REPORT ORGANIZATION

Chapter I of this paper provides historical background to the problem. It also defines the research and objectives, and discusses the benefits and importance of the topic. Chapter II will take a look at the relevant literature surrounding the topic of organizational models. Chapter III will present the data that will be considered for the analysis, which will be conducted in Chapter IV. Finally, Chapter V will summarize the conclusions of the study.

I. SUMMARY

This chapter has provided an overview of RTC's instrumentation engineering capabilities and organizational structure. RTC's history as a test organization was explored, showing how RTC's missile and aviation test functions were developed over the decades and coalesced into a single test outfit. The overall current structure of RTC was discussed, and the capabilities, responsibilities, and importance of the electrical and mechanical instrumentation engineers was established. This background info set the stage for the problem, which was defined to show that RTC in general, and ECTD in particular, need some improvements in how the instrumentation capabilities are organized. RTC's organizational culture was explored, and the vision of the leadership was detailed. Finally, the research questions were listed, and how data will be collected, presented, and analyzed was listed. Next, we will take a closer look at the literature concerning organizational models.

II. LITERATURE REVIEW

Chapter I provided a background for this research by giving an overview of RTC's history and current organization, and setting the stage for the issues that will be addressed by this research. This chapter will focus on the research questions regarding the literature that discusses organizational structure and affecting organizational change. First we will survey some common ways that businesses and other entities organize to accomplish their mission. From there, we will consider the Rogers' Five Factors of Innovation, and examine how those principles can be used to look at changes in general and organizational changes in particular. Finally, we will look at possible barriers to organizational change.

A. ORGANIZATIONAL STRUCTURES

This section will consider a few common organizational structures, and will discuss the strengths and weaknesses of each.

1. Functional Structures

The first type of structure is known as a Functional structure. In this style, like capabilities are organized together. People who perform similar jobs and possess similar skills and knowledge are grouped together organizationally. For example, sales people might be functionally grouped together, while research and development might make up a second group, and manufacturing a third. These groups would interface with each other and work together, but organizationally would be isolated.

This structure has some important benefits. First, it is very efficient. With a common pool of talent utilizing similar skills, economies of scale are created. It is very easy to plug and play personnel as different projects demand. There are also very clear career paths for those seeking to advance, and strong opportunities for mentorship. However, this structure is not without its drawbacks. Because functional units of the organization are isolated from each other, collaboration between functions can suffer if it is not tightly coordinated. Also, functions can begin to pursue their own goals rather than the goals of the organization as a whole. And in instances where some functions are insulated from direct contact with the organizations' customers, it makes parts of the organization less-responsive to customer needs (Gibbons, 2016). See Figure 1 for a common representation of this structure.

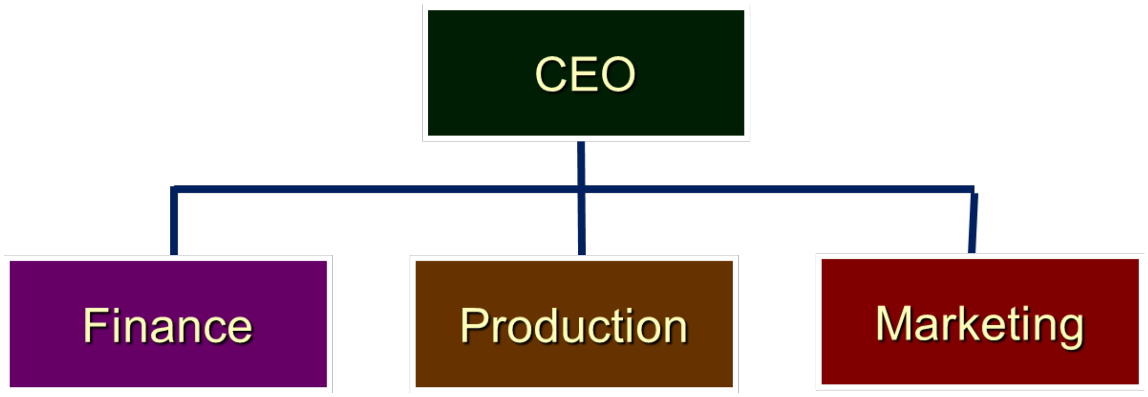

Figure 1. Functional Structure Example. Adapted from Gibbons (2016).

2. Divisional Structures

A second type of structure, in contrast to the first, could be called a Divisional structure. In this arrangement, rather than having like functions grouped together, common customers, products, or geographic areas are organizationally combined. For instance, a particularly large company like Boeing might have separate segments focused on military and commercial products. A company like Apple might have separate units focused on personal computers, phones, and tablets. Or, a multi-national company might have separate segments for each geographic region in which it is active. In each of these examples, the company organizes divisions to handle specific products or customers, not specific functions.

This arrangement also has some unique strengths. For one, it is much more responsive to the customer. With the business, engineering, and manufacturing people all tightly focused on their particular product or customer, they can be more agile in meeting customer needs. This is especially apparent in diverse geographic areas, where the needs of a customer in North America might be different than the needs of a customer in Southeast Asia. Division structures are also well-poised to accommodate growth, since they can expand with their customers or markets. Unfortunately, this structure is very inefficient. With each product or geographical area having its own business and engineering groups, there is not a lot of collaboration, and efforts wind up getting duplicated. Similar problems end up getting solved by different groups several times. And silos of knowledge can be created, where different groups are not even aware of the work that their counterparts have already accomplished (Gibbons, 2016). Figure 2 shows a graphical example of this structure.

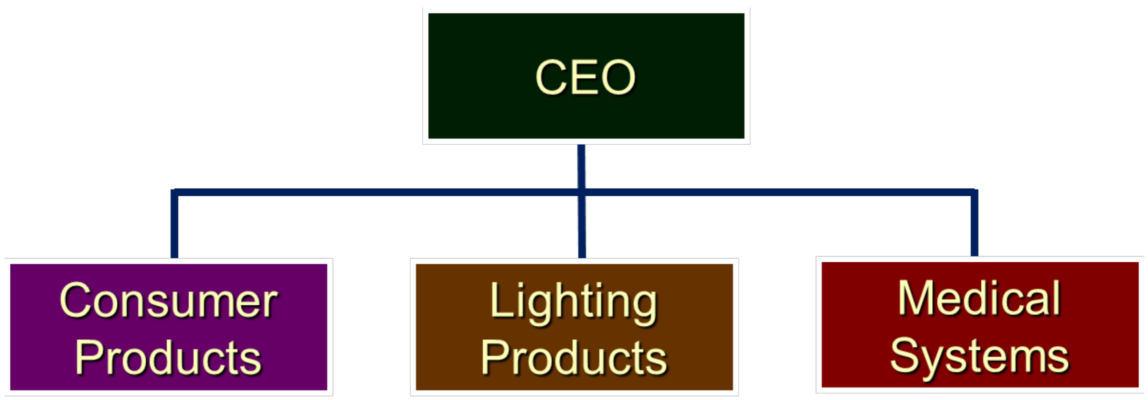

Figure 2. Divisional Structure Example. Adapted from Gibbons (2016).

3. Matrix Structures

A hybrid of the two previous approaches is the Matrix structure. Under this arrangement, people are arranged into teams according to their knowledge or skill sets. Like a functional structure, there are specific groups for doing engineering, sales, manufacturing, and so on. However, members of each group are chosen to form cross-organizational integrated product teams that focus on specific customers, products, or projects. These teams have their own managers who are responsible for their team. Thus, employees are members of permanent functional groups, but are temporarily “matrixed” to a specific functional grouping. Each employee has a functional boss, and a product/ project boss. Figure 3 illustrates this arrangement.

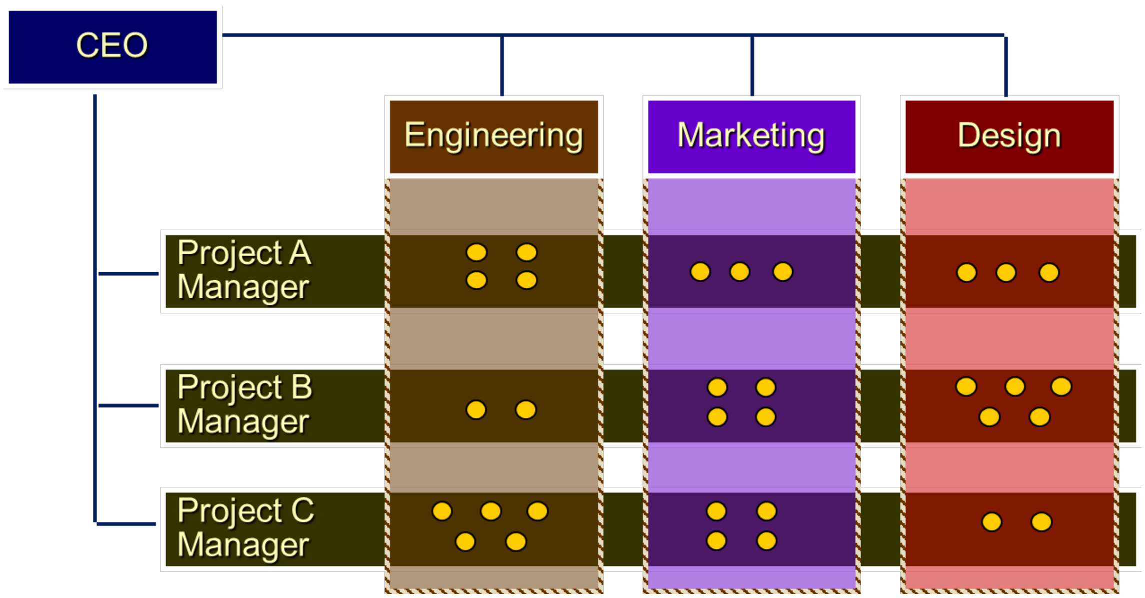

Figure 3. Matrix Structure Example. Adapted from Gibbons (2016).

This attempts to combine the benefits of both functional and division structures. Like in the functional arrangement, resources are used very efficiently, and communication flows well. The same economies of scale are present when it comes to talent usage, and there are the same opportunities for mentoring. And like in a division arrangement, employees are flexible and able to innovate for specific customer needs. Because an employee is beholden to more than one boss, they are less likely to protect their groups' interests at the expense of the larger organization. However, a matrix structure has some significant issues. The biggest one is related to each employee having two bosses. This creates a management nightmare, as the accountability of each employee is diluted, and the stress on the employee concerning which boss to report to is increased. In addition to the management and coordination issues, there is also the potential for power struggles, as functional managers jockey for position with project managers. Matrix structures solve many problems related to functional and division groupings, but create new problems that neither of those structures possess (Robbins & Judge, 2016, pp. 256–258).

Given these major strengths and difficult but not unmanageable weaknesses, matrix structures are quite common among engineering and technology firms. Being a leader in a matrix environment requires the capability to operate with both functional and divisional mindsets. Rick Lash, a talent and leadership manager at the management consulting services firm Hay Group, lists six characteristics of a successful matrix leader. These characteristics are:

1. Enterprise perspective – they have a comprehensive understanding of the company's overall business strategy and how the joint work they are leading aligns with that strategy. They use this understanding to resolve any conflicts that may arise.

2. Cross-functional perspective – they understand the needs, metrics, incentives and deliverables of different functions and business units. They can align these competing priorities within the operating model.

3. Customer perspective – they not only understand the customers' interests and needs, they also know how to keep the team focused on making the decisions that enhance the overall customer experience.

4. Self-management – they exhibit self-control when challenged. They have patience when dealing with colleagues who may have trouble understanding the shared purpose of the collaboration initiative. They do not take disagreements personally.

5. Listen with respect – they listen objectively and respectfully to multiple opinions. They empathize with colleagues whose position, situation or perspective may differ from their own. They start with the assumption that collaborators are capable and will do their best.

6. Matrix influencing – they excel at communicating with different stakeholders and influencing them to support collaborative projects. (Lash, 2012)

These characteristics address the strengths and weaknesses of the matrix organization itself, showing how a manager in this setting can help make the strengths stronger and help mitigate the weaknesses. Effective matrix leaders encourage communication and efficiency and keep the goals of the overall organization paramount, while discouraging politics and helping employees understand their accountability. These characteristics are important when considering a change to a matrix structure.

4. Formal vs. Informal Structures

The structures covered to this point are more formal; that is, they are governed by defined rules and relationships that are well understood and can be effectively managed.

Even a matrix structure, which is somewhat harder to tackle than functional or divisional structures, is still something that can be defined on paper. However, co-existing with the formal structure of an organization is its informal network, those relationships that form across functional or divisional lines to accomplish tasks quickly. Speaking metaphorically, the formal organization functions as the skeleton or backbone of a business, providing the structure that supports all activities. The informal, then, is analogous to the central nervous system, which allows the various groups to communicate with each other. Professor David Krackhardt and consultant Jeffrey Hanson (1993) describe the relationship between formal and informal relationships this way:

> Designed to facilitate standard modes of production, the formal organization is set up to handle easily anticipated problems. But when unexpected problems arise, the informal organization kicks in. Its complex webs of social ties form every time colleagues communicate and solidify over time into surprisingly stable networks. Highly adaptive, informal networks move diagonally and elliptically, skipping entire functions to get work done.

According to Krackhardt and Hanson, the formal organization is about showing who is on top of the hierarchy and who is accountable to whom, while the informal network is about the relationships of trust and communication that exist irrespective of organizational boundaries.

Over the past couple of decades, researchers have come to believe that the informal structure is more important than the formal. Consider a book by Harvard Professor Rosabeth Moss Kanter et al. from 1992:

> Relationships, communication, and the flexibility to combine resources are more important than the formal channels and reporting relationships represented on an organizational chart. In an environment requiring speed and dexterity, what is important is not how responsibilities are divided but how people can pull together to pursue new opportunities. (p. 232)

A more recent quote from management consultants Jeffrey Oxman and Brian Smith in 2003 conveys a similar sentiment. Oxman and Smith believe that “thousands of companies continue to spend millions of dollars continuously trying to identify an optimal hierarchy—one that employees then frequently proceed to ignore in favor of operating within their informal networks." They list the following example from the oil company BP:

> BP Plc (formerly known as British Petroleum) has been so successful in this regard that its managers are now given incentives to not only manage vertically but also to provide horizontal "peer assists" to others throughout the global organization. A generation more advanced than the classic matrix, BP's organization effectively mobilizes the right resources for the right job, regardless of their location or hierarchy. When a series of lightning strikes damaged pumping facilities in Siberia, local engineers, inexperienced in dealing with this type of problem and facing a bewildering array of remedial options, were quickly routed to valuable guidance from a Houston expert and participants in a Canadian network forum on the subject. Countless other tales illustrate the mobilization of global talent to increase the efficiency of retail operations, evaluate tanker-financing options and launch new plants in remote areas. Connectivity and assistance are readily available in the company's marketplace of experience, and, within reason, it is expected that cross-unit assistance be asked for and provided.

These quotes illustrate the idea that the informal network is more important than the formal structure. The formal structure reflects upper management's particular goals. If they wish to promote efficiency, they organize functionally. To instead promote customer-responsiveness, they organize divisionally. Or, to attempt to gain the best of each goal, they organize in a matrix. But according to people like Kanter, Oxman, and Smith, the real work happens because of the relationships that exist informally. People who interact with each other through work and non-work relationships build trust and kinship, which in turn helps accomplish tasks. To explore how this looks in a real-world context, the example of Cisco Systems is particularly enlightening.

5. Lessons from Cisco Systems

Cisco Systems is a multinational telecommunications company that designs and sells networking equipment. Throughout its history as a company, Cisco has reorganized its structure several times, both due to internal and external factors. These reorganizations, and their leveraging of both formal and informal structures, were the subject of a recent Organization Science journal article by Ranjay Gulati and Phanish Puranam. From 1997–2001, Cisco was organized around three distinct lines of business, each focused on a specific customer type: internet service providers, enterprises, and small to medium sized businesses. Each line of business had its own sales group, engineering group, and so on. Using the categories developed earlier, this would best be described as a divisional organization structure. Figure 4 displays Cisco's structure at the time.

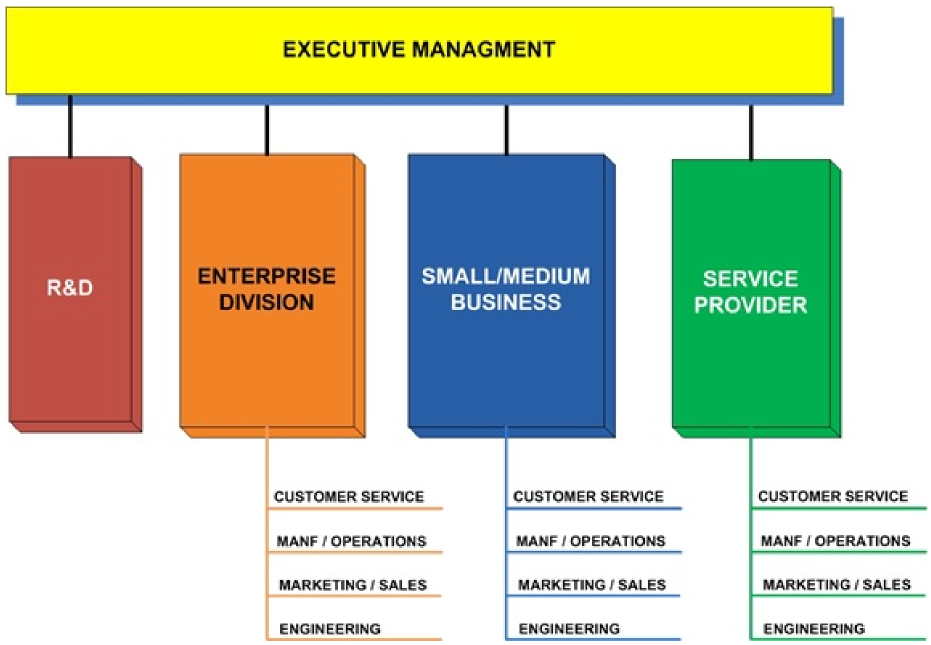

Figure 4. Cisco Organizational Structure in 1997. Source: Hubli (2009).

According to Gulati and Puranam, this structure allowed the company to be extremely responsive to the distinctive needs of specific customers. One manager said, "I think the market was expanding like a rocket ship, so I think the good part about that organization was to allow the various business units to really focus on their primary customers, who were really driving the requirements" (Gulati & Puranam, 2009).

However, by 2001, the dot-com bubble had popped, and Cisco was losing money. Looking for ways to cut costs and promote efficiency, they began examining their organizational structure. What they found was that the weaknesses of a divisional structure were extremely expensive. To correct this inefficiency, in 2001 Cisco reorganized into a functional structure, grouping like capabilities together. Describing the change, one manager said, “If there was a (customer) problem, we’d get whatever resources were required to fix it and then execute on it, quickly. But the problem was that ten people would be doing the same thing across the company ten times over, at ten times the cost. And they’d get it done quickly, probably in about one tenth the time that we do now, but it was just incredibly inefficient” (Gulati & Puranam, 2009).

This reorganization to being functionally-focused rather than customer-focused was not without its drawbacks. Quoting Gulati and Puranam (2009):

> While conducive to eliminating redundancies in technology development, it also placed organizational boundaries between engineers who worked on different technologies that would need to be assembled into a solution, as well as between engineers and marketing personnel who would need to work together to customize solutions based on customer requirements. Indeed, many senior managers recognized that the new structure made integration across technologies (horizontally) and with customers (vertically) a specialist’s job, whereas it was “everyone’s job” in the older structure. As one senior manager put it, “We moved the inflection point back towards engineering. This allows the technology to be used in multiple customer segments but it does put engineers farther away from the customers.

Figure 5 is an illustration of the structure Cisco had reorganized to as of 2001.

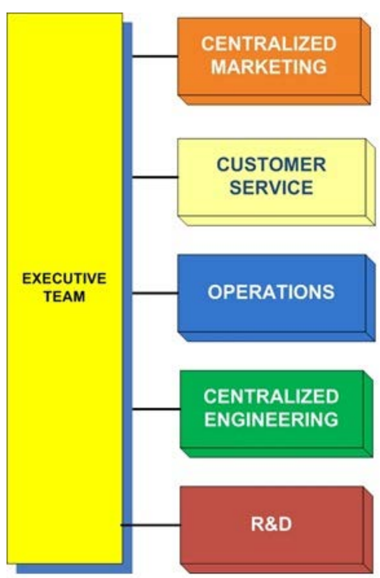

Figure 5. Cisco Organizational Structure in 2001. Source: Hubli (2009).

The changes did appear to result in changing fortunes for Cisco. They went from losing $1 billion in 2001 to making a profit of $3.5 billion in 2003. Gulati and Puranam theorize that this was partially the result of the reorganization from a divisional to a functional structure, and partly due to the informal networks that remained in place despite the formal organizational change. The old structure featured a culture of customer advocacy that survived the formal organizational change, such that Cisco was able to maintain its customer focus despite the new emphasis on efficiency. Employees in the new structure continued to collaborate with other functional units, even when such collaboration was not part of their formal scope of work. One manager said, “We have been working together for a lot of years, the engineers and the marketers know each other really well ... this helps now, and there are a fair number of collaborations that go on across the business unit, even across technology groups. You can always pick up the phone and find someone on a certain project that you might have had a relationship with in the past” (Gulati & Puranam, 2009). While the formal structure was oriented towards efficiency at the expense of customer responsiveness, customer responsiveness was maintained thanks to the lingering emphasis of the old structure that was still present in the informal relationships of the employees.

Over time, however, the benefits of the 2001 reorganization began to show signs of having a shelf life. Cisco did not wholesale abandon their reorganization, but as time put more distance between the customer-focus of the past and the technology-focus of the present, the customer-focus began to wane. Thus, by 2004 Cisco instituted what they called formal business councils, which were cross-functional leadership teams convened to make sure the needs of the customer were being met. These integrated product teams formed the basis of a full-on matrix structure that Cisco adopted in 2007, shown in Figure 6.

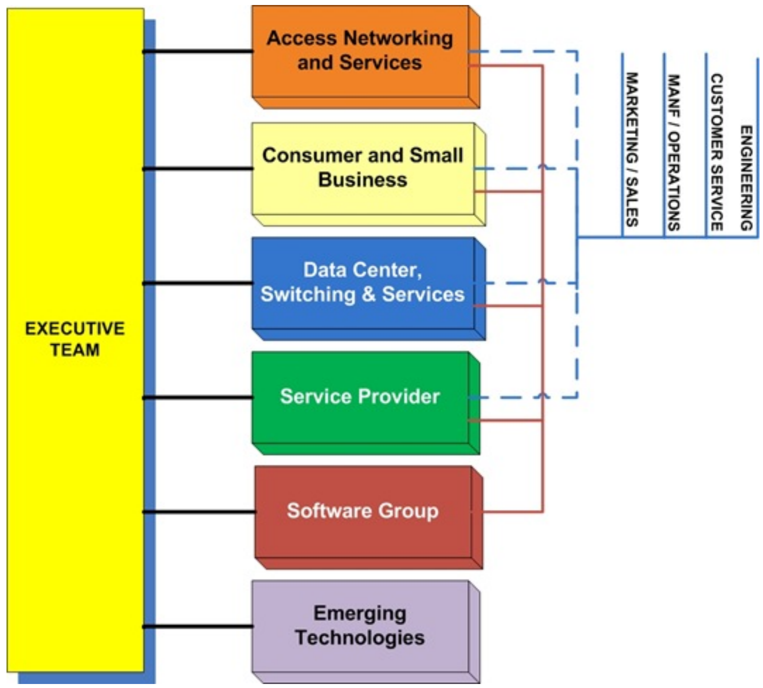

Figure 6. Cisco Organizational Structure in 2007. Source: Hubli (2009).

Viewing their formal structure in terms of a pendulum swing, in 1997 Cisco was swinging their pendulum towards customer responsiveness, and so their formal structure was aimed toward that end. By 2001, Cisco wanted to swing the pendulum towards efficiency rather than customer responsiveness, and therefore changed from a divisional, product-line structure to a functional, capabilities structure. This worked for a time, until the pendulum swung too far, and Cisco had to change again.

It appears, then, that Cisco each time had to reorganize in order to meet the changing conditions of the market. They did so knowing that no solution was perfect, and that any structure would have strengths and weaknesses. They mitigated the weaknesses of the new formal structure by utilizing informal vestiges of the old structure. And as the benefits of the new structure waxed and then waned, Cisco began changes afresh. Gulati and Puranam (2009) summarize this well:

> The optimal formal organization capitalizes on yesterday's informal organization and lays the ground for tomorrow's. An inconsistent formal organization (achieved through reorganization, for instance) leverages the existing informal organization to motivate the mix of behaviors needed to

> achieve compensating fit. The formal organization itself focuses on the behaviors that are not adequately encouraged by the informal organization. However, the choice of today's formal organization also shapes tomorrow's informal organization (within limits), due to the process of eventual adjustment between the two.

In short, Gulati and Puranam illustrate well the relationship between formal and informal networks. The formal reflects the current goals of management, while the informal contains the relationships between employees that enable successful completion of various tasks. Gulati and Puranam add to this the idea that organizational change is necessary in order to achieve new goals and to build up and maintain the informal relationships, which will deteriorate over time.

The example from Cisco shows that both formal and informal networks are important, and that changing them is often necessary to achieve certain goals or emphases. Examining the factors that influence an organizations' structure is the task of the next section, and will help determine how best to realize managements' goals.

6. Factors Influencing Structure

In addition to formal versus informal structures, there are other broad descriptions available for different organizational types. For example, structures could be classified as either centralized or decentralized. A centralized structure features the locus of power concentrated on a small number of individuals or groups, with the employees of the organization having very little empowerment. In contrast, in a decentralized structure, power is dispersed throughout the organization, with the employees having more say-so in their decision making. Centralized organizations are better for when the goal of the company is known and must be enforced from the top down, while decentralized organizations are better when the environment is changing and the goals emerge from the bottom up (Gibbons, 2016).

Similar to the centralized versus decentralized categorization is the mechanistic versus organic organization. A mechanistic structure is one that compels people to act in defined, predictable ways. It is formal and centralized, with a rigid chain of command and standardized processes. On the other hand, an organic structure promotes flexibility and adaptability. It is informal and decentralized, with cross-functional and cross-hierarchical teams. Like centralized and formalized structures, mechanistic models are better when rigid uniformity of behavior is expected. And like decentralized and informal networks, organic models are better when outside-the-box thinking is paramount (Robbins & Judge, 2016, p. 262).

Given these types of structures, there are four factors that determine which to adopt. Before settling on a particular model, an organization should determine its strategy. If the organization wishes to pursue innovations, including new products or applications, organic models are better. If the goal is controlling costs and promoting efficiency, mechanistic organizations offer better oversight. Also, the size of the organization is a factor. Larger organizations have a greater need to be mechanistic, while smaller organizations thrive in more organic arrangements where excessive management would be a hindrance rather than a help. Third, the nature of the work the organization is doing is a factor. If the work is routine and repetitive, it lends itself to a mechanistic framework. But, if the work is a new challenge or problem each day, the flexibility and adaptability of an organic structure is needed. Finally, and similar to the third factor, is the environment the organization in which the organization operates. If it is a static, well-defined environment, a mechanistic structure is useful. If the environment is constantly changing, an organic structure is best (Robbins & Judge, 2016, pp. 263–264). Table 1 lists some factors that influence the ideal organizational structure.

Table 1. Factors Influencing Organizational Structure

	Mechanistic/Formal/ Centralized	**Organic/Informal/ Decentralized**
Strategy	Cost control	Efficiency
Organization Size	Big	Small
Nature of Work	Repetitive	Non-repetitive
Environment	Static	Dynamic

This section has examined the different types of formal and informal structures, and looked at their strengths and weaknesses. Having established the necessity of organizational change in order to achieve certain goals, and with the various factors that determine the ideal structure in mind, it will be useful to consider reasons organizational change is resisted, and how best to overcome that resistance.

B. ROGERS' FIVE FACTORS APPLIED TO ORGANIZATIONAL CHANGE

Before embarking on an organizational restructure, it is helpful to consider how a change will be received by the rank and file employees. One way to consider that is using Rogers' five factors. Everett Rogers was a communication scholar and sociologist in the late Twentieth Century who originated the diffusion of innovations theory. This theory sought to explain the reason why, and the methods by which, ideas and technologies are adopted. Rogers came up with five product-based factors that determine the rate at which an idea or technology diffuses throughout a culture. These factors concern how the adopter of the innovation perceives the innovation's characteristics. The five factors are:

- *Relative Advantage* – the degree to which an innovation is perceived as being better than the idea it supersedes (Rogers, 1995, p. 212)
- *Compatibility* – the degree to which an innovation is perceived as consistent with existing values and experiences of the potential adopter (Rogers, 1995, p. 224)
- *Complexity* – the degree to which an innovation is perceived as relatively difficult to understand and use (Rogers, 1995, p. 242)
- *Trialability* – the degree to which an innovation may be experimented with on a limited basis (Rogers, 1995, p. 243)
- *Observability* – the degree to which the results of an innovation are visible to others (Rogers, 1995, p. 244)

One thing that is readily apparent about these factors is that they are based on perception. They will vary from person to person. Thus, it is important when analyzing an innovation to consider the innovation in different contexts and from various points of view. Something that might seem like a great idea to one person, given his perceptions and biases, might seem awful to another person. It is the task of someone seeking to manage innovation to not only consider the innovation itself, but also the perceptions of that innovation.

Typically these factors are used to discuss the likelihood of an innovation being adopted quickly. But they can also be used to gauge the receptiveness of an idea, such as organizational change. Consider the first factor, relative advantage. How agreeable someone will be to a new organizational model will somewhat depend on how they perceive the advantages of the new model as compared to the model it is replacing. It is therefore necessary to communicate the benefits of the new model to anyone effected by its adoption. In terms of compatibility, one must ask whether the organizational change is consistent with the perceived values and experiences of the organization, and of the individuals within it. The change will be viewed more favorably the more consistent it is with the organization and the individual's goals.

With respect to complexity, an organizational change will only be received well if it does not make things more complicated than the status quo. The trialability factor suggests that the organizational change will diffuse if it can be tried out on a limited basis. This might not be possible when it comes to the large undertaking of rearranging an organization, but it might be helpful to point out that no change is permanent. Finally, in terms of observability, if there are other, similar organizations who have reorganized in a like way, considering their example would help the reorganization be successful.

If reorganizing an organization is considered an innovation, and if acceptance of that reorganization is considered diffusing, then Roberts' five factors can be considered a useful rubric for thinking of restructuring. Knowing what makes people amenable to change allows leadership to plan for dealing with any obstacles to that change.

C. DEALING WITH OBSTACLES TO CHANGE

In terms of organizational change, part of the challenge is determining what structure aligns best with what the organization is trying to accomplish. Once that is determined, the other part of the challenge is achieving buy-in from the employees who will be affected by the change. This section will look at reasons that change is resisted, and illustrate a few methods for overcoming that hesitation.

1. Communication, Collaboration, Innovation, and Organizational Change

Before moving further, some definitions will be helpful. Communication is people or groups talking to each other, and collaboration is those groups working together on common goals. Communication is essential in any organization. One business professor writes that communication "is the process most central to the success or failure of an organization. Many of the problems that occur in an organization may be attributed to failure of communication.... If employees are not given adequate information nor allowed to contribute to the solution of problems, they may revert to being the cause of them, resulting in increased absenteeism, lower productivity and grievances and so on" (Raina, 2010). And indeed, General Stanley McChrystal has noted that "most organizations are more concerned with how best to control information than how best to share it" (McChrystal, Collins, Silverman, & Fussell, 2015, p. 141). Clearly, communication and collaboration are not default settings, even though failure to do them well is disastrous for any organization.

Communication and collaboration are not goals in and of themselves, but rather the means by which goals are achieved. For instance, consider a goal like innovation. Innovation is defined as "the process of translating an idea or invention into a good or service that creates value or for which customers will pay" (BusinessDictionary.com, 2016). It is the lifeblood of businesses. And it is not something that happens accidentally; it must be intentionally pursued. According to one business journal, innovation happens when companies establish a culture that promotes "the formation of teams and task forces; recruitment of new staff with new ideas; application of strategic plans that focused on achieving innovation; and the establishment of internal research and development programs that were likely to see tangible results" (Rule & Irwin, 1988). Innovation does not happen in a vacuum; it can only be achieved through conscious effort and management emphasis.

Innovation and communication march hand in hand. New innovations build on previous ones, and that only happens if knowledge is transferred from one group to the next. MIT Professor Fiona Murray and University of California at Davis Professor

Siobhan O'Mahony list three antecedents that must happen before innovation can take place:

> First, to cumulatively build on the ideas that came before, the innovator must know what came before; this requires disclosure on the part of prior generations.
>
> Second, the innovator must be able to access these ideas. We distinguish disclosure from access because to build on the knowledge disclosed by someone else one must understand how the original knowledge was developed and have access to the various inputs (tools, materials, information, techniques).
>
> Third, both of these conditions depend on rewards, to encourage earlier innovators to both disclose their ideas and provide access so that later generations can usefully integrate these ideas. (Murray & O'Mahony, 2007)

It is worth noting that the first two of the three antecedents are directly dependent on people communicating with each other. Murray and O'Mahony go on to conclude that "the ability of future innovators to build cumulatively on an idea is not an inherent property of an innovation itself." Communication must accompany innovation, or future innovation does not happen. Indeed, if someone builds a better mouse trap, but never shares it with anyone, did they really even build it?

If a goal like innovation is to be realized, it can only happen through communication and collaboration between individuals and groups. Management that wants innovation to happen often tries to accomplish it through rearranging their personnel groupings. By putting people in new arrangements, it forces new communication and collaboration, and innovation happens, or so the logic goes. But people are resistant to change, and need reasons to accept it.

2. Obstacles to Organizational Change

There are two main reasons people or groups do not wish to accept change. The first is what can best be termed as the inertia of the status quo. This refers to the idea that people prefer the current way of doing things, and will resist any attempts to change it. From the Rogers' five factors, they perceive the relative advantage of the change as being low; that is, they either think the benefits of the change are minimal, or that the cost of change is too high, or both. This is partly due to what is known as Prospect Theory. Prospect Theory is a Nobel Prize-winning theory of behavioral economics which teaches that people tend to overestimate the cost or pain of something by a factor of three, and also tend to undervalue the gain or benefit of something by a factor of three. The same effect is present in the minds of the people advocating for the change, by minimizing the cost and overstating the gain. With the employee overstating the value of the status quo, and the manager overstating the value of the change, they are clearly an order of magnitude apart in their estimations of cost and benefit. New York City Police Commissioner William Bratton is famous for introducing sweeping changes to the NYPD, and he remarks of the Prospect Theory that "if you're selling a better mousetrap, it has to be ten times better" to overcome the difference in perceived cost and benefit (Bratton & Tumin, 2012, p. 181).

In addition to overvaluing the status quo, the second main reason people or groups are resistant to change is what might be called the problem of stovepipes. In this, people tend to group together with those whose capabilities they respect and whose results they trust. This is not necessarily a bad thing; in its most benign forms, stovepipes are groups of people with a singular focus that can achieve great results. However, stovepipes often lead to insular, paranoid thinking, where the goals and agendas of the group are pursued even if they are at odds with or at the expense of the goals of the organization as a whole. Stovepipes are often inherently suspicious of other groups that they do not know and trust, and they become actively resistant to anything they perceive will interfere with their operations. One chief creative officer at a prominent ad agency, in discussing stovepipes, says:

> Take out your business card and look at it. That business card will have more value if any one of you succeeds here, even if you're not remotely part of that success. You are not competing with each other in here. If you think you win when your idea wins out over your neighbor's, that's a pretty small gain. In fact, I would suggest that you help your neighbor's ideas get better. I would suggest that if you look at something and you have a better idea, that you generously give that idea to someone and make them better. Because if we all do that, we all win. The minute you're the only good thing at this company, we're done. (Bryant, 2014, p. 179)

Warring factions within a company or organization will ultimately result in that company or organization's downfall. The CEO of a realty company in Michigan says that preventing stovepipes from becoming self-destructive, or breaking up existing stovepipes, is one of a manager's biggest challenges (Bryant, 2014, p. 175).

3. Addressing Obstacles to Change

Whether people are resisting the change because of the inertia of the status quo, or because of paranoid loyalty to their group at the expense of other groups, there are some useful ways of getting people on board with organizational change. Harvard Professor Rosabeth Moss Kanter has come up with what she calls the Ten Commandments of Change, which are worth exploring further (Kanter, Rosabeth Moss; Stein, Barry A; Jick, Todd D., 1992, p. 383).

The first commandment is to analyze the organization and its need for change. Managers need to understand the operations of the organization, along with its strengths and weaknesses. Knowing how that organization will be affected by potential changes is vital to forming successful plans. The second commandment is to create a shared vision and common direction. This involves communication between management and employees, in an attempt to create what an ideal future for the company would be. Commandment three is to separate from the past. The idea here is to take the processes and routines that no longer work and completely remove them, such that there is no option to go back to the status quo. This is similar to the famous example of the Spanish conquistador Hernán Cortés, who burned his boats upon arrival in the New World to show his men that they had to either move forward or die. This plays well into the fourth commandment, creating a sense of urgency. The organization has to be rallied around the need for change.

The next commandment is to support a strong leader role. A strong leader is needed to inspire the change. This leader will play an important role in making sure that the organization's vision is embraced by the rank and file. The leader will help reward those who embrace the vision, and will discipline (as much as possible) those that oppose. Commandment six is to line up political sponsorship. Power struggles cannot be avoided, but they can be managed. There is a strong need for people who have bought-in to the change to work with the stakeholders and the power sources to make things happen. The seventh commandment is to craft the implementation plan. This is the road map for the change effort, including cost and schedule. It is the nitty gritty advice on what to do and when to do it.

The eighth commandment is to develop the necessary enabling structures. That means things like pilot programs, where people can observe the trialability (from the Rogers' five factors). This commandment also refers to setting up training and reward systems, and even planning the physical layout of any new or different work spaces. Commandment nine is to communicate, involve people, and be honest. This commandment is crucial, because it is the most potent tool for overcoming resistance and creating a personal stake in the outcome for employees. Finally, the tenth commandment is to reinforce and institutionalize the change. This commandment is about being committed to the change wholeheartedly, and seeing it through. Half-hearted efforts are doomed to failure.

These commandments should go a long way towards addressing the obstacles to change. By creating incentives to accept the change and penalties for not cooperating, these commandments will help people perceive the benefit of the change and the cost of the status quo. And by separating from the past, stovepipes can be torn down. These ten commandments of change provide a useful guide to follow when an organization decides that structural change is needed.

D. SUMMARY

This chapter discussed relevant literature regarding organizational structures and organizational changes. It surveyed different types of formal and informal arrangements, with particular emphasis given to the lessons learned from Cisco Systems. It also considered the Rogers' five factors, and applied those to understanding how to get organizational change to take hold. Finally, it studied some potential obstacles to organizational change, and revealed possible remedies. The next chapter will detail RTC's current organizational structure.

III. DATA AND ANALYSIS

The previous chapter answered the first set of research questions regarding organizational structures and affecting organizational change. This chapter will answer the second set of questions about RTC/ECTD's organizational model. It will list the current Department of the Army Civilian (DAC) and Contractor personnel at each division, and will note which of these personnel have instrumentation design-related responsibilities. The section will also offer a brief overview of the instrumentation design capabilities of MSTD and AFTD, the other two test directorates within RTC. After considering the current organization of RTC, areas of inefficiencies due to poor standardization and lack of communication will be illuminated.

A. ECTD CURRENT ORGANIZATIONAL MODEL

ECTD consists of five separate divisions. Each of the divisions performs specific functions. This section will provide an overview of each division, with special emphasis on their custom instrumentation design and development capabilities. It will also outline the extent to which each division collaborates with other groups throughout Redstone Test Center.

1. Electromagnetic and Environmental Effects Test Division

As its name suggests, the Electromagnetic and Environmental Effects Test Division (commonly abbreviated as E3) is responsible for electromagnetic testing of aviation (manned and umanned) and missile systems. This involves checking systems and subsystems both for radiated emissions as well as their susceptibility to interference from ambient RF signals. E3 also has facilities for conducting lightning tests, and has ways of measuring power quality. They are heavily involved in testing for MIL STD 704, 461, and 464, which are standards related to power and to HERO (Hazards of Electromagnetic Radiation to Ordinance). E3 is divided into a few functional teams, depending on whether the tests involve electromagnetic interference or radiated hazards, or aviation or missile systems. Many of E3's tests are quite dangerous.

E3 consists of 50 personnel. About 75% of them are contractor technicians responsible for conducting the various tests or for handling some of the logistics and administrative functions of the division. The 13 DACs are the test engineers and leads over the different functional teams. E3 has 3 DACs who do instrumentation development work.

The instrumentation design and development at E3 mainly consists of designing specialized instrumentation for faking a system into believing it is in operation. This involves stimulating the system's sensors with false data, so that it thinks it is in flight or in motion. E3's instrumentation developers use microcontrollers, custom circuit boards, and embedded software written in C to accomplish these tasks. They also use Matlab for analyzing the data they collect, and they have a machine for building up custom printed circuit boards so that they can tightly control board trace lengths and impedances.

E3's involvement in cross-center work is limited. They do rely on one other group within the center that specializes in building shielded cables for some of their cabling needs. And they do help coordinate radar spectrum with the testers at the Aviation Flight Test Directorate. The instrumentation developers reported that they do not have much collaboration with other instrumentation developers in RTC.

2. Climatic Test Division

ECTD's Climatic Test Division, abbreviated ECC, is responsible for all of the climatic testing covered in MIL STD 810. This includes temperature, humidity, pressure, rain, salt, and fog tests. They also conduct metrology testing, which is responsible for measuring specific parameters of the system under test, as well as X-rays of what are known as "all up rounds," which are fully functional missiles including warheads. In instances where a subsystem of a missile needs to be tested without the warhead attached, ECC is responsible for modifying that missile to get the subsystems in a testable state. ECC stores and conditions all of the munitions used by RTC, and at any given time they have a small arsenal's worth of dangerous weapons on-hand. Because these munitions are being conditioned around the clock, ECC maintains 24 hour continuous operations.

ECC consists of approximately 72 personnel. 59 of those people are technicians who support testing, test reporting, logistics, maintenance, or safety. The 13 DACs are test engineers responsible for specific customers or specific capabilities. For example, some of the DACs strictly support customers like Hellfire, TOW, Javelin, PATRIOT, Stinger, or Unmanned Aerial Systems. Other test engineers support functions like climatic chambers, X-ray tests, or instrumentation. ECC has two engineers who work primarily with test instrumentation, but it is not instrumentation design and development.

For test instrumentation, ECC mostly uses off-the-shelf data acquisition products from National Instruments. These products enable engineers to pick a suite of sensors, like thermocouples or strain gauges, with the output of these sensors being fed into a recorder. Labview is the National Instruments software product that takes the recorded sensor data and presents it in a format that can be parsed and analyzed. ECC maintains a small capability for working with Labview code, but prefers to farm out any complicated software efforts to other groups within RTC or to contractors in the local area.

ECC does coordinate some efforts with other divisions. Because they are both governed by MIL STD 810, the standard dealing with climatics and dynamics, ECC works closely with the Dynamics Test Division. ECC also shares management of some temperature chambers with the Components and Surveillance Test Division, and is working on coming up with a centralized way of controlling instrumentation that is located across the Center. ECC also works closely with testers at Aberdeen Proving Grounds, which is where the Army Test and Evaluation Command is located.

3. Dynamic Test Division

The Dynamic Test Division, abbreviated ECD, is responsible for all of the shock and vibration testing covered in MIL STD 810. This includes vibration, mechanical shock, pyro-shock, centrifuge, and vibro-acoustic tests on energetic test items at temperature extremes. Many of these tests occur in controlled environments on shaker tables, while others are road or rail impact tests. ECD also conducts safe and arm fuze testing, which is the ability to replicate the real-world exposure of safe and arm devices, to conduct functional tests on the test items during exposure, and to detonate the devices in a controlled manner. ECD has the ability to shake systems in all six degrees of three-dimensional freedom, a unique capability. Some of the personnel at ECD are responsible for authoring the shock and vibration test standards that are used by NATO countries world wide. ECD also has engineers who specialize in finite element analysis to determine how different systems will respond to various vibration profiles. Concurrently, ECD also conducts modeling and simulation of systems.

ECD consists of 36 personnel, 25 of which are contractors who are test technicians, mechanical support, or administrative personnel. The 11 DACs are test engineers who conduct the tests and perform the analyses of the test data. ECD's primary customers are Hellfire for acceptance testing and stockpile reliability, JAGM for qualification, and Javelin for lot verification. They also do shock and vibration for aviation components. ECD has two DAC engineers who are widely recognized as experts in their field of modeling and simulation of dynamic test environments.

In terms of test instrumentation, ECD is like the Climatic Test Division in that they prefer to buy their instrumentation off the shelf rather than designing anything in house. This is mainly because both divisions simply measure parameters of the systems under test rather than commanding or controlling them, or interfacing directly with subsystem electronics. Thus, their instrumentation is limited to devices like thermocouples and signal conditioners. Because these off the shelf devices are the main way they acquire test data, maintaining calibration is a significant issue for ECD as well as their ECC brethren. When ECD does need custom software to be designed, for data acquisition or analysis, they pay contractors to develop it.

ECD coordinates with other groups within RTC on testing, but not much on instrumentation. They share resources with teams from the Missile and Sensors Test Directorate (MSTD) at Test Area 5, where static firing of rocket motors is conducted. They also use custom telemetry equipment that was developed by the MSTD instrumentation design group. And as mentioned, they work closely on MIL STD 810 tests with the Climatic Test Division.

4. Component and Surveillance Test Division

ECTD's Component and Surveillance Test Division is commonly abbreviated ECL. This group is responsible for a few distinct types of tests. For example, they conduct engineering evaluation tests, such as failure analysis and load cell testing. They measure power output, temperature, and vibration of missile and aviation systems. They also have surveillance vans, which are specially equipped vehicles that have missile test sets, enabling them to take the vehicle to remote locations to conduct stockpile reliability test and quality inspections for different missile customers. Finally, they conduct some metrology tests in cooperation with the metrology group from the Climatic Division.

ECL consists of 70 personnel, of which 53 are contractors and 17 are DACs. As with most ECTD divisions, the contractors are primarily involved in test technician support, safety, administrative tasks, maintenance, and contract support. The DACs are primarily test engineers who conduct the various types of tests, analyze the test data, and prepare reports. ECL's list of customers is similar to that of its sister divisions: on the missile side, Javelin, Hellfire, TOW, JAGM; on the aviation side, components from CH-47s and UH-60s as well as unmanned systems.

ECL uses both off the shelf instrumentation suites as well as customized test sets built in-house by RTC engineers. However, they do not design and build these custom test sets themselves; they rely on engineers from the Subsystem Test Division for all of the test sets that go in their surveillance vans. ECL shares a mechanical design group with the Subsystem Test Division that is responsible for designing and manufacturing test fixtures and enclosures. ECL uses products from National Instruments for their data acquisition, and when they need custom Labview code to support this hardware, they hire that work out to contractors.

Because ECL has temperature chambers and a metrology lab, they coordinate some efforts with the Climatic Test Division. Also, as mentioned, they work closely with the Subsystem Test Division on the custom test sets used in the surveillance vans. ECL's mechanical design group is also a shared group with Subsystem Test. Beyond this collaboration, ECL does not work with other divisions or directorates within RTC.

Outside of the mechanical design group, they do not have any engineers dedicated strictly to design and development.

5. Subsystem Test Division

The final division within ECTD is the Subsystem Test Division, abbreviated as ECS. This group is made up of several different teams, each focused on a particular type of customer. The first team is the Hellfire team, which creates test sets that stimulate the various components of the Hellfire missile. This team also uses those test sets in a lab environment to test missile components. There is also a hardware in the loop facility for testing the Longbow variant of the Hellfire missile, which fools the missile into believing it is in flight. This facility test hundreds of rounds each year. Almost mirroring Hellfire, there is a Javelin team, which is responsible for building test sets that stimulate a Javelin missile and its various components. The Javelin team also tests missile components and has a Hardware in the Loop facility for simulated flight that tests dozens of missiles per year. On the aviation side, ECS also has a team dedicated to testing manned and unmanned aviation components and systems. This team also develops custom equipment for fooling aviation subsystems into believing they are in operation, and supports aviation testing in the lab as well as in the field.

There are 92 personnel within ECS, of which 69 are contractors and 23 are DACs. Like most divisions in ECTD, contractors are responsible for technician work as well as logistics, purchasing, facilities, and so on. Unlike other divisions, though, ECS has a significant number of contractors who do custom hardware, software, and mechanical design work. Among the DACs, most are involved in managing the efforts of the contractors who are actively testing or designing test capabilities. However, a significant number of DACs also design and develop customer instrumentation hardware, software, firmware, and mechanical enclosures. ECS's primary customers are Hellfire, Javelin, and TOW on the missile side, and the Aircraft Survivability Equipment Project Office on the aviation side.

Because of the unique nature of their work, ECS designs and develops almost all of their instrumentation. However, there is little standardization between the aviation and missile development teams in terms of processes and tools. The aviation team develops printed circuit boards using Mentor Graphics, while the missile team uses Altium. The aviation team has several Labview experts that develop in a Windows environment, while the missile team writes mostly C++ in a Linux environment. Both teams develop firmware using Altera's Quartus tools, but the aviation team writes primarily in Verilog while the missile team uses mostly VHDL. Finally, the aviation and missile mechanical design folks use Solidworks and Autocad, respectively.

In terms of collaboration, the Hellfire missile and Javelin missile teams generally do not work together. They collaborate with other divisions that test their respective missiles, but do not share talent or resources. Additionally, neither missile team works much with the aviation team. The Javelin team does work with the Missile and Sensors Test Directorate personnel who conduct live firings of missiles at Test Area 1, and instrumentation developers do collaborate in limited ways. The aviation team supports tests that occur as part of the Aviation Flight Test Directorate's activities.

B. AFTD AND MSTD CURRENT ORGANIZATIONAL MODEL

1. Aviation Flight Test Directorate

RTC's Aviation Flight Test Directorate conducts testing of cargo and fixed wing aircraft, aviation systems, avionics, and unmanned systems. Organizationally, there are two main groups, one that conducts tests and one that supports the testers. The testing divisions each conducting tests for specific customers: Attack/UAS, Cargo/Fixed Wing, and Utility. The support group consists of divisions like Maintenance, Logistics, Airworthiness, and Instrumentation Development. For the purposes of this overview, the focus will be on AFTD's instrumentation capabilities.

Unlike ECTD, which has instrumentation development capabilities scattered throughout the directorate, AFTD has its instrumentation grouped together into one division. This division is 47 personnel strong, of which 38 are contractors and 9 are DACs. Many of the contractors work in the machine shop and install instrumentation on the aircraft, while others are involved in data reduction and programming. The 9 DACs are also involved in this type of technical work. AFTD consciously tries to avoid designing customized hardware solutions for its instrumentation needs, preferring instead to buy off the shelf recorders and sensors for collecting test data. On the rare occasions that they need a customized piece of hardware, they either get developers from another RTC directorate to build it for them, or they pay a contractor firm.

Something interesting about the instrumentation division within AFTD is that they do not view the various aviation project offices as their customer. Instead, they believe they are working for other divisions within AFTD. Suppose that the Unmanned Aerial Systems (UAS) test division is conducting a test and requires instrumentation on the aircraft. In that instance, the instrumentation group would instrument the aircraft and collect the test data as a service not for whoever is paying the UAS division to conduct its test, but rather the UAS division itself. This way of looking at things is in stark contrast to the rest of RTC's instrumentation engineers, who typically view themselves as providing a service to RTC's customers directly rather than to other RTC entities.

2. Missiles and Sensors Test Directorate

The Missiles and Sensors Test Directorate was previously organized around geography almost exclusively. All firing of missiles was conducted at Test Area 1, the Missile Flight Test division. Static firings of rocket motors was conducted at Test Area 5, the Propulsion Test division. Field sensor testing was done by the Field Sensors division at Test Area 3, and telemetry products were designed and developed by the Telemetry and Data Management division. Each division had duplicate capabilities, in that each range had their own instrumentation and support personnel, their own ammo haulers, their own safety groups, and so on.

RTC Management recently decided to reorganize the directorate around common functions. Since every test range had support personnel, all of those personnel were grouped into a common Range Operations division. Since test engineers at Test Area 5 and Test Area 1 both pulled triggers and wrote reports, those engineers were consolidated into a common Test Engineering division. And the instrumentation personnel from each division were pulled into a common Instrumentation division.

The new Instrumentation division groups together not just the instrumentation development engineers that had been scattered throughout MSTD, but also the range instrumentation engineers and technicians. The instrumentation development engineers are all on one team within the division, and this team consists of about 10 contractors and DACs who design custom hardware, software, firmware, and mechanical enclosures. These engineers tend to use common toolsets and follow similar design procedures, though as the reorganization continues those toolsets and procedures are being redefined.

C. AREAS OF INEFFICIENCIES

Having considered the various instrumentation design engineers scattered throughout ECTD and across RTC as a whole, it is apparent that the main groups within RTC who do this kind of work are located in ECTD's Electromagnetic and Environmental Effects Test Division, Subsystem Test Division, and Component and Surveillance Test Division, as well as MSTD's Instrumentation Division. The following sections will give specific examples of low standardization, poor communication, and other inefficiencies.

1. Low Standardization

One main area that exhibits almost no standardization across the various instrumentation design teams is in the area of tools, specifically the software tools that each group uses to accomplish similar tasks. Table 2 illustrates this clearly.

Table 2. RTC Instrumentation Design Teams and the Tools They Use

	Mechanical Design	PCB Design	Software OS	Software Language	Firmware Language
Subsystem Test Aviation Team	Solidworks	Altium	Windows	Labview	AHDL/ Verilog
Subsystem Test Missile Team	N/A	Mentor Graphics	Linux	C++	VHDL
E3 Instrumentation Team	N/A	Eagle	Windows	C	N/A
Component and Surveillance Mechanical Team	Autocad	N/A	N/A	N/A	N/A
MSTD Instrumentation Design Team	Solidworks	Altium	Windows	C++	VHDL

This table shows that all of the groups doing common types of work within RTC do not work with common tools. This creates a host of inefficiencies. For example, some of the tools, like the PCB design software, require the purchase of specific licenses in order to operate. Different tools with different licenses adds significant cost, both in terms of buying the licenses (which in some cases are thousands of dollars), and in terms of the personnel responsible for tracking when the various licenses expire. Further, being an expert in one particular set of tools does not mean that the knowledge and experience easily translates to other sets of tools. This creates a problem for moving personnel from one group to another as the workloads of the various groups changes. Finally, the use of different tools means that a solution to a particular problem, perhaps a section of code or a drawing of an assembly, might not be easily ported to a different set of tools in the future. Thus, problems that were solved by one group might have to be re-implemented in a different way by a subsequent group later on. These are just some of the ways that a lack of standardization contributes to inefficiencies across RTC.

2. Poor Communication

A lack of communication between groups also contributes to inefficiency. For recording data from various systems under test, RTC has developed various methods using diverse media formats, depending on the application. In instances where both the data rate and the amount of data generated are small, RTC has used SD cards. For applications where the data rate or amount of data is large, RTC uses solid state SATA hard drives. However, recording to hard drives requires a special type of firmware known as a “core” that gets loaded onto the custom electronic circuitry, and these cores need a very expensive license file in order to operate. Since 2012, three separate groups of instrumentation design engineers have independently arrived at the conclusion that one particular core is the best for recording data to hard drives. The Subsystem Test Aviation Team, the MSTD Instrumentation Design Team, and the Subsystem Test Missile Team each independently purchased the core, at a cost of $25,000 each instance, and spent a considerable amount of time writing their own firmware code to implement the core’s functionality. Had these groups communicated with each other, the second and third groups in line would have benefited from the work already done by the first group instead of solving the same problem all over again. Poor communication cost RTC’s customers thousands of dollars in material purchases, and even more in lost labor hours. This failure is particularly glaring, as two of the teams are located within the same division.

A second example can be found in the area of component footprints for Printed Circuit Boards (PCBs). When a new microchip is identified for use in a circuit, that component has a footprint signifying its dimensions and shape, as well as what function each of the connections on the chip serve. Capturing this data into a format for use in the PCB design tools is a laborious process that is also prone to error, as small mistakes in the dimensions of one component can make an entire PCB unusable. Unfortunately, each of the PCB design engineers across RTC maintains his or her own library of components. These engineers do not communicate with one another, such that different engineers might end up building the same footprint at different times. And even if they did communicate, often the engineers use different tools altogether, as discussed in the previous section, which makes collaboration impossible. If the engineers did communicate, and if they had standardized toolsets, they could share the work that they have done, and help their peers avoid mistakes they might have made in the past. In short, a lack of communication means that engineers find themselves solving problems that others within their organization have already solved, which is extremely inefficient.

3. Other Inefficiencies

Perhaps the most glaring inefficiency across RTC is in the area of workload balancing. Some groups occasionally find themselves swamped with tasks from customers and awash in funding, at the same time as other groups find themselves with lighter workloads. This is part of the ebb and flow of test efforts. However, because the various groups are not standardized and do not communicate, when their workloads become significant they feel like they have no other option but to hire outside contractors to help them complete their tasks. RTC is paying other outfits to do work, while at the same time paying under-burdened engineers on other instrumentation design teams to sit idle while they wait for new tasks. This is very inefficient.

D. SUMMARY

While the previous chapter dealt with answering questions related to the theory of organizational structures and organizational change, this chapter looked at the current organizational structure of Redstone Test Center's Environmental and Components Directorate. Each division within ECTD was profiled, with particular interest given to the number of personnel they have, what their roles are, what customers they serve, and how well they work with other groups within RTC. Specific attention was given to their instrumentation capabilities and whether or not the groups practice actual instrumentation design and development or not. Next, the other directorates within RTC were examined to consider their organization and their instrumentation design capabilities. Finally, some specific inefficiencies in the data were revealed and analyzed to show that the current teams are not working well together. With these research questions in mind, the next chapter will consider some findings from the analysis.

IV. FINDINGS / RESULTS

This chapter will consider the research questions related to the theory of organizational structures and affecting change and will apply that theory to the current ECTD organizational model with an eye toward improving efficiency, standardization, innovation, and communication.

A. ANALYSIS OF CURRENT ORGANIZATIONAL MODEL

ECTD is currently broken into five divisions arranged around the functions they perform. Each division has some overlap in the customers they support, and the personnel needed to support those customers often perform similar functions. In the case of the Environmental and Electromagnetic Effects Test Division, the Subsystem Test Division, and to a lesser extent the Components and Surveillance Test Division, there are instrumentation design engineers with similar capabilities who do not communicate and do not conform to any explicit design standards. ECTD's organization could best be described as a hybrid between a functional and divisional structure. A functional structure has groupings based off common capabilities, and a divisional structure has groupings based off common products or customers. ECTD has divisions that support distinct functions (climatic, dynamic, electromagnetic testing), and within those divisions there are instrumentation design customer teams that do not communicate much with each other. Furthermore, there is no one management individual who knows what each design team is working on. Communication and efficiency are less than optimum. Innovation is good, because the design teams focus on bringing advanced, valuable solutions to their customers. But that innovation does not disseminate throughout the rest of the organization. When it comes to the specific type of functional testing that each division does, they have the strengths associated with a functional structure: efficient, and very competent at the tasks they perform. Even the weaknesses of a functional structure, the lack of customer responsiveness, is somewhat mitigated by each divisions' desire to provide world-class service for its customers. However, the instrumentation design engineers scattered throughout the directorate stick out for their duplication of capability and lack of coordination. They are inefficient parts of the larger whole.

Further, as discussed in the Cisco Systems case, changes to the organizational structure are one of management's tools for attaining particular goals. Disrupting the formal structure of an organization is one way to make employees form new informal networks. And as the research showed, informal networks are the important part of how relationships of trust are built and work gets accomplished. While the divisions within ECTD have grown or split on a few occasions, there has not been a large scale realignment of the existing structure within ECTD in the past two decades. Thus, the formal and informal networks are quite entrenched, and attitudes are quite unmalleable. Stove pipes are a present problem. Reorganization of the structure is an important way to force the stove pipes to change.

Perhaps more important than the organizational structure is the fact that there are no design standards or configuration control for the various design groups. The research showed that while each group practices solid engineering discipline, the tools and procedures vary from team to team. There is also no formal design review process at key stages of projects. Some of this is because the projects are not high dollar amounts and the number of end products that get produced is low. In those instances, formalized design procedures might be more of a hindrance than a help. Because there are times when these standardized procedures would not be helpful, many instrumentation design engineers have been reluctant to adopt standards of any kind, preferring to make their own decisions about how to operate. Leadership is needed to both develop standards and enforce them.

Finally, while each division chief has a good grasp of the current work load of the instrumentation design engineers under his or her supervision, that knowledge is not well known across the various teams. Thus, at times some teams have more projects than they can handle, while others have a light schedule. If there were someone to coordinate the active projects of all the teams, efficiency of work allocation could be vastly improved.

The current organizational model has strengths in the way that customers are served and solutions are innovated. However, when it comes to the instrumentation design and development engineers, there are some significant problems. The thesis of this project is that the current organizational structure of the instrumentation design engineers is lacking, and that thesis appears to have been validated by the data. Fortunately, these problems can be overcome by changes to the organizational structure and by some commitments from leadership toward encouraging collaboration and standardization.

B. SUMMARY

Based on the research conducted in the prior chapters, this chapter considered how to apply the findings to the specific situation of ECTD’s instrumentation design engineers. The formal structure of ECTD’s internal divisions has not been changed in many years, and the research shows that change is necessary in order to force informal networks to build new relationships of trust.

The next chapter will draw some conclusions based on the findings, summarize the contents of this project, and provide recommendations for further study.

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V. CONCLUSIONS, RECOMMENDATIONS, SUMMARY, AND AREAS FOR FURTHER STUDY

A. RECOMMENDED ORGANIZATIONAL CHANGES

There are a three possible ways that the organizational structure could be changed to facilitate collaboration, standardization, and efficiency. One would be to stand up a new division within ECTD that consists of the various instrumentation design engineers and their support technicians from throughout the directorate. This division would be different than the other divisions in that it would not require a lot of the same support elements, in terms of maintenance or safety, because it would not be directly involved in any test activities. This new division would itself be a support division, designing and building equipment that would be used by other divisions to conduct testing. The division would consist of project teams devoted to particular RTC customers, but none of the teams would have a fixed-membership; that is, design engineers would float from project to project, gaining knowledge and experience that is both deep and wide. Having all of the engineers in one division would facilitate communication, as new informal networks begin to develop and relationships of trust are established. Standardization would be much easier to enforce, and efficiency much easier to manage. A potential downside to this relationship is that, as engineers are no longer devoted to one customer for extended periods of time, it is possible that their ability to anticipate customer needs would suffer. Also, instrumentation developers would have to split time being geographically co-located in the same office, and at the location where their equipment is being used. This could lead to the matrix weakness of not knowing what the chain of command is. Does the engineer report to her instrumentation lead or to her range or lab lead? These potential problems could be solved by encouraging engineers to maintain relationships with RTC's end customers, reinforcing the informal relationships that currently exist. And the matrix problem could be solved by clearly defining lines of accountability. Reorganizing the instrumentation design engineers into their own division could go a long way to improving communication, standardization, and efficiency, without creating new problems that are unmanageable.

A second possible solution would be to take the first option a step further. Rather than consolidating the instrumentation design people from ECTD into one division, it is possible to pull the instrumentation design people from ECTD, MSTD, and AFTD and stand up a separate instrumentation directorate. Every one of the strengths of the previous model would be present in this one as well. Standardization in tools and processes could be developed and enforced across the entire center. Engineers would move back and forth between projects at the airfield, at the open air ranges, and in the laboratories without boundaries. Efficiency could be vastly improved as management would have a better feel for all of the active instrumentation projects across the center. And innovation could theoretically improve as the best and brightest minds work together to develop new solutions. However, this structure suffers from the same weaknesses as the previous proposal. Engineers would be organizationally that much further from the customers they are supporting, which might weaken their relationships. And the "who reports to whom" issue would be significant, as an engineer in the new instrumentation directorate would have responsibility across many divisions. An additional weakness of this model is that its radical nature might be too much change at once. MSTD is in the process of a reorganization, and creating a separate directorate might create too much pushback from the stakeholders. Rogers' Five suggests that a change is more likely to be adopted if it is uncomplicated and the benefits are observable. This particular model might be a bridge too far.

The last possible organizational change is to leave the current formal organizational structure in place, but to create a separate integrated capability team. This would recognize all of the engineers across the various divisions and directorates who do instrumentation design work, and to form a team capable of handling all instrumentation design projects. The engineers would remain in the current divisions, reporting to and being evaluated by their current division chiefs. However, being part of a new, matrixed team would form new informal networks, and would facilitate improvements in communication, standardization, and efficiency. This solution suffers from the same weaknesses as creating a distinct instrumentation design division, but also offers similar benefits. What sets this solution apart from the others is that it is not a radical change.

Rather than drastically redrawing the organizational lines, this solution takes a more modest step of leaving those lines in place while defining a separate team. Rogers' Five suggests that a change is more likely to be accepted if it is trialable. This modest proposal can be tried and evaluated, such that if it works further changes could be incrementally made if needed, and those changes have a higher probability of success. Creating an integrated team that exists on top of the current formal structure, but without actually changing the formal structure, would be a good way to slowly change the culture towards communication, collaboration, standardization, and so on.

B. RECOMMENDED LEADERSHIP CHANGE

Regardless of the change to the organizational structure, another necessary ingredient to improving communication, standardization, and efficiency without stifling innovation is to create a new leadership position. This position, which could best be termed as an Instrumentation Design Coordinator, would have several responsibilities. First, this person would be in charge of helping to shepherd the organizational structure change. As the research shows, people need to be sold the benefits of the change and made to understand the consequences of not cooperating. The Instrumentation Design Coordinator would be charged with communicating this to the engineers. Second, this position would be responsible for creating and enforcing standard processes and procedures. This position would attend design reviews, and interface with all of the instrumentation development personnel to facilitate cooperation, sharing of resources, and knowledge management. Next, this person would help maintain a list of all the active and proposed instrumentation design projects, so that resource planning could take place and efficiency could be attained. The position would be responsible for building up the informal network. It would be a non-supervisory role, in the sense that the instrumentation engineers still would report directly to their division chief. However, this position would be a secondary-rater on each engineer's annual performance reviews, providing input as to how well they performed from a technical perspective and how well they collaborated with others. This position would work to implement mentorship opportunities for younger engineers to learn from more experienced senior engineers. In terms of efficiency, this position would have an understanding of what solutions each engineer has already accomplished, such that no one would have to solve a problem that has already been tackled. Finally, this position would serve as the instrumentation design subject matter expert at RTC, the technical authority for all matters related to the design and development of custom hardware, software, firmware, and mechanical constructs. Because of this technical expertise as well as the fact that the position will need some designated authority to enact some of its responsibilities, it is recommended that this position be at the GS14 level. Additional characteristics of a technical position such as this can be found in Appendix B.

If this position is created, there are several metrics that can be used to determine whether this position is successful. First, standard design practices, documentation processes, and configuration management procedures should be identified and implemented. A program for rotating development engineers across different projects should be set up, in order to get maximum exposure and experience for the engineers. A new informal network should be established and mapped, as much as possible, to understand who approaches who for advice and what individuals work best together. A list of active and proposed projects should be developed and maintained. And finally, specific inefficiencies should be identified and corrected. In short, this person should be a part of helping to change the organizational culture from the ground up, such that the goals of better communication, standardization, efficiency, and innovation become ideals that everyone buys into.

C. SUMMARY

This project was born out of the need to better understand the instrumentation design capabilities within Redstone Test Center’s Environmental and Components Test Directorate. It started by giving a historical overview of RTC, and a brief overview of the different directorates within RTC and what their functions are. Next, the project provided further context by differentiating the use of traditional instrumentation from the more sophisticated efforts to develop customized hardware and software solutions for test items that are not commercially available. With this capability in mind, it was shown that while RTC is an innovative authority in this field, inefficiency, lack of communication, and lack of standardization are problems. Thus, it was determined that research was needed to consider how severe the problems are, what organizational structure changes would address these problems, and how best to convince the rank-and-file engineers to be accepting of these changes.

The research began by surveying a few different types of organizational structures. Next, an extended look at the difference between formal structures and informal networks revealed that both are important. The formal structure conveys a particular set of goals that management wishes to achieve, while the informal network is the set of trust relationships where the "real" work gets done. Organizational change is necessary because goals and ideals become stagnant, and only by compelling employees to tackle tasks in fresh ways can new goals be achieved. Cisco systems provided a compelling example of this principle, that change to the formal structure is necessary so that the informal networks remain vibrant.

The research then considered the Rogers' Five Factors of innovation and applied it to organizational change. Psychologically, it provided a useful framework for evaluating the reasons people are willing or unwilling to accept new things. Research then showed the ten commandments of change, which help everyone within the organization buy-in to the goals management is trying to achieve.

The next step was to create a picture of the current organizational structure and capabilities of the various groups within ECTD. Interviews with RTC personnel revealed which groups are responsible for which tasks, what customers they support, and to what extent the groups work with other groups. Particular attention was paid to the instrumentation design capabilities throughout the various groups, and the suspected problems of inefficiency and poor communication were confirmed.

Armed with the results of this research, analysis provided some ways to correct the problems of standardization, communication, and inefficiency, while maintaining RTC's innovative mindset. Two possible organizational structure changes were recommended, along with a third option that does not formally change the structure but encourages cooperation among engineers with like capabilities. Also, the creation of a new leadership position was advised, with the goal of spearheading both the execution of the change and the enactment of the problem solutions. By consolidating the instrumentation engineers together organizationally, and by empowering one person to oversee the technical and psychological aspects of this group, the goals of standardization, communication, and efficiency could be attained. And increased innovation could be achieved, as the technological experts from across RTC who were previously isolated could begin working together to solve new, complex problems and provide visionary capabilities.

D. RECOMMENDATIONS FOR FURTHER STUDY

One interesting opportunity for further study is to consider other opportunities for organizational change. This study focused primarily on instrumentation design and development capabilities, to the exclusion of areas where the rest of RTC's test engineers could communicate and collaborate better. Further research into overlaps in capabilities between the Climatic and Dynamic Test Divisions, for example, might show enough common function that these divisions could be consolidated. This same study could be executed with capabilities other than instrumentation design in mind, to reveal other areas where inefficiencies could be corrected through organizational change or leadership emphasis.

A second opportunity for study is to consider the ongoing reorganization of the Missile and Sensors Test Directorate. This directorate has adopted radical changes to its organizational model, grouping like functions together in such a way that people in disparate geographic locations throughout RTC report to the same boss, while people in offices or cubes next to each other report to different bosses. This reorganization was undertaken without the benefit of the Rogers' Five Factors observability or trialability, such that it is quite unknown how effective the new organization will be. Since MSTD reorganized its instrumentation design team as well, a study such as the one from this paper could be conducted on those personnel to either attempt to predict how well the reorganization will go, or to analyze in hindsight why the reorganization did or did not work as planned.

APPENDIX A. REDSTONE TEST CENTER ORG CHART

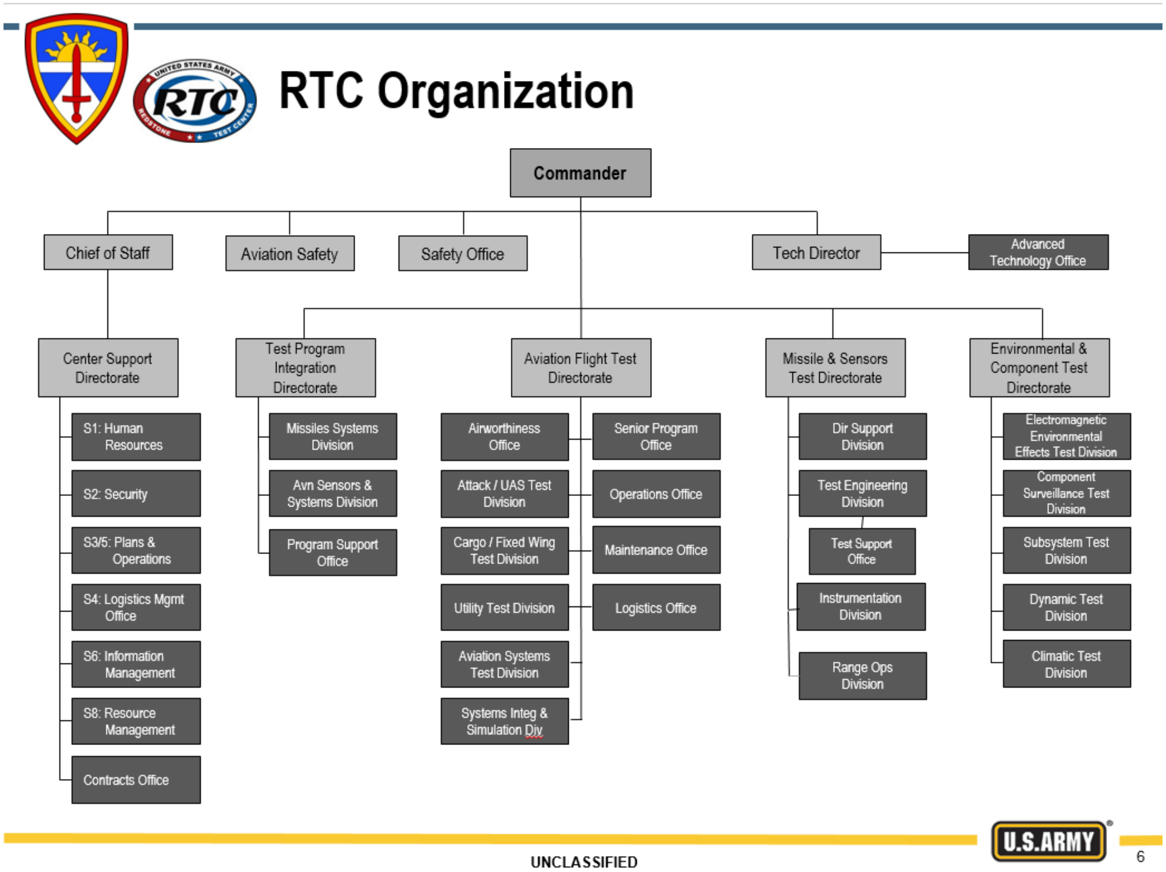

Figure 7. RTC Organizational Chart as of March 2016. Source: Redstone Test Center (2016).

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APPENDIX B. TECHNICAL MANAGER CHARACTERISTICS

Steven Sinofsky was the president of Microsoft's Windows division during the design, development, and roll out of the Windows 7 operating system. He wrote a series of blog posts discussing organizational culture and management philosophy of Microsoft. These blog posts became the basis of a book with Marco Iansiti of the Harvard Business School. As a highly technical company, many of the lessons learned in developing Windows 7 are applicable to the highly technical world of instrumentation development. One such lesson is Sinofsky's description of the six major responsibilities of a manager in charge of developers (Sinofsky & Iansiti, 2010, p. 189).

The first responsibility Sinofsky lists is to know the code. He believes that a manager must be the source for skill and experience for the code developers, participating in reviews and offering assistance. Ultimately, the responsibility for code quality rests with the manager, so he or she must have the background necessary to get the job done. The second responsibility is to help the developers know what they need to do. The manager is like a coach, instructing the developers not just in the specifics of their code implementation, but also in how that relates to other functional areas. For Microsoft, those areas were things like security, globalization, accessibility, and so on. The next responsibility of the manager is related to work balancing. The manager has to determine what tasks need to be accomplished and by whom. This means the manager should know each member of the team's skills and abilities as well as their work loads, and should work with the team to prioritize schedule and task lists.

Fourth, a manager has the responsibility to assist in skills development. Since not every member of the teams has all of the skills necessary, it is important for managers to make sure their subordinates have the tools and time needed to get up to speed. Knowledge transfer is paramount when a company's main product is intellectual property, and it is crucial for managers to work with the less experienced members of the team to help train them. Next, Sinofsky believes managers must communicate with their team and with other teams. This means managers have to work with their own teams, but also with the managers of other teams that depend on their teams' output. Fifth, managers are responsible for evaluating the performance of their subordinates. Rather than framing this in a threatening way, Sinofsky describes this as managers being very in touch with their subordinates' accomplishments and sensibilities, as well as subordinates being equally aware of what their managers expect. Finally, Sinofsky believes managers must be responsible for selecting the members of their team. Managers must hire and recruit team members to train, and must help integrate them with the team to achieve the end goal.

Most management classes teach that it is not necessary to understand the nitty-gritty details of a technical process in order to be able to manage effectively. While that is true to some extent, leading a group of highly technical, innovative people does require a certain familiarity with the underlying engineering concepts. The list of characteristics Sinofsky presents are useful when considering candidates for the leadership position that this project recommends.

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