Fall 2013

The role of face-to-face interactions in the success of virtual project teams

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THE ROLE OF FACE-TO-FACE INTERACTIONS IN THE SUCCESS OF VIRTUAL PROJECT TEAMS

by

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A DISSERTATION

Presented to the Faculty of the Graduate School of the

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

In Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY
in
ENGINEERING MANAGEMENT

2013

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ABSTRACT

This dissertation examines the importance of in-person Face-To-Face (FTF) interactions in virtual engineering development projects. The basis for this investigation will be the hypothesis that FTF interactions increase the effectiveness, quality of communication, and the trust between participants beyond that achieved with purely computer mediated communication.

Through a combination of a literature review and empirical research, this dissertation addresses the following questions:

- How important is FTF interaction in virtual development work?
- Do various functional areas and age groups rate the importance of FTF interactions differently?
- How does FTF interaction affect the levels of trust and communication within virtual team and between the virtual team members and the organization?
- How do FTF interactions affect overall project success?

The participants in the research study were experienced engineers, technicians and program managers working in a virtual product development environment at a mid-tier defense contractor. As such, the data obtained can reasonably be extrapolated to the aerospace/defense industry.

ACKNOWLEDGMENTS

I'd like to acknowledge the support of Dr. Abhijit Gosavi, my advisory committee members at Missouri S & T (Drs. Susan Murray, Ruwen Qin, and Brian Smith) and at the University of South Florida (Dr. Kingsley Reeves), and especially my wife Virginia for the constant encouragement and putting up with the long nights.

Special thanks to Chris Lettiere, Sr. Vice President of Engineering, my fellow employees who participated in the survey and the management of DRS Technologies, for allowing me to conduct the research used herein.

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LIST OF ABREVIATIONS

Acronym	Definition
FTF	Face-to-face (In person)
FTP	File Transfer Protocol
IT	Information Technology
ICT	Information and Communication Technology
PE	Project Engineer
PM	Project Manager
KM	Knowledge Management
TM	Transactive Memory
CMC	Computer Mediated Communication
DRS	DRS Technologies
VPN	Virtual Private Networks

1 INTRODUCTION

Virtual team management is not a new topic in project/organizational management. Ironically, the military, from where many management practices in the United States have originated, has been utilizing this organizational form for a millennium and continues to employ it today (Ahlstrom et al. 2009). In this section, some history of virtual team management is provided, which is followed by a definition of virtual teams and the role of Face-To-Face (FTF) interactions. This section concludes with an outline of this dissertation.

1.1. HISTORY OF VIRTUAL MANAGEMENT

Even two thousand years ago, when Rome's armies stretched across the known world (geographically distributed locations), orders and status updates were dispatched via the most up-to-date communication technologies (couriers on horseback), there were failures in Information Technology infrastructure (lost horse shoes); one example of disastrous miscommunication was The Battle of Teutoburg Forest (Wells 2003). Since most battles were then fought "offsite," effective virtual management with today's standards might have produced a different world. For instance, had Napoleon received a timely email warning him of the status of the Prussians advancing to Waterloo, his battlefield strategy might have been modified. If General Lee had a real time satellite image of Gettysburg or even a topographical output from Google Maps provided by his scouting and survey organization, the battle and war might have ended in his favor.

"Might" is the operable word as even the most up-to-date communication channels are useless unless the data being transferred is understood and acted upon correctly.

The major differences between historical and present-day communications, aside from the content of the messages, are in the methods and speed of communication. However, even with perfect transfer of accurate data in a timely fashion, miscommunications still occur as subjective human factors come into play. The rapid advance in communication infrastructure due to the Internet is allowing more and more companies to attempt virtual development teams. Unfortunately, in many instances, the success of these teams, in terms of project efficiency and stakeholder satisfaction, has not improved as dramatically. One reason for this inconsistency is that even though the tools for virtual team communication may be available across the sites and their usage taught, there are non-technological factors that do not transfer across the Internet (Burgoon et al. 2002).

Unlike in co-located teams, subtle yet important cues are easily missed in the virtual environment (Pauleen and Yoong 2001). Once a web conference has been terminated, it is unlikely that the same follow up that happens in the hallways or by the water coolers of the co-located team members will occur between virtual team members and a valuable communication opportunity is lost. This misstep occurs at both the peer-to-peer level and at the manager to report level.

Returning to the military paradigm, one constant that was recognized by all successful military leaders, which continues today for managers, is the need for face-to-face interaction with direct reports and team members (Majchrzak et al. 2004).

These meetings are not just a means of passing information, which could be done with letters or telegrams, but rather a way to improve understanding, develop trust and provide a basis for future communication. They often included informal dialogues or campfire chats, where the members could get a better understanding of the person at the other end of the command chain and the idiosyncrasies of their personal styles and effectiveness of communication.

The impact of FTF derived trust on the command chain is exemplified by generals through history from Washington staying with his men at Valley Forge, to Schwarzkopf traveling to Iraq during Operation Desert Storm (Ricks 2012). In World War II, General Patten had a practice of daily inspections and meeting with his subordinates and troops; not just to communicate orders, but more importantly to build trust between himself and his troops (see Figure 1.1).

Figure 1.1: Significant Face-to-face Interactions throughout History[1]

[1] The last image in Figure 1.1 was inserted as it illustrates the fact that all major religions have some reference to a direct intervention of their God or Gods and humans. It can therefore be surmised that the vast majority of the population believe face-to-face interaction is important enough that even their Supreme Being in whatever form it takes, needs to use FTF meetings on occasion.

Of course, this type of personal interaction has never come without a cost. While there were probably accountants in the government that fought the travel expense associated with President Roosevelt traveling to Tehran in 1943 to attend a summit with Churchill and Stalin, the understandings that came out of that meeting, for better or worse, helped define the post-war relationships between the three countries. Given the importance placed on personal interaction of non-collocated teams throughout history by the military hierarchy, it appears prudent that virtual team managers make similar investments in time and funding to meet with their teams FTF with some level of frequency.

The question that arises is: How does one justify the subjective benefits of trust and camaraderie against the objective costs associated with increased travel?

Due to the associated cost and difficulty in concentrating a large multi-functional employee base at each site, corporations are now running large engineering development projects across multiple divisions. Fortunately, Information Technology (IT) has greatly improved within the last decade due to the Internet and the increased bandwidth of telecommunication tools, which greatly simplifies virtual work. As this technological advancement accelerates, it is becoming more and more unlikely that all project team members will be located at a single site.

The most common form of this dispersed development project team is referred to as a virtual project development team where members working “together” in fact seldom, if ever, physically meet. Virtual Management is a phrase that has been expounded in the last dozen or so years to address organizing, motivating and directing the activities of these individuals and groups that are not collocated in the traditional manner.

Unlike traditional project teams, virtual teams by definition utilize distributed communication channels with minimal FTF interaction. While these technologies, namely telecoms, web conferences, and video conferences enable the formal transfer of data and information, informal communication such as water cooler and hallway discussions do not take place. Moreover, the subtle non-verbal facets of communication such as body language can be missed or worse, misinterpreted when the team members never meet in person to develop personal relationships (Burgoon et al. 2002).

A recurring theme in the area of virtual team management is the need for trust to be developed between team members and the project management (Mitchell and Zigurs 2009). This study will also weigh the importance of FTF meetings in the development of a trusting relationship and ultimately project success. There are a myriad of aspects to virtual team management and most research identifies communication and trust across the team as the primary enablers for success (Jarvenpaa et al. 2004). While there are many methods of improving communication and trust in both co-located and virtual development teams, one area that is considered a given in the former and an exception to the rule in the latter is face-to-face in-person interaction.

Much of the literature on virtual teams deals with the challenges and methods of communication and management tools applicable for a totally virtual structure. Likewise, traditional management publications are focused on co-located management practices while giving limited space to virtual team management. In today's organizations, the reality is somewhere in between. Few virtual teams are 100% virtual and few "traditional' development teams are totally co-located. While both structures will benefit from an increase in communication effectiveness, co-located teams have an

additional advantage in that face-to-face communication occur on both formal and informal basis. As the vast majority of papers state there is no better method of communication than FTF communication (MacDonnell et al. 2009). The central theme of this dissertation is to evaluate the need for FTF communication in virtual development teams and highlight not only the importance of these meetings, but also to identify at what point during a project they are most needed, who benefits the most from these interactions, and to determine the value for this virtual interaction.

The balance of this section describes the terms used and areas addressed throughout the dissertation.

1.2. DEFINITION OF VIRTUAL TEAMS

Considering the advances that have occurred in communication technology in recent years, virtual teams is the next logical step in the evolution of organizational structure, with over 8.4 million employees being members of one or more virtual groups (Aubert and Kelsey 2003). The definitions of virtual team are as varied as the tasks being undertaken. The most fundamental definition, of course, is a team that is geographically dispersed. Recent advances in technology, however, have allowed distance workers to become truly virtual. A more up-to-date definition that incorporates the impact of technology is that virtual teams are: "…groups of workers with unique skills, who often reside in different geographical places and who have to use for co-operation means of information and communication technologies (ICT) in order to span the boundaries of time and distance" (Kirkman and Mathieu 2004).

1.3. FACTORS AFFECTING A VIRTUAL PROJECT

The potential for success of a virtual project can be predicted by evaluating the various contributors that affect its performance. While there are an infinite number of factors that can be applied, this dissertation will concentrate on a dozen major contributors in three specific areas:

- Factors internal to the virtual team members
- Factors external to the team
- Common factors present in both co-located and virtual projects

It was found that despite the variety of the factors, one common denominator in those factors was the advantage of FTF interactions. More detailed evaluations of these factors are presented in the literature review (in Section 3) and the survey analysis presented later (Section 4).

1.4. OUTLINE OF THE DISSERTATION

The rest of this dissertation is organized as follows. The next section provides the background for this research. Section 3 discusses the existing literature, while Section 4 provides a background on the survey that was conducted for this dissertation. Section 5 contains an initial analysis that was done on the survey data, while Section 6 presents the main results of this dissertation. Section 7 concludes this dissertation summarizing the main findings and providing some direction for future research.

2 A BACKGROUND ON VIRTUAL TEAMS

This section identifies the critical elements of virtual management that are addressed in this dissertation. Later sections identify how these are affected by face-to-face interaction.

2.1. DETERMINATION OF CRITICAL ELEMENTS AND COSTS

In the initial phase of this dissertation, interviews were conducted with individuals across the targeted engineering groups to determine the crucial elements affecting virtual teams and their performance. Two elements that were found to be particularly significant were (i) inter-personal factors (with both internally and externally groups across the broader organization) and (ii) non-relationship factors affecting efficiency and communication either through technological roadblocks or simply misunderstanding.

The first element encompasses the relationship challenges that a virtual team faces. These relationships can consist of interactions between the remote team and other team members, the parent organization and even entities outside the organization such as vendors and suppliers. The second element addresses additional factors that affect virtual teams. In aggregate, these elements either directly or indirectly impact the communication channels, working relationships and overall efficiency with which the team performs its tasks.

An analysis of these elements, prior to initiation of a project, can aid in providing a projected cost analysis of the viability of having virtual teams. The outcome of that study may be an allocation of certain tasks to the virtual portion team members and certain tasks to the co-located members, or even a determination that the task is complex

enough to warrant the relocation costs of a wholly co-located team. Appendix 3 offers one approach to identifying these costs and a possible justification for the costs associated with improving the efficiencies of virtual work through the evaluation of the various factors studied herein. Personal experience shows that a person conducting typical week long trip typically has a travel expense of $1500 to $2000 including airfare within the continental United States, auto rental, hotel costs and per diem at the government contractor rate.

The rest of this section presents a background on the inner workings of virtual teams and their relationships. This background also helps motivate taking a closer look at a subset of factors that can potentially affect performance of virtual teams.

2.2. VIRTUAL TEAM RELATIONSHIPS

For purposes of this dissertation, virtual work will be defined as multiple nodes of geographically dispersed engineers working on a common development project under the direction of a common lead (Cramton 2001). There are two types of relationships in the virtual organization: those between virtual team members and those between the virtual participants and the parent company.

2.3. INTERNAL TEAM RELATIONSHIPS

Internal virtual team relationships involve same managerial issues as team relationships in traditional co-located teams with the added complexity of delays and "noise" in the communication channels. Since the members of engineering development teams are typically professionals, their working relationships are kept at a certain level of professionalism.

One notable exception is when members do not know the nuances of distance communication, such as responding to emails, not shouting (TYPING IN ALL CAPS), forwarding long email strings containing data that was not meant to be shared, etc.

The relationships formed across the team are typically not as personal as in co-located teams since the shared experiences of working in the same building do not occur. Employee lunches, baseball games, and simply discussions in the hall are replaced by email notifications and, at best, video conferences. However, a team relationship does occur within the group as a different type of shared experience occurs that is more task-oriented and less personal.

2.4. EXTERNAL TEAM RELATIONSHIPS

Virtual work covers a multitude of configurations, including virtual teams, hot-desking (multiple employees using a single desk), and telecommuting from home, working from satellite offices or customers' facilities and even tele-presence where an individual uses a remote robot-like device to physically interact at another site. A graphical representation of types of virtual participants in this theoretical model is shown in Figure 2.1.

Virtual entities are shown as nodes, which can represent a single individual working from home, a subsidiary office, vendors' facilities, an integration site, the customer, and, of course, the main project office. These are sites where the primary mode of communication to other participants is not to Face-to-Face (FTF), and relationships are built via electronic channels (Pauleen and Yoong 2001).

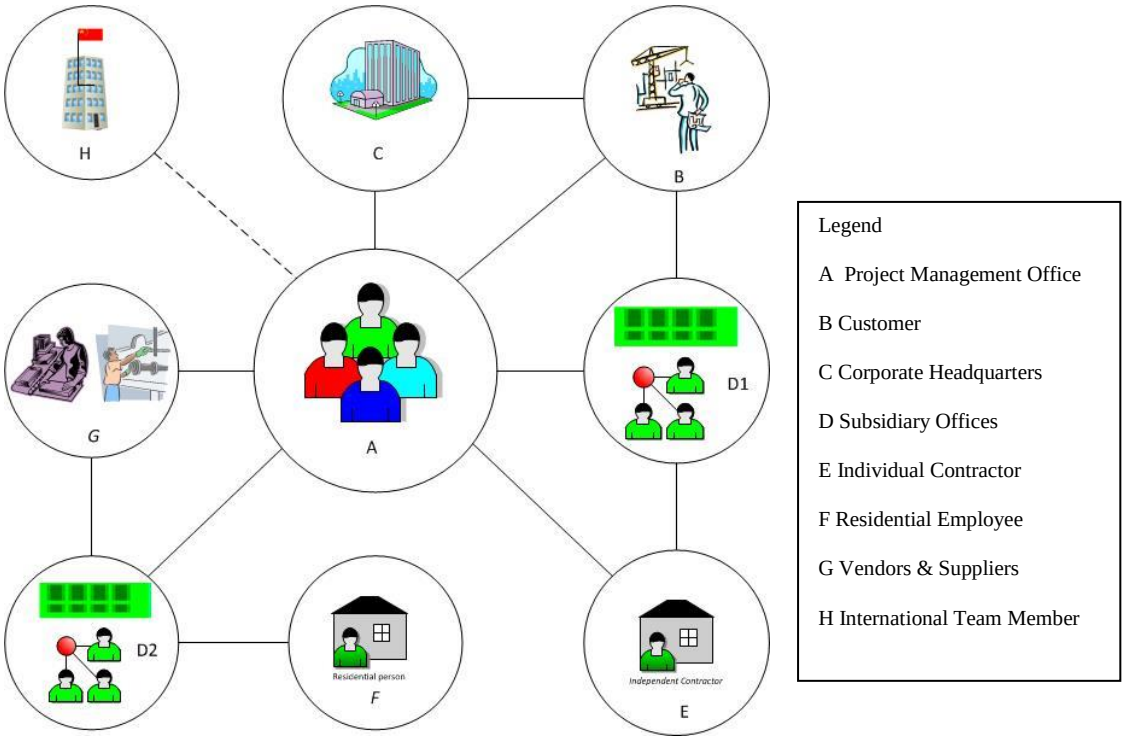

Figure 2.1: Typical Virtual Team Entities and Communication Channels

Connecting links represent virtual communication channels. While there are other virtual interactions going on and less used communication channels exist between ancillary parties such as purchasing and finance, for brevity, only the major engineering related participants and links are shown. A brief description is now presented of each of the nodes in Figure 2.1 and how the virtual communication function takes place between participating nodes.

2.4.1. Node A: Program Management Office (PMO). The Program Management Office represents administrative leadership of the project. Often co-located, the program manager, project engineer, financial leads, business development leads, and corporate officers provide overall direction to the program team (Zhai et al. 2009).

The PMO site often contains the largest group of co-located workers or those with the most project-oriented knowledge. The business development organization who defined the project with the customer, the PMO and the responsible project engineer typically reside at this site. This node acts as the central processing area and provides direction to the other members of the team (Aubry et al. 2012). While subsidiary nodes certainly communicate with each other as members of the virtual team, the PMO must be kept abreast of any decisions that affect the outcome of the project. The primary method of communication today, is email which enables an immediate information transfer while providing a searchable record for both the sender and recipient.

Ideally, any significant communication between subsidiary nodes would be copied to the PMO to avoid confusion and ensure the single point of contact philosophy is maintained. This comes closer to fruition in an organization with a mature virtual philosophy that appreciates the importance of formal communication documentation.

2.4.2. Node B: Customers. Customers typically interact with the PMO during the course of a program except for formal design review meetings. The exception is direct engineering to engineering interfaces.

These often take the form of video conferences, emails and web conferences. Even in those cases, the PE, PM or a PMO representative is involved in the call and leads

the dialog. The face-to-face interaction between engineering and the customer typically is in the form of formal reviews such as the Preliminary Design Review, Critical Design Review, Test Readiness Review and Formal Acceptance Testing.

2.4.3. Node C: Corporate Headquarters. Both small and large companies participate in virtual development, however large companies by their very nature, corporations are forced to perform more distance projects that require virtual work. The survey portion of this paper examines a typical mid-tier defense contractor with responses from five geographically separated subsidiary facilities representing middle to large organizations.

Corporations typically have a headquarters site that has overall responsibility for the profitability of the company and as such a need for communication with the program office. Unless the PMO is co-located with the corporate headquarters, this communication is primarily virtual supplemented by quarterly face-to-face meetings. In matrix organizations, the corporate headquarters may contain the functional lead individuals and develops the standards for the various engineering practices utilized in the development process.

2.4.4. Node D: Subsidiary Offices. Most corporations have several remote groups working on a project. These are referred to as subsidiary offices in this paper. These offices range from a few individuals to sites as large as the PMO office.

Virtual team members at subsidiary nodes are co-located with others at their site, conducting traditional face-to-face communications and deal virtually with other groups.

2.4.5. Nodes E and F: Individual Contributors. Individuals in these groups either work from home or individual offices. These are the most virtual warriors whose face-to-face interactions are extremely limited. They typically have unique skills that are either needed infrequently by the parent organization or they are of such high value that the organization will deal with the inefficiencies of their remoteness.

2.4.6. Node G: Vendors. Vendors such as fabricators or Original Equipment Manufacturers (OEMs) typically work with passive virtual data, i.e. engineering drawings or specifications that do not require a lot of communication. By definition, most discussion that does occur is performed virtually with few face-to-face meetings.

2.4.7. Node H: International Team Members. The last node represents the international aspect of development teams. In the aerospace and defense industries, this aspect of business communication is regulated through a number of export control requirements. Communications between individuals and foreign companies is often choreographed

2.5. FACTORS AFFECTING VIRTUAL TEAMS' PERFORMANCE

Based on interviews with participants and managers at the organizations surveyed, and an extensive literature review, a number of factors affecting virtual teams were identified. They are shown in Figure 2.2. These factors address questions of efficiency, communication effectiveness, motivation and organizational culture. While it may be possible to use objective measurements to define some factors such as the cost of

virtual IT tools, other factors can only be subjectively estimated as efficiencies in performing task virtually compared to using co-located personnel.

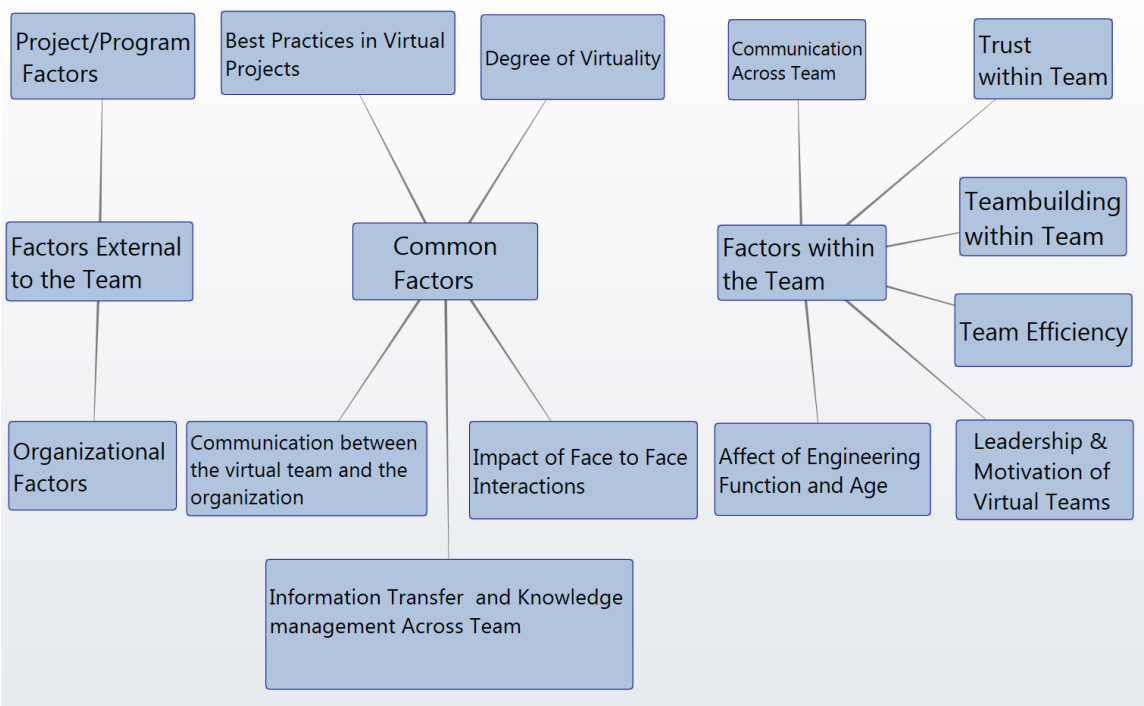

Figure 2.2: Factors Affecting Virtual Teams

3 LITERATURE REVIEW

This section presents a literature review related to a number of factors that affect the efficiency and effectiveness of a team, along with the need for face-to-face interactions. Factors internal and external to the group were researched using literature published with in the last 14 years.

3.1. GOAL OF LITERATURE RESEARCH

The goals of this literature review were to: (i) understand the need for face-to-face interactions in a virtual team, (ii) determine and study related issues, and (iii) identify the gap in the literature to be addressed in this dissertation. A detailed study of these findings played a key role in defining the questions to be included in the survey.

The literature review resulted in a delineation of subject areas into factors that directly affected the efficiency and performance of virtual teams. Obviously many of these items also impact co-located development teams. This overlap is to be expected as virtual teams are essentially co-located teams separated by distance. Areas that seem unique to virtual teams, such as culture and time zones, can be seen in any organization. Examples include the differences in race, background, and whether the team members are “morning” people or “night owls”. Figure 2.2 identified the classification of various contributors to success and failures of virtual teams as found in the literature. This diagram will serve as an outline of the various factors affecting the virtual team specifically in this section but also throughout the entire dissertation.

Broadly speaking, a study of the literature reveals the following. There are two distinct areas that impact the results of virtual teams: those that are primarily "within" the team and those that are "external" to the team. In addition, there is a third area of "common factors," which overlaps these two groups. The research cited in this dissertation shows that activities on both sides of the chart can benefit from face-to-face (FTF) interactions, but at different levels, and for different reasons. FTF meetings improve teamwork and trust and as a result communication and efficiency within the team. Outside the team, it appears that FTF helps with the organization's communication with the distant members and promotes acceptance and support of virtual team activities.

Effectiveness and efficiency of a virtual team can sometimes be simply measured based on the team's output compared to the output of a similar co-located group working on a similar project. However, since no two projects are identical and the quality of the teams also varies, these measurements can be very subjective. Even more subjective is the evaluation of virtual team management.

The rest of this section is devoted to a review of the literature related to how the factors identified above can influence the progress and success of a project and how FTF interactions can moderate those factors.

3.2. INTERNAL FACTORS

Internal factors refer to those areas affecting the team that are internal to the team.

3.2.1. Communication Within the Virtual Team. De Jong et al. (2008) suggest that when adequate communication channels are not developed in a virtual organization, small problems can fester and lead to disintegration of the team and failure of the project.

Communication within the virtual team can depend on the technological mediums used (Pauleen and Yoong 2001), the existence of effective virtual communication protocols, and as with co-located teams the relationships within the team (Montoya et al. 2009). While the first dependency is driven by the organization's technical capabilities and management styles, the last two are developed by the team members themselves who define the communication process within the team and develop the relationships between the team members. Communication processes and the relationships they generate become interdependent when the social aspects of the various virtual communication mediums are considered in the context of social presence and group identity (Andres 2008).

3.2.2. Trust Within the Virtual Team. Trust represents the same key element regardless of whether the team is virtual or co-located team. However virtual teams, due to their lack of constant contact, possibly require trust more than co-located teams. A trusting climate within a team enables the building of commitment and cohesion as well as the development of new ideas and creativity despite differences in opinion or conflict (Henttonen and Blomqvist 2005).

One excellent definition of trust in the virtual setting is "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the

other party will perform a particular action important to the trustee, irrespective of the ability to monitor or control that other party". Developing trust between the organization as a whole and the team as well as between team members has been identified as one of the most challenging aspects of virtual management. Trust must be established and maintained by all parties. The most critical building block of trust is an understanding of the individual being trusted. In a team environment, interpersonal relationships, what each member is focused on, their methods of decision-making and even how they feel about each other are contributors to effective team building (Holton 2001).

Harell and Daim (2009) described trust as a series of gradually expanding circles referred to as the "radius of trust". There is no substitute for spending "time in the trenches," however, periodic FTF interaction, especially in problem solving situations, helps build similar bonds. This is especially effective early on in a project to create a sense of belonging to the group (Ahuja 2010).

Mutual trust among team members is the expectation of the behavior of another party. Trust in the virtual team has been defined as the degree of confidence team members have in one another (Pinjani and Palvia 2013). This trust may be improved through social communication that compliments task communication. This type of social interaction is best nurtured with periodic face-to-face meetings that facilitate social understanding among participants.

3.2.3. Team Building and Relationships. Team building is a combination of effective technical information sharing and social interactions.

Studies have found that there are different rationales for team building based on the timeline of the project being undertaken. In short-term projects, the act of "liking" specific individuals is based on task-related behavior or how they perform the tasks they are assigned. Long-term projects benefit from the exchange of sociability, and favorable relationships are formed based on shared human experiences (Walther and Bunz 2005).

A 2011 review of the literature associated with building and maintaining virtual teams (Brandt et al. 2011) identified the critical challenges due to differences between co-located and virtual teams as trust, cultural differences, communication, social skills, mission, goal clarity and finally rewards and recognition. Just as the relative importance of each of these varies with each article, in the workplace, their relative significance also varies with each project and virtual team.

3.2.4. Team Diversity. Team diversity shows itself in both the social and technical skill sets of the virtual team members. These are reflections of the diversities found in co-located teams, but with additional complications due to distance. Socially diverse members have varied backgrounds and life experiences and may form incorrect assessments of fellow team members.

This is especially true when the members' cultural histories not just different but at some point in the past may have even been in conflict. Statements that are acceptable by one group are often not taken in the same context as intended resulting in emotional disconnects.

These fractures can be quickly healed during the daily FTF meetings common for co-located teams yet grow into fissures for virtual teams with less direct communication (Staples and Zhao 2006). The virtual leader in a culturally diverse team, especially one with global distribution must first be clear about the team's mission and values (Davis 2004). He or she must have the character to appreciate and work across cultures, and he or she must be able to appreciate both the financial aspect of the project and the personal needs of the team.

Technical diversity refers to the normal differences in technical skill sets associated with the different engineering areas that must work together as a cross-functional team. While technical differences are by definition typically associated with objective issues, there are common conflicts between various functional groups that present themselves in both virtual and co-located teams. As with social diversity, unaddressed functional differences can negatively affect a team's chances of success.

3.2.5. Geographical and Cultural Issues. Geographic dispersion affects innovation by increasing the coordination requirements of the team. In highly dispersed teams, certain team members may be inadvertently left out of decision making sine they are not physically present with the large body of the team or co-located with the PMO (Cramton 2001).

While it may be associated with geographical dispersion, cultural isolation is a different problem that includes historical biases as well as differences in time zones and dialect. There are positive aspects of a multi-cultural team, such as increased creativity, innovation and the benefits of multiple points of view, but there are also negative impacts

such as difficulty in communicating, misunderstandings, and increased conflict (Staples and Zhao 2006). It has been proposed that the very electronics disconnects that degrade communication in virtual teams may partially negate the negative aspects associated with cultural differences.

3.3. EXTERNAL FACTORS

External factors, those areas which are outside of the team yet influence the success of a virtual team include project related and organization related issues.

Virtuality provides the organization with access to geographically distributed technical resources or personnel/that may not be available at a single site. Hence a simple working definition of a virtual organization would be any organization with non-co-located entities and resources, necessitating the use of virtual space for interaction between the people in these entities to achieve organizational objectives (Shekhar 2006). Successful implementation of a virtual team environment obviously includes optimizing communication channels. It is important to note that for the organization to simply provide the IT tools is not sufficient. The team members must be coached in their use and develop a rhythm of actually using the tools to solve daily problems.

During a study of British Petroleum by Cohen, an unplanned finding emphasized this fact (Cohen 1999). At one point in the study, a particular project was subject to budget cuts, and the network of geoscientists and engineers was set up without the standard coaching. This group was given the equipment, but essentially left alone to determine how to implement its use. Of the five projects evaluated, this was the only one that failed. “The problem wasn’t that the group couldn’t make the technology work—it

was fairly simple to operate. What they lacked was an understanding of why they should bother." Remarks from the team centered on the perception that the members did not see how the tools fit in with their work and the people they needed to talk to weren't on the network. Since no one was there to help the group explore the value of the system and overcome their skepticism, their virtual network use declined and eventually ceased to exist.

Via a case study of a County Capital Works Program in New South Wales, Australia, Kuruppuarachchi (2009) identified organizational functions needed for success. These functions were categorized into three areas: establishment of support systems for virtual teams, carefully planned launch of virtual projects, and efficient ongoing monitoring and controlling.

3.3.1. Organizational Trust. Virtuality requires trust to make it work: technology on its own is not enough. The efficiency offered by virtual work is based on speed and flexibility. Those attributes require high levels of mutual trust and cooperation (Nandhakumar and Baskerville 2006).

Building organizational trust in the virtual environment is complicated by the fact that the individuals are not operating face-to-face and frequent interaction, shared information and the development of a common organizational culture (Mancini 2010). When the virtual teams are dispersed by large distances or even continents, cultural differences in communication will complicate the level of trust between members.

As companies place utilize more knowledge workers, there is more emphasis on trust between collaborating individuals. This trust is greatly influenced by familiarity of

the individuals, shared experiences and goals, reciprocal disclosure between individuals and a history of non-exploitation over time (Dani et al. 2006). In the organizational setting, developing this trust requires these interactions to occur between the representatives of the parent organization, typically in the PMO and the team members. While this is time consuming in a co-located state, they require more work in the virtual world.

3.3.2. Corporate Culture. Organizational culture is defined as a set of beliefs, values and assumptions that are shared by members of an organization. Taken together, they influence the behavior of members as they are used to guide their decisions and actions (Gregory et al. 2009). Dani et al. (2006) identified four types of organizational culture: "The Clan culture that focus on concern for people and sensitivity to customers, the Adhocracy culture that focuses on entrepreneurialism with a high degree of individuality, the hierarchy culture that focuses internally with a formal environment and the Market culture that focuses externally but is primarily results oriented with highly competitive employees with an emphasis on winning".

While it is possible for the virtual team to operate in any of these cultures, they require different perspectives and virtual relationships. The friendly Clan culture is probably more likely to participate in face-to-face interactions and video conferencing. The Adhocracy culture is used to working outside the box and considers virtual work a necessary and normal activity. Hierarchy culture traditionally seeks stability and is not at all excited about the loss of control associated with virtual work. The Market culture is made up of employees that prefer to operate independently as self-drivers. This group

prefers the freedom and challenge of virtual work, but combining them for a group project will be difficult

The organizational culture also plays a part in the act of knowledge sharing and knowledge management (KM). KM is the act of transferring the knowledge from its developers, experts, subcontractors or particular development teams across the team and to the organization where it can be acted upon (Wiewiora et al. 2013). KM consists of both the technical aspect of setting up data repositories and transfer mechanisms (SharePoint, FTP sites, VPNs) to the development and implementation of processes to create a rhythm of data transfer. The organizational culture impacts the latter of these activities, where human interactions come into play. Culture establishes an organizational context for social interaction and creates norms of what is right and wrong. Therefore it can influence how people communicate and share knowledge.

3.3.3. Past Virtual Experience. Several earlier citations identified the need for relationships forged over time, common experiences, and reciprocal disclosures over time. This is true for both co-located and virtual development teams. It also applies to the organization as a whole. If the organization is to embrace virtual work, it must trust that the output justifies the expenditure. Nothing is better at proving this than documented past experience. For that reason, it is important that each virtual project is concluded with a “lessons learned” session where both successes and failures are recorded.

3.3.4. Corporate Management Buy-in and Trust. Corporate management must buy into the theory of virtual teams and realize that the geographical dispersion of members will result in a lack of direct and immediate control. This is an especially difficult realization for micro-managing personalities.

Control of the virtual team actually lies somewhere between the virtual project's PMO/PE and the distributed team members themselves. Professionals in co-located development teams also share this freedom to some extent; however the ability to spread out work over a 24 hour day gives virtual workers far more flexibility. Corporate management must understand with a transition to the virtual model managing the completion of project milestones is more successful than monitoring daily hours spent on tasks (Cascio 2000). This is challenging in today's DOD industry where "earned value" programs may be dictated by the customer. In point of fact, if done correctly, monitoring task completion can be a more efficient means of project management as the critical metric should be the completion of the design task, not the number of hours spent vs. the original schedule. The optimum control lies somewhere between micro-managing and complete freedom from upper management at the corporate level.

In a study by Drouin et al. (2010) of two high technology Canadian companies, functional processes in virtual teams were found to be heavily dependent on organizational support systems. Figure 3.1 shows a conceptual framework relating the virtual team structural factors and support systems provided by the parent company along with mechanisms used by the organization to monitor and reward the performance of the virtual team.

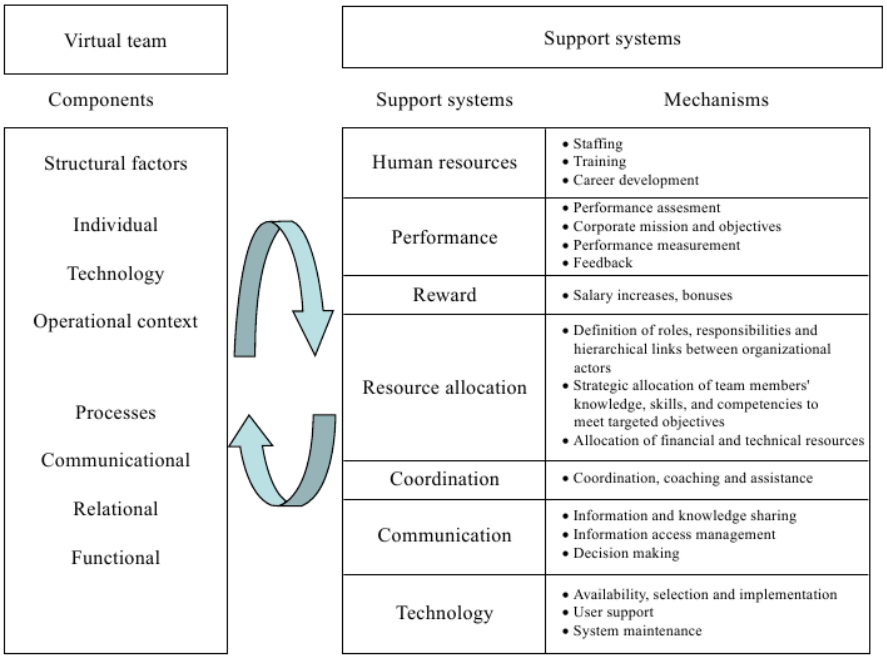

Figure 3.1: A Framework of Virtual Team and Organizational Support Systems (Drouin et al. (2010)

3.3.5. IT Infrastructure Maturity. Another critical factor for virtual success is the maturity of the IT organization within the corporation. Regardless of the level of the sophistication of the technologies used for communication across the virtual team, they must be integrated with the work processes within the teams.

If the IT organization is not sufficiently knowledgeable about the implementation of the virtual communication methodologies the tools themselves will prove inefficient (Malhotra and Majchrzak 2004).

Often neither the teams nor the IT groups are mature in advanced communication tools and knowledge transfer is via email, File Transfer Protocol (FTP) site or similar

non-concurrent methodology. These modes of data transfer eliminate the personal aspect of the interaction which is automatic in co-located teams and increase the potential for errors in communication. The implementation of any tools must be understood by the team members, the IT organization and the company as a whole. Advances in IT communication technologies if integrated correctly can assist the virtual teams to address both current and new challenges (Dubé and Robey 2009)**.** If only partially integrated, or if sufficient training is not provided, they will simply be ignored.

3.3.6. Project and Product-Related Factors. To a large extent the project timeline and nature of the product being developed are outside of the influence of the development team members though they have significant impact on the success of the team. The project schedule and product requirements are usually dictated by the customer in the form of delivery dates and specifications. Once these are negotiated with the customer the PMO must direct the team to understand, develop and distribute the design requirements. These will be the guiding documents that guarantee the team is working toward the same goal. Clear communication across the team is essential. The project schedule will of course vary dependent on the complexity of the product or system being developed, however all projects go through the same phases. These differ between co-located projects and virtual projects.

3.3.7. Product Maturity. It may sound odd to talk of product maturity in a development process, however, few development projects start with a totally "blank piece of paper." Most are modifications of existing designs or at least a

customer's requirement document. Product maturity refers to both the maturity of the product being developed and the completeness of the customer's specification and statement of work (SOW) that defines the requirements for the output. The more mature the product, either physically or in its documentation, the less subjectivity is carried into the task definitions and the more efficiently it can be parsed across a virtual team. When the product or its documentation is not sufficiently defined more interaction is needed across the design team. The potential for miscommunication increases and the efficiency of a virtual task suffers.

3.4. COMMON FACTORS AFFECTING THE ORGANIZATIONAL AND VIRTUAL TEAM SUCCESS

3.4.1. Information Transfer. Information transfer is a critical component of communication, dealing with the transfer of data as well as the added aspects of data generation, storage and sharing across the team members. A multitude of engineering analysis and design tools such as requirement tracking software, Computer Aided Design (CAD), structural and thermal analysis, etc. are used to generate this data. Storage of the data is specifically covered under the shared services category and File Transfer Protocol sites and email records.

SharePoint© sites and simple password protected corporate drives accessible via Virtual Private Networks (VPN) are also popular as common remote access data repositories. Dissecting communication into those areas associated with information transfer results in the following best practices (Malhotra and Majchrzak 2004):

- Establish norms for the data collected
- Identify critical knowledge resources (who knows what) and establish contingencies if those individuals are not available
- Educate members about pitfalls of failing to share situational information, making assumptions instead of investigating
- Establish a knowledge storage site and ensure all members have the same access to information
- Analyze breakdowns in data transfer as a team

3.4.2. Virtual Work Experience. The amount of experience an organization and the virtual team members have is reflected in the quality of the relationships. If the virtual activities are supported by the organization's infrastructure and the team members are trained in the use of the communication tools displayed a higher effectiveness and smoother operation (Drouin et al. 2010). The support and interaction between the distant members and the parent organization is not limited to IT tools, but needs to extend to human relations (HR) and the relational ties across the team. As such, it is important that these auxiliary functions also be familiar with the workings of the virtual organization.

3.4.3. Degree of Virtuality. When virtual teaming was first being implemented and studied in the 1980s and 1990s, the definition of a virtual team was a group with geographically distributed members, telecommunicating to achieve a single goal.

Early organizational research only considered the two extremes of purely virtual or purely co-located based teams (Gibson and Gibbs 2006).

Over the last 20 years, multi-dimensional definitions have been employed. Unfortunately, though the pure binary definition has by now been discarded, few investigators agree on what parameters and measurements should be used to objectively define "Degree of Virtuality". There are a number of ways to look at the degree of virtuality, but perhaps the most basic is simply the ratio of the hours spent doing work virtually vs. the total hours spent on the project, essentially a Virtuality Index (VI) where:

$$V_I = \frac{\text{Total hours spent working virtually by all project participants}}{\text{Total hours spent by all project participants}}$$

Other measurements of virtuality are the ratio of face-to-face and CMT communication, distance between team members, number of working sites and number of members at the distributed sites (Hertel et al. 2005). It is now generally agreed that multiple metrics such as time spent using various IT mediums, corporate culture, trust and familiarity with team members etc. that are unique for each team and situation and should be factored into the equation. Current measurement methodologies used in determining project virtuality run the gamut from basic to extravagant. Griffith et al. (2003) define the degree of virtuality simply as the percentage of work performed remotely as opposed to traditional face-to-face interaction. Using Griffith's interpretation, virtuality is solely a time allocation issue as shown in Figure 3.2, and not directly affected by physical distance.

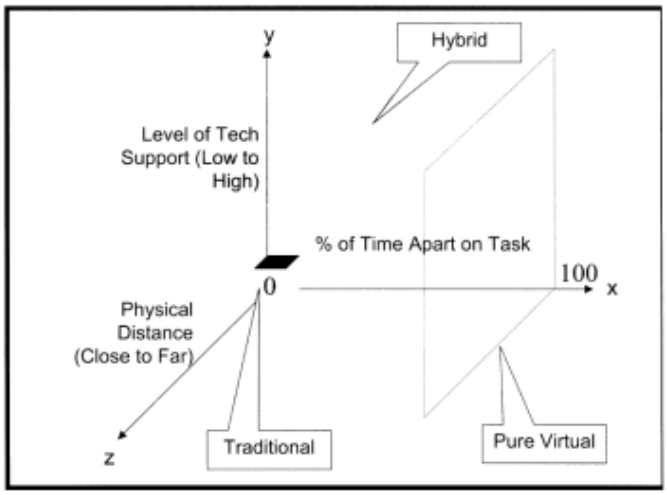

Figure 3.2: Dimensions of Virtuality Griffith et al. (2003)

A more detailed treatment of virtuality that expands on Griffith's work is that defined by Chudoba et al. (2005) as "a summation of discontinuities that challenge the virtual team". These discontinuities include geographic dispersion, time zones, culture, work practices and technologies. Many of these hurtles can be lowered by channeling additional funds to virtual teambuilding, communication and implementation of work processes. One of the most important aspects of this study is that it found that the physical dispersion of the team had less impact than differences associated with work practices, cultural dissimilarities, and employee mobility and lack of a team synergy.

A study by Dixon and Panteli (2010) goes further in the definition of degree of virtuality by arguing that in addition to these discontinuities there are mitigating "virtual continuities" that can be employed to improve the efficiency of virtual work. The criticality of each discontinuity will of course vary for each instance based on the background of the corporation, team, individual and project. While objective

differentiators such as geographic dispersion and time zone problems can be clearly identified, the subjective cultural and work practice differences are harder to quantify.

While the ratio of time spent in virtual vs. face-to-face communication may be straightforward it in itself is not as important as the significance of the information discussed and quality of the knowledge transfer. For instance, a twice a week all-hands video conference may result in the distance audience spending a significant portion of the time "multi-tasking" on unrelated projects. A smaller focused meeting within the design team may be conducted in a fraction of the time and result in more significant progress.

A more important measurement may be an analysis of the effectiveness of virtual work accomplished during each virtual interaction. This could be conducted using a brief on-line questionnaire that polled the participants on such topics as relevance of the meeting, success of the meeting in transferring data, and criticality of the data transferred. These surveys should be collected at the end of the meeting while it is still fresh in the participants' minds (probably through a third party) and published with the meeting minutes and action items.

The prior section dealt with the degree of virtuality of the project; however the term can also be applied to the organization as a whole. Since the end game of any organizational structure is success in the project, it should be noted that while success or failure of a project is not directly attributable to the degree of virtuality, it is often viewed as a catalyst. Ahuja (2010) found that the basic attributes defining project virtuality can be identified as the following.

- It should not be co-located. It should be geographically dispersed.
- There must be members from different organizations.

- There must be a common goal.
- Technology should be used to communicate.

It was also identified that a typical virtual team will have the following characteristics:

- It will be of limited duration.
- It will be inter-dependable and mutually accountable.
- It will consist of limited number of members.
- There should be free entry and exit for team members.
- The team should have knowledge workers.

While physical dispersion is a feature of the virtual team, the same problems can occur in co-located team members who reside near each other, but who never meet (Fiol and O'Connor 2005). Whether purely virtual or traditional co-located, the success of development teams are driven by both internal and external factors that determine their outcome (Leonard-Barton 1992). Since the virtual aspect is an obvious discriminator, it is far easier to point to the unique nature of virtual teams as the reason for any problems. This is especially true for projects with a high degree of virtuality where the "finger pointers" are the non-virtual members of the organization with daily face-to-face access to management.

3.5. IMPACT OF FACE-TO-FACE INTERACTION

In a 2000 study (Maznevski and Chuboda 2000), it was shown that the early stages of the formation of a virtual team, face-to-face interactions are important, especially if complex issues are central to the performance of the team or when high levels of coordination are required between team members. Ineffective teams did not

place this emphasis on early relationship buildings. Although the amount of face-to-face communication used by team members is often considered an important element of virtual team effectiveness, the degree of familiarity that one has with other team members, i.e. both face-to-face time and shared experiences contribute to the relationship and quality of the virtual work performed.

FTF communication is synchronous, which provides for continuous discussions whereas virtual communication is often asynchronous, resulting in disjointed discussions. The former allows for instantaneous feedback and give and take which is often not possible across the electronic medium (Peters and Manz 2007). When combined with the hesitancy to respond with "permanent" records associated with email and electronic communication technology, it is understandable why face-to-face discussions result in better feedback than electronic dialog.

There is general consensus throughout the literature that some level of face-to-face contact is necessary - although opinions differ as to when this should take place. Cascio and Shurygailo (2008) recommend that when a team is set-up, key team members should meet at a kick-off meeting to allow interpersonal relationships to form. It is unclear however, why bonding should only be the reserve of 'key team members'. Lee-Kelley and Sankey (2008) preferred a broader and more inclusive approach since team members reported that for a team to achieve optimum performance it was necessary to operate initially in a face-to-face meeting. Alternately, Kirkman and Mathieu (2004) argue that face-to-face interaction is not mandatory if there is trust between team members. This perspective assumes trust as enduring and static, which is contrary to many studies have found trust to be dynamic, and role and context specific. If the more

accepted dynamic nature of project trust is correct, periodic face-to-face meetings are an effective means of achieving the desired outcome.

The leadership of either a co-located or virtual development team is based on the communication methods employed and the skill and personal qualities of the leader. One leadership trait that has surfaced as significant in a study by Purvanova and Bono (2009) is transformational leadership. Transformational leadership refers to an individual's charisma, inspirational motivation and intellectual stimulation capabilities. Charismatic leaders inspire devotion and loyalty, and stress the importance of a collective mission. Their study showed that leaders that exhibited these qualities obtained higher efficiencies in virtual teams.

Since it is hard to display and project the charisma of an individual across computer mediated communication which lacks the non-verbal cues of in person interaction the question arises: How does a charismatic leader communicate that trait to a distributed virtual development team? One obvious solution, expressed in the introduction of this paper and employed by successful military leaders through history is for the leader to meet with the virtual team on a periodic basis. While this leadership is important, as with a football team, the product depends primarily on the participants, not the coach. Virtual team members need to take responsibility for developing each other. Success by the team requires a positive attitude toward teamwork and a willingness to cooperate (Williams and Castro 2010). This teamwork is common within well-directed co-located teams where personal relationships are common. In the virtual team, these relationships must be formed by face-to-face meetings in the early stages and periodically throughout the project.

An example was given by Kezsbom (2000) “At the start of the development of the 777, Boeing brought members of the design team from dozens of companies to the corporate headquarters for a period of 18 months to learn how to function within the company’s virtual project management system. The shared experiences also developed a level of trust between the team members that later allowed them to overcome the obstacles caused by their separation during the project. Linked by a network of 1700 workstations across a dozen countries, the Boeing team launched the 777 30 to 40 percent faster than comparable co-located paper-based designs.” A significant portion of this improved efficiency in the 777 aircraft development was undoubtably due to the advances in CAD technology over paper design work, however that tool was also instrumental in allowing the digital distribution of the design across the globe. The primary finding of the Boeing study as it pertains to this paper is the decision by Boeing to invest in the added cost of face-to-face meetings and the development of personal relationships throughout the project. The relationships formed by this extended interaction allow the participants to develop contextual knowledge of the other group members (D’Souza and Colarelli 2010).

Knowing the context with which other team members are communicating clarifies the information transfer and lowers misconceptions that can form in geographically distributed teams. Contextual knowledge is intuitively shared by co-located teams via face-to-face discussions, direct meetings and hallway conversations. This ancillary transfer of understanding is difficult in virtual teams. An example is provided by De Pillis and Furumo (2006). “When a team member does not attend a meeting due to a local holiday, other team members can link this to laziness which can cause conflict and

difficulties between the team members." In a co-located setting, there would be a common understanding of local traditions and more frequent communication to avoid this type of misinterpretation.

3.6. CITATIONS RELATIVE TO THE USE OF LIKERT SCALE FORMATTED SURVEY QUESTIONS

While many statistical authors state that since Likert scale responses cannot be proven to be truly of the class called "interval data" and may not follow normal distribution, it is not a candidate for parametric analysis (Bertram 2006; Harwell and Gatti 2001), others state just as strongly that this methodology is valid and that respondents interpret the technically ordinal responses as points on a continuum.

Norman (2010) in his study indicates that a number of researchers have shown using theoretical distributions that the Pearson correlation is robust with respect to skewness and non-normality. According to his publication, these researchers concluded that "the Pearson Correlation Coefficient, *r*, is rather insensitive to extreme violations of the basic assumptions of normality and the type of scale". Considering that cases can be made for and against this, and since a majority of academic surveys utilize this methodology and are evaluated with ANOVA and similar parametric tools, this survey will assume responses to be distributed normally, and suitable for parametric analysis. In a separate verification, Kruskal-Wallis analyses were conducted, which do not require the normality assumption. The P-values from those Kruskal-Wallis calculations and the ANOVAs were found to be very close

3.7. CORRELATION, ANOVA AND REGRESSION

Pearson correlation, ANOVA and regression are some of the most popular statistical methods used for statistical analysis of survey data. All show how a dependent variable is numerically related to an independent variable. For the purposes of this dissertation, Pearson correlation and ANOVA were found to provide useful results. The following discussion provides a comparison of these approaches.

Typical Use of ANOVA (Brantmeier 2004):

- Identifying general relationships between categories or groups
- Comparison of groups means
- Testing of hypotheses

Assumptions:

- Data are score or ordinal scale data that are continuous.
- Data are independent; the comparison is between groups.
- There is a normal distribution of scores within each group.
- There is a minimum of five observations per cell.

Typical Use of Regression (Chatterjee and Simonoff 2013):

- Modeling a numeric relationship between X and Y
- Testing of hypotheses

Assumptions

- The variables entered in the regression formula should not be highly inter-correlated.
- The errors are normally distributed.

Typical Use of Pearson Correlation

- Refers to the interdependence or co-relationship of variables
- Pearson's product moment correlation coefficient is a measure of a linear relationship from $r = 0$, no relationship to $r = 1$ or -1 showing perfect positive and negative linear correlations respectively

Assumptions

- At least one variable follows a normal distribution

3.8. GAP IN THE LITERATURE AND CONTRIBUTIONS OF THIS DISSERTATION

The review indicates that there are numerous factors that can potentially affect the success of a virtual team – FTF meetings being one of them. Literature on virtual teams describes a variety of aspects that affect the success or failure of virtual teams along with the benefits of a purely co-located working environment. However, the benefits of adding personal interaction time (e.g., FTF meetings) to the virtual development process have not been addressed in a comprehensive manner in the existing literature.

This research for the first time seeks to address the role of FTF interaction in active virtual projects by involving a large technical cross-section of engineering professionals currently working in a virtual environment. Results from a survey conducted are analyzed from a variety of viewpoints to uncover the need for FTF interactions for a virtual team. Future analysis of this data, which covered a number of critical dimensions of virtual team management, may also prove to be beneficial for managers directing virtual development teams.

4 SURVEY BACKGROUND

The survey for this dissertation was conducted in the Fall of 2012 canvassing engineers and technical support personnel at DRS Technologies (DRS), a mid-level aerospace-defense corporation. Data was collected from six sites that are geographically separated and work in different areas of the defense industry. These sites included St. Louis, Missouri, Merrimack, New Hampshire, Dayton, Ohio, Buffalo, New York, Gaithersburg, Maryland and Ft. Walton Beach, Florida. Products being developed at these sties included UAVs, military training systems, electronic warfare systems, avionics and communication equipment. The methods used and specifics of this survey are detailed in the balance of this section.

The survey questions were presented to several layers of DRS management in the areas of engineering, human resources and the legal department to ensure compliance with corporate guidelines and to ask some company specific questions. Minimal changes were requested and these were incorporated into the version that went out to the engineers. The survey was sent to 450 individuals consisting of engineering managers, systems, software, electrical and mechanical engineers, designers and technical support staff. At DRS, all members of management have engineering degrees and are experienced engineers in their own right. Approximately 25% of those surveyed responded.

The balance of this section deals with background metrics and information related to the survey conducted. Results of the survey are outlined in later sections.

4.1. SURVEY PARTICIPANTS AND DEMOGRAPHICS

The introduction of the survey required that all participants have virtual team experience. Since DRS is a defense systems company with a broad range of products requiring varying types of expertise, the skill sets of the respondents were similarly extensive. The participants ranged from designers working with vendors to systems and project engineers leading both in-house virtual design teams, to functional engineering managers directing activities across sites in different states. All participants were members of DRS Technologies Engineering department, which encompasses "core" engineering functions such as mechanical, electrical, software and systems engineering as well as project engineers and technical support personnel working in Integrated Logistic Services (ILS) and documentation control.

Questions 1 – 5 of the survey were used to aid in identifying the demographics of the participants. Several observations can be made from this initial group of responses.

The first question dealt with the functional areas of the participants. While there is a higher level of representation of hardware engineers (mechanical and electrical) in comparison to other branches, each of the three core groups was well represented. Project engineers and technical program managers are combined and represented in the fourth group. The final group, program support, consists of technicians, technical writers and development team members who are not necessarily those with formal engineering degrees. These last two groups were also well represented in the cross section. Figure 4.1 shows the functional makeup of the respondents. As mentioned earlier, each of the groups were well represented by the respondents.

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1. What most closely describes your area of engineering expertise that was utilized in the virtual team?

	Response Percent	Response Count
a) Hardware (Mechanical or Electrical)	32.4%	36
b) Systems	19.8%	22
c) Software/Firmware	13.5%	15
d) Project Engineer	14.4%	16
e) Program Support (Integration, Test, Tech. Writing, areas not listed above)	19.8%	22
answered question		111
skipped question		1

Figure 4.1: Engineering Functions

Question 2 and Question 4 shown in Figure 4.2 identify the years of experience and age of the participants. The responses to Question 2 indicate that 75% of the engineers who responded to the survey had more than eight years of experience in their engineering field, which is only to be expected when 86% of the group was born prior to 1980 (as revealed by answers to Question 4). In retrospect, the range should have been expanded to allow dissection of the experience factor. It is readily apparent that the participants in the survey are primarily experienced technical personnel with significant experience in their fields.

2. 2. How many years of experience do you have in your current field?

	Response Percent	Response Count
a) 0 – 2	2.7%	3
b) 2 – 4	3.6%	4
c) 4 – 6	11.8%	13
d) 6 – 8	7.3%	8
e) Over 8	**74.5%**	**82**
	answered question	**110**
	skipped question	**2**

4. Which age group were you born into?

	Response Percent	Response Count
a) Pre-Boomers (Born before 1945)	1.9%	2
b) Boomer generation (Born 1946 -1964)	**60.2%**	**65**
c) Generation X (Born 1965 – 1980)	24.1%	26
d) Generation Y (Born 1980 – 1990)	13.9%	15
e) Born after 1990	0.0%	0
	answered question	**108**
	skipped question	**4**

Figure 4.2: Years of Experience and Age Groups

Question 3 and Question 5 shown in Figure 4.3 deal with the level of expertise of the participants in the virtual environment. Question 3 asks for the number of months participating in a virtual team, and Question 5 inquires about the level of expertise in the tools used in virtual communication.

3. How many total months have you spent participating in virtual development teams?

	Response Percent	Response Count
a) 0 – 6	26.4%	29
b) 6 – 12	12.7%	14
c) 12 – 18	10.0%	11
d) 18 – 24	8.2%	9
e) Over 24	**42.7%**	**47**
	answered question	**110**
	skipped question	**2**

5. What is your level of expertise with the technology used in virtual communication?

	Response Percent	Response Count
a) Very Rudimentary	2.7%	3
b) Minimal	12.7%	14
c) Moderate	**39.1%**	**43**
d) Extensive	36.4%	40
e) Expert	9.1%	10
	answered question	**110**
	skipped question	**2**

Figure 4.3: Months Participating and Expertise in Virtual Tools

Several observations can be made regarding the demographic questions: First, the participants were generally older engineers with over 60% born between 1946 and 1965, making them between 47 and 58 years old at the time of the survey. Many of these

veterans began their engineering careers prior to the widespread computer proliferation of the 1980s and were already experienced engineers during the birth of the Internet and the dawn of virtual communication. Many, including the author, actually utilized slide rules and drafting boards and relied on the US postal service, telephones and the FAX machines as the primary tools of the trade.

The second observation is that the majority of participants considered their expertise in virtual communication as either moderate or extensive. Since these individuals work in a high technology defense organization, it is to be expected that they are all very computer literate and familiar with the tools they each use. However this is not to say that everyone is totally up to date on the latest technology, or even with the latest technology available, only that they are comfortable with the technology they use.

In the literature survey portion of the dissertation, it was noted that many virtual teams utilize lower technology communication methods with which they are familiar rather than more advanced resources that provide better fidelity that are new to them (Berry 2011). Survey Question 23 asked if video conferencing was readily available. Though it was confirmed that every site did in fact possess video conferencing capability, and every computer had Skype video capability, 44% of the participants responded that video conferencing was not available; an additional 36% responded that it was available but not convenient.

Questions 30, 31 and 32 asked if the respondents had previous work experience with the virtual team members, or if they were co-located with the project team leader during the particular virtual project, or if they were co-located with the project team leader prior to the project respectively. The results of these questions dealing with past familiarity are

shown in Figure 4.4. The number of participants that were co-located with the team leader prior to or during the project is approximately evenly split. Responses to Q30 indicate that more than half had no in-person work history with participants of the virtual team.

30. What previous in-person work experience did you have with any participants of the virtual team?

	Response Percent	Response Count
No prior in person work history	**54.5%**	**54**
Formal meetings only	13.1%	13
Informal discussions	16.2%	16
Co-located team members on a similar project(s)	14.1%	14
Personal friend and co-located co-worker	2.0%	2
answered question		**99**
skipped question		**13**

31. Were you co-located with the leader of the team during the project?

	Response Percent	Response Count
Yes	**50.5%**	**50**
No	49.5%	49
answered question		**99**
skipped question		**13**

32. Were you co-located with the leader of the team prior to the project?

	Response Percent	Response Count
Yes	44.4%	44
No	**55.6%**	**55**
answered question		**99**
skipped question		**13**

Figure 4.4: Prior Personal Experience with Virtual Team Members and Team Leader

4.2. RESEARCH HYPOTHESES TO BE TESTED BY THE SURVEY RESPONSES

The four main hypotheses being tested in this dissertation that are specifically related to the effect of incorporating face-to-face (FTF) interactions to virtual development projects are:

H1: FTF interactions are helpful in virtual project work

H2: Virtual team communication is improved by FTF interactions

H3: Virtual working relationships improve with FTF interactions

H4: The potential for project success is improved by FTF interactions

Some additional hypotheses were also tested, and are discussed later.

4.3. FORMAT OF SURVEY QUESTIONS

Virtual work is dependent on the individuals involved, the relationships between virtual team members and the organizations themselves. Questions 1 – 5 represented individual demographic factors. Questions 6 – 24 represent the heart of the survey dealing with topics of project success and communication. Questions 30 – 34 were developed to differentiate between various aspects of employee relationships.

With a few exceptions, the survey was structured using the traditional Likert scale, 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. This was chosen due to its familiarity with the participants of the survey. Some questions required "Yes-No" answers or were structured for the benefit of gathering information for DRS, not for analysis in the dissertation.

4.4. DATA COLLECTION METHODOLOGY

Since there is often a bias of retaliation when a corporate survey is conducted and the responses sent to someone in the corporation, an independent third party survey collection agency was used to conduct the survey. After the initial target engineering personal were identified, email notifications were sent inviting them sign on to their web site and take the test with the understanding that the responses were totally anonymous. Each participant was then given an identification number that allowed paired evaluation of the responses across the audience while maintaining confidentiality.

5 INITIAL ANALYSIS

This section conducts an initial analysis of the survey data in order to determine whether significant relationships exist between the responses to the various survey questions and the groupings that resulted. In particular, the Pearson Correlation Test is used extensively. Further, the analysis performed in this section helped identify interesting hypotheses that were tested in Section 6.

5.1. DATA FILTERING

There are approximately 800 possible unique two-factor relationship combinations of the 39 questions. While some were obviously intended to be factors and others responses, many combinations do not at first blush identify obvious cause and effects. As a first screening, a complete two-factor Pearson linear Correlation analysis was conducted on all the data to determine if any significant correlations exist between any responses that would justify additional analysis. The output is the chart shown in Figure 5.1 which consists of the Pearson's linear correlation coefficient analysis results (*r* values) for all combinations of responses (A higher resolution copy is included in Appendix B). Once this screening was performed, pairs with significant correlation factors were identified for further investigations and combined into groups with similar relationships. The matrix was constructed with questions along both the horizontal and vertical axes and the intersecting cells contain the Pearson Linear correlation coefficient for that pairing. The cells relating to questions dealing with FTF topics are highlighted with a darker gray.

Pearson Correlation Coefficient Chart		Engineering Function	Year of experience	Experience in virtual teams	Age Group	Level of expertise	Level of comfort in Virt. Comms.	Significant issue with VC	Was VC augmented with F2F	Transfer of Tech Rqmts	Miscommunications with Virtual	Benefit from more F2F	Lost time initiating	Outside influences	Meeting Tech specs	Meeting Schedule	Meeting Budget	Working Relationship	Well Defined I/Os	Product Maturity	Concise requirements & specs	F2F as often as needed	F2F meetings were helpful	Criticality of Data passed in F2F mtgs.
	QUESTION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	27a
Engineering Function	1																							
Year of experience	2	0.013																						
Experience in virtual teams	3	0.01	0.254																					
Age Group	4	-0.06	-0.41	-0.1																				
Level of expertise with virtual Tech.	5	-0.09	0.172	0.433	0.201																			
Level of comfort in Virt. Comms.	6	-0.11	0.099	0.019	-0.02	0.025																		
Significant problem	7	0.058	-0.05	0.156	-0	0.151	0.093																	
Was VC augmented with F2F	8	0.077	0.068	0.024	-0.22	-0.01	0.246	0.094																
Transfer of Tech Rqmts	9	-0.09	0.017	0.144	-0.09	0.153	0.363	0.095	0.092															
Miscommunications	10	-0.01	0.125	-0.03	0.032	0.013	-0.27	0.029	-0.16	-0.26														
Benefit from more F2F	11	0.039	0.214	0.042	0.078	0.198	-0.28	0.107	-0.26	-0.15	0.554													
Lost time initiating	12	0.132	0.165	0.174	-0.09	0.059	0.107	0.032	0.153	0.342	-0.1	-0.2												
Outside Influences	13	-0.2	0.028	-0.15	0.138	-0.06	0.049	0.228	0.092	0.129	0.123	0.16	-0.05											
Meeting Tech. Specs.	14	-0.01	0.248	0.429	0.024	0.292	0.168	0.083	0.085	0.401	-0.13	-0.04	0.39	0.003										
Meeting Schedule	15	0.045	0.163	0.145	0.003	0.117	0.274	0.063	0.182	0.241	-0.27	-0.22	0.396	0.051	0.446									
Meeting Budget	16	0.031	0.07	0.141	0.117	0.181	0.374	-0.01	0.167	0.272	-0.23	-0.26	0.438	0.009	0.45	0.804								
Working Relationship	17	-0	0.12	0.042	0.08	-0.01	0.285	0.061	0.341	0.147	-0.14	-0.25	0.323	-0.01	0.351	0.296	0.38							
Well Defined I/Os	18	0.069	0.105	0.125	-0.02	0.095	0.295	0.071	0.274	0.311	-0.13	-0.08	0.392	-0.06	0.466	0.501	0.443	0.38						
Product Maturity	19	-0.03	-0.01	-0.09	-0.05	0.009	0.2	0.137	0.014	0.351	-0.07	0.139	0.006	0.095	0.044	0.166	0.111	0.043	0.24					
Concise requirements & specs	20	-0.01	-0.04	0.044	-0.04	0.05	0.014	0.038	0.151	0.235	0.182	0.14	0.129	0.08	0.073	0.039	-0.01	0.035	0.293	0.363				
F2F meetings as often as needed	21	0.017	-0.02	-0.09	0.067	0.016	0.123	-0.04	0.601	-0.01	-0	-0.23	0.08	0.078	0.102	0.267	0.269	0.247	0.239	0.019	0.136			
F2F mtgs were helpful	22	0.101	0.137	0.215	0.14	0.158	-0.27	-0.06	0.051	-0.04	0.433	0.411	0.167	-0.01	0.21	-0	0.053	0.041	0.125	-0.02	0.144	0.192		

Figure 5.1: Response Correlation Summary Chart

NOTE: A higher resolution copy is included in Appendix B

5.2. SIGNIFICANT CORRELATION COEFFICIENT VALUES

Relative to the filtering criteria, published data from Weathington et al. (2012) shows that for $\alpha = 0.01$ and a degree of freedom greater than 90, the significant value of *r* is > 0.27 so that value was used as the indicator of significant correlation. Other authors identify a wider range of values corresponding to greater significance. Since the Pearson test is a linear correlation test, other pairings with non-linear correlations may also be missed. It was found that the majority of the responses showed correlation coefficients of less than 0.27. These were set aside. As expected, these pairing also had associated p values significantly greater than 0.05. Approximately 110 responses showed a medium correlation (*r* coefficients ranging from 0.27 to 0.50) and 21 pairs had high Pearson correlation coefficients with $r > 0.50$.

5.3. GROUPING OF HIGH CORRELATION COEFFICIENT RESPONSES

The question pairs with response coefficients indicating moderate to high correlation were grouped into three categories of relevance to this study

Group 1: Distinct Face-to-face (FTF) interaction relevance responses

Group 2: Working relationships related responses

Group 3: Communications related responses

5.3.1. Group 1: Responses Dealing with Distinct FTF Interactions. The responses identified in Table 5.1 show those relationships which are directly attributable to questions with FTF topics, whose Pearson Correlation Coefficients were found to be either strong (>0.5), moderately-strong (0.4 – 0.5) or moderate (0.3- 0.4).

Table 5.1: Grouping of Responses Directly Concerning FTF Interaction

Response Pair		Correlation Coeff (*r*)	Survey Question Topics
10	11	0.55	There were more miscommunications with Virtual Communications within the Virtual Team would have benefited from more FTF meetings
10	22	0.43	There were more miscommunications with Virtual FTF meetings were helpful
11	22	0.41	Communications within the Virtual Team would have benefited from more face-to-face meetings FTF meetings were helpful
11	27a	0.383	Communications within the Virtual Team would have benefited from more face-to-face meetings Criticality of information passed via FTF
22	27a	0.383	FTF meetings were helpful Criticality of information passed via FTF
22	28a	0.383	FTF meetings were helpful Success of data transfer via FTF
8	17	0.34	Virtual communication was augmented with FTF as needed The virtual portion of the project was successful in developing a working relationship with distant team
28a	29e	0.34	Success of data transfer via FTF Success in Transfer of Tech Knowledge
8	29e	0.31	Virtual communication augmented with FTF as needed Success in Transfer of Tech Knowledge
10	27a	0.31	There were more miscommunications with Virtual Criticality of data in FTF

There is a general correlation that relates increased FTF interaction and success of the various aspects of the project, as well as development of good working relationships, which agrees with the published literature (Andres 2002; Begley 2004).

5.3.2. Group 2: Responses Dealing with Virtual Relationships. There are multiple strong correlations between the success in forming working relationships and the success of the virtual projects as a whole. Table 5.2 shows pairs of responses that indicate the significance of forming relationships in virtual teams.

Table 5.2: Grouping of Responses Showing the Importance of Relationships

Response Pair		Correlation Coeff (*r*)	Survey Question Topics
29d	14	0.41	Success in forming working relationships The virtual portion of the project was successful in meeting the technical specifications imposed by the customer
29d	15	0.31	Success in forming working relationships The virtual portion of the project was successful in meeting the project schedule
29d	16	0.33	Success in forming working relationships The virtual portion of the project was successful meeting the project budget
29d	18	0.31	Success in forming working relationships The inputs, outputs and gates of the virtual tasks were well defined
29d	29e	0.71	Success in forming working relationships Success in transfer of technical knowledge and skills

It is well-known that success is dependent on team work. As personal interaction promotes the relationships that facilitate teamwork, FTF interaction plays a key role in virtual project success by fostering these relationships. As shown in this study, success in the meeting the project's budget, schedule and customer technical requirements correlate to the development of good relationships.

5.3.3. Group 3: Responses Dealing with Communication. Communication is also critical to any developmental project. It plays a larger role and is even more difficult to achieve in virtual projects. Several survey responses showed significant correlation to each other as shown in Table 5.3.

Table 5.3 Grouping of Responses Dealing with Communication

Response Pair		Correlation Coeff (*r*)	Survey Question Topics
10	11	0.554	There were more miscommunications with Virtual Communications within the Virtual Team would have benefited from more face-to-face meetings
6	9	0.363	What is your level of comfort with virtual communications compared to face-to-face communication? The transfer of technical requirements across the virtual team was better than in collocated teams
8	17	0.341	Virtual communication was augmented with face-to-face meetings as frequently as needed The virtual portion of the project was successful in developing a working relationship with distant team members.
8	29e	0.312	Virtual communication was augmented with face-to-face meetings as frequently as needed How successful was the Transfer of technical knowledge and skills in the virtual portion of the project

The majority of individuals who responded that there was more miscommunication in virtual projects also stated that communication would have benefitted from more FTF meetings. In those instances where FTF meetings were conducted as frequently as needed, the transfer of technical knowledge and the development of working relationships were ranked as successful. This finding agrees with the published data (Begley (2004); Pauleen and Yoong (2001)) that indicates that factors such as trust and relationship-building supported improve communication. There

are two primary reasons for this. First, when team members have developed a strong relationship, either through past co-located work or in-person activities, the terminology used in their communications is understood by both parties. Second, when there is some disconnect, the parties are more likely to realize a problem exists and reformat their statements until a mutual understanding is reached. Much of the credit for this is tied directly to their shared experiences, particularly shared in-person experiences.

The literature points to two areas that represent these aspects of virtual teamwork and identifies them as Transactive Memory and Collective Efficacy (Griffith and Neale (2001); Cordey and Soo (2008)). Both refer to a mutual understanding and shared knowledge base among team members. When these ancillary communication tools are not available and the team members are solely transferring data via a SharePoint or FTP site, there is little chance to rectify miscommunications on a personal level.

5.4. VIRTUAL COMMUNICATION RELATED QUESTIONS

In this section, responses to three questions related to virtual communication are presented. While detailed statistical analysis was not performed for these responses, nonetheless, one can make some interesting observations from the responses.

5.4.1. Q6: Level of Comfort with Virtual Communication.

Figure 5.2 displays a histogram of the responses relative to the participants' level of comfort with FTF versus virtual communication, showing the strong preference for FTF communication.

No respondents strongly preferred virtual communications over FTF communications.

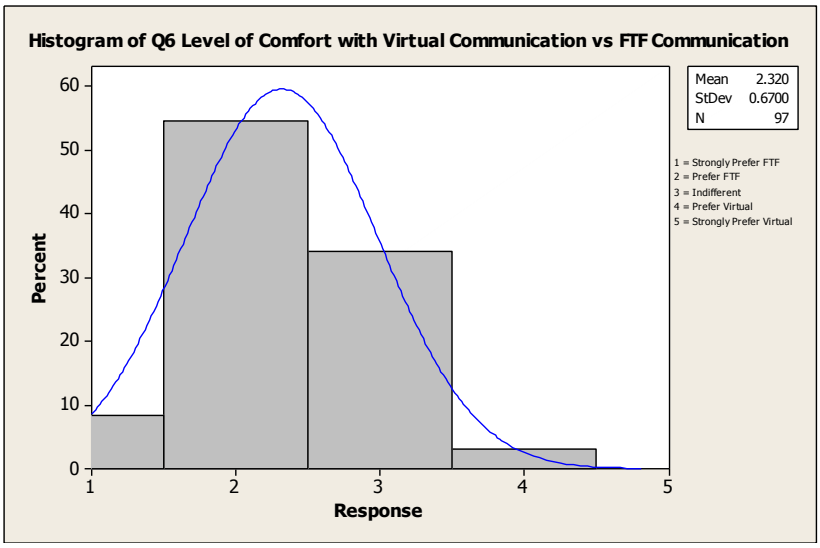


Figure 5.2: Histogram of Level of Comfort with Virtual Vs FTF Communications

5.4.2. Q7: Most Significant Problem Being on a Virtual Team. Figure 5.3 shows the most significant problems associated with being on a virtual team, with communication problems taking the top two categories.

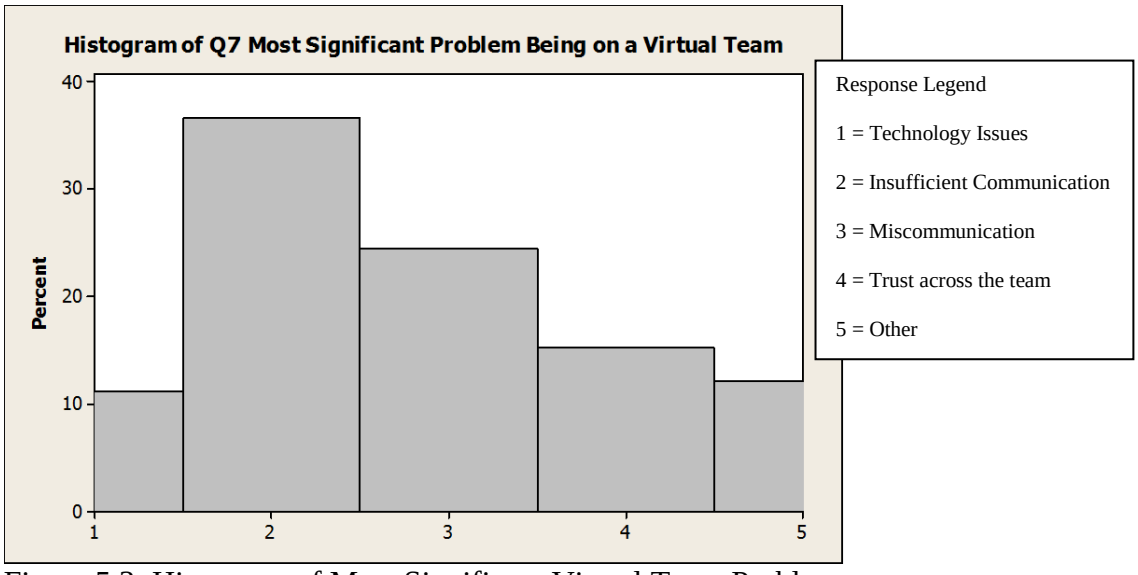


Figure 5.3: Histogram of Most Significant Virtual Team Problems

5.4.3. Q24: Did You Communicate with Virtual Team Members as Often as Co-located Team Members?

Figure 5.4 shows a histogram for the responses related to whether the participant communicated with the virtual team members as often as the collocated team members. The response is as expected, with almost 70 percent indicating they communicated more with co-located members. This is due to both the increased opportunity to meet with those individuals and possibly the better working relationships formed among co-located personnel.

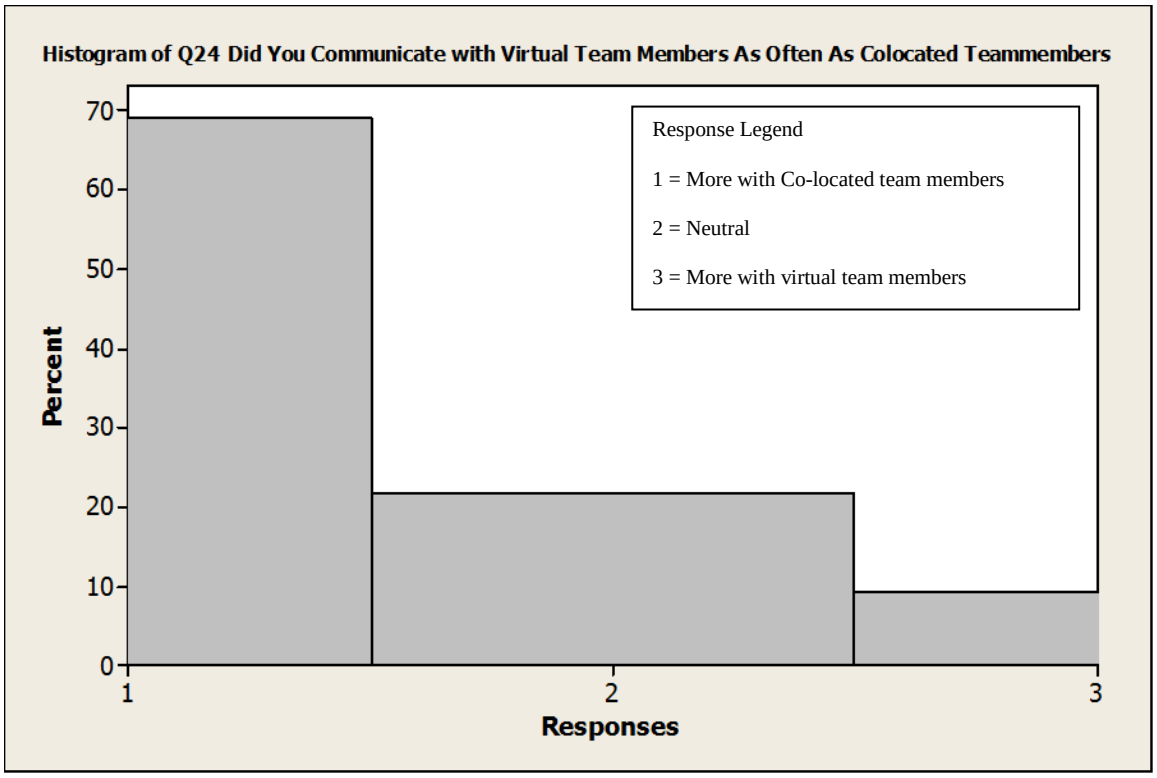


Figure 5.4: Histogram of Virtual vs Co-located Communication

6 VALIDATION OF HYPOTHESES

This section will describe the various statistical analysis methods used to test the validity of the hypotheses and the relationships between the responses. Each hypothesis will be examined by presenting the raw survey data in graphic format, and statistical analysis. The analyses will include simple binominal analysis (see, e.g. Johnson and Bhattacharyya (1985)) comparing the statistical significance of the proportions of the positive and negative responses as well as One-Way ANOVAs.

The binomial tests verify the statistical significance of the responses using the normal approximation for the confidence intervals. The data was condensed to the binomial form of "Positive" and "Negative" responses. The "Agree" and "Strongly Agree" responses were grouped into Positive Responses. The "Strongly Disagree," "Disagree" and "Neutral" responses were grouped into Negative Responses. This test determines proportions for the positive and negative responses and a margin of error which is then used to identify significant upper and lower limits for the *positive* responses; the confidence interval is defined in Equation 6.1:

$$\left(p + Z_{\alpha/2}\sqrt{\frac{p\,q}{n}} \quad , \quad p - Z_{\alpha/2}\sqrt{\frac{p\,q}{n}}\right) \qquad \text{Eq. 6.1}$$

where:

n = the total number of responses

p = (the number of positive responses/n)

$Z_{\alpha/2}$ = the Z-value for a 95% confidence; α = 5% i.e., $\alpha/2$ =0 .025 and hence $Z_{\alpha/2}$ = 1.96

$\sqrt{pq}$ = the standard deviation of the Binomial distribution

q = 1 – p

These values and limits are used to create confidence intervals. If the confidence intervals do not overlap, the responses are considered significant at the 95 percent confidence level.

6.1. H1: FACE-TO-FACE (FTF) INTERACTIONS ARE HELPFUL IN THE VIRTUAL ENVIRONMENT

Obviously the first question related to the value of face-to-face (FTF) interactions is whether the respondents thought they were helpful. Question 22 was inserted to evaluate this facet of virtual work and determine if there was even a need for FTF meetings in virtual projects in this day of video conferencing, instant messaging, email and webinars.

Since the participants in the survey were highly educated engineers working in advanced technology development, it was not a forgone conclusion that there would be support for in-person meetings. However, as shown in Figure 6.1, 84% of those surveyed either agreed or strongly agreed with the statement that FTF meetings were helpful. 12% were neutral, and 4% either disagreed or strongly disagreed with the statement.

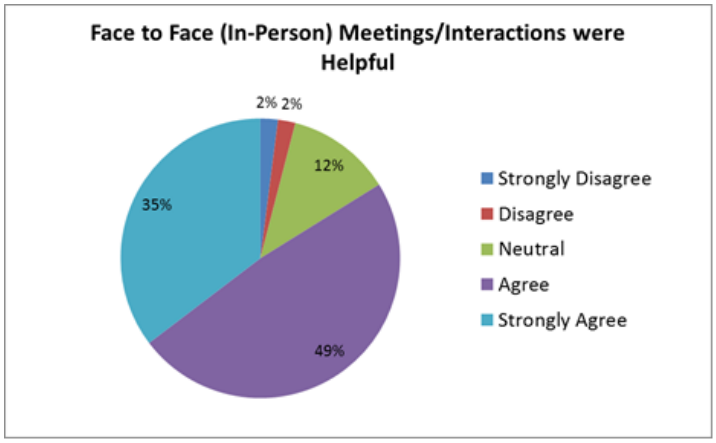


Figure 6.1: Pie Chart Showing FTF Meetings were Helpful

Assigning linear values from 1 (Strongly Disagree) to 5 (Strongly Agree), a value of 3 (Neutral) would be expected as the mean for the totality of responses if there was no preference. As the histogram in Figure 6.2 shows, the mean for the responses is 4.16 showing a distinctive preference for more face-to-face interaction.

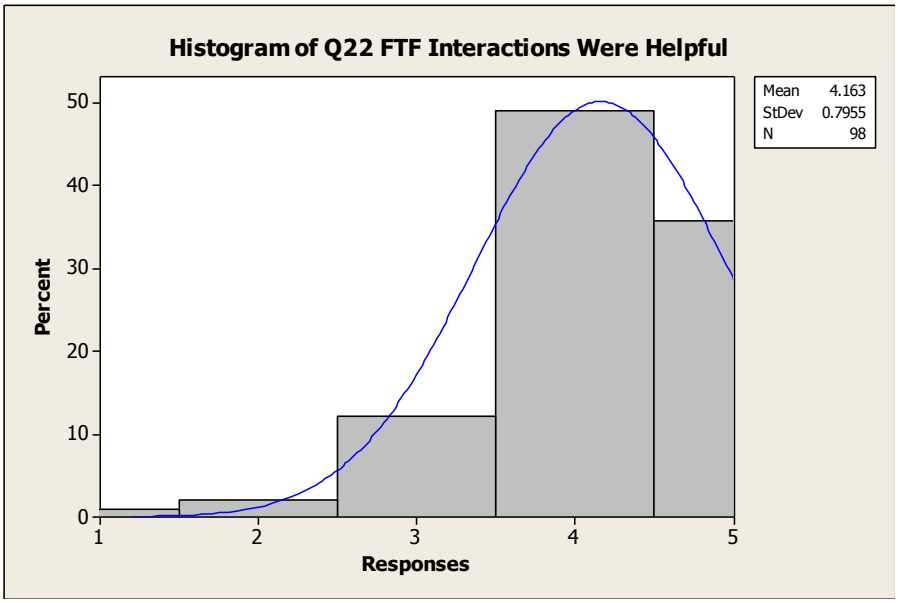


Figure 6.2: Histogram of Q22, FTF Interactions Were Helpful

When the binomial test was applied to the responses from Q22, it was confirmed that the data was statistically significant as shown in Table 6.1. Based on these responses, it can be asserted that the individuals felt that FTF interactions were helpful.

Table 6.1: Binomial Analysis of Question 22

	Strongly Dissagree	Dissagree	Neutral	Group 1 Negative Responses		Agree	Strongly Agree	Group 2 Positive Responses			Group 1 Negative Responses			Group 2 Positive Responses		
Question	SD	D	N	SD+D+N		A	SA	A+SA	Total	Margin of Error	Lower Limit	Negative Response Percentage of total	Upper Limit	Lower Limit	Positive Response Percentage of total	Upper Limit
22	1	2	3	6		45	35	80	86	5.38	1.59	6.98	12.36	87.64	93.02	98.41

6.2. H2: VIRTUAL COMMUNICATION IS BENEFITTED FROM FTF INTERACTIONS

Question 11 asked if communications within the virtual team would have benefitted from more FTF interaction. This is a bit more specific than Question 22 in that it deals specifically with communication and not the overall success of the project. The results from this question are shown in Figure 6.3. 75% of the respondents either agreed or strongly agreed with that statement. 14% were neutral and 11% either disagreed or strongly disagreed. As shown in the histogram of Figure 6.4, the mean of the responses was 3.755.

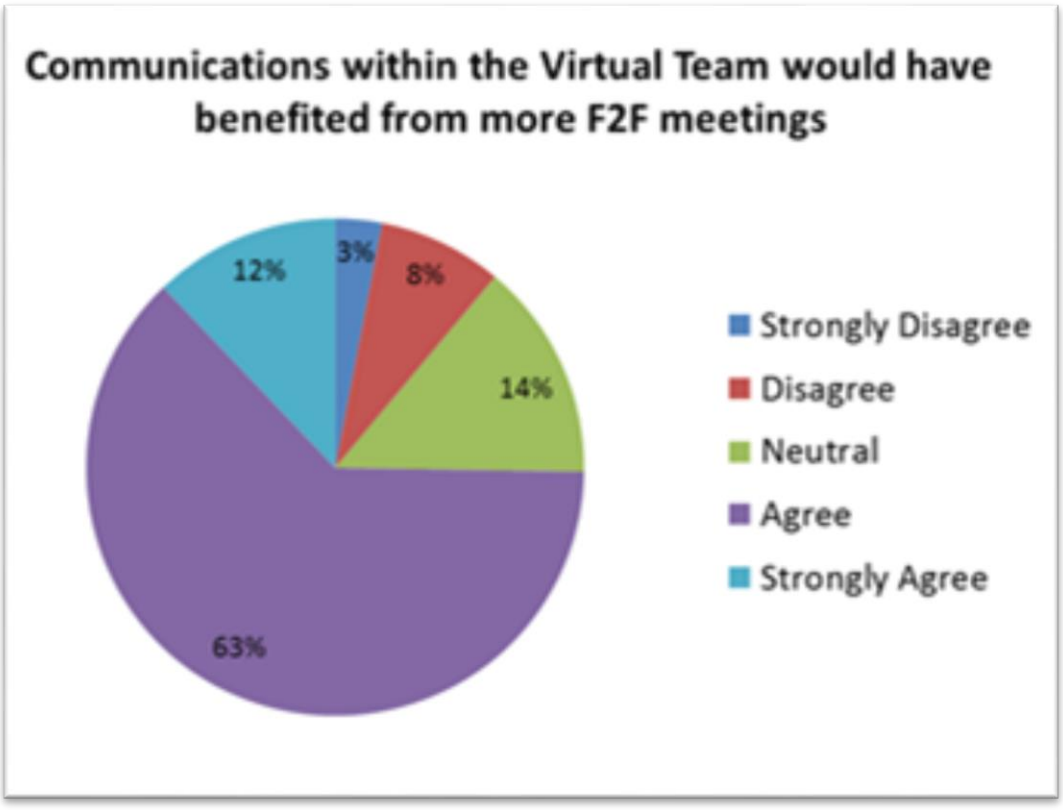


Figure 6.3: Communications within the Virtual Team would have benefitted from more FTF Meetings

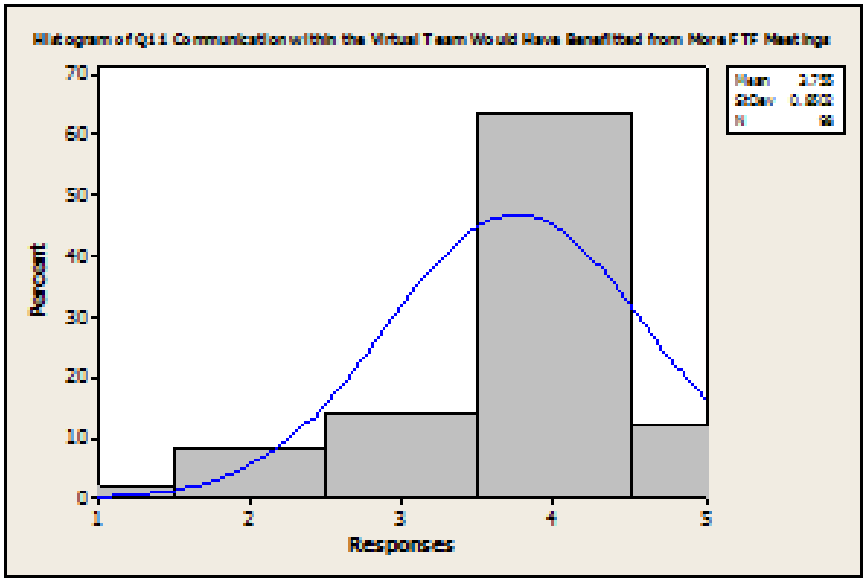


Figure 6.4: Histogram Showing Benefit of Additional FTF Meetings

Based on these responses it can be asserted that the individuals that felt that there were communication issues with virtual communication thought more FTF time would have proved helpful and benefitted the project. A binomial analysis was performed on the data to verify the statistical significance of the responses using the large sample confidence interval equation 6.1 confirming that that the data was statistically significant as shown in Table 6.2.

Table 6.2: Confidence Interval for Q11, Would the Virtual Portion of the Project have benefitted from more FTF Interactions.

	Strongly Dissagree	Dissagree	Neutral	Group 1 Negative Responses		Agree	Strongly Agree	Group 2 Positive Responses				Group 1 Negative Responses			Group 2 Positive Responses		
Question	SD	D	N	SD+D+N		A	SA	A+SA	Total	Margin of Error		Lower Limit	Negative Response Percentage of total	Upper Limit	Lower Limit	Positive Response Percentage of total	Upper Limit
11	2	9	11	22		59	12	71	93	8.64		15.02	23.66	32.29	67.71	76.34	84.98

Insufficient Communication and Miscommunication are the Most Significant Problems in virtual work and Question 7 asked: "What was the most significant problem you've experienced with being in a virtual team". As shown in Figure 6.5, two related responses: "Insufficient communication between virtual team members" and "Miscommunication between team members" did account for 60.6% of the responses. Infrastructure technology issues, issues of trust and "other" together only account for 39.4%.

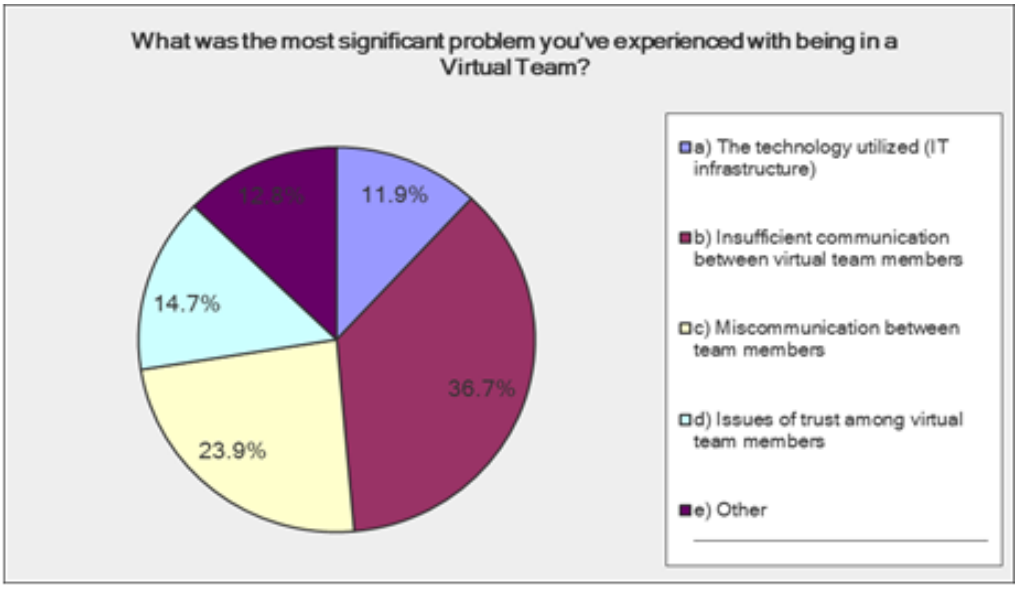


Figure 6.5: Pie Chart of Significant Communication Problems

6.3. H3: VIRTUAL WORKING RELATIONSHIPS ARE IMPROVED WITH PAST FTF INTERACTION

This hypothesis is verified by comparing the answers to questions 33 and 34.

Q33: Rate the working relationship between yourself and the virtual team members with whom you had previous in-person work experience.

Q34: Rate the working relationship between yourself and the virtual team members with whom you did not have previous in-person work experience.

Figures 6.6 and 6.7 show the difference in success in developing working relationships on a project when the participants had previous co-located or FTF experience.

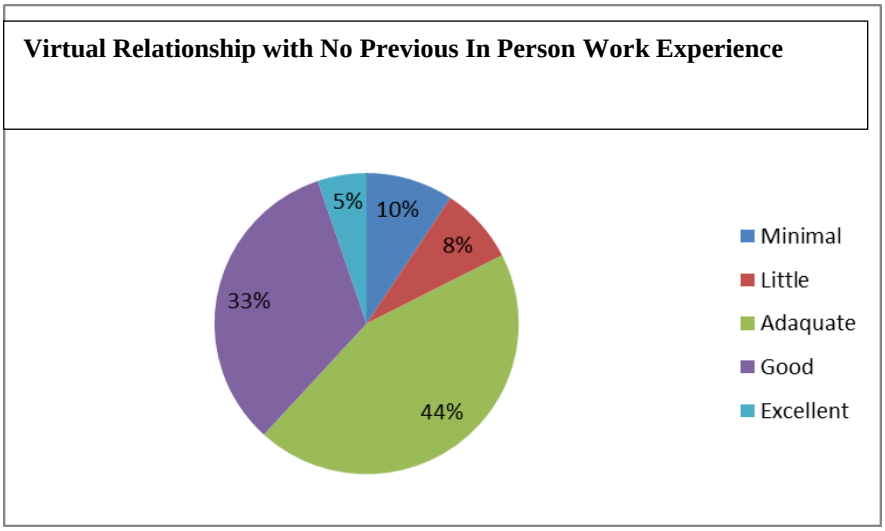


Figure 6.6: Quality of Virtual Relationships with No Previous FTF Experience

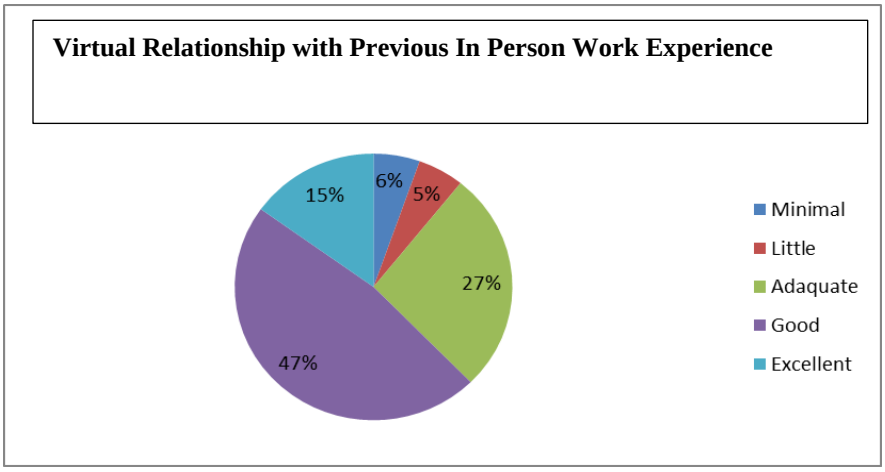


Figure 6.7: Quality of Virtual Relationships with Previous FTF Experience

There was a difference in mean from 3.165 to 3.612, a 14% improvement in the development of working Virtual Working Relationships (VWR) for individuals with prior FTF work experience than for individuals that did not have previous FTF work experience. The percentage of participants, who rated their VWR as Excellent, rose from 5% to 15%. Those who rated their VWR as good rose from 33% to 47%. Those with negative responses, i.e. minimal or little relationships also showed an improvement from 18% for those without prior FTF to 11% for those that had previous FTF work experience. The Pearson Correlation Coefficient between these two questions is 0.428 indicating a strong correlation.

The ANOVA shown in Table 6.3 was conducted between the five responses in Question 33 and the five responses of Question 34 showing an extremely low *p* value. This was then checked with a Tukey's method family error rate plot, confirming the finding is statistically significant. The complete calculations are included in Appendix B.

Table 6.3: One-Way ANOVA Factor (Q34) vs. Response (Q33)

Source	DF	SS	MS	F	P
Factor Q34	5	35.59	7.12	5.36	0.000
Error	92	122.26	1.33		
Total	97	157.85			

Based on these responses it can be asserted that virtual working relationships are more successfully formed among participants having had prior in-person work experience. Optimally, the prior experience would have been for an extended period, however as noted in the literature (Fiol and O'Connor et al. 2005), any amount of FTF interaction improves the relationship.

6.4. H4: THE POTENTIAL FOR PROJECT SUCCESS IS IMPROVED WITH FTF INTERACTIONS

One definition of project success is the ability of the team to meet customers' technical specifications (Q14) and developing a working relationship with distant team members (Q17), within the schedule (Q15) and budget (Q16) as dictated by the PMO – along with the efficient transfer of technological knowledge (Q29e). As shown in the correlation chart of Figure 5.1, the one factor that shows a significant correlation to all of these factors is Q29d, i.e., "Success in forming virtual working relationships," which shows the criticality of working relationships.

An ANOVA was run using answers to Q17 as the factor versus the answers to Q29d ("developing working relationships") as the response variable. The resulting ANOVA output is shown in Table 6.4. The results show that the factor is significant.

Table 6.4 One-Way ANOVA Factor (Q17) and Response (Q29d)

Source	DF	SS	MS	F	P
17	4	23.417	5.854	7.11	0.000
Error	90	74.120	0.824		
Total	94	97.537			

S = 0.9075 R-Sq = 24.01% R-Sq(adj) = 20.63%

6.5. ADDITIONAL HYPOTHESES

The following data represents secondary findings gleaned from the specific questions of the survey responses that may be of interest to the researcher, but are not included as the primary focus of this dissertation. As such, the data is presented with minimal analysis.

6.5.1. H5: Virtual Communication was Augmented with Face-To-Face Meetings as Frequently as Needed.

As shown in Table 6.5, there is a separation between the negative response confidence interval of 56.81 to 75.82 and the positive response confidence interval of 24.18 to 43.19, showing a statistically significant negative response to the question at the 95% confidence level. This indicates that the majority of participants (66.32%) favored additional Face-to-face interactions.

Table 6.5: Binomial Test of Q8, Virtual Communication was Augmented with Face-To-Face Meetings as Frequently as Needed

SURVEY RESPONSES								BINOMIAL ANALYSIS							
	Strongly Dissagree	Dissagree	Neutral	Group 1 Negative	Agree	Strongly Agree	Group 2 Positive Responses			Group 1 Negative Responses			Group 2 Positive Responses		
Question	SD	D	N	SD+D +N	A	SA	A+SA	Total	Margin of Error	Lower Limit	Negative Response Percentage of total	Upper Limit	Lower Limit	Positive Response Percentage of total	Upper Limit
8	6	34	23	63	28	4	32	95	9.50	56.81	66.32	75.82	24.18	33.68	43.19

6.5.2. H6: The Transfer of Technical Requirements Across Virtual Teams Vs Collocated Teams.

Question 9 dealt with the transfer of technical requirements across the virtual team as opposed to the co-located team members. Unlike technical knowledge, this question deals with the specific transfer of the customer's specifications and project requirements. There is a distinct negative response with over 67% of the respondents disagreeing or strongly disagreeing with this statement indicating that this information transfer was not conducted as well across the virtual team members. When combined with the neutral responses, which are grouped into the negative column, the non-positive responses are over 90%. This indicates a strong belief that co-located teams are better at distributing the technical requirements of a project. The binomial test in Table 6.6 shows that this is statistically significant finding at the 95% confidence level as the positive and negative confidence intervals do not overlap.

Table 6.6: Binomial Test of Q9, The Transfer of Technical Requirements across the Virtual Team Was Better Than in Co-located Teams

SURVEY RESPONSES									BINOMIAL ANALYSIS							
											Group 1 Negative Responses			Group 2 Positive Responses		
Question	Strongly Dissagree SD	Dissagree D	Neutral N	Group 1 Negative SD+D +N	Agree A	Strongly Agree SA	Group 2 Positive Responses A+SA		Total	Margin of Error	Lower Limit	Negative Response Percentage of total	Upper Limit	Lower Limit	Positive Response Percentage of total	Upper Limit
9	17	48	22	87	7	2	9		96	5.83	84.79	90.63	96.46	3.54	9.38	15.21

6.5.3. H7: Virtual Communication Resulted in More Miscommunications than in Co-located Teams.

The issue of miscommunication across virtual teams as opposed to co-located teams was addressed in Question 10. The responses are shown in the Table 6.7. This data shows a positive response with 66.7% of the participants either agreeing or strongly agreeing with the statement. As the positive and negative confidence intervals do not overlap, the difference is statistically significant at the 95% level.

Table 6.7: Binomial Test of Q10, Virtual communication resulted in more miscommunications than in co-located teams

SURVEY RESPONSES								BINOMIAL ANALYSIS							
	Strongly Dissagree	Dissagree	Neutral	Group 1 Negative	Agree	Strongly Agree	Group 2 Positive Responses			Group 1 Negative Responses			Group 2 Positive Responses		
Question	SD	D	N	SD+D+N	A	SA	A+SA	Total	Margin of Error	Lower Limit	Negative Response Percentage of total	Upper Limit	Lower Limit	Positive Response Percentage of total	Upper Limit
10	3	11	18	32	57	7	64	96	9.43	23.90	33.33	42.76	57.24	66.67	76.10

6.5.4. H8: Communications within the Virtual Team Would Have Benefited from More FTF Meetings.

Perhaps the most important question of the survey is Question 11, asking if the team would have benefitted from additional FTF interaction. The responses are shown in Table 6.8, with over 73% believing that additional in person interaction would have benefitted the team. The negative responses, i.e., those answering they strongly disagree, disagree or are neutral represented only 25% of the respondents. Since the confidence intervals do not overlap, this finding is statistically significant at a 95% confidence level.

Table 6.8: Binomial Test of Q11, Communications within the Virtual Team would have benefited from more face to face meetings

SURVEY RESPONSES									BINOMIAL ANALYSIS							
	Strongly Dissagree	Dissagree	Neutral	Group 1 Negative	Agree	Strongly Agree	Group 2 Positive Responses				Group 1 Negative Responses			Group 2 Positive Responses		
Question	SD	D	N	SD+D +N	A	SA	A+SA	Total	Margin of Error	Lower Limit	Negative Response Percentage of total	Upper Limit	Lower Limit	Positive Response Percentage of total	Upper Limit
11	2	9	14	25	59	12	71	96	8.78	17.26	26.04	34.82	65.18	73.96	82.74

6.5.5. H9: The Communications Methods Used in Virtual Team Meetings were Initiated with Minimal Lost Time.

This question is not associated with FTF interaction; however, it was included at the request of DRS management to determine if there was a significant amount of lost time associated with the initiation of virtual meetings, web-conferences, etc. Table 6.9 shows the result of this question in a binomial test at a 95% confidence level. Over 64% of the respondents replied with a negative (or neutral) response indicating that there was a greater than a "minimal" amount of lost time.

Table 6.9: Binomial Test of Q12, Virtual Communication was Initiated with Minimal Lost time

SURVEY RESPONSES									BINOMIAL ANALYSIS							
	Strongly Dissagree	Dissagree	Neutral	Group 1 Negative	Agree	Strongly Agree	Group 2 Positive Responses				Group 1 Negative Responses			Group 2 Positive Responses		
Question	SD	D	N	SD+D +N	A	SA	A+SA	Total	Margin of Error	Lower Limit	Negative Response Percentage of total	Upper Limit	Lower Limit	Positive Response Percentage of total	Upper Limit
12	5	26	28	59	30	3	33	92	9.80	54.33	64.13	73.93	26.07	35.87	45.67

6.5.6. H10: The Level of Success on the Project was Primarily Driven by Outside Influences.

This question was inserted to determine if the success of the project was unduly influenced by individuals, functions or activities outside the virtual group. Typical examples would be finance driven decisions, export limitations, conflicts with other departments, etc. Though a majority of the respondents answered in the negative, since the positive and negative confidence intervals overlap, it is not possible to stastically answer this question at a 95% confidence level. The binomial test results are shown in Table 6.10.

Table 6.10: Binomial Test of Q13, The Level of Success on the Project was Primarily Driven by Outside Influences

SURVEY RESPONSES								BINOMIAL ANALYSIS							
	Strongly Dissagree	Dissagree	Neutral	Group 1 Negative	Agree	Strongly Agree	Group 2 Positive Responses			Group 1 Negative Responses			Group 2 Positive Responses		
Question	SD	D	N	SD+D +N	A	SA	A+SA	Total	Margin of Error	Lower Limit	Negative Response Percentage of total	Upper Limit	Lower Limit	Positive Response Percentage of total	Upper Limit
13	5	19	30	54	32	8	40	94	10.00	47.45	57.45	67.44	32.56	42.55	52.55

6.5.7. H11: The Virtual Portion of the Project was Successful in Meeting the Customer's Technical Specifications.

This question deals with the ability of the virtual team to develop a product or system that meets the technical specifcations of the customer.

Unlike previous questions that dealt with more subjective topics such as communication, trust and working relationships, this question deals with the basic

engineering question of whether the product or system designed did in fact do what the customer requested.

As with the last question, there is an overlap of the positive and negative confidence intervals. Table 6.11 shows this overlap hence it is not possible to make a statistically significant statement regarding the response.

Table 6.11: Binomial Test of Q14, The virtual portion of the project was successful in meeting the technical specifications imposed by the customer

SURVEY RESPONSES								BINOMIAL ANALYSIS							
	Strongly Dissagree	Dissagree	Neutral	Group 1 Negative	Agree	Strongly Agree	Group 2 Positive Responses			Group 1 Negative Responses			Group 2 Positive Responses		
Question	SD	D	N	SD+D +N	A	SA	A+SA	Total	Margin of Error	Lower Limit	Negative Response Percentage of total	Upper Limit	Lower Limit	Positive Response Percentage of total	Upper Limit
14	0	13	28	41	48	6	54	95	9.96	33.20	43.16	53.12	46.88	56.84	66.80

7 DISCUSSION

The primary goals of this dissertation were to mine the current literature and determine coverage of the effects of adding face-to-face (FTF) interaction to the virtual development process and to survey a significant group of virtual engineering professionals to determine if they see a benefit in the addition of FTF interaction and if so why such interactions benefit a virtual project. A literature review was conducted to identify gaps in the literature pertaining to this topic.

It was found that no scientific survey that studies the need for FTF interaction in virtual teams exists in the literature. It was also found that much of the literature on virtual teaming deals specifically with virtual, non-face-to-face aspects of the workgroup with in-person (i.e., FTF) interactions barely mentioned. Co-located project teams were universally identified as more efficient, but the more common hybrid setting, in which teams are not co-located but meet FTF with some frequency, has not been analyzed in the literature. One interesting literature finding was the fact that virtuality is more of a communication process and a relationship issue than purely a distance issue. Further, while much of the literature identified an "in-person" advantage that co-located teams have in terms of developing these working relationships, the differences were not studied in depth, and no attempt was made, to the best of this author's knowledge, of analyzing the potential benefits of such interactions in a virtual team.

About 100 individuals were surveyed from DRS Technology, which is a defense firm that regularly gets projects requiring virtual teaming. The questions in the survey were related to seeking answers to the goals mentioned above. An initial analysis of the

survey's results was conducted to determine the management factors that could potentially affect success in the virtual team. A number of hypotheses related to the gaps in the literature were formulated. Thereafter, a detailed statistical analysis of the data gathered was performed.

7.1. SUMMARY OF FINDINGS

- The major statistically significant finding from the survey was that FTF interaction increased chances of success in a virtual team environment by improving the working relationship of the team members. FTF interaction was shown to improve communication, trust, and performance of the teams.
- The fact that virtuality is more of a communication/relationship issue was borne out in the empirical research that showed strong correlations between the quality of working relationships and virtual project success, independent of the distance between participants. The empirical research conducted in this study also indicates that in-person interaction between virtual team members does in fact play an important role in developing virtual working relationships. As the formation of these relationships is an important contributor to success, it points directly to the benefit of FTF interaction in virtual projects.
- It was anticipated that the different functional groups might express a difference in preferences for FTF interaction, based on preliminary discussions. Typically software engineers are thought to show less inclination for personal interaction. However, the survey data did not reflect this. There is also a belief that the age of the participants may prove to be a discriminator because younger engineers are

perceived to be more computer literate. This also proved to be incorrect; the age factor was not found to be a statistically significant factor for virtual project success. In fact, there were no correlation coefficients with $r > .2$ for any of the performance or communication related questions. The only topics showing even moderate correlations coefficients were those associated with past relationships and locational oriented factors that are more situation than performance factors.

One possible explanation for this that is provided in the literature is that communication processes and inter-personal relationships play a significant role in success, and both of those factors are independent of age or function.

7.2. APPLICABILITY OF THIS RESEARCH TO THE DEFENSE INDUSTRY

While DRS Technologies is a mid-tier defense contractor, it is similar in technology, functionality, and structure to larger organizations like Raytheon, Lockheed Martin, and General Dynamics. In fact, most of the upper management in DRS came from those larger organizations, and many of the rank and file engineers had prior work experience at the larger corporations.

This research was conducted at DRS Technologies' IDSS divisions in Florida, Missouri, Maryland, New Hampshire, New York, Ohio, and Pennsylvania. These groups develop equipment and systems for the electronic warfare, communication, aviation and simulation markets. While the groups surveyed are geographically separated, there is a common engineering structure across all groups, and similar engineering processes prevail at all sites. The products developed by these individuals range from the discrete to the complete battalion level "systems of systems." Due to the complexity of the systems

developed, most of the projects undertaken require coordinated development using skills from across the organization and correspondingly a significant amount of virtual teamwork. Given the diversity in technical function, location and product lines of these divisions, the findings of the survey are applicable to the defense industry as a whole.

7.3. FUTURE RESEARCH

At least two significant directions for future research can be visualized. One could study how virtual working relationships are formed and determine how much interaction should ideally be used in specific circumstances. The added travel costs associated with in-person interaction combined with the inefficiency costs of even optimized virtual work will result in a more accurate prediction of project costs. Another research direction would be to empirically investigate alternative metrics for measuring the "degree of virtuality," which was briefly discussed in this dissertation.

APPENDIX A
SURVEY RESULTS

1. What most closely describes your area of engineering expertise that was utilized in the virtual team?

	Response Percent	Response Count
a) Hardware (Mechanical or Electrical)	32.4%	36
b) Systems	19.8%	22
c) Software/Firmware	13.5%	15
d) Project Engineer	14.4%	16
e) Program Support (Integration, Test, Tech. Writing, areas not listed above)	19.8%	22
answered question		111
skipped question		1

2. 2. How many years of experience do you have in your current field?

	Response Percent	Response Count
a) 0 – 2	2.7%	3
b) 2 – 4	3.6%	4
c) 4 – 6	11.8%	13
d) 6 – 8	7.3%	8
e) Over 8	74.5%	82
answered question		110
skipped question		2

3. How many total months have you spent participating in virtual development teams?

	Response Percent	Response Count
a) 0 – 6	26.4%	29
b) 6 – 12	12.7%	14
c) 12 – 18	10.0%	11
d) 18 – 24	8.2%	9
e) Over 24	**42.7%**	**47**
	answered question	**110**
	skipped question	**2**

4. Which age group were you born into?

	Response Percent	Response Count
a) Pre-Boomers (Born before 1945)	1.9%	2
b) Boomer generation (Born 1946 -1964)	**60.2%**	**65**
c) Generation X (Born 1965 – 1980)	24.1%	26
d) Generation Y (Born 1980 – 1990)	13.9%	15
e) Born after 1990	0.0%	0
	answered question	**108**
	skipped question	**4**

5. What is your level of expertise with the technology used in virtual communication?

	Response Percent	Response Count
a) Very Rudimentary	2.7%	3
b) Minimal	12.7%	14
c) Moderate	39.1%	43
d) Extensive	36.4%	40
e) Expert	9.1%	10
answered question		110
skipped question		2

6. What is your level of comfort with virtual communications compared to face to face communication?

	Response Percent	Response Count
a) Strongly prefer to communicate face to face	9.2%	10
b) Prefer Face to Face communication	52.3%	57
c) Indifferent	34.9%	38
d) Prefer Virtual communication	3.7%	4
e) Strongly prefer to communicate virtually	0.0%	0
answered question		109
skipped question		3

7. What was the most significant problem you've experienced with being in a Virtual Team?

	Response Percent	Response Count
a) The technology utilized (IT infrastructure)	11.9%	13
b) Insufficient communication between virtual team members	36.7%	40
c) Miscommunication between team members	23.9%	26
d) Issues of trust among virtual team members	14.7%	16
e) Other _____	12.8%	14
Other (please specify)		18
answered question		**109**
skipped question		**3**

8. Virtual communication was augmented with face-to-face meetings as frequently as needed.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
	7.0% (7)	35.0% (35)	23.0% (23)	31.0% (31)	4.0% (4)	2.90	100
answered question							**100**
skipped question							**12**

9. The transfer of technical requirements across the virtual team was better than in co-located teams.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
	18.2% (18)	**48.5% (48)**	22.2% (22)	9.1% (9)	2.0% (2)	2.28	99
						answered question	99
						skipped question	13

10. Virtual communication resulted in more miscommunications than in co-located teams.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
	4.0% (4)	12.0% (12)	17.0% (17)	**60.0% (60)**	7.0% (7)	3.54	100
						Comment?	18
						answered question	100
						skipped question	12

11. Communications within the Virtual Team would have benefited from more face to face meetings.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
	3.0% (3)	8.1% (8)	14.1% (14)	**62.6% (62)**	12.1% (12)	3.73	99
						Comment?	12
						answered question	99
						skipped question	13

12. The communications methods used in virtual team meetings were initiated with minimal lost time.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
	6.3% (6)	27.4% (26)	30.5% (29)	**33.7% (32)**	2.1% (2)	2.98	95
						answered question	95
						skipped question	17

13. The level of success on the project was primarily driven by outside influences. (Individuals/Functions/Activities outside the virtual team)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
	6.2% (6)	20.6% (20)	30.9% (30)	**35.1% (34)**	7.2% (7)	3.16	97
						Comment?	12
						answered question	97
						skipped question	15

14. The virtual portion of the project was successful in meeting the technical specifications imposed by the customer

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
	1.0% (1)	13.1% (13)	28.3% (28)	**51.5% (51)**	6.1% (6)	3.48	99
						answered question	99
						skipped question	13

15. The virtual portion of the project was successful in meeting the project schedule

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
	7.1% (7)	**31.6% (31)**	25.5% (25)	**31.6% (31)**	4.1% (4)	2.94	98
					answered question		98
					skipped question		14

16. The virtual portion of the project was successful meeting the project budget

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
	9.4% (9)	29.2% (28)	**30.2% (29)**	28.1% (27)	3.1% (3)	2.86	96
					answered question		96
					skipped question		16

17. The virtual portion of the project was successful in developing a working relationship with distant team members.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
	6.2% (6)	22.7% (22)	24.7% (24)	**38.1% (37)**	8.2% (8)	3.20	97
					answered question		97
					skipped question		15

18. The inputs, outputs and gates of the virtual tasks were well defined on that project

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
	6.2% (6)	**35.1% (34)**	30.9% (30)	26.8% (26)	1.0% (1)	2.81	97
					answered question		97
					skipped question		15

19. The product being developed already had a high level of maturity in the area of your expertise on that project.

	Strongly Disagree	Disagree	Neutral	AGREE	Strongly Agree	Rating Average	Response Count
	11.5% (11)	39.6% (38)	24.0% (23)	22.9% (22)	2.1% (2)	2.65	96
					answered question		96
					skipped question		16

20. The product development was driven by a concise set of customer requirements and/or specifications.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
	14.3% (14)	33.7% (33)	19.4% (19)	29.6% (29)	3.1% (3)	2.73	98
					answered question		98
					skipped question		14

21. Face to Face (In person) meetings were conducted as needed.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
	2.1% (2)	36.1% (35)	20.6% (20)	**38.1% (37)**	3.1% (3)	3.04	97
					answered question		97
					skipped question		15

22. Face to face (In person) meetings/interactions were helpful.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Rating Average	Response Count
	2.0% (2)	2.0% (2)	12.1% (12)	**48.5% (48)**	35.4% (35)	4.13	99
					answered question		99
					skipped question		13

23. Was video conferencing readily available to you?

		Response Percent	Response Count
Not available		**44.4%**	**44**
Available but not convenient		36.4%	36
Available		19.2%	19
		answered question	99
		skipped question	13

24. Did you communicate with your virtual team members at least as often as your co-located team members? (Include all forms of communication)

	Response Percent	Response Count
No, I had more interactions with my co-located teams	69.4%	68
Neutral, About the same level of communication	21.4%	21
Yes, I had at least as many or more interactions with the virtual members	9.2%	9
answered question		98
skipped question		14

25. What were the most effective forms of communication utilized during each phase of the VT project among non-collocated team members?

	Award to Kickoff	Kickoff to PDR	PDR to CDR	Integration and Test	Response Count
Face to Face (in Person)	54.9% (45)	52.4% (43)	54.9% (45)	**59.8% (49)**	82
Web-Conference (Presentation with minimal verbal responses)	34.0% (16)	**66.0% (31)**	55.3% (26)	19.1% (9)	47
Web-Video-Conference with full participation	34.9% (15)	53.5% (23)	**72.1% (31)**	20.9% (9)	43
Telephone Conference Calls	51.5% (35)	45.6% (31)	**64.7% (44)**	60.3% (41)	68
E-Mails	60.3% (44)	**72.6% (53)**	**72.6% (53)**	67.1% (49)	73
FTP file transfer site or SharePoint site	37.0% (20)	57.4% (31)	**74.1% (40)**	59.3% (32)	54
answered question					94
skipped question					18

26. At what points in the project would face to face (in person) meetings be most helpful?

	Response Percent	Response Count
Award to Kickoff	18.8%	18
Kickoff to PDR	37.5%	36
PDR to CDR	24.0%	23
Integration and Test	19.8%	19
answered question		96
skipped question		16

27. Rate the criticality of the information passed in the various forms of communication.

	Worthless	Questionable Value	Some Value	Important	Critical	Response Count
Face to Face (in Person)	1.0% (1)	1.0% (1)	3.1% (3)	**52.0% (51)**	42.9% (42)	98
Web-Conference (Presentation with minimal verbal response)	2.2% (2)	20.4% (19)	**40.9% (38)**	35.5% (33)	1.1% (1)	93
Web-Video-Conference with full participation	3.4% (3)	9.0% (8)	37.1% (33)	**48.3% (43)**	2.2% (2)	89
Telephone Conference Calls	1.0% (1)	3.1% (3)	18.8% (18)	**59.4% (57)**	17.7% (17)	96
E-Mails	1.0% (1)	2.1% (2)	11.3% (11)	**47.4% (46)**	38.1% (37)	97
FTP file transfer site or SharePoint site	1.1% (1)	8.6% (8)	22.6% (21)	**47.3% (44)**	20.4% (19)	93
answered question						99
skipped question						13

28. How successful was the transfer of information during the following communication methods used during the project?

	Complete Failure	Moderate Failure	Neutral	Moderately Successful	Highly Successful	Response Count
Face to Face (in Person)	2.0% (2)	1.0% (1)	10.2% (10)	38.8% (38)	**48.0% (47)**	98
Web-Conference (Presentation with minimal verbal responses)	3.1% (3)	13.5% (13)	**46.9% (45)**	33.3% (32)	3.1% (3)	96
Web-Video-Conference with full participation	3.3% (3)	5.6% (5)	**44.4% (40)**	41.1% (37)	5.6% (5)	90
Telephone Conference Calls	2.1% (2)	6.4% (6)	22.3% (21)	**55.3% (52)**	13.8% (13)	94
E-Mails	1.0% (1)	2.1% (2)	19.6% (19)	**47.4% (46)**	29.9% (29)	97
FTP file transfer site or SharePoint site	2.1% (2)	3.2% (3)	34.7% (33)	**35.8% (34)**	24.2% (23)	95
					answered question	**98**
					skipped question	**14**

29. How successful were the following aspects of that project?

	Complete Failure	Moderate Failure	Neutral	Moderately Successful	Highly Successful	Response Count
Meeting Technical Specifications	2.0% (2)	9.2% (9)	23.5% (23)	**48.0% (47)**	17.3% (17)	98
Meeting Schedule	16.5% (16)	**30.9% (30)**	20.6% (20)	22.7% (22)	9.3% (9)	97
Meeting Budget	15.6% (15)	**34.4% (33)**	30.2% (29)	11.5% (11)	8.3% (8)	96
Developing working relationships	3.1% (3)	17.5% (17)	24.7% (24)	**42.3% (41)**	12.4% (12)	97
Transfer of Technical knowledge and skills	4.1% (4)	16.5% (16)	32.0% (31)	**39.2% (38)**	8.2% (8)	97
					answered question	**98**
					skipped question	**14**

30. What previous in-person work experience did you have with any participants of the virtual team?

	Response Percent	Response Count
No prior in person work history	54.5%	54
Formal meetings only	13.1%	13
Informal discussions	16.2%	16
Co-located team members on a similar project(s)	14.1%	14
Personal friend and co-located co-worker	2.0%	2
answered question		99
skipped question		13

31. Were you co-located with the leader of the team during the project?

	Response Percent	Response Count
Yes	50.5%	50
No	49.5%	49
answered question		99
skipped question		13

32. Were you co-located with the leader of the team prior to the project?

	Response Percent	Response Count
Yes	44.4%	44
No	55.6%	55
answered question		99
skipped question		13

33. Rate the working relationship between yourself and the virtual team members with whom you had previous in-person work experience

	Response Percent	Response Count
Minimal	5.4%	5
Little	5.4%	5
Adequate	26.9%	25
Good	47.3%	44
Excellent	15.1%	14
answered question		93
skipped question		19

34. Rate the working relationship between yourself and the virtual team members that you did not have previous in-person work experience with.

	Response Percent	Response Count
Minimal	9.3%	9
Little	8.2%	8
Adequate	44.3%	43
Good	33.0%	32
Excellent	5.2%	5
answered question		97
skipped question		15

35. Were there items that were not completed due to the fact that the project had a larger virtual content?

	Response Percent	Response Count
Yes	29.3%	27
No	70.7%	65
Other (please specify)		10
answered question		92
skipped question		20

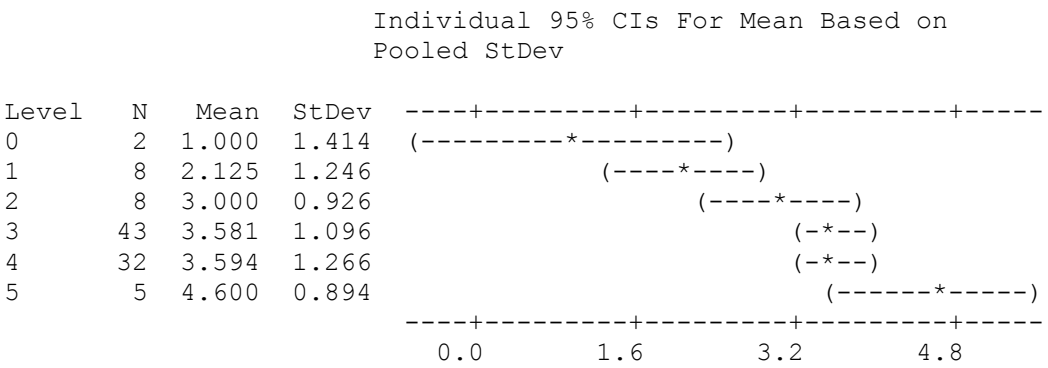
APPENDIX B

ANOVA AND TUKEY CALCULATIONS

One-way ANOVA: Factor 33 versus Factor 34

Source	DF	SS	MS	F	P
Factor 34	5	35.59	7.12	5.36	0.000
Error	92	122.26	1.33		
Total	97	157.85			

S = 1.153 R-Sq = 22.55% R-Sq(adj) = 18.34%



Pooled StDev = 1.153

Grouping Information Using Tukey Method

Factor 34	N	Mean	Grouping
5	5	4.600	A
4	32	3.594	A
3	43	3.581	A
2	8	3.000	A B
1	8	2.125	B
0	2	1.000	B

Means that do not share a letter are significantly different.

APPENDIX C

CORRELATION CHART

Pearson Correlation Coefficient Chart

	QUESTION	Engineering Function	Year of experience	Experience in virtual teams	Age Group	Level of expertise	Level of comfort in Virt. Comms.	Significant issue with VC	Was VC augmented with F2F	Transfer of Tech Rqmts	Miscommunications with Virtual	Benefit from more F2F	Lost time initiating	Outside influences	Meeting Tech specs	Meeting Schedule	Meeting Budget	Working Relationship	Well Defined I/Os	Product Maturity	Concise requirements & specs	F2F as often as needed	F2F meetings were helpful	Criticality of Data passed in F2F mtgs.
	QUESTION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	27a
Engineering Function	1																							
Year of experience	2	0.013																						
Experience in virtual teams	3	0.01	0.254																					
Age Group	4	-0.06	-0.41	-0.1																				
Level of expertise with virtual Tech.	5	-0.09	0.172	0.433	0.201																			
Level of comfort in Virt. Comms.	6	-0.11	0.099	0.019	-0.02	0.025																		
Significant problem	7	0.058	-0.05	0.156	-0	0.151	0.093																	
Was VC augmented with F2F	8	0.077	0.068	0.024	-0.22	-0.01	0.246	0.094																
Transfer of Tech Rqmts	9	-0.09	0.017	0.144	-0.09	0.153	0.363	0.095	0.092															
Miscommunications	10	-0.01	0.125	-0.03	0.032	0.013	-0.27	0.029	-0.16	-0.26														
Benefit from more F2F	11	0.039	0.214	0.042	0.078	0.198	-0.28	0.107	-0.26	-0.15	0.554													
Lost time initiating	12	0.132	0.165	0.174	-0.09	0.059	0.107	0.032	0.153	0.342	-0.1	-0.2												
Outside Influences	13	-0.2	0.028	-0.15	0.138	-0.06	0.049	0.228	0.092	0.129	0.123	0.16	-0.05											
Meeting Tech. Specs.	14	-0.01	0.248	0.429	0.024	0.292	0.168	0.083	0.085	0.401	-0.13	-0.04	0.39	0.003										
Meeting Schedule	15	0.045	0.163	0.145	0.003	0.117	0.274	0.063	0.182	0.241	-0.27	-0.22	0.396	0.051	0.446									
Meeting Budget	16	0.031	0.07	0.141	0.117	0.181	0.374	-0.01	0.167	0.272	-0.23	-0.26	0.438	0.009	0.45	0.804								
Working Relationship	17	-0	0.12	0.042	0.08	-0.01	0.285	0.061	0.341	0.147	-0.14	-0.25	0.323	-0.01	0.351	0.296	0.38							
Well Defined I/Os	18	0.069	0.105	0.125	-0.02	0.095	0.295	0.071	0.274	0.311	-0.13	-0.08	0.392	-0.06	0.466	0.501	0.443	0.38						
Product Maturity	19	-0.03	-0.01	-0.09	-0.05	0.009	0.2	0.137	0.014	0.351	-0.07	0.139	0.006	0.095	0.044	0.166	0.111	0.043	0.24					
Concise requirements & specs	20	-0.01	-0.04	0.044	-0.04	0.05	0.014	0.038	0.151	0.235	0.182	0.14	0.129	0.08	0.073	0.039	-0.01	0.035	0.293	0.363				
F2F meetings as often as needed	21	0.017	-0.02	-0.09	0.067	0.016	0.123	-0.04	0.601	-0.01	-0	-0.23	0.08	0.078	0.102	0.267	0.269	0.247	0.239	0.019	0.136			
F2F mtgs were helpful	22	0.101	0.137	0.215	0.14	0.158	-0.27	-0.06	0.051	-0.04	0.433	0.411	0.167	-0.01	0.21	-0	0.053	0.041	0.125	-0.02	0.144	0.192		
Criticality of data in F2F	27a	0.231	0.068	0.066	0.081	0.108	-0.19	0.056	0.064	-0.03	0.306	0.383	0.1	0.039	0.067	-0.11	-0.11	-0.08	0.021	-0.02	0.167	0.101	0.574	
Criticality of data in min part. Web	27b	-0.04	0.136	0.129	-0.13	0.079	0.067	-0.13	0.021	0.288	-0.1	0.004	0.195	-0	0.121	-0.01	-0.02	-0.1	0.108	-0.02	-0.13	-0.04	0.227	0.273
Criticality of data in full part Web	27c	0.058	0.331	0.118	-0.2	0.17	0.06	-0.05	0.246	0.054	0.139	0.222	0.134	-0.04	0.214	0.032	0.017	0.139	0.114	-0.08	0.091	0.024	0.192	0.363
Criticality of data in phone calls	27d	-0.04	0.319	0.153	0.015	0.047	0.176	-0.01	0.025	0.13	0.159	0.125	0.229	0.005	0.226	0.133	0.151	0.213	0.207	0.093	0.167	0.083	0.237	0.183
Criticality of data in emails	27e	0.027	0.225	0.11	0.056	-0.04	0.193	0.106	-0.02	0.203	0.012	0.012	0.337	0.117	0.193	0.245	0.223	0.156	0.233	0.023	0.128	0.027	0.14	0.199
Criticality of data in FTP	27f	0.137	0.146	0.168	-0.09	0.024	0.224	0.09	0.069	0.225	0.155	0.152	0.111	-0.06	0.249	0.126	0.045	0.112	0.366	0.215	0.253	0.099	0.312	0.294
Success of data transfer via F2F	28a	0.036	0.197	0.305	-0.03	0.093	-0.09	0.065	0.069	-0.07	0.281	0.275	0.287	-0.09	0.267	0.088	0.057	0.083	0.113	-0.07	0.178	0.122	0.487	0.52
Succ. Of data xfer video min. part	28b	-0.13	0.189	0.193	-0.07	-0.03	0.173	-0.03	0.07	0.105	-0.17	-0.14	0.255	-0.06	0.126	0.026	0.062	0.032	0.11	-0.1	-0.13	0.061	0.106	0.165
Succ.of data xfer video full part.	28c	0.012	0.295	0.149	-0.08	0.058	0.079	0.067	0.109	0.079	-0.04	0.196	0.242	0.132	0.2	0.153	0.137	0.124	0.102	0.066	0.143	-0.08	0.122	0.103
Succ of data xfer phone calls	28d	-0.02	0.324	0.313	0.079	0.198	0.22	0.038	0.057	0.011	0.089	0.132	0.166	-0.11	0.315	0.085	0.171	0.185	0.284	0.07	0.23	0.053	0.256	0.224
Succ of data xfer email	28e	0.001	0.218	0.152	0.053	0.071	0.251	0.008	0.063	0.186	-0.03	0.03	0.302	0.1	0.324	0.323	0.409	0.202	0.284	0.064	0.18	0.098	0.152	0.259
Succ of data xfer FTP site	28f	0.035	0.134	0.105	-0.01	-0	0.239	-0.02	0.131	0.161	0.096	0.153	0.175	-0.12	0.264	0.156	0.159	0.214	0.354	0.137	0.255	0.167	0.366	0.336
Meeting Tech specs	29a	0.011	0.093	0.217	-0.07	0.013	0.112	0.074	0.051	0.255	-0.02	-0.08	0.376	-0.1	0.395	0.402	0.358	0.148	0.46	0.151	0.373	0.109	0.161	0.104
Meeting Schedule	29b	0.099	0.169	0.073	-0.1	-0	0.191	0.027	0.166	0.323	-0.06	-0.03	0.323	-0.15	0.328	0.577	0.521	0.234	0.514	0.372	0.353	0.182	0.118	0.024
Meeting Budgets	29c	0.026	0.084	0.08	-0.01	0.035	0.181	0.038	0.137	0.31	-0.06	-0.07	0.305	-0.17	0.231	0.574	0.55	0.22	0.482	0.348	0.343	0.173	0.148	0.007
Forming working relationships	29d	-0.05	0.085	0.275	0.149	0.115	0.193	0.126	0.278	0.231	-0.12	-0.2	0.281	0.021	0.409	0.309	0.332	0.455	0.313	-0.03	0.146	0.261	0.163	0.147
Transfer of Tech knowledge	29e	-0.05	0.179	0.203	0.025	0.033	0.224	0.157	0.312	0.202	-0.11	-0.15	0.304	0.065	0.309	0.25	0.221	0.404	0.288	-0.06	0.184	0.24	0.12	0.171
What previous in-person work experience did you have with any participants of the virtual team?	30	0.067	0.156	0.23	-0.19	0.023	-0.09	0.06	0.129	0.085	-0.12	0.003	0.176	0.103	0.186	0.166	-0.02	-0.06	-0.01	0.186	0.076	0.18	0.059	0.097
Were you co-located with the leader of the team during the project?	31	-0.03	0.227	-0.01	-0.42	-0.12	0.113	-0.05	-0.03	0.043	-0.11	-0.08	0.045	-0.05	-0.01	-0.04	-0.01	-0.03	-0	-0.03	-0.08	-0.2	-0.2	-0.12
Were you co-located with the leader of the team prior to the project?	32	-0.1	0.175	0.006	-0.28	0.08	0.023	0.025	0.019	0.006	-0.01	0.054	-0.02	0.005	0.012	-0.1	0.021	0.028	0.019	-0.14	-0.09	-0.05	-0.15	-0.1
Rate the working relationship between yourself and the virtual team members with whom you had previous in-person work experience	33	0.055	0.267	0.333	-0.35	0.152	-0.12	0.114	0.061	0.078	-0.06	-0.02	0.31	0.09	0.152	0.068	0.039	0.166	0.051	0.042	0.154	-0.01	0.186	0.109
Rate the working relationship between yourself and the virtual team members that you did not have previous in-person work experience with.	34	0.098	0.164	0.13	-0.18	-0.04	0.09	-0.12	0.18	0.031	0.067	-0.12	0.283	-0.07	0.217	0.033	0.177	0.376	-0	-0.19	0.046	0.146	0.209	0.15

APPENDIX D

VIRTUAL INEFFICIENCY COSTS

Often when projects are initially bid, the managers make estimates based on the time it would require a traditional co-located team to perform the tasks. In today's environment, with the large number of projects having virtual content, those estimates are likely to be inaccurate if they do not include a modifier for the inefficiencies associated with the tasks that are performed virtually.

Upon reviewing a new project that may include a virtual component, the potential fixed and variable costs associated with the virtual component should be considered. The evaluation of the virtual costs vs. the cost of developing co-located teams may affect which tasks are conducted at specific facilities, or even if virtual work is warranted at all. Assuming there is some virtual portion, the following provides one possible approach to assessing the cost of that virtuality and the start of a ROI analysis weighing mitigation of inefficiency factors to minimize the financial impact on the program.

Engineering development projects typically consist of two critical functions, data transfer between team members and the actual performance of development tasks. The data transfer time includes time spent in communication between team members and the parent organization, storage of information developed and reporting of status. Task performance time consists of the actual research, analysis, design and development activities. The total time required to perform all tasks in a project can simply be represented as:

$$\mathbf{T_{Tot} = \Sigma(T_C + T_P)} \qquad (1)$$

Where Tc is the communication time and Tp is the time to actually perform the development tasks.

In most project using traditional co-located teams, task performance represents the vast majority of the time spent on a project, with communication typically being integrated directly into the performance of the task. This is not quite the case for virtual teams where communication is more complicated and represents a higher percentage. The additional communication time required for virtual work can be estimated by an estimate of the number of additional calls, emails and video conferences and the inefficiencies associated with those modes of communication.

The cost to implement these technologies, such as improvement in communication infrastructure and training are upfront fixed costs. These are incurred prior to and often priced separate from the project and tied into some overhead pool. The project also has fixed costs associated with the number of communication hours anticipated for the additional virtual communication meetings. This time is represented by:

$$T_{\text{communication fixed}} = \Sigma \Delta C \qquad (2)$$

Virtual tasks are typically performed with less efficiency than co-located tasks hence the time required for each virtual task will be higher. This difference can be represented by dividing the time to perform the task in a traditional co-located setting by

what is essentially a virtuality efficiency factor. If we define the virtual efficiency as the virtual time associated with each virtual performance task is:

$$\mathbf{P_{virtual\ task\ delta} = P_j/h_i} \qquad (3)$$

The additional virtual project time (aka cost) associated with the performance of all virtual tasks can be represented as the sum of the communication and performance tasks.

$$\mathbf{T}_{\text{Virtual Delta}} = \mathbf{\Sigma \Delta C} + \mathbf{\Sigma\ P_j/h_i} \qquad (4)$$

The communication and performance efficiencies for each task are unique for that task, the parent organization, the project and the project team performing those tasks. It is obvious from equation 3 that improving the efficiency of the virtual tasks will have them approach the execution time of co-located tasks.

The virtual costs above the co-located costs are a combination of fixed start-up costs and variable costs. The former are simple one-time infrastructure and training calculations, the latter is a function of the efficiency or rather inefficiency with which each task is performed. A basic spreadsheet is shown in below.

Startup Fixed Costs	Cost in $		Total Cost ΔC
Hardware Infrastructure Required			
Common Data Storage			
Training			
	TOTAL FIXED STARTUP COST		
Fixed Virtual Project Costs	Cost in Hrs.	verage hourly rate	Total Cost ΔC
Additional IT support			
Team Selection Meetings			
Virtual Kickoff Meeting			
Weekly Virtual Meeting			
Ad Hoc Virtual Meetings			
Virtual Conference Calls			
	TOTAL FIXED VIRTUAL PROJECT COST		

Variable Virtual Project Costs	Costs in Hrs. of equivalent co-located task P	Combined inefficiency 1/h	Average hourly rate	Delta cost for virtual project P$/h
Task 001				
Task 002				
Task 003				
Task 004				
	TOTAL VARIABLE VIRTUAL PROJECT COST			

Most of the project costs are those listed in the variable virtual project costs portion of the spreadsheet, and the critical modifier of these values is the virtual efficiency factor. If it is determined that a specific series of tasks would take 1000 hours to accomplish in a traditional collocated environment and there is a 80% inefficiency factor for going virtual, the projected cost to the project is 1250 hours. The 250 hour virtual cost is significant, but possibly the best option if the particular knowledge is just not available at the principle site or when compared to the cost to relocate personnel.

The challenge is in determining this inefficiency factor. While the best approach would be to evaluate the metrics of past tasks and projects, in reality, that data is seldom taken with sufficient accuracy during the projects. Without hard data, managers must

resort to subjective evaluation. That evaluation should not come from a single source, but be a summation of data from past virtual participants, co-located members on the same project, the PMO and the functional managers to minimize personal bias by specific groups.

Referring back to Figure 2.2, "Factors Affecting Virtual Teams", as a framework, the managers in the virtual estimating team can poll this representative group to determine how they are impacted by each pertinent factor. Tasks that show poor efficiency values can then be mitigated through training, processes or by increasing the face-to-face time which the literature shows improves efficiency across the board.

BIBLIOGRAPHY

Ahlstrom, David, David Lamond, and Zhujun Ding. 2009. Reexamining some management lessons from military history. *Asia Pacific Journal of Management*. Springer.

Ahuja, J. 2010. A Study of Virtuality Impact on Team Performance.

Andres, H. P. 2002. A comparison of face-to-face and virtual software development teams. *Team Performance Management*. MCB UP Ltd.

Andres,H.P. 2008. The impact of communication medium on virtual team group process *Innovative Technologies for Information Resources Management*.

Aubert, B. A., and B. L. Kelsey. 2003. Further understanding of trust and performance in virtual teams. *Small Group Research*. Sage Publications.

Aubry, Monique, Hélène Sicotte, Nathalie Drouin, Hélène Vidot-Delerue, and Claude Besner. 2012. Organisational project management as a function within the rganisation. *International Journal of Managing Projects in Business*. Emerald Group Publishing Limited.

Begley, Kathleen A. 2004. *Face to Face Communication: Making Human Connections in a Technology-Driven World*. Axzo Press.

Berry, G. R. 2011. Enhancing Effectiveness on Virtual Teams. *Journal of Business Communication*. SAGE Publications.

Brandt, V., W. England, and S. Ward. 2011. Virtual Teams. *RESEARCH-TECHNOLOGY MANAGEMENT*.

Brantmeier, Cindy. 2004. Statistical procedures for research on L2 reading comprehension: An examination of ANOVA and regression models. *Reading in a Foreign Language*. Reading in a Foreign Language, National Foreign Language Resource Center, 1859 East-West Road,\# 106, University of Hawai'i, Honolulu, HI 96822.

Burgoon, Judee K, Joseph A Bonito, Artemio Ramirez, Norah E Dunbar, Karadeen Kam, and Jenna Fischer. 2002. Testing the interactivity principle: Effects of mediation, propinquity, and verbal and nonverbal modalities in interpersonal interaction. *Journal of communication*. Wiley Online Library.

Cascio, Wayne F. 2000. Managing a virtual workplace. *The Academy of Management Executive*. Academy of Management.

Chatterjee, Samprit, and Jeffrey S Simonoff. 2013. *Handbook of Regression Analysis*. Vol. 5. Wiley. com.

Cohen, D. 1999. Knowing the drill: virtual teamwork at BP. *Perspectives on Business Innovation*.

Cordery, John L, and Christine Soo. 2008. Overcoming impediments to virtual team effectiveness. *Human Factors and Ergonomics in Manufacturing \& Service Industries*. Wiley Online Library.

Cramton, Catherine Durnell. 2001. The mutual knowledge problem and its consequences for dispersed collaboration. *Organization science*. INFORMS.

D'Souza, G. C., and S. M. Colarelli. 2010. Team member selection decisions for virtual versus face-to-face teams. *Computers in Human Behavior*. Elsevier.

Dani, SS, N. D. Burns, CJ Backhouse, and AK Kochhar. 2006. The implications of organizational culture and trust in the working of virtual teams. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*. Prof Eng Publishing.

Davis, D. D. 2004. The Tao of leadership in virtual teams. *Organizational Dynamics*. Elsevier Science.

Dubé, L., and D. Robey. 2009. Surviving the paradoxes of virtual teamwork. *Information Systems Journal*. Wiley Online Library.

Fiol, C. M., and E. J. O'Connor. 2005. Identification in face-to-face, hybrid, and pure virtual teams: Untangling the contradictions. *Organization Science*. JSTOR.

Gibson, Cristina B, and Jennifer L Gibbs. 2006. Unpacking the concept of virtuality: The effects of geographic dispersion, electronic dependence, dynamic structure, and national diversity on team innovation. *Administrative Science Quarterly*. SAGE Publications.

Gregory, Brian T, Stanley G Harris, Achilles A Armenakis, and Christopher L Shook. 2009. Organizational culture and effectiveness: A study of values, attitudes, and organizational outcomes. *Journal of Business Research*. Elsevier.

Griffith, Terri L, and Margaret A Neale. 2001. 8. Information processing in traditional, hybrid, and virtual teams: From nascent knowledge to transactive memory. *Research in organizational behavior*. Elsevier.

Henttonen, K., and K. Blomqvist. 2005. Managing distance in a global virtual team: the evolution of trust through technology-mediated relational communication. *Strategic Change*. Wiley Online Library.

Hertel, G., S. Geister, and U. Konradt. 2005. Managing virtual teams: A review of curren t empirical research. *Human Resource Management Review*. Elsevier.

Holton, J. A. 2001. Building trust and collaboration in a virtual team. *Team Performance Management*. MCB UP Ltd.

Jarvenpaa, S. L., T. R. Shaw, and D. S. Staples. 2004. Toward contextualized theories of trust: The role of trust in global virtual teams. *Information systems research*.

Johnson, Richard Arnold, and Gouri K Bhattacharyya. 1985. *Statistics: principles and methods*. Wiley.

Kirkman, Bradley L, and John E Mathieu. 2004. THE ROLE OF VIRTUALITY IN WORK TEAM EFFECTIVENESS. In *Academy of Management Proceedings*, 2004:L1–L6.

Leonard-Barton, Dorothy. 1992. Core capabilities and core rigidities: A paradox in managing new product development. *Strategic management journal*. Wiley Online Library.

MacDonnell, R., T. O'Neill, T. Kline, and L. Hambley. 2009. Bringing group-level personality to the electronic realm: A comparison of face-to-face and virtual contexts. *The Psychologist-Manager Journal*. Taylor \& Francis.

Majchrzak, Ann, Arvind Malhotra, Jeffrey Stamps, and Jessica Lipnack. 2004. Can absence make a team grow stronger? *Harvard business review*.

Malhotra, Arvind, and Ann Majchrzak. 2004. Enabling knowledge creation in far-flung teams: best practices for IT support and knowledge sharing. *Journal of Knowledge Management*. Emerald Group Publishing Limited.

Mancini, D. J. 2010. Building organizational trust in virtual teams. *Journal of Behavioral Studies in Business*.

Mitchell, A., and I. Zigurs. 2009. Trust in virtual teams: solved or still a mystery? *ACM SIGMIS Database*. ACM.

Montoya, M. M., A. P. Massey, Y. T. C. Hung, and C. B. Crisp. 2009. Can You Hear Me Now? Communication in Virtual Product Development Teams*. *Journal of Product Innovation Management*. Wiley Online Library.

Nandhakumar, J., and R. Baskerville. 2006. Durability of online teamworking: patterns of trust. *Information Technology \& People*. Emerald Group Publishing Limited.

Pauleen, D. J., and P. Yoong. 2001. Facilitating virtual team relationships via Internet and conventional communication channels. *Internet Research*. MCB UP Ltd.

Peters, Linda M, and Charles C Manz. 2007. Identifying antecedents of virtual team ollaboration. *Team Performance Management*. Emerald Group Publishing Limited.

Pinjani, Praveen, and Prashant Palvia. 2013. Trust and knowledge sharing in diverse global virtual teams. *Information \& Management*. Elsevier.

Purvanova, R. K., and J. E. Bono. 2009. Transformational leadership in context: Face-to-face and virtual teams. *The Leadership Quarterly*. Elsevier.

Ricks, Thomas E. 2012. *The Generals: American Military Command from World War II to Today*. Penguin.

Shekhar, S. 2006. Understanding the virtuality of virtual organizations. *Leadership \& Organization Development Journal*. Emerald Group Publishing Limited.

Staples, D. S., and L. Zhao. 2006. The effects of cultural diversity in virtual teams versus face-to-face teams. *Group Decision and Negotiation*. Springer.

Walther, J. B., and U. Bunz. 2005. The rules of virtual groups: Trust, liking, and performance in computer-mediated communication. *Journal of Communication*. Wiley Online Library.

Weathington, Bart L, Christopher JL Cunningham, and David J Pittenger. 2012. *Understanding business research*. Wiley. com.

Wells, Peter S. 2003. *The battle that stopped Rome: Emperor Augustus, Arminius, and the slaughter of the legions in the Teutoburg Forest*. WW Norton \& Company.

Wiewiora, Anna, Bambang Trigunarsyah, Glen Murphy, and Vaughan Coffey. 2013. Organizational culture and willingness to share knowledge: a competing values perspective in Australian context. *International Journal of Project Management*. Elsevier.

Williams, E. A., and S. L. Castro. 2010. The effects of teamwork on individual learning and perceptions of team performance: A comparison of face-to-face and online project settings. *Team Performance Management*. Emerald Group Publishing Limited.

Zhai, Li, Yanfei Xin, and Chaosheng Cheng. 2009. Understanding the value of project management from a stakeholder's perspective: Case study of mega-project management. *Project Management Journal*. Wiley Online Library.

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