NEEDED ACTIONS WITHIN DEFENSE ACQUISITIONS BASED ON A FORECAST OF FUTURE MOBILE INFORMATION AND COMMUNICATIONS TECHNOLOGIES DEPLOYED IN AUSTERE ENVIRONMENTS

THESIS

Andrew T. Soine, Captain, USAF

AFIT-ENV-13-M-28

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT-ENV-13-M-28

NEEDED ACTIONS WITHIN DEFENSE ACQUISITION BASED ON A FORECAST OF FUTURE MOBILE INFORMATION AND COMMUNICATIONS TECHNOLOGIES DEPLOYED IN AUSTERE ENVIRONMENTS

THESIS

Presented to the Faculty

Department of Systems and Engineering Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Research and Development Management

Andrew T. Soine, BS

Captain, USAF

March 2013

AFIT-ENV-13-M-28

NEEDED ACTIONS WITHIN DEFENSE ACQUISITIONS BASED ON A FORECAST OF FUTURE MOBILE INFORMATION AND COMMUNICATIONS TECHNOLOGIES DEPLOYED IN AUSTERE ENVIRONMENTS

Andrew T. Soine, BS

Captain, USAF

Approved:

//signed//	5 Mar 2013
Alan R. Heminger, PhD (Chairman)	Date
//signed//	5 Mar 2013
Alfred E. Thal, Jr., PhD (Member)	Date
//signed//	5 Mar 2013
Lt Col Brent T. Langhals (Member)	Date

AFIT-ENV-13-M-28

Abstract

The purpose of this research was twofold. First, it developed a forecast of future mobile information and communications technologies (ICT) suitable for use by military forces in austere environments in 5-10, 10-20, and beyond 20 years. Secondly, it explored whether or not current acquisitions practices will be adequate to meet the needs of warfighters who depend on mobile ICT. These questions were explored by conducting utilization of the Delphi technique. Eight panelists from within the private sector conducted three rounds of iterative feedback. This research resulted in a technology forecast for the three timeframes aforementioned, and the potential impacts to the defense acquisitions community. First, current acquisitions practices are unlikely to meet the needs of warfighters dependent upon mobile ICT and streamlining efforts are not likely to result in sufficient lessening of development timelines to maintain technological currency. Secondly, it is foreseeable that military forces will become increasingly dependent upon technologies developed by the private sector. An acquisitions model which exploits technological advances in the form of smart phones and tablets and a secure repository for approved applications and data services is feasible and may help defense acquisitions to maintain technological currency as they replace dedicated, single-purpose equipment. Finally, it suggested that developing the organizational flexibility to adapt to emerging technological trends will become more important than detailed planning and budgeting beyond 10 years.

Acknowledgments

I would like to dedicate this work to my Lord and Savior who has demonstrated his faithfulness time and time again. Also to my wife, who has stood by my side throughout our life's journey.

Table of Contents

Page

Abstract iv
Table of Contents vi
List of Figures ix
List of Tables x
I. Introduction 1
General Issue 1
Background 1
Problem Statement 3
Research Questions 3
Methodology 4
Scope of Research 5
Summary 5
II. Literature Review 7
Chapter Overview 7
Communication and the Impacts of ICT 7
Importance of ICT Forecasting 8
Current Trends in Mobile ICT 10
Nanotechnology: An Emerging Trend in ICT 13
Exponential Growth in ICT Capability 15
The Department of Defense No Longer Drives Technological Advancement 20
The Joint Capabilities Joint Capabilities Integration Development System 21
The Delphi Method 25

Page

Chapter Summary.....28

III. Methodology.....29

Chapter Overview.....29

Why the Delphi method?.....29

Past Efforts in ICT Forecasting Using Delphi.....30

The Five Knowledge Areas.....32

Number of Panelists.....35

Targeted Demographics of the Panel of Experts.....35

Conducting the Delphi.....36

Number of Rounds.....39

Summary.....39

IV. Analysis and Results.....40

Chapter Overview.....40

The Panel of Experts.....41

The Future of ICT Deployed in Austere Environments: 5-10 Years......42

The Future of ICT Deployed in Austere Environments: 10-20 Years.....46

The Future of ICT Deployed in Austere Environments: Beyond 20 Years.....49

Research Questions from an Acquisitions Perspective.....51

Summary.....57

V. Discussion and Recommendations.....58

Chapter Overview.....58

Summary of Findings on the Future of ICT in Austere Environments.....58

Discussion of Questions from an Acquisitions Perspective.....63

Page

Recommendations 68

Limitations of Research...69

Future Research...70

Summary...72

Appendix A: Round 1 Research Instrument 73
Appendix B: Round 2 Research Instrument 77
Appendix C: Round 3 Research Instrument 83
Appendix D: Final Prediction 95
Bibliography 98
Vita 104

List of Figures

Page

Figure 1. Cloud benefits: Efficiency, Agility, Innovation 12

Figure 2. Physics, biology and chemistry meet in nanotechnology................................ 14

Figure 3. How exponential growth surpasses both linear and cubic growth. 15

Figure 4. Exponential growth in the paycheck of the savvy worker 16

Figure 5. The power of the fastest computers has grown exponentially. 19

Figure 6. Optical transmission capacity has grown exponentially 19

Figure 7. Three Critical Interacting Processes 22

Figure 8. The quality of forecasts varied across topical areas 31

Figure 9. The ICT Capability Creation model 34

Figure 10. The Delphi Approach 38

List of Tables

Page

Table 1. Description of Knowledge Areas 33

Table 2. The Panel of Experts 42

NEEDED ACTIONS WITHIN DEFENSE ACQUISITIONS BASED ON A FORECAST OF FUTURE MOBILE INFORMATION AND COMMUNICATIONS TECHNOLOGIES DEPLOYED IN AUSTERE ENVIRONMENTS

I. Introduction

General Issue

According to the 2010 Quadrennial Defense Review (QDR), "modern armed forces cannot conduct effective high-tempo operations without resilient, reliable information and communication networks and assured access to cyberspace" (QDR, ix). Accordingly, there exists an enduring requirement to support deployed forces with effective, state-of-the-art information and communications technology (ICT) capabilities. As the capabilities of ICT continue to increase, newer generations of warfighters have come to expect increasingly higher levels of technological capability on and off the battlefield. What these future capabilities will be, how to exploit them, and how to effectively deliver them poses challenge for decision-makers in the operational community as well as in the defense acquisitions community. This chapter will first briefly provide background information providing justification of this research. Next, it will define the purpose statement and define specific research questions to be explored. Then it will define the methodology throughout the entire research process and define the scope of the effort.

Background

A report from the National Defense University on the state of the ICT Industry states, "ICT is an all-encompassing term that combines the terms and concepts of information technology (IT) and electronic communications" (NDU, 2007:4). Literature on ICT and technology forecasting indicates increasingly rapid growth in all facets of technology (Kurzweil, 2001; Magee & Devezas, 2011; Nagy et al., 2011). Recent years have seen numerous paradigm-changing advances in ICT capabilities including smart phone technologies, ad hoc networking, cognitive networking, and cloud computing. These technologies show great potential for military application within the combat communication community deployed to austere environments where little to no existing infrastructure is available. Furthermore, research indicates that the capability of ICT has been increasing exponentially, a trend which is expected to continue for the foreseeable future (Tague et al., 1981; Nagy et al., 2011). This trend in information and communication technology supports the possibility of many more revolutionary innovations in ICT capability in the near future.

While this state of increasingly rapid advancement can invoke excitement about future breakthroughs in ICT, it also creates a great deal of uncertainty for decision makers who must allocate increasingly scarce resources to combat perceived threats to our national security. Furthermore, it carries significant implications towards the defense acquisitions community which relies on bureaucratic, time-consuming processes to validate and prioritize warfighter requirements and subsequently develop them into military capability. To illustrate, the Government Accountability Office (GAO) found that the Joint Capabilities Integration and Development System (JCIDS) "has not yet been effective in identifying and prioritizing warfighter needs" (2008:0). In addition, the 2010 QDR notes that "the conventional acquisitions process is too long and too cumbersome to fit the needs of the many systems that require continuous changes and upgrades" (xiv). Considering current trends in the mobile ICT industry, the Department of Defense is increasingly at risk of developing technical capabilities at considerable expense to meet perceived warfighter needs which become obsolete before they reach the battlefield.

Problem Statement

A main objective for the Department of Defense is to "buy weapons that are usable, affordable, and truly needed while ensuring that taxpayer dollars are spent wisely and responsibly" (QDR, 2010:iii). Decision makers require current and accurate technology forecasts to efficiently allocate scarce resources to generate those capabilities which are truly needed to maintain technological superiority over potential adversaries while avoiding wasteful spending on obsolete technologies. However, the effects of the rapid advancement of mobile ICT capabilities upon the combat communications community as well as the defense acquisitions community are not well understood. This research will develop a forecast on the future of mobile information and communication technology deployed in austere environments in 5-10 year, 10-20 year, and beyond 20 year timeframes. This forecast will aid decision makers in the combat communications community in future mission planning and resource allocation. Furthermore, it will investigate how this research may impact the defense acquisitions community with regards to mobile ICT technologies.

Research Questions

Two key issues will be investigated:

- What can we forecast for mobile ICT capabilities suitable for use in austere environments across 5-10 year, 10-20 year, and beyond 20 year timeframes?

- Will current acquisitions practices be adequate to meet the needs of warfighters who depend on mobile ICT? If not, what recommendations can be made?

Methodology

This effort will create a forecast of the capabilities of mobile, deployable ICT technologies suitable for use in an austere environment, as well as the timing of its occurrence using the Delphi technique. Additionally, it will explore potential impacts of the forecast upon the defense acquisitions community. The Delphi method was developed by the Rand Corporation at the beginning of the Cold War. It is a structured communication technique, originally developed as a systematic, interactive forecasting method which relies on a panel of experts well versed in a particular area of focus. Delphi is based on the principle that forecasts (or decisions) from a structured group of individuals are more accurate than those from unstructured groups (Woudenberg, 1991).

The first step for this effort is to conduct a review of literature pertaining to the Delphi method and trends in information and communications technologies. The next step is to identify a panel of experts who have extensive experience within the ICT industry. Next, this effort will include an anonymous, interactive electronic Delphi study with the panel on the future of ICT. Then, a technology forecast for mobile, deployable information and communications technologies within the 5-10 year, 10-20 year, and beyond 20 year timeframe will be generated.

In addition to the technology forecast, this research will investigate the impacts of future technological advancement upon the defense acquisitions community. The panel will investigate whether the current JCIDS process is adequate to maintain technological currency in comparison to rapid advancements within the private sector. If JCIDS is not adequate, the panel will investigate possible recommendations to senior Air Force leadership.

Scope of Research

This study's primary focus is mobile communications technology for use in austere environments rather than the ICT industry as a whole. The field of ICT is too large to address in its entirety, so it is impractical to select representative experts from every conceivable sector of the ICT industry, and it is unlikely we will be able to elicit the participation of an expert who transcends all disciplines within ICT. Therefore, the forecast may not apply to all military organizations due to the wide range of environments in which deployed forces may need to operate. Furthermore, this study will be conducted primarily utilizing experts external to the United States Air Force, such as the private sector, academia, and other government agencies. It excludes participation from military experts at the request of the sponsoring agency. Finally, this study will be purely qualitative in nature; no statistical analyses will be performed.

Summary

This chapter introduced the overall purpose of this thesis and provides a brief background on mobile ICT and the effects of its rapid advancement. The problem statement and research questions were defined providing direction towards the methodology. The methodology was declared followed by the research scope and limitations of the study. Chapter 2 contains the synthesis of relevant knowledge on the Delphi technique, communications technology forecasting, current trends in the ICT industry, exponential growth theory, and issues pertaining to the JCIDS process. Chapter 3 describes the Delphi technique in detail, explains why it was selected for use in this study, and the specific approach to gather research. Chapter 4 contains a summary of results from the Delphi panel responses. Finally, Chapter 5 provides a discussion of the findings, articulates conclusions ascertained from the panel's inputs and corresponding recommendations, presents limitations of the study, and suggests opportunities for further research.

II. Literature Review

Chapter Overview

This chapter provides a literature review of the key concepts pertaining to this research effort. First, it defines Information and Communication Technology (ICT) and establishes the importance of technology forecasting for decision makers. Next, it presents current trends within the ICT field and how they might affect a prediction on the future of the technology field. Then, it explores the accelerating growth in performance within the ICT industry and discusses its possible implications to defense acquisitions. It will discuss how technology development has transferred to the private sector. Then, it will discuss the Joint Capabilities Joint Capabilities Integration Development System (JCIDS) which is the processes used to verify and validate as well as prioritize user requirements. Finally, it will provide a review of the Delphi technique and how it can be used to address an important shortfall in JCIDS' ability to verify and validate user requirements in a timely manner, particularly in light of accelerating technological advancement.

Communication and the Impacts of ICT

Advancements in information and communications technologies have had a significant impact upon modern military operations. The Department of Defense states that "modern armed forces simply cannot conduct effective high-tempo operations without resilient, reliable information and communication networks and assured access to cyberspace" (QDR, 2010:ix). Therefore, an enduring requirement exists to support deployed forces with effective, state-of-the-art communications capabilities from forward operating bases.

From a national defense perspective, communication is "an enabling capability that is interwoven into every facet of military ops" (Wilson, 2007:7). A report from the National Defense University (NDU) on the state of the ICT Industry defines ICT as "an all-encompassing term that combines the terms/concepts of information technology (IT) and electronic communications" (NDU, 2007:4). On the global importance of ICT, the NDU states,

> Three conditions are particularly noteworthy in examining this industry. First, ICT has enabled growth globally. Second, and closely related, ICT has had a "flattening" effect, enabling countries to compete globally for ICT related work. Third, ICT has had a significant social impact throughout the world, and especially in the US. Taken together, these conditions convey that ICT is making a significant global impact. (NDU, 2007:4)

Importance of ICT Forecasting

Some may question the usefulness of expending resources towards forecasting revolutionary technologies in an era of increasing fiscal austerity. When faced with shrinking budgets, many would advocate the deferment of revolutionary and perceptibly high-risk technology development in favor of a more incremental approach using mature technologies which pose relatively little risk. Bishop et al. (2007:5) disagree when stating that "it is vitally important that we think deeply and creatively about the future, or else we run the risk of being surprised and unprepared." Albright (2002) points out that long-range technology forecasting can be an especially useful tool to assist decision-makers in ascertaining future solutions to yet unforeseen problems. He argues,

> Product and technology planners must look for disruptive innovations that could change the technical and economic playing field in an industry. In some cases, entire industries must be on the lookout for disruptive technical innovations that could change the basis of competition. More accurate forecasts can improve planning in all of these things. (2002:444)

It shouldn't be difficult to understand why decision-makers in both the private and public sector would want an accurate prediction on future technologies. The NDU (2007:4) report states,

> ICT continues to significantly influence world economies, world socio-cultures, and global governance, politics, and policies. This dynamic industry's impact on the world over the last 15 years is undeniable. Still, this industry has many challenges and only appropriate public policy that ensures its health and continued growth will enable it to continue its positive and lasting impact.

The NDU (2007:6) report adds "ICT is revolutionizing the way Americans work and interact socially. Today's American youth, who have never lived without computers or cell phones, will further steer both workplace and social network norms into uncharted territory." This visible trend can be expected to occur in the global environment, rather than only in the United States of America. Newer generations of warfighters have come to expect high levels of technological capability on and off the battlefield; given the significance ICT plays in our society, economy, and increasingly on the battlefield, accurate forecasts on the capabilities of future technologies as well as the demands of future users are critical in aiding decision-makers in operational planning and the efficient allocation of resources.

Current Trends in Mobile ICT

As ICT is becoming increasingly powerful, portable, and capable of ever-increasing data rates, the combination of modern mobile ICT with online social media has played a decisive role in numerous revolutionary conflicts overseas and is expected to increase (Lysenko & Desouza, 2012). Accordingly, Nokia Siemens Networks “expects mobile data traffic to grow 300-fold between 2009 and 2015” (Smura & Sorri, 2009:79). On an organizational scale, continuing advances in ad hoc networking are enabling scalable, robust multi-media capabilities for humanitarian relief and military operations in even the most austere environments (Ramanathan & Redi, 2002). Nelson et al. (2011) discuss the advent of Hastily Formed Networks, which made recent earthquake relief efforts in Haiti unique from prior relief deployments through the unprecedented usage of data-intensive technologies. Hastily Formed Networks are “portable IP-based networks which are deployed in the immediate aftermath of a disaster when normal communications infrastructure has been created or destroyed” (467). These networks were “small and lightweight enabling responders to physically carry them into hard-to-access areas, were created with commercially available technologies, energy independent, and flexible to adjust capabilities to match current needs” (468). Developments in cognitive radio technologies are enabling communication infrastructure to behave almost autonomously by interacting within its environment without human intervention (Gorcin & Arslan, 2008). Accordingly, networks are increasingly able to self-configure to optimize spectrum and bandwidth usage, adapt to user requirements, and even troubleshoot themselves (Fortuna & Mohorcic, 2009). These new capabilities have great potential to improve the capabilities of the combat communications community in terms of modularity, scalability, and adaptability while decreasing their logistical footprint in austere environments.

One other current trend showing promise as another potential paradigm shift is that of cloud computing. The National Institute of Standards and Technology (2010) defines cloud computing as "a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." Cloud computing is based upon the principle of considering ICT resources as a commodity rather than a firm asset. Using this concept, organizations can have the capability to rapidly upscale or downscale their ICT capacity to match changing operating requirements. A number of federal organizations are already incorporating cloud computing into their operations including the General Services Administration, the National Aeronautics and Space Administration, the Department of Health and Human Services, even the White House (Wyld, 2010).

Vivek Kundra, the U.S. Chief Information Officer, considers cloud computing a particular technology of interest. Accordingly, Kundra has directed various federal industries to begin institutionalizing it as a means to combat the federal government's generally low ICT asset utilization, fragmented demand, and asset redundancy while increasing efficiency, agility, and innovation (Kundra, 2011). Figure 1 compares the potential capabilities of widespread incorporation of cloud computing into federal services as compared with current ICT practices.

EFFICIENCY	
Cloud Benefits	**Current Environment**
• Improved asset utilization (server utilization > 60-70%) • Aggregated demand and accelerated system consolidation (e.g., Federal Data Center Consolidation Initiative) • Improved productivity in application development, application management, network, and end-user	• Low asset utilization (server utilization < 30% typical) • Fragmented demand and duplicative systems • Difficult-to-manage systems
AGILITY	
Cloud Benefits	**Current Environment**
• Purchase "as-a-service" from trusted cloud providers • Near-instantaneous increases and reductions in capacity • More responsive to urgent agency needs	• Years required to build data centers for new services • Months required to increase capacity of existing services
INNOVATION	
Cloud Benefits	**Current Environment**
• Shift focus from asset ownership to service management • Tap into private sector innovation • Encourages entrepreneurial culture • Better linked to emerging technologies (e.g., devices)	• Burdened by asset management • De-coupled from private sector innovation engines • Risk-adverse culture

Figure 1. Cloud benefits: Efficiency, Agility, Innovation (Kundra, 2011:3)

Kundra (2011:8) states that in traditional infrastructures, "IT service reliability is strongly dependent upon an organization's ability to predict service demand, which is not always possible." In his 2011 report on Federal Cloud Computing Strategy, he offers the example of "Cash for Clunkers" where government officials expected a demand of 250,000 inquiries over the life of the program. However, the system was overwhelmed by approximately 690,000 inquiries within the first three months of the program resulting in frequent system disruptions, which could have been reduced or eliminated altogether had the system been built with the ability for technicians to quickly increase its capability to meet the unexpectedly high user demand.

Kundra's (2011) report mainly concentrates on organizations utilizing ICT capabilities in the context of government services in the continental United States, but the concepts can be useful in austere environments as well. The rapid scalability provided by cloud computing can reduce instances where the demand for ICT resources outstrips limited supply, as well as avoiding instances where redundant equipment is unnecessarily deployed thereby creating a larger, more costly logistical footprint.

Nanotechnology: An Emerging Trend in ICT

A significant trend in ICT has begun to attract attention as possibly the next long-term growth area: the convergence of previously distinct technologies or solutions (Hacklin, Marxt, & Fahrni, 2009). Devezas et al. (2005:932) observe that "boundaries are becoming blurred between the biology, chemistry, and physics. Information technology is converging with the molecular technologies, that is, nanotechnology and biotechnology. Thus it appears that biology and chemistry are virtually turning into computer sciences." As ICT continually becomes smaller and more powerful, numerous technical disciplines have begun to converge into what researchers call nanotechnology. Tegart (2003:2) defines nanotechnology as "materials and systems whose structures and components exhibit novel and significantly improved physical, chemical, and biological properties, phenomena and processes due to their nanoscale size." Hacklin et al. (2009) predict this field may have a market exceeding $1 Trillion market within a decade.

Experts believe this emerging field may signify a revolution in ICT solutions (Tegart, 2003). Akyildiz & Jornet (2010:63) predict a future environment in which nanoscale devices will incorporate communications and networking technologies and ultimately connectivity to the internet, impacting "almost every field of our society, ranging from health care to homeland security or environmental protection." Albright (2002) also identifies nanotechnology as a key growth area. He applies his findings on enabling technologies to help forecasters make accurate predictions on tomorrow's ICT capabilities. Tegart (2003) illustrates how various scientific backgrounds, once distinct disciplines, have been converging over the previous decades as shown in Figure 2.

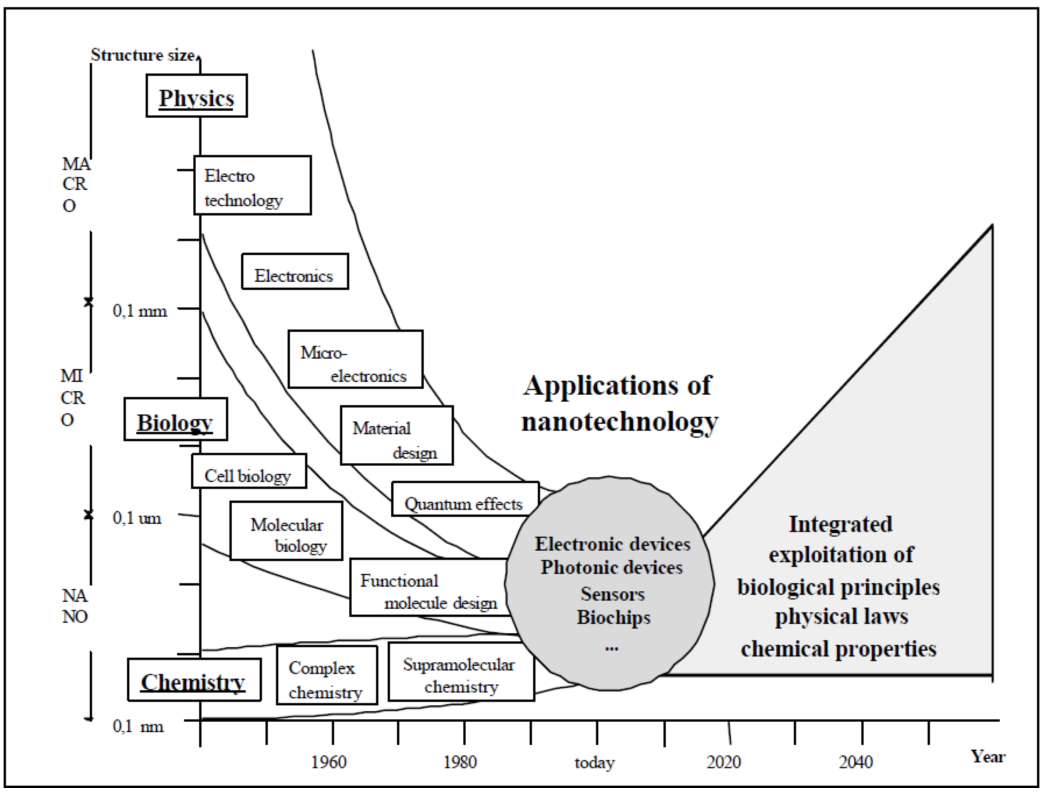

Figure 2. Physics, biology and chemistry meet in nanotechnology (Tegart, 2003)

Exponential Growth in ICT Capability

With the miniaturization of ICT and its increasing technical capability in recent decades, its impact on every aspect of our society is undeniable and is likely to result in profound impacts towards military operations in austere environments. Researchers are becoming increasingly aware that these capabilities are actually increasing in a predictable, albeit non-linear fashion. In fact, current studies show that the capability of ICT is increasing at an exponential rate. Merriam-Webster (2013) defines an "exponential" as that which is characterized by or being an extremely rapid increase (as in size or extent). Figure 3 graphically illustrates exponential growth as compared to linear growth and cubic growth.

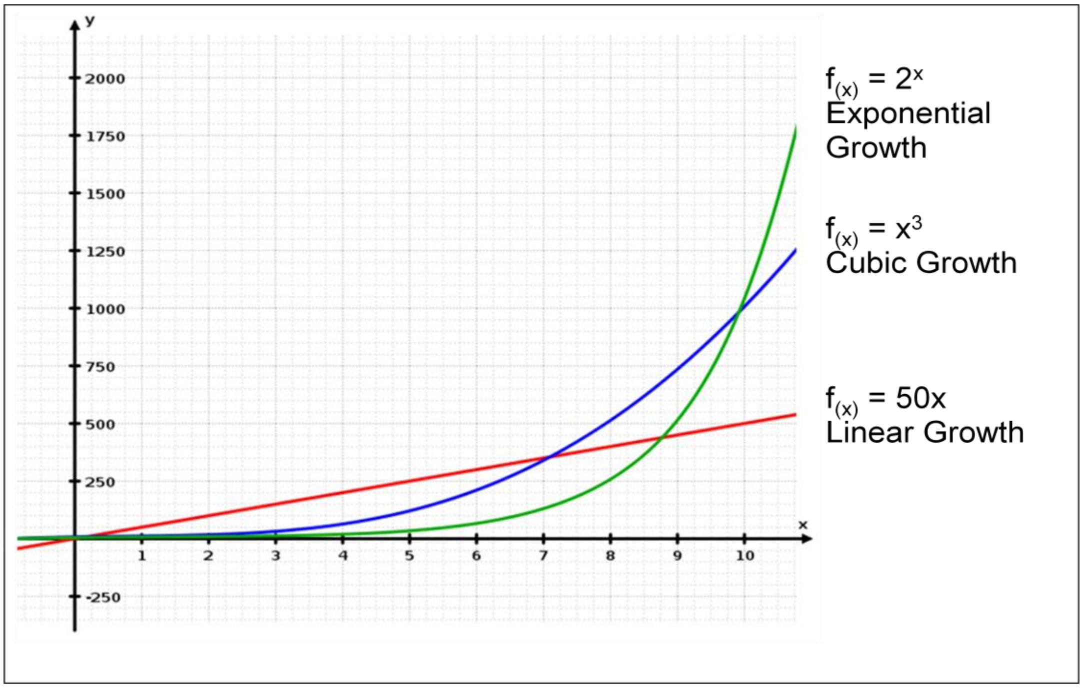

Figure 3. How exponential growth surpasses both linear and cubic growth. (Lunkwill, 2005)

There is an adage of a worker who requests initial payment of $0.01 per day for his labor. The condition for employment at such a reasonable starting salary is that each subsequent work day the payment amount doubles. As result, the worker initially brings home next to nothing for the first three weeks yet yields a daily paycheck of over $1 million by the end of the month, as seen in Figure 4.

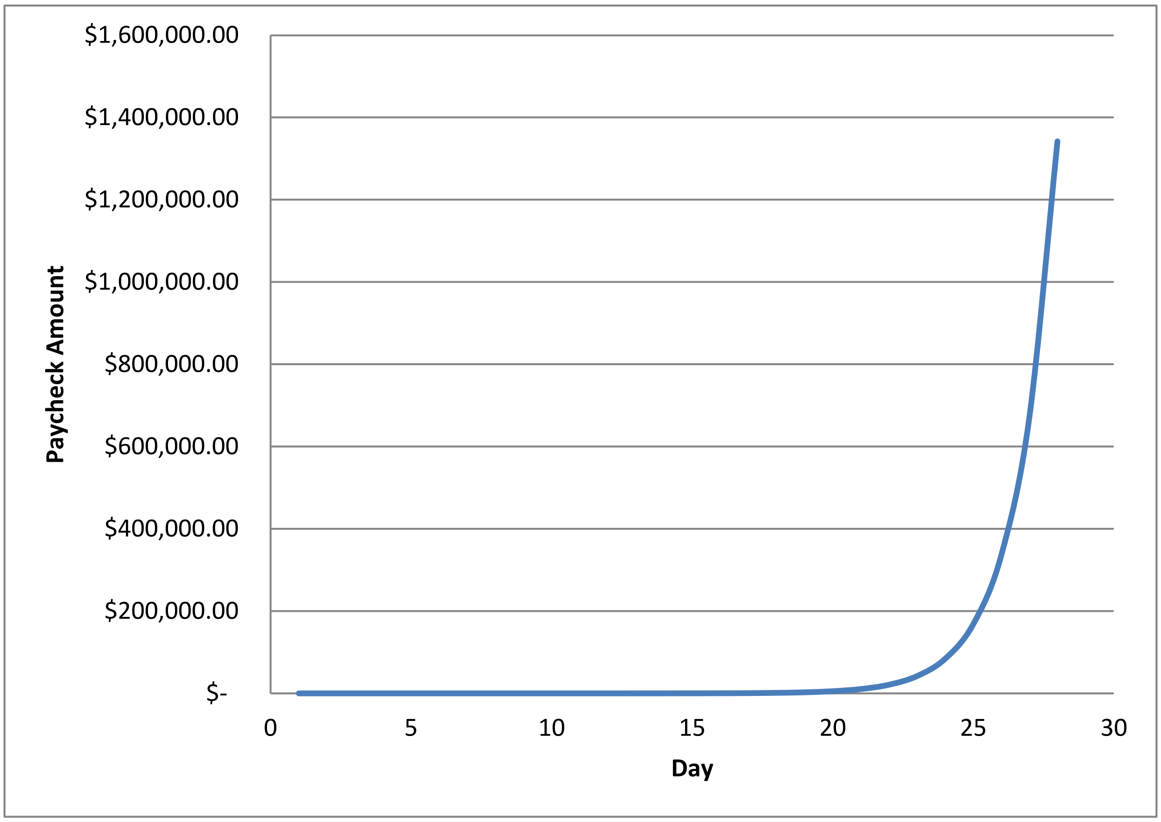

Figure 4. Exponential growth in the paycheck of the savvy worker

This example is a relatively simple illustration of the power of exponential growth; casual observers initially see seemingly negligible growth for a seemingly lengthy amount of time, but this growth eventually yields sudden, explosive, and accelerating growth. Over long periods of time, this rate of change is often indiscernible to people living through the early phases of an exponential growth trend. Kurzweil, a prominent author, inventor, and futurist, discusses in detail the exponential growth of human technology:

> The first technological steps-sharp edges, fire, the wheel-took tens of thousands of years. For people living in this era, there was little noticeable technological change in even a thousand years. By 1000 A.D., progress was much faster and a paradigm shift required only a century or two. In the nineteenth century, we saw more technological change than in the nine centuries preceding it. Then in the first twenty years of the twentieth century, we saw more advancement than in all of the nineteenth century. Now, paradigm shifts occur in only a few years time. The World Wide Web did not exist in anything like its present form just a few years ago; it didn't exist at all a decade ago. (2001:4)

Miranda & Lima (2012) believe that the inflection point of the exponential growth curve occurred in post-World War II era, around the year 1950. They assert:

> It was in this revolutionary new context that the modern ICT was nested. During the 1st two decades after the greater technological divider landmark year (1950), the improvements in transistor technology, the developments of magnetic tape drive, moving head disk drive, integrated circuits and the early bases of the electronic data computing, among so many other fundamental devices, as well as of influential computer languages, such as Fortran and Algol, set the stage for the explosive development of the information and communication sector... we are just apparently witnessing, these very days, the birth of a new radical change in ICT. (2012:748)

Another well-known example of exponential growth in the ICT field is that of Moore's law, which was developed in the 1960s and predicted that the number of transistors on a computer chip would double every 18 months (Moore, 1965). This trend has largely held true and is expected to continue until semiconductor technology reaches its theoretical limit when transistors are only a few atoms wide. There is a growing body of research giving support to the phenomena of exponential growth in capability in a number of enabling technologies within the ICT industry. Albright (2002) demonstrates this in the exponential growth in computing power and fiber optic bandwidth, as seen in Figures 5 and 6.

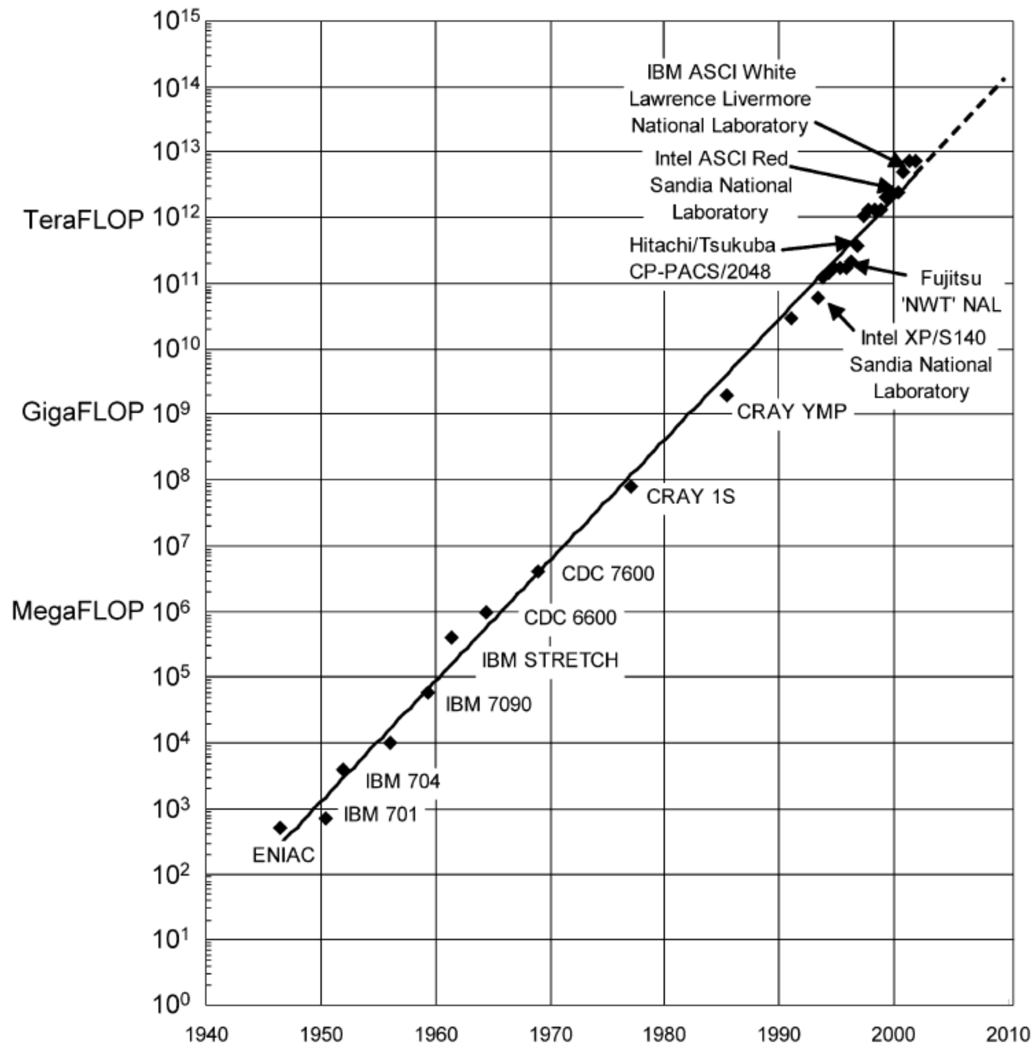

Figure 5. The power of the fastest computers has grown exponentially since the 1940s (Albright, 2002:455).

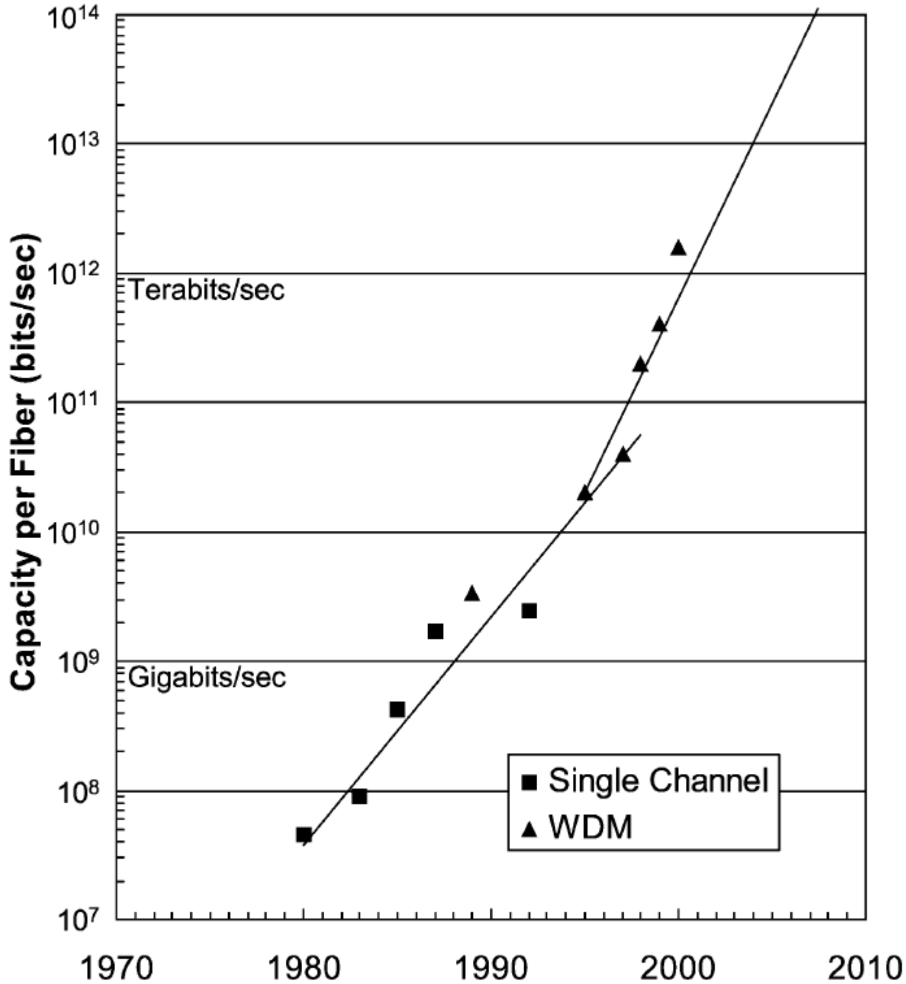

Figure 6. Optical transmission capacity has grown exponentially for 20 years (Albright, 2002:457)

Even more recently, Nagy et al. (2011) find that these trends are not be merely exponential, but may in fact be super-exponential. That is to say, the technological advancement shows an exponential trend within an exponential trend, across a range of measurable ICT capabilities. This rate of increasingly rapid change has led to the prediction of the emergence of a technological singularity in the ICT industry within our lifetime (Kurzweil, 2001; Magee and Devezas, 2011; Nagy et al., 2011). Kurzweil (2001:1) describes a technological singularity as "technological change so rapid and profound it represents a rupture in the fabric of human history." Those experiencing a singularity will observe technological advancement so rapid it will become nearly impossible to follow, much less predict, its impacts upon society.

The Department of Defense No Longer Drives Technological Advancement

Military standards, regulations commonly known in the United States as Mil-spec, have historically played an important role in the standardization of components and equipment inventoried by the Department of Defense (DoD). The DoD utilizes the Defense Standardization Program (2011) "to promote standardization of materiel, facilities, and engineering practices to improve military operational readiness, and reduce total ownership costs and acquisition cycle time." DoD 4120.24-M, DSP Policies and Procedures (2000) states that standardization helps to provide equipment that is interoperable, reliable, and technologically superior. However, keeping military standards current over time became difficult as military systems grew increasingly complex.

On June 29, 1994, the Secretary of Defense William Perry initiated acquisition reform which included efforts to begin the phase out of the use of Mil-specs in defense acquisitions. At a time when technology was beginning to advance at a rapid pace, Secretary Perry saw a possibility of more efficient use of national resources in military acquisitions in the form of performance based acquisitions. He recognized that the commercial sector was more effective at innovation and saw the value of utilizing more efficient commercial methods and technologies in the private sector to meet warfighter needs. This represented a major shift towards reliance on the commercial sector, particularly on the use of commercial standards rather than Mil-spec. Under performance based service acquisitions, warfighter needs were to be described as performance requirements rather than mandating highly detailed and often arduous Mil-specs which direct defense contractors on how to build a particular system. This was aimed to eliminate military-unique requirements which often added little value but substantial cost to defense acquisitions (Saunders, 2001).

In 1996, Walter Bergmann, Director of Acquisition Practices, Office of the Assistant Secretary of Defense, re-emphasized the importance of acquisition reform efforts which had begun two years earlier. He stated,

> We must remove impediments to getting state-of-the-art technology into our weapon systems. While we drove technology developments for many years, this largely is no longer the case. For many leading-edge technologies critical to battlefield success – such as information systems, telecommunications, and micro-electronics – the greatest advances are occurring in the commercial sector. (1996:32).

As technologies continue to advance at an increasingly rapid rate, the defense acquisitions community will likely continue to trend towards even greater reliance upon the commercial sector rather than organically developed capabilities.

The Joint Capabilities Joint Capabilities Integration Development System

The prospect of such rapid and profound change can generate a great deal of excitement. However, accelerating capability growth in the ICT industry poses a significant challenge to the defense acquisitions community as well as decision makers in the combat communications community who must plan and budget to meet emerging capability needs. The defense acquisitions community relies on an increasingly burdensome and lengthy acquisitions process to transform warfighter requirements into military capabilities using the Department of Defense (DoD) Decision Support System. This system is comprised of three interacting processes: the Joint Capabilities Integration Development System; the Planning, Programming, Budgeting, and Execution system; and the Defense Acquisition System, as shown in Figure 7.

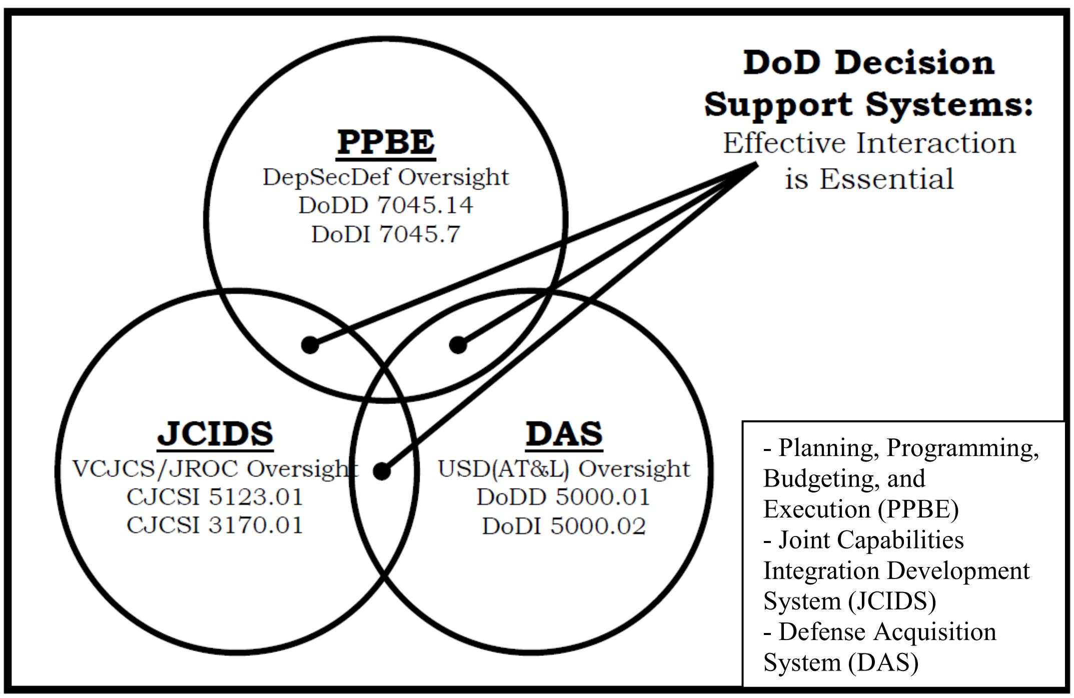

Figure 7. Three Critical Interacting Processes (CJCSI 3170.01H, 2012:A5)

The Planning, Programming, Budgeting, and Execution (PPBE) process allocates resources while the Defense Acquisition System (DAS) transforms validated requirements into capability solutions. These processes are outside the scope of this effort, but it is important to show their relation to the JCIDS process, which is responsible for "identifying, assessing, validating, and prioritizing joint military requirements" (CJCSI 3170.01H, 2012:1). It is this system that first identifies and validates a warfighter need before it can enter the formal acquisitions process to be developed into a materiel solution. JCIDS can reduce duplication of effort by forcing the services to consider materiel solutions from a joint perspective, as well as consider non-materiel solutions. The intent is to save resources to the maximum extent practical. However, in this process it begins to become clear just how significant an effect the accelerating growth of ICT can have on the acquisitions process as a whole.

The Government Accountability Office (GAO, 2008) highlights the ineffectiveness of JCIDS in indentifying and prioritizing warfighter needs in a timely manner. The findings contained in the report indicate that on average, this process requires upwards of ten months to validate a capability need once it has been submitted by a sponsoring agency. Considering that the sponsoring agency can spend over a year to draft and staff a capability needs assessment, the process can require as many as two years to fully validate a warfighter need, before it can enter the formal acquisitions process (GAO, 2008). Furthermore, Chyma (2010:13) estimates that "it can be expected to take at least five to six years from the time that a capability gap is identified to when a materiel solution is fielded under the best conditions." According to Chyma, this assumes that the capability is not technically complex, is not joint but service-unique, has a small budget and low visibility, and already has programmed funding.

These concerns are echoed in the 2010 QDR, which identifies DoD acquisitions as an institutional challenge. It states "the conventional acquisition process is too long and too cumbersome to fit the needs of the many systems that require continuous changes and upgrades – a challenge that will become only more pressing over time" (QDR, 2010:75). Larkowski (2009:1) observes that "the technology change is only getting faster…yet our mechanisms for spending money, allocating resources, and adapting to changing technology requirements is either unchanged or taking even longer to complete for each development cycle." Cherry (2010:18) furthers the dialogue to consider the impact of exponential growth on the acquisitions process and offers a chilling prediction:

> If Kurzweil is right, a capabilities development system that takes years to validate and approve will be obsolete before it can be fielded…furthermore, if our costs to address emerging threats continue to rise at current rates, while the barriers to entry for potential enemies continues to decline, we will find ourselves continuously responding to threats and unable to keep pace with increasingly sophisticated competitors.

Considering the growing body of research demonstrating that ICT capabilities are accelerating exponentially, it becomes clear that the JCIDS process will not be capable of keeping up with the rate of future advancement. One suggested approach is the formalization of some of the decentralized processes currently being used by Special Operations Command (SOCOM) and the Army's Rapid Equipping Force (Chyma, 2010). Another approach could be "the development of IT acquisition as a separate entity from both space and non-space acquisitions" (Larkowski, 2009:55). Still another recommended approach advocates scrubbing federal acquisition regulations to reduce bureaucratic hurdles (Cherry, 2010; Chyma, 2010). Though these approaches have merit as attempts to streamline the acquisitions processes as a whole, these approaches are lacking in pro-activity with regards to capturing requirements before a capability gap has been realized, much in the same way that JCIDS lacks pro-activity (GAO, 2008).

Rather than relying on the JCIDS process to validate a need once a capability gap has already been identified, it may be better to forecast future technology requirements before such a gap manifests itself. Zhu and Porter (2002) argue that governments should utilize technology forecasting considering the rapid pace of technological change amidst increasingly constrained budgets. Such a pro-active approach may effectively integrate into the JCIDS process to address potential capability gaps before they present themselves. The acquisitions community needs a method to pro-actively forecast future technologies and analyze them for useful military capability before capability gaps emerge, and before the acquisitions community expends increasingly scarce resources to deliver obsolete technology to the field.

The Delphi Method

Much has been written on the Delphi method since it was originally developed by the Rand Corporation in the 1950s. The method was originally used in an attempt at "the selection, from the point of view of a Soviet strategic planner, of an optimal US industrial target system, with a corresponding estimation of the number of atomic bombs required to reduce munitions output by a prescribed amount" (Rowe & Wright, 1999:354). Since then, it has been used extensively to assist decision makers by creating forecasts in a wide variety of disciplines in which other statistical methods are not possible or practical, or when reliable information is not readily available. Delphi is a structured communication technique which relies on an anonymous panel of experts who are well versed in a particular area to develop a forecast using multiple rounds of iterative feedback. Delphi is based on the principle that forecasts (or decisions) from a structured group of anonymous expert individuals are more accurate than those from unstructured groups or from a single expert. Details on the specific implementation of the Delphi Method for this research effort will be provided in Chapter 3.

Criticisms of Delphi.

The Delphi technique is not without its critics. Some researchers have declared a lack of evidence supporting its reliability as a scientific technique (Hasson et al., 2000; Williams and Webb, 1994). One specific concern pertains to the selection of panelists. First, it is difficult to define and measure those qualities which makes someone an expert (Clayton, 1997; Mishra et al., 2001). This challenge implies that the credibility of the overall research effort may be directly affected by the level of expertise the researcher may be able to obtain. Perhaps most importantly is its "grayness" as a technique which leads some to question its scientific rigor (Hasson and Keeney, 2011). Indeed, there is no firmly established method on how to conduct a Delphi study and the technique is frequently modified. McKenna and Keeney (2008) cite the numerous adaptations of Delphi as a main criticism threatening its reliability and validity. Further still, "every new application of the method involves the creation of a new measuring instrument" which can result in the possible introduction of variance with each new iteration (Zolingen and Klassen, 2003:329). These concerns highlight the importance of taking care to adequately define the expertise of panelists within context of the research effort and proper execution of the study.

Scientific Reliability of Delphi.

Still, even with its criticisms, the body of literature does lend the technique credibility as a reliable scientific technique. Some criticize Delphi as lacking replicability which may cause its reliability to suffer, but other research finds just the opposite. (Mitchell, 1991). Hasson and Keeney (2011) establish its external validity by showing it to pass test re-test reliability measures over time. Woudenberg (1991) shows that the Delphi technique is more accurate than unstructured interactions. Rowe and Wright (1999) further demonstrate reliability by analyzing existing studies on the technique. They show a 12 to 2 ratio of studies establishing the Delphi method as having scientific reliability to those which did not.

Further Strengths of Delphi.

The Delphi technique has a number of inherent strengths which help offset of its perceived weaknesses. First of all, whereas some consider the "grayness" of the technique as a weakness, it is considered to be strength in terms of its flexibility (Woudenberg, 1991). Additionally, the anonymous nature of Delphi allows for free exchange of thoughts and ideas between panelists without adverse social interactions such as conflict or groupthink, which are often seen in other structured communication techniques (Williams and Web, 1994). The iterative nature of Delphi allows experts to consider the inputs of others and allows them to revise their earlier statements which can give an overall greater range of response than with singular expert opinion (Williams and Web, 1994). In more recent times, speed has become a significant strength of the technique whereas it was once considered a weakness. Early Delphi studies required long lead times between iterations through the use of mail to disseminate questionnaires and responses, whereas the use of electronic media has drastically shortened the execution time. Studies have shown that a Delphi utilizing email or other electronic media can be conducted in as little as four weeks (Chou, 2002). Other potential strengths include the ability to assess contemporary developments, its relative simplicity, its ease of application in the absence of past data, and its cost effectiveness (Mishra et al., 2001).

Chapter Summary

This chapter defined communications and ICT as well as the impacts ICT has upon modern society. It then placed emphasis on the importance of forecasting ICT capabilities towards senior decision makers. Next, it discussed emerging trends in ICT, particularly in the field of nanotechnology and the exponential growth in ICT capabilities. Subsequently, it covered the JCIDS process and how the defense acquisitions community verifies and validates joint warfighter requirements in the challenges faced in light of accelerating growth. Finally, it discussed the Delphi method. The next chapter contains detailed information on the use of Delphi to collect data which will be used to generate a forecast of ICT.

III. Methodology

Chapter Overview

This chapter will discuss the rationale for choosing the Delphi method. Then it will discuss the success of previous key efforts using Delphi to forecast ICT. Then it will describe the panel of experts and how the research team derived the knowledge areas panelists will represent. Finally, it will describe the process on how the study will be implemented and the actual research instrument which will be disseminated to the expert panel.

Why the Delphi method?

It is a difficult task to create a reliable picture of the future in an environment of accelerating change with traditional forecasting methods, many of which rely on an existing past history. Past datum on the ICT field fall short in helping the forecaster to determine what lies ahead. Accordingly, the Delphi method "has become a fundamental tool for those in the area of technological forecasting" (Linstone and Turoff, 2002:11). Many researchers advocate the Delphi method in research involving subjects in which previous datum are unavailable or non-existent, but there is no shortage of experts on the subject. Rowe and Wright (2001:125) argue, "Expert opinion is often necessary in forecasting tasks because of a lack of appropriate or available information. One solution is to use a structured group technique, such as Delphi, for eliciting and combining expert judgments." Oliver et al. (2002:2) argue that "Delphi is best suited for evaluating the alternatives of some definable although not necessarily narrow issue in which the expertise of experts is of particular value."   Finally, Mishra, Deshmukh, and Vrat (2002) performed an analysis to match forecasting techniques with specific technologies. In this study, the authors found the Delphi method to be a particularly good fit for IT-related studies. Mitchell (1991) further advocates the use of Delphi when a topic experiences a large degree of product innovation and change, as well as when industries are subject to forces difficult to quantify and a lack historical data.

Past Efforts in ICT Forecasting Using Delphi

Attempting to predict the future of technological advancement is "difficult but not impossible" (Albright, 2002:540). In fact, research shows that predicting the future capability of ICT in particular can be accomplished with a higher degree of accuracy than other technical or non-technical fields. An often cited technology forecast using a variation of the Delphi method was authored in 1967 by Herman Kahn and Anthony Weiner (1967) which offered a technology forecast for new innovations for the latter third of the twentieth century. Albright (2002) used the Delphi method with a panel of eight technical experts to categorize Kahn and Weiner's predictions into topical areas and judge the accuracy of their prediction. His panel judged that over 80% of Kahn and Weiner's predictions of the capabilities of ICT have occurred, whereas roughly half of the rest of the predictions in other fields have been judged to have occurred. The results of the success of this study are shown in Figure 8.

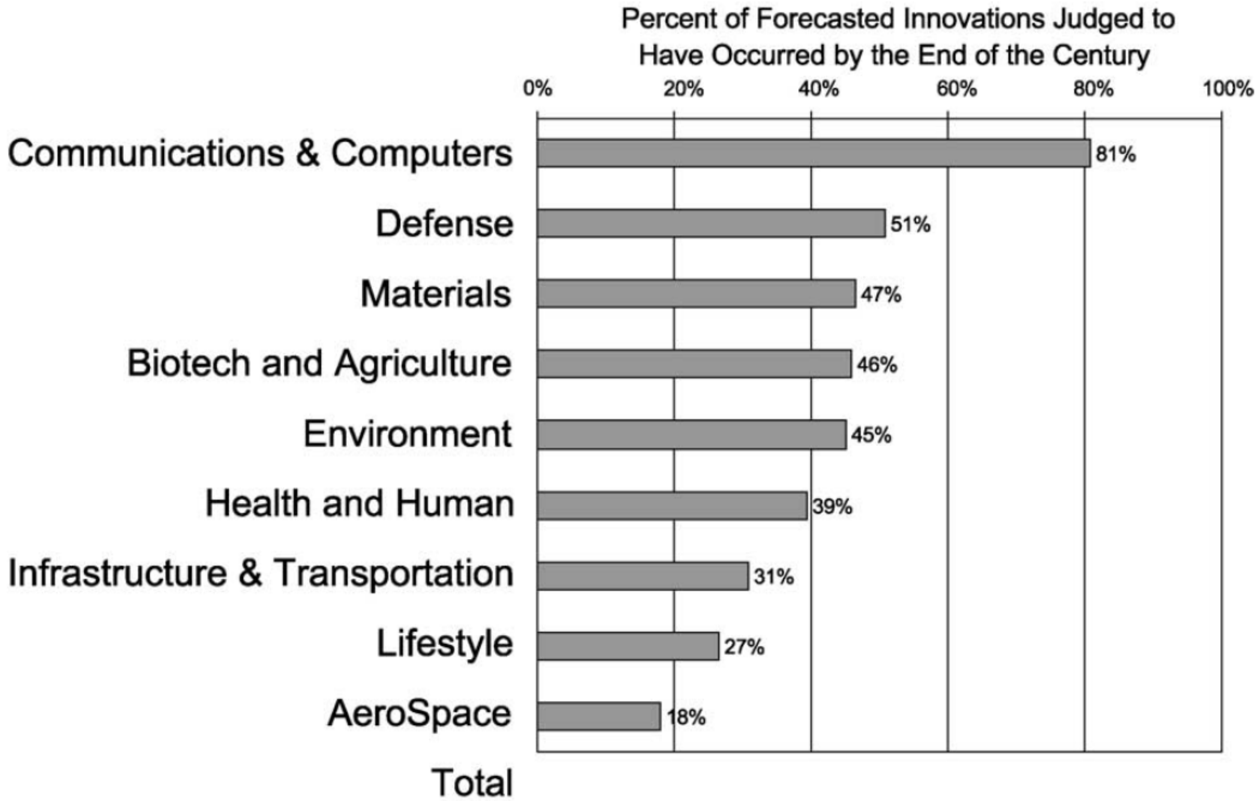

Figure 8. The quality of forecasts varied across topical areas (Albright, 2002:446)

Albright (2002) analyzed the underlying reasons as to apparent success in predicting the future of ICT capabilities and suggested methods with which future technologists can improve their own forecasts. He postulates that forecasts in ICT tend to have a much higher rate of accuracy than other types of forecasts due to the somewhat predictable trends in enabling technologies. He states that "sustained trends in enabling technologies that were apparent in the late 1960s enabled the forecasters to extrapolate trends with a high degree of accuracy" (Albright, 2002:446). He reasons that when seeking to improve future forecasting methodologies, one should specifically focus on long-term trends in current enabling technologies. For example, the explosive growth in bandwidth and computing power has followed a predictable trend; applying this as part of a defined methodology can help researchers make predictions grounded in reality rather than wishful thinking, thereby avoiding Schnarr's trap of technological wonder—where forecasters generate an unrealistic prediction based on imagination or wishful thinking.

The Five Knowledge Areas

The NDU (2007:17) presents four major categories which comprise the ICT industry. These include hardware, software, information services, and communications. It further divides these categories into sectors such as cable, telecommunications, manufacturing, cellular phones, software, computer and networking hardware, the Internet, data storage, as well as associated services and applications. In the context of the report, these categories were developed by the NDU to capture the state of the ICT industry as it exists in the present. However, the research question being investigated pertains to the predicted capabilities of ICT in future states. Certain knowledge areas which would be useful in generating a forecast, such as analyzing trends, generating revolutionary concepts, and basic and applied research, did not seem to be well represented in the existing categories as defined. Therefore, we examined the major categories of the ICT field and derived five general knowledge areas which described the sectors defined by the NDU which would be more practical for generating a forecast on future capabilities. These knowledge areas include Concept Design & Demand, Research and Intellectual, Technology, Application, and Employment. These five knowledge areas represent a spectrum of perspectives within the ICT industry as recommended by Linstone and Turoff (2011) who advocate the importance of capturing multiple disciplines and their expert perspectives in the analysis of a complex issue. Table 1 describes the knowledge areas.

Table 1. Description of Knowledge Areas

Knowledge Area	**Expertise**	**Potential Sources**
Concept Design and Demand	Predict trends in user needs	Marketing Market research Product testing Science fiction Professional futurists
Intellectual and Research	Generate ideas, basic & applied research	Advanced Research Academia Think tanks
Technology	Development of new physical capabilities	Telecom industry Networking Hardware producers Consumer devices
Application	Apply existing technologies in new ways	Industrial innovation App development Social networking Software engineering
Employment	User/consumer of technology who applies technology to accomplish a mission	International corporations Humanitarian organizations News and Information

These knowledge areas will often follow a logical progression as shown in Figure 9. Experts in the Concept Design/Demand knowledge area develop the concept of a user need not yet established or demand not currently being met. Secondly, the experts within the Research knowledge area develop the necessary enabling technologies required to support a potential concept. After adequately refining and maturing the enabling technologies, experts within the Technology knowledge area develop the product from research into a physical capability. Next, those experts in the Application knowledge area develop new applications or uses for new or existing technologies in ways to fulfill a need or complete or improve upon a process. Finally, those in the Employment knowledge area use the completed technology or capability to accomplish a mission as well as provide feedback on desired capabilities not currently being met. It would also be logical to assume that evolutionary developments in existing technologies, applications or processes could be improved upon at any point of this model. One example would be when warfighters utilized chat room capabilities during early days of Operation Iraqi Freedom. The technology already existed in some form; it was simply being used in new ways (application) to accomplish a mission (employment).

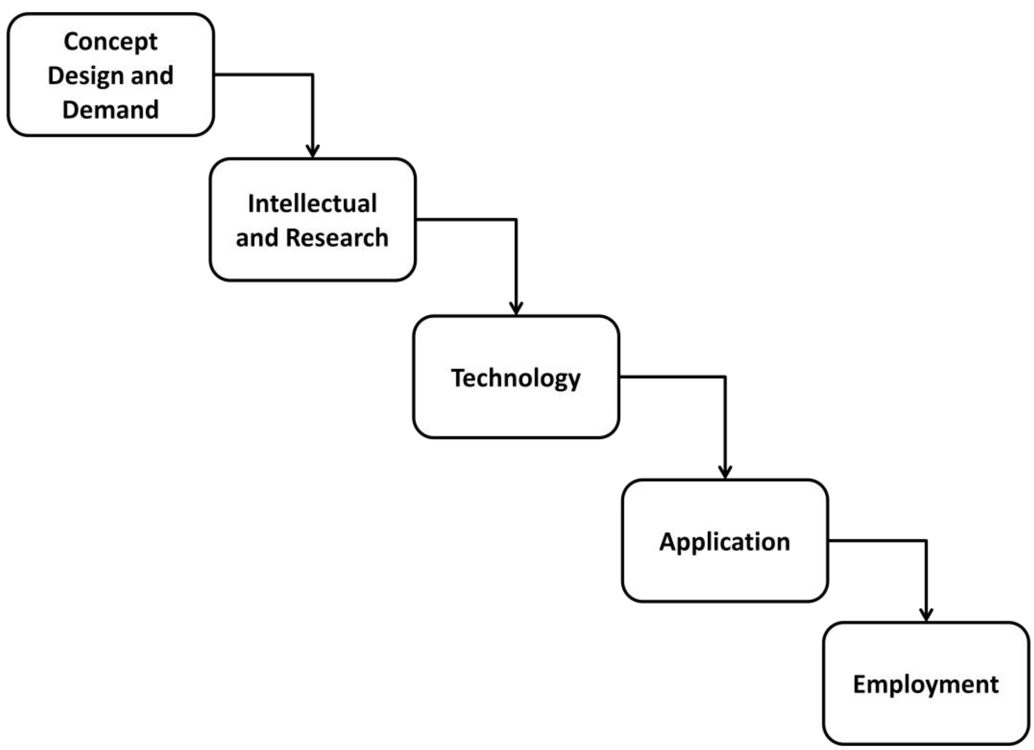

Figure 9: The ICT Capability Creation model

Number of Panelists

There is no firm agreement on how many panelists are required for an effective Delphi (William and Webb, 1994). Studies show Delphi panels typically use between 15-20 respondents (Ludwig, 1997). Chan et al. (2001) find ten members to be an adequate number of panelists to represent a sufficiently wide distribution of opinion. On the other hand, some studies show no consistent relationship between panel size and effectiveness (Brockhoff, 1975; Bojoe & Mornighan, 1982). Regarding the minimum number of panelists, Des Marchais (1999) indicates a minimum of six. In comparison, Rowe and Wright (1999) indicate a minimum of five is required for the panel. The target panel size for this study was 12 confirmed panelists.

Targeted Demographics of the Panel of Experts

The previous chapter described the difficulty of defining those criteria that makes someone an expert in a particular area of focus. Merriam-Webster (2012) defines an expert as “one with the special skill or knowledge representing mastery of a particular subject.” For the purposes of this study, we use Mitchell’s (1999) definition of an expert as one who has had a significant amount of involvement within the industry, both past and present. Many studies offer a recommendation of a minimum of five years of specific experience in the particular industry, which was used as the defining factor, though most panelists exceeded this criterion (Mitchell, 1991; Rowe and Wright, 1999; Dawson & Brucker, 2001). Other factors include level of education, current duty title, and previous experience in primary expertise. Ten weeks were spent developing an extensive list of potential panelists across the five knowledge areas using the internet, academic journals, and through social networking. Upon completion of the list of potential candidates, the list was reviewed with the sponsoring agency to develop a prioritized list of candidates.

Conducting the Delphi

To conduct a Delphi study, the research team first defines the problem to be investigated. For this research effort, it is to determine the future of mobile communications while addressing the research questions proposed in Chapter 1. Secondly, the research team must select panel members based upon their experience with the area of focus. After the panel has been formalized, the next step is to develop the research instrument and distribute it to the panel. The study instruments used in this research effort for each round can be found in appendices A through C. This instrument was based upon the model recommended by both Rowe and Wright (1999) and Clayton (1997) in that the first round is generic and largely unstructured, allowing the individual panelists a wide degree of latitude to explore the question. This approach gives the panelists the opportunity to identify issues they believe are most relevant and gives them the autonomy in freedom of response.

Panelists were given two weeks to formulate their responses and return them to via email. Once all responses were collected, the results were aggregated to find common themes. The overall results were then consolidated into a single narrative. This step signified the end of round one. Round two was initiated when the narrative was returned to the panelists for review. The panelists were given two weeks to review and comment on the single narrative. Additionally, a set of revised comments pertaining to the results from round 1 from an acquisitions perspective was included for comment. Once the round 2 comments were returned by the panelists, the results were again analyzed to see if consensus or stability has been achieved. This step signified the end of round two. The responses were once again aggregated and returned to the panel as a revised narrative, initiating round three. Additionally, a series of short narratives resulting from the aggregation of the responses to the acquisitions-related questions presented in round two was included for review and comment. The panelists were once again given two weeks to further review the responses from the rest of the panel and revise their responses and comment upon the short narratives. Upon receipt of the revised responses to the revised narrative as well as the four acquisitions-related narratives, the content was analyzed. This signified the end of round three and subsequently the end of the Delphi study. Figure 10 graphically depicts the traditional Delphi process.

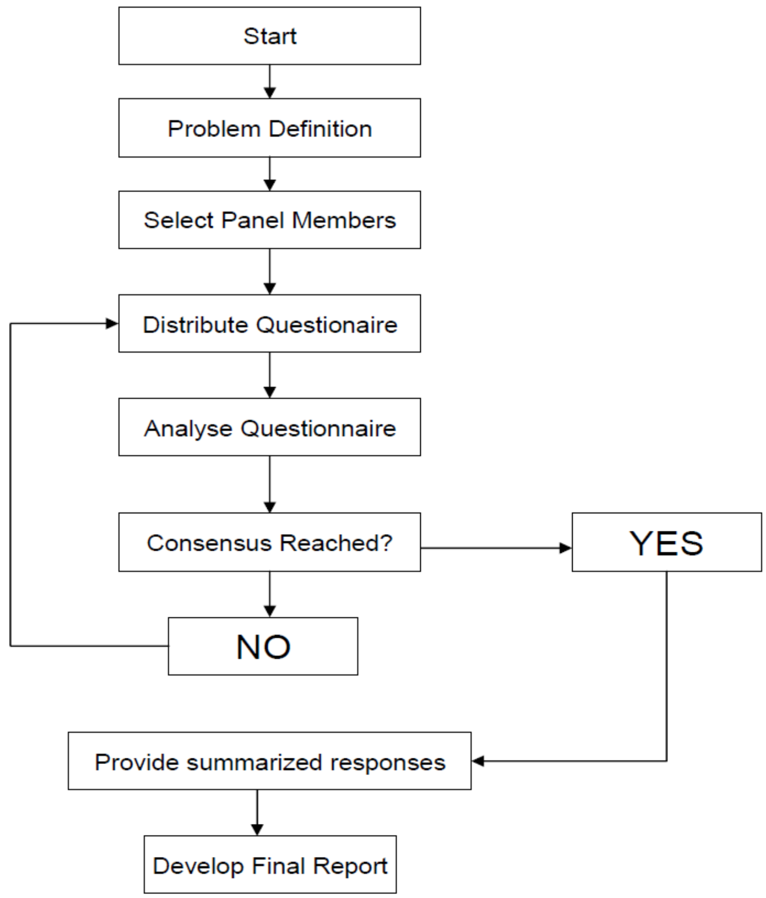

Figure 10: The Delphi Approach (Neal, 2004)

The literature indicates that while many researchers will strive towards consensus, others argue that researchers should strive for stability in panelist response rather than consensus as a measure of achieving success (Rowe and Wright, 2001; Linstone and Turoff, 2011). That is, if experts have a divergence of opinion, they suggest that it would be a mistake to hold additional rounds in hopes of forcing panelists to amend their responses if they have a good basis to refuse to further amend their responses to shift towards consensus.

Number of Rounds

There is no general consensus on the number of rounds required to execute a successful Delphi, but studies show this to be ideally between two and four rounds. Rowe and Wright show that three rounds are generally sufficient (1999, 2001). Erffmeyer, Effmeyer and Lane (1986) find the quality of estimates actually begins to decrease after the fourth round. For this effort, it is estimated that no more than three rounds would be required, including the opening round and two iterations.

Summary

This chapter discussed why the Delphi method was chosen to generate the forecast on the future of mobile information and communication technology and highlighted previous successes in using this method for ICT forecasting. Then, it discussed the five knowledge areas, the panel of experts, as well as the specific research instrument used to collect data. Next, it discussed the specific implementation of the Delphi study itself. The next chapter will present the results of the finished Delphi study.

IV. Analysis and Results

Chapter Overview

This chapter provides the make-up of the panel of experts and presents the results by round from the study. This study consisted of three rounds. Round 1 gathered basic information on the panelists and presented basic, open-ended questions to the panelists on the future of ICT deployed in austere environments. The responses were then aggregated into a single narrative. For round 2, the single narrative was given back to the panelists for review and further comment. Additionally, round 2 presented four questions with an acquisitions perspective pertaining to the narrative which addressed the research questions proposed in Chapter 1. The responses to the single narrative were incorporated into a revised narrative, and the responses to the four questions were aggregated into four short narratives. For round 3, the revised narrative and the four acquisitions narratives were presented for further comment. After the third round, the revised narrative and the four short narratives from an acquisitions perspective were further revised into final narratives. All research instruments in the form in which they were given to panelists can be found in appendices A through C.

During the execution of each round, panelists were presented with a research instrument that covered all three timeframes. That is, panelists were asked to comment on the forecasts for 5-10 years, 10-20 years, and beyond 20 years, in that order, during the execution of each individual round. For enhanced readability, this paper presents the results grouped into timeframes and how each the forecast for each individual timeframe developed through the execution of the study rather than by individual round. For example, the results for the 5-10 year timeframe are presented by round 1, then how the forecast changed for round 2, then final revisions for round 3. Then, the results for the 10-20 year and the beyond 20 year timeframes are presented in a similar fashion.

The Panel of Experts

As stated in chapter 3, the goal for the size of the panel of experts was twelve panelists. Twenty-five panelists were contacted directly asking for their participation and eleven panelists indicated an interest in participation for the study prior to the initiation of round 1. However, participant attrition is a known and common issue with studies using methodologies such as Delphi (Mitchel, 1991). This study was no different. One panelist later dropped out immediately upon receipt of the round 1 research instrument due to sudden difficulties in occupational responsibilities. Two others did not respond once the study began and were considered to have dropped out upon completion of the first round. As such, the study was initiated with eight panelists.

The research sponsor requested a higher proportion of those experts from the application and employment knowledge areas. Two of the eight panelists were from application and two were from employment, comprising half of the panel. All panelists have over 20 years of expertise in their field. The general demographics of the panel are depicted in table 2.

Table 2. The Panel of Experts

Panelist Number	Knowledge Area	Primary Expertise	Years of Experience
1	Concept Development/ Demand	Foresight methods, organizational foresight	20
2	Intellectual/ Research	Defense electronics, communications, signal processing	40
3	Intellectual/ Research	Information and System Security	20
4	Technology	Deployable Communications and Information Systems	20
5	Application	Supercomputing-based intelligence analysis systems	20
6	Application	Telecommunications, Innovation Science and Operations Management	20
7	Employment	Wireless Communications	20
8	Employment	Computer Engineering	20

The Future of ICT Deployed in Austere Environments: 5-10 Years.

Round 1 Results for the 5-10 Year Timeframe.

Initial responses on the future of ICT deployed in austere environments forecast indicated that technologies will trend towards smaller, faster, and cheaper devices akin to handheld tablets and smart phones. Technology convergence and the increased use of applications and data services will reduce the size and amount of dedicated communication equipment and lessen the logistical footprint and overall necessary infrastructure.

Everything over Internet Protocol (EoIP) will be the medium of choice for voice, data, and video. Exponential increases in user demand for bandwidth will drive advances in satellite technologies. In austere environments, satellite communications will be the backbone infrastructure of choice, though linked drones may offer a viable alternative. Increases in satellite bandwidth and cloud computing will enable linkage to global networks. Advancements in cyber security will enable low probability of intercept/low probability of detection as well as anti-jamming capabilities. Finally, a number of responses indicated that there will be incremental advancements in remote power generation, including fuel cells, improved solar, and batteries.

Round 2 Results for the 5-10 Year Timeframe.

For round 2, responses for round 1 for the 5-10 year timeframe were aggregated into a single narrative. This single narrative was fed back to the panelists for review and further comment. The forecast for the future of ICT deployed in austere environments in 5-10 years produced some divergent opinions in several key areas. First, there was a degree of divergence in how advancements in ICT would impact the logistical footprint of combat communications operations. There was no disagreement pertaining to the trend towards smaller and faster devices and technology convergence replacing dedicated equipment which led to the prediction of a smaller footprint. However, some panelists indicated that infrastructure may actually become larger and more complex due to the increased bandwidth demands of device to device communications, increased use of unmanned aerial vehicles, robots, sensors, etc.

Another topic which generated disagreement among panelists pertained to the role of satellite technologies in this timeframe. Initial discussions led to the conclusion that advancements in satellite technologies would enable it to become the backbone of choice. There was sharp disagreement in this assessment. While many still expressed confidence in the future of satellites, some expressed concerns such as limitations in bandwidth as compared to other methods currently in use. Additionally, satellites are vulnerable to jamming by peer nations. These disadvantages may necessitate the development of alternatives such as optical transmission and Very High Frequency (VHF) technologies, as well as linked drones which could be utilized as mobile, autonomous signal repeaters to perform reach back to a distant, more established infrastructure.

There were some concerns about confidence in predicted advancements in cyber security. Panelists with experience in this field indicated that while advancements are likely, potential adversaries can also be expected to adapt or develop new tactics to overcome them. In effect, they indicated that the threat towards cyber security can be expected to remain constant over time.

Finally, panelists introduced a new topic of discussion, green technologies. Improved solar capabilities and batteries are likely to experience advancements which will supplement power generation and storage in austere environments.

Round 3 Results for the 5-10 Year Timeframe.

For round 3, the feedback on the single narrative was collected and incorporated into a revised narrative for the 5-10 year timeframe. This revised narrative was fed back to the panelists for further review and comment to ensure that comments were captured correctly and determine whether or not any further issues needed to be explored. Several areas were expanded upon in round 3. First, panelists continued to discuss the future of infrastructure in austere environments, due to the proliferation of device to device communications, unmanned aerial vehicles, robots, sensors, etc. The panelist responses seem to indicate that the trends towards smaller, highly portable equipment and technology convergence with data services and applications to replace dedicated equipment may be offset by exponential increases in bandwidth demands. These demands may in fact increase the complexity of infrastructure, rather than decrease it. However, subnets and gateways will become more modular, adaptable, and autonomous which will increase access and capabilities.

Secondly, there was continued discussion on the role of satellite technologies in austere environments, resulting in two possible scenarios. Some panelists cited current trends and advancements in satellite technologies in terms of bandwidth and security are expected to continue well into the future. However, some panelists continued to cite the inherent vulnerabilities and connection limitations due to environmental factors such as foliated canopies, inside buildings, and underwater. Panelists who shared these views stood by their assessment that technologies such as linked drones, optical transmission, and Very High Radio Frequencies (VHRF) technologies will be developed as alternatives which will surpass the perceived limitations of satellites. These options, however, may be heavily reliant upon sufficient funding, particularly from the U.S. government as their usefulness in the private sector may be limited. If funding is not sufficient, then it is probable that satellites will remain as the austere environmental infrastructure backbone.

Finally, there was further expansion of the suggested incorporation of higher usage of green technologies in austere environments. Many suggested that the future capabilities of green technologies such as wind and solar may be insufficient to meet the power needs of deployed forces on a large scale. Therefore, if green technologies display a slower, incremental rate of advancement, there may be limitations in their potential to present a distinct military advantage over peer nation adversaries, thereby prompting continued reliance upon more traditional methods of power generation and storage.

The Future of ICT Deployed in Austere Environments: 10-20 Years

Round 1 Results for the 10-20 Year Timeframe.

Initial responses towards the future of ICT deployed in austere environments for the 10-20 year timeframe indicated that mobile devices will proliferate. Miniature, wearable computing devices may advance to the point where they approximate human mental capabilities. Human-technology interfaces will progress towards sensory applications (visual, tactile, etc), possibly even biological in nature.

Infrastructure will include robust global ICT capabilities and further reductions in necessary deployable communications equipment. Commercial entities will provide communication mediums with much broader global coverage, driven largely by market forces and demand for technology by local populations in austere locations where such technology is currently unavailable. Satellite technology will continue to progress allowing for constant network connectivity and very high data rates. There will be advancements in specialized communication mediums, including optical communications, space, underwater, underground, foliated canopy, and GPS-denied territories.

Advancements in remote power generation will include wireless power technology and nuclear batteries. For individual technologies, devices become low-power, charged by physical movement, respiration, possibly even using electro-chemical methods such as human blood sugars.

Round 2 Results for the 10-20 Year Timeframe.

For round 2, responses for round 1 for the 10-20 year timeframe were aggregated into a single narrative. This single narrative was fed back to the panelists for review and further comment. Feedback from round 2 indicated that global infrastructure can be expected to grow and evolve in attempts to sustain global ICT capabilities. Constant network connectivity and very high data rates may be obtained through ad hoc topologies employing devices as both individual consumers and as inter-networked components of a global network. However, a fully integrated global network may not be achievable in this timeframe as originally predicted. Required deployable communications may not diminish but will change in size, capability, and purpose.

This round uncovered divergence regarding deployed forces utilizing expanded network connectivity occurring due to market forces. Though areas currently considered austere in terms of an ICT perspective may in fact become much less so, many panelists expressed concerns about deployed forces relying on network connectivity developed by commercial entities. Responses indicated that this type of connectivity may carry significant security risk to deployed forces stemming from persistent social, political, and economic instability in many parts of the globe, at least as a primary source of connectivity. Furthermore, despite the increase in demand, some areas may remain un-served by the commercial sector due to poor projected profits resulting in the continued need for an organic military capability.

Finally, panelists introduced a new topic of discussion for this time frame, green technologies. Alternatively, advances in power generation will focus on fuel cells, wind, and solar for austere environments. It was also suggested that the earlier prediction for large scale wireless power may not be feasible due to radio frequency interference and possible adverse health effects as seen in current generations of this technology. These issues will need to be overcome if this is to become a viable option for deployed forces.

Round 3 Results for the 10-20 Year Timeframe.

For round 3, the feedback on the single narrative was collected and incorporated into a revised narrative for the 10-20 year timeframe. This revised narrative was fed back to the panelists for further review and comment to ensure that comments were captured correctly and determine whether or not any further issues needed to be explored. There was further expansion suggesting the incorporation of higher usage of green technologies in austere environments in this timeframe. Some panelists continued to predict the expansion of usage of green technologies. However, many suggested that the future capabilities of green technologies such as wind and solar may be insufficient to meet the power needs of deployed forces on a large scale and therefore will not be used in austere environments on a large scale within 20 years. There was some late discussion on thorium-based nuclear power generation. Otherwise, round 3 experienced relatively little expansion upon the results obtained in the previous round for this time frame.

The Future of ICT Deployed in Austere Environments: Beyond 20 Years

Round 1 Results for the Beyond 20 Year Timeframe.

Initial responses indicated that the sensory integration of small ICT devices will be mature technology, possibly even implantable. Displays will be holographic using physical motion as the keyboard, mouse, and similar technologies will have become obsolete. Crystalline storage systems will be developed. The global environment will have few locations which will be considered to be austere from an ICT perspective. Specialized communications disciplines such as combat communications may be eliminated as network connectivity will be global and mobility therefore becomes transparent. Users will have personal satellite uplinks. Networks will be enabled with robust satellite defenses, smart security, and cloud protection.

Round 2 Results for the Beyond 20 Year Timeframe.

For round 2, responses for round 1 for the beyond 20 year timeframe were aggregated into a single narrative. This single narrative was fed back to the panelists for review and further comment. The integration of small ICT devices was expanded upon in that they will also be interconnected. This will require robust security due to the potential for severe negative impacts should they be compromised.

Data archival methods were further explored. Rather than specifying crystalline storage devices, discussions indicated that any technologies will simply be multiple generations beyond current capabilities. This will allow users to securely store and retrieve data with an accessible lifespan of 50-100 years.

Panelists introduced a new topic of discussion for this time frame, manufacturing materials and environmental factors. New materials crucial to ICT manufacturing will need to be explored due to the possible scarcity of precious metals and petroleum products used in current manufacturing techniques. Furthermore, the negative environmental impacts from the mining of these materials and the continued use of petroleum products for their manufacture and disposal will need to be considered.

Finally, panelists expanded upon the notion that few locations will be considered austere from an ICT perspective. Austerity as it pertains to mobile or deployable ICT will be more of an occurrence of an event within an environment, rather than a characteristic of a particular location as advances in global networking technologies will have made mobility transparent. Events such as natural disasters, power grid failures, war, etc., are all potential situations which may render an otherwise “developed” area austere.

Round 3 Results for the Beyond 20 Year Timeframe.

For round 3, the feedback on the single narrative was collected and incorporated into a revised narrative for the 5-10 year timeframe. This revised narrative was fed back to the panelists for further review and comment to ensure that comments were captured correctly and determine whether or not any further issues needed to be explored. Individual devices may draw sufficiently low amounts of power that physical movement, respiration, possibly even electro-chemical methods other than batteries may be viable. This prediction was originally proposed in the 10-20 year timeframe resulting from round 2, but has been moved to this time-frame. Otherwise, round 3 experienced relatively little expansion upon the results obtained in the previous round for this time-frame.

Research Questions from an Acquisitions Perspective

After the completion of round 1 and development of a derived narrative forecasting the future of deployed ICT in austere environments, round 2 presented basic background on the JCIDS process as well as four questions the second research objective proposed in Chapter 1, section 1.3. These questions investigated the following issues:

- What would be a reasonable target timeframe to develop a new technology to a fielded capability in order to stay up to date with regards to technology in 5-10, 10-20, and beyond 20 years?
- Can you foresee a time when the defense acquisitions community will be required to rely almost exclusively upon technology developed commercially to stay current with technology trends?
- Rather than developing dedicated equipment for a specific function or capability, imagine an acquisitions model similar to the app stores currently in use in the private sector, where programmers can create apps and upload them to an online repository which can be vetted and approved by the Department of Defense. Is this model feasible, and if so, what is a practical timeframe?
- Is it still practical for a large organization to expend significant resources to plan and budget beyond 5-10 years? If so, what challenges would senior leaders need to overcome in order to be more proactive? If not, would it be more practical to focus on developing the organization flexibility to adapt to technologies as they emerge?

These questions comprised part II of the research instrument for rounds 2 and 3. All research instruments in the form in which they were given to panelists can be found in appendices A through C. Panelist responses to these questions were aggregated into four short narratives, each narrative corresponding to the questions that were presented.

Part II, Question 1: Predicting a Target Development Timeframe to Maintain Currency with ICT.

Chapter 2 presented the exponential growth currently being seen in the ICT field, whereas defense acquisitions timeframes have either remained constant or become longer with time. The goal was to determine whether or not panelists would be able to predict a target timeframe in which an organization should be able to organically develop and field a new capability in order to remain current with technology trends.

Round 2 Results for Part II, Question 1.

Initial responses to this question diverged into two main categories. First, several indicated that it is difficult to make a prediction as to an appropriate timeframe. This is due to the fact that there are many variables involved such as the level of urgency, and the specific type of technology being developed. Alternatively, differing development timelines suggested were as early as 3 months to 3-4 years to keep up with the rate of technology change.

Regardless of the timeline offered, most agreed that traditional government methodologies are inadequate in the arena of ICT given the rate of change and efforts to streamline current practices are unlikely to result in significant benefit. Rather than trying to keep up, it was predicted that the government may adopt trends in private sector practices such as rapid prototyping, extreme programming, and shifting research and development efforts toward development or re-engineering of existing technologies rather than organically developed capabilities.

Round 3 Results for Part II, Question 1.

The responses for question 1 were aggregated into a short narrative which was presented to the panelists for review and further comment for round 3. Most panelists still agreed that it is difficult to make a prediction as to an appropriate development timeframe, traditional government acquisition methodologies are inadequate, and efforts to streamline current practices are unlikely to result in significant reduction. No further exploration as to any specific target timeframe emerged.

Several panelists indicated there are other causal factors leading to long development timelines other than the JCIDS process which need to be considered, such as military-specific requirements including interoperability, accountability, security, and costs. These panelists responded that “passing on” development to the private sector or adopting their practices is unlikely to resolve persistent issues with long development timelines, nor will the continued modification of commercially developed products.

Part II, Question 2: Predicting When DoD Acquisitions Can Not Keep Up.

The background on the JCIDS process given prior to part II details that it can take as many as two years for a warfighter need to become a validated requirement, and as many as six more years to organically field a basic capability. This assumes a particular program is not technically complex, has low visibility, and has programmed funding. The goal was to determine whether or not the panelists can foresee a timeframe in which defense acquisitions will become increasingly reliant upon technologies strictly developed in the private sector due to the rate of technological change in attempts to avoid obsolescence, as compared to developing organic capabilities or modifying technologies for military use.

Round 2 Results for Part II, Question 2.

Responses towards the possibility of a time when DoD acquisitions cannot keep up with technological advancement indicated that this is foreseeable and is possibly already the case. Panelists indicated that the government is already heavily dependent upon the private sector for mobile ICT capabilities and no longer does significant development of ICT. However, many further indicated that it is likely that there will always be an intrinsic need for some level of technology development for military applications when commercial technologies are inappropriate or unacceptable. The ability to quickly re-engineer or adapt existing commercial technologies will likely be more important than organic development in the future.

Round 3 Results for Part II, Question 2.

The responses for question 2 were aggregated into a short narrative which was presented to the panelists for review and further comment for round 3. This round experienced little further exploration for this topic. Most still agree that it will not be long before traditional DoD acquisitions can no longer keep up with the rate of change in the ICT field, or that this is already the case. No specific timeframe was explored. One panelist did express disagreement, citing avenues to fast track urgent joint operational needs.

Part II, Question 3: Presenting A New Acquisitions Model for Mobile ICT.

This question presented a new model for defense acquisitions which considers the technology trend towards portable devices such as smart phones or tablets using data services. Rather than using dedicated, single purpose equipment, users equipped with advanced mobile devices would have the capability to access an online repository and generate a tailored suite of capability to fit a particular mission, or download services and applications in the field as the operating environment changes. This type of model is already in use in the private sector as seen in applications such as the Apple iStore, but the goal is to ascertain the feasibility for utilizing such a model for military purposes.

Round 2 Results for Part II, Question 3.

Responses indicated that an acquisitions model which exploits smart phone technologies and features an online DoD repository of downloadable data services and applications in lieu of dedicated equipment for a specific single function is feasible. In fact, several panelists indicated that this model is already in use on a corporate level, not just by consumers. However, there must be a formalized process to ensure security and military-specific requirements are met and maintained in order for this to become a practical model for defense acquisitions. A motivated development effort may make this model ready for use in as few as 1-2 years once resources to execute are in place. Once the infrastructure and processes have been finalized, the creation of new capabilities may be completed in as few as 1-3 months.

Round 3 Results for Part II, Question 3.

The responses for question 3 were aggregated into a short narrative which was presented to the panelists for review and further comment for round 3. Panelists unanimously agreed that this approach is feasible and there were no further developments on this topic.

Part II, Question 4: Practicality of Detailed Planning Beyond 20 Years.

Few panelists offered significant input in this target timeframe. The goal was to ascertain whether or not it is still worthwhile to commit increasingly scarce resources to technology development further than 5-10 years into the future, or if it would be better for organizations which rely on ICT to accomplish their mission to develop the flexibility to adapt considering the rapid rate of change in the ICT field.

Round 2 Results for Part II, Question 4.

Responses diverged into several categories. Many panelists responded that it is in fact practical to expend resources beyond 10-20 years. However, resourcing efforts should be focused upon maintaining awareness of trends in technology, scenario planning, and developing the organizational flexibility to adapt to new ICT trends. Development efforts will trend towards smaller scale, incremental developments or upgrades rather than large, expensive development programs. However, there will still be a need for some level of long-range resource planning for uniquely large and complex developments for military-unique requirements in austere environments.

Alternatively, it will not be practical to expend significant resources beyond 5 years for development efforts. The Department of Defense does not show support for large, expensive development efforts of this kind but will rather focus on emerging urgent needs. Regardless, the defense acquisitions community will still need to develop the flexibility to adapt to new ICT trends.

Round 3 Results for Part II, Question 4.

The responses for question 4 were aggregated into a short narrative which was presented to the panelists for review and further comment for round 3. For this round, panelists seemed to agree more with the first category as mentioned in the previous section which expressed higher emphasis on maintaining awareness of technology trends and incorporating organizational flexibility. Some panelists foresee a need to maintain long-range research and development efforts beyond 5-10 years, rather than simply maintaining awareness and developing organizational flexibility. Finally, one panelist suggested incorporating some form of indictor or milestone in advancement of technology capabilities to trigger a response or activity which could be incorporated into strategic planning efforts.

Summary

This chapter discussed the composition of the panel of experts and the execution of the research study by round. It presented the findings organized by time period and how the panelist discussions on the forecast changed throughout each of the three rounds. In addition, it discussed the research questions from Chapter 1 and how the panelist discussions changed throughout rounds 2 and 3.

V. Discussion and Recommendations

Chapter Overview

This presents an overall summary and interpretation of findings on the results obtained in Chapter 4. First, it will discuss the summarized forecasts on the future of ICT deployed in austere environments. Then, it will discuss the results to the research questions pertaining to the forecast from an acquisitions perspective. The final forecast in its entirety can be found in appendix D. Finally, it will present recommendations, limitations of this research, and suggest areas of further study.

Summary of Findings on the Future of ICT in Austere Environments

The Forecast for 5-10 Years.

- Equipment used by individual users in austere environments will trend towards smaller, faster, cheaper devices akin to modern handheld tablets and smart phones. Using these devices, data services and applications will begin to replace dedicated equipment. The amount of equipment required by individual users will be reduced.
- The overall logistical footprint for a deploying force may not be reduced due to exponential growth in bandwidth demands. However, ease of access and modularity will significantly improve.
- EoIP will be the medium of choice for voice, data, and video.
- Satellite technologies will continue to improve and be a primary option for combat communications forces.
- Alternatives to satellites in environments such as foliated canopies, underwater, inside buildings, etc., as well as very high radio frequencies may emerge.
- There will be incremental advancements in existing power generation technologies as well as fuel cells.
- The emergence of improved "green" technologies such as wind and solar may supplement the power needs of deployed forces.

The Forecast for 10-20 Years:

- Mobile devices will proliferate and become mainstream. Human interfaces with technologies will become sensory, possibly even biological in nature. Individual user devices will be inter-networked at a tactical level.

- Satellite technologies will continue to evolve. Network connectivity will become global in nature, which may be as a result of market forces. Many places considered austere will become much less so from an ICT perspective due to consumer demand in developing areas. This offers an interesting option for deployed forces, but security concerns due to persistent socio/economic/political instability may make it a poor first choice for military operations. Combat communications organizations will likely need to maintain their own organic deployable capabilities.

- Power generation will focus on fuel cells and green technologies in austere environments. Alternatives include thorium-based nuclear batteries and wireless power if radio frequency interference and possible adverse health effects as seen in current generations are overcome.

The Forecast Beyond 20 Years.

- Sensory integration of small devices will be a mature technology, possibly even implanted.

- Devices will be interconnected, requiring robust security due to potential for severe impacts in the event of compromise.

- Individual user devices may draw sufficiently low amounts of power that physical movement, respiration, possibly electro-chemical methods other than batteries may be viable.

- Network connectivity will become global in nature. Austerity as it pertains to mobile ICT will be due more to an occurrence of an event within an environment rather than characteristic of the location as mobility will have become transparent. Events such as natural disasters, power grid failures, war, etc., are potential situations which may render an otherwise "developed" area austere.

Areas of Divergence on the Future of ICT Deployed in Austere Environments.

Responses saw divergence in several distinct areas. First, there was significant discussion as to the role of satellite technologies. Some panelists foresee a continued reliance upon satellites. The commercial sector appears to be investing heavily in this area, which was reflected by panelists from these types of organizations. These panelists see continued growth in capability for the foreseeable future which, from their perspective, will be sufficient to overcome any perceived limitations of current technologies, particularly bandwidth. If advancements are in fact sufficient to address the expected increase in user bandwidth demand, satellites will remain as the ideal technology for connectivity in austere environments. However, some panelists from government organizations external to the DoD cited inherent limitations in satellites including bandwidth but also others such as vulnerabilities to cyber and non-kinetic which may limit their usefulness for deployed forces on a large scale. Panelists from government organizations external to the Air Force are investigating alternatives which could be used in foliated canopies, underwater, and inside buildings, areas in which current satellite technologies have limited capabilities. Additionally, optical and VHRF technologies may present superior bandwidth than satellites and may be better suited to handle the expected increase in user demand. However, these technologies may be dependent upon government investments into their development. Therefore, considering current budgetary constraints, it seems more likely that satellites technologies will present a better option for connectivity for forces deployed in austere environments.

The second area of continued divergence pertained to the use of green technologies. Some panelists foresaw a greatly increased utilization of technologies such as wind and solar in both the 5-10 and 10-20 year timeframes. Discussions on green technologies seemed to indicate environmental concerns, an important factor to commercial entities. This is unlikely to be a significant concern for military operations. What may be of greater importance is that these technologies offer the possibility of providing inexpensive, locally-produced power which can be used to supplement existing power-generation technologies. This could help to reduce future logistical footprints as well as recharging batteries for mobile equipment rather than relying on expendable batteries. Therefore, while green technologies may not offer significant military benefits over peer nations as a primary source of power generation, it would be inadvisable to ignore their possible benefit. As a primary source of power, it seems more likely that combat communications forces will continue to rely upon incremental advancements in existing technologies, at least in the near term. Longer term, it seems likely that combat communications forces can expect reductions in power needs and subsequent infrastructure as individual devices become smaller with less power demand. Perhaps then, green technologies will present a more useful option for meeting demand on a larger scale.

Discussion on the Forecast.

The original goal for the forecast was to determine “what’s next” with regards to ICT deployed in austere environments. Early in the study, the sponsoring agency decided that it wished to refocus efforts to forecast “what’s coming after next.” The Army is investing research and development resources into smart phone technologies and the capabilities they can provide soldiers in the field (Mlot, 2012). In the near term, the capabilities brought by smart phone technologies appear to be "what's next" for combat communications forces; the forecast developed from this study for the 5-10 year timeframe appears to support this trend. It is worthy of mentioning, however, that this research indicates that "what's next" for combat communications forces is in actuality "what's now" in many areas of the private sector. Unfortunately, this means that combat communications forces may already be falling behind in terms of technological currency. On the other hand, it also means that many of the technologies needed to reach the next level are already in existence and are simply waiting to be exploited which could result in substantial cost savings when compared to an organic development program.

For "what's after next," senior leadership for combat communications forces can expect technology convergence, further miniaturization, and increased capabilities that these technologies present, which will reduce the size and amount of dedicated single-purpose equipment needed by individual users. Simultaneously, infrastructure becomes more modular and easier to access regardless of location, but it also becomes more complex. The combination of small, powerful, and ever increasingly mobile ICT devices with current advancements in ad hoc networking, cloud computing, and cognitive radio technologies promise to revolutionize how combat communications forces will operate in austere environments. Again, many of these technologies are either in development or are ready for exploitation.

It is foreseeable that within a decade a user or small group of users could arrive in an austere location and be able to carry all the equipment required to set up a highly capable and interconnected network, with the ability to increase capabilities to accommodate a much larger force in a small amount of time. In two decades, setting up a network may not even be necessary as local connectivity will already existence when the user steps off the aircraft, regardless of the location. It cannot be overemphasized that as commercial technologies increase in capability alongside increased global connectivity, the ability to provide security and defense against malicious cyber attacks will become an increasingly critical skill set.

Discussion of Questions from an Acquisitions Perspective

Predicting a Target Development Timeframe to Maintain Currency with Mobile ICT.

This research effort did not develop a specific target timeframe toward which the defense acquisitions community should strive in order to keep up with the rate of change in the mobile ICT field in the time periods given. There seems to be too many factors such as urgency, system complexity, the specific technologies involved, etc., to derive any kind of meaningful metric. Interestingly, private sector perspectives indicate that streamlining techniques are unlikely to provide significant improvement in development timelines.

This may carry significant implications for process improvement activities which strive for incremental process improvement. Though this study focuses on a relatively narrow field within the defense acquisitions community, perhaps it helps to explain why the Air Force has been unable to achieve lasting transformational change in this area. This study simply suggests that acquisitions practices in general, with the JCIDS process in particular, are inadequate to maintain technological currency in the face of accelerating advancement in mobile ICT. A system lacking in pro-activity is unlikely to effectively meet the needs of warfighters who rely on mobile ICT when this system is faced with exponential growth. This study further highlights the need for meaningful acquisitions reform in this area.

Predicting When DoD Acquisitions Can No Longer Maintain Currency With Mobile ICT.

It was difficult to develop a specific timeframe in which the DoD would be unable to keep up and therefore be forced to become uncomfortably reliant on commercial sector products to maintain currency with technological advancements rather than attempting to develop organic capabilities. Some expressed serious concerns about such a situation, while some panelists argued that this has already taken place. Either way, many argued the DoD is already heavily reliant upon the private sector in the ICT field overall in that the military already adapts much of its mobile ICT technologies from products originating in the commercial sector. This does not mean that the defense acquisitions community will ever be able to completely rely upon the private sector. The DoD will likely always need to maintain some organic capability for developing technologies or adapting existing technologies due to unique requirements which may not exist or are perceived to be unprofitable in private industry. Nevertheless, there is an argument to be made that without significant reductions in development timelines, the military is increasingly at risk of a situation where technologies developed at considerable taxpayer expense will become obsolete before they reach the battlefield, having been made vulnerable or even irrelevant by widely available commercial technologies. Accordingly, combat communications forces may soon be at risk of deploying forces with increasingly less effective ICT capabilities relative to potential adversaries which will almost certainly exploit increasingly advanced technologies originating in the private sector.

A New Acquisitions Model for Deployable ICT.

The panel was unanimous in the feasibility of the acquisitions model discussed in Chapter 4. In fact, several panelists responded that this type of model is already in use in the private sector, not just for individual consumer applications but at the corporate level as well. Panelists point out that the collective efforts in the inter-connected marketplace have proven to be able to bring solutions to the user more effectively than individual development efforts as seen with the proliferation of new services and capabilities using current market methods such as the Apple iStore. Such methods are arguably superior with respect to cost, user satisfaction, and time to delivery than is seen with traditional defense acquisition practices. The replacement of dedicated communications equipment with small, low-power mobile devices, combined with a secure web-based repository for data services and application with global connectivity has great potential for future combat communications forces. Deploying forces will be able to quickly build a suite of capabilities tailored to specific mission or training needs with a lower logistical footprint for individual users as single-purpose equipment is phased out. Also, users will have a more direct avenue to provide approved developers with descriptions of desired capabilities as opposed to utilizing lengthy conventional acquisitions processes. Users will perhaps have the ability to develop their own or modify an existing data service or application. Finally, users will have the means to provide other user with immediate feedback to developers as well as other users as to the effectiveness and suitability towards a particular service or application.

From an acquisitions perspective, this model offers numerous additional benefits. Most obviously, a model such as this could offer lower development and manufacturing costs as dedicated military hardware, the materiel required for manufacturing, as well as the logistical infrastructure to support and maintain it is eventually phased out and replaced with downloadable data services and applications. Assuming deploying forces have the ability to procure sufficient numbers of mobile devices for their troops, there would be no further need for product centers in the acquisitions community to procure and distribute sufficiently large amounts of physical single-purpose hardware to their customers. The timeframe to develop and deliver a new capability to the user could be greatly decreased, not to mention upgrading a capability or fixing a defect in a data service or application when compared to physical equipment. Capability deliveries could be significantly improved with more direct user-developer relationships. These methods should enable more efficient technology "push" where developers can easily offer newly developed capabilities to potential users in the DoD repository, as well as technology "pull" where users can freely advertise to developers the need for a new or improved capability. There could also be less delay to deliver the finished product to the warfighter both preparing to deploy as well as those already in the field; the speed of the delivery of a capability would only be limited by available bandwidth.

It should be cautioned that there are many challenges to overcome in order to implement this model. For example, there are many framework and security oversight issues which need to be resolved before this could become a viable option. There are currently no security protocols dictating how a developer would create these capabilities and distribute them to the end user in such a manner that would ensure the product meets complex information assurance requirements. Additionally, there is a lack of operational doctrine directing how such a model would be implemented. There may be inter-operability issues between the various applications and data services that would need to be addressed. Finally, actions would need to be taken to ensure that these technologies do not end up in the hands of rival nations as they would undoubtedly attempt to acquire them considering the widespread availability of commercial technologies capable of utilizing them.

The Practicality of Detailed Long-Range Planning.

Considering the exponential rate of technological advancement in the mobile ICT field, it is arguable that to conduct long-range, detailed strategic technology planning is becoming an exercise in futility for organizations which rely on these types of technologies. At the very least, there appears to be a level of diminishing returns for detailed strategic-level planning beyond ten years. This seems to indicate that it may be a better allocation of increasingly scarce resources for the defense acquisitions community, in partnership with the combat communications community, to maintain keen awareness of technological trends and develop the organizational flexibility to adapt to them. This approach may require a much higher degree of budget autonomy and flexibility in order to quickly react to emerging trends. This is in sharp contrast to the rigid and formal JCIDS process which, as stated, can require upwards of two years for a warfighter request to become a valid need before it can become a formal acquisitions program. How many consumers would be willing to wait that long to replace cellular phones and their applications once the need is identified?

Recommendations

This study should be another wake-up call for the defense acquisitions community. The JCIDS process for identifying and prioritizing requirements in time to provide meaningful impact in this particular technology field is unlikely to be capable of meeting future warfighter needs where users are heavily dependent upon mobile communications technologies in austere environments. Senior leadership must give new attention towards meaningful acquisitions reform, not just to the JCIDS process, but to all aspects of defense acquisitions to reduce development timelines for both organically developed capabilities and modifications to existing commercial technologies. It may become necessary to allow combat communications forces more autonomy with their resources by giving them their own budget authorization and formalization of some of the decentralized processes currently being used by Special Operations Command as was suggested by Chyma. Perhaps this will allow organizations heavily dependent upon mobile ICT the flexibility to adapt to emerging technologies as they occur rather than waiting for a capability gap to present itself.

Both combat communications organizations as well as acquisitions organizations should take steps to increase their organizational flexibility as well as increase awareness of technological trends by increasing partnerships with research and development organizations, both in the private sector and other areas of government such as the Defense Advanced Research Projects Agency (DARPA) and Air Force Office of Scientific Research (AFOSR). As stated earlier, there are many technologies and concepts which are not only feasible but immediately available which could provide significant increases in capability. Adapting or modifying these technologies as necessary, as well as developing the training and procedures for which to exploit them, will ensure that combat communications forces have the technologies and skill sets needed for future operations in a proactive manner. This is highly preferable to reacting to advances in increasingly advanced commercial technologies which will certainly be exploited by our adversaries who are unencumbered by burdensome acquisitions processes.

Finally, the defense acquisitions community in partnership with combat communications and advanced research organizations should take steps to further refine the acquisitions model presented. The exploitation of these existing technologies offers the potential to greatly improve the capabilities of deployed forces in austere environments in a relatively short timeframe at a minimal cost.

Limitations of Research

As is the case with any Delphi study, the results obtained are heavily dependent upon the quality, personal opinions, and experiences of the panelists. It is possible that an identical study with a different set of panelists could arrive at a slightly different forecast. Furthermore, the study relied on fewer panelists than was originally hoped. Though the number of panelists met the minimum requirement for scientific rigor, only eight individuals participated when the target size for the panel of experts was twelve individual experts. Additionally, one panelist was not able to provide responses for the final round due to workload obligations. It is possible that having this restricted further exploration of the issues and therefore may have limited the amount and diversity of input with which the final forecast was derived. In addition, the differing success rates between the knowledge areas may increase the degree of error in the final technology forecast, but this is unavoidable as it proved to be more difficult than expected to find good contact information on potential panelists.

It has already been discussed that panelists from within the military were not solicited for participation in this research at the request of the sponsoring agency. The intent was to gain a perspective external to the Air Force as to the future of ICT in austere environments in an attempt to prevent any military bias from affecting the results. However, it can be argued that excluding a specific perspective may result in the failure to capture important aspects with which individuals from the private sector or non-military government organizations may not be able to foresee, but yet may be quite pertinent towards the forecast.

This study did not investigate implementation issues such as Information Assurance (IA) in reference to the acquisitions model. IA is a considerable issue affecting all defense acquisitions, information systems in particular. Numerous panelists cited security and trust concerns as a major factor in implementing the acquisitions model presented. This must be accounted for during a formal acquisition of a materiel solution, but it falls outside the scope of this research effort.

Future Research

There are several opportunities for future research. This field is experiencing a rapid rate of change, the future is very uncertain. Therefore, it may be beneficial to repeat this study in 5-10 years with a new panel of experts to see whether or not the forecast holds true. It is entirely possible that breakthrough technologies which are unforeseeable at this time will emerge in any of the three target timeframes which may make the findings contained in this study obsolete.

Another possibility would be to repeat this study using only military experts. Researchers could compare the results with the results of this study to see how the perspectives from within the military differ with those in the private sector or non-military government organizations. Using this information, it may be possible to determine whether or not the acquisitions community needs to change course with ongoing project development.

An important area requiring further study is the implementation of the acquisitions model presented. There are many security and trust issues which need to be thoroughly investigated before a model such as this could become feasible for wide-scale implementation. IA is a challenge in the acquisitions of information systems and the implementation of a model such as this is a perfect example. Furthermore, how this model would be implemented with regards to the operational community needs further study. There may be significant impacts to Air Force procedures and doctrine which need to be investigated.

Finally, a topic which may warrant further exploration would be the topic of power generation in austere environments. The research team had expected the study to focus exclusively on the communications aspect of ICT, but many of the panelists provided inputs on this topic as well. Simply stated, there can be no ICT if there is no power. Therefore, it is certainly relevant towards operations in austere environments and was therefore explored, but only with a cursory level of detail. The importance of power is sufficiently significant that it may warrant its own study.

Summary

This chapter summarized the findings and presented the final forecast of the future of ICT deployed in austere environments. Then it discussed some of the areas of divergence as well as the implications of this forecast towards combat communications forces. The next section discussed the questions pertaining to an acquisitions perspective. Then it presented recommendations to senior leaders in both combat communications organizations as well as the defense acquisitions community. Finally, it presented the limitations of this research and presented opportunities for future research.

Appendix A: Round 1 Research Instrument

Delphi Study on the Future of Mobile Information and Communication Technology (ICT)

Thank you for participating in this research. I appreciate your time and candid responses. Please complete this instrument and return it electronically no later than **15 Oct 2012**.

The ICT industry is undergoing a period of rapid change which presents a challenge to decision makers who must plan for future contingencies and allocate increasingly scarce resources to develop the capabilities to meet warfighter needs. According to the 2010 Quadrennial Defense Review (QDR), "modern armed forces cannot conduct effective high-tempo operations without resilient, reliable information and communication networks and assured access to cyberspace". Accordingly, there exists an enduring requirement to support forward-deployed air and joint forces with effective, state-of-the-art ICT capabilities. To prepare for future combat requirements, the 689th Combat Communications Wing (CCW) has commissioned this research study with the Air Force Institute of Technology.   The desired outcome of this effort is to create a forecast of specific information and communication technologies and capabilities.

The research will take place in several rounds, with each of the participants provided an opportunity to respond to a series of questions. After each round, the researcher will aggregate individual responses into a coherent whole and then send out to the group a refined series of questions and an instrument to assess the group responses from the previous round. The end goal is to reach clarity on the group's assessment of the topic.

Please note the following:

1. Benefits and risks: There are no personal benefits or risks for participating in this research. Your participation should take less than one hour per round.

2. Voluntary consent: Your participation is completely voluntary. You have the right to decline to answer any question, as well as refuse to participate in this study or to withdraw at any time. Your decision of whether or not to participate will not result in any penalty or loss of benefits to which you are otherwise entitled. Completion of the questionnaire implies your consent to participate.

3. Confidentiality: Your responses are completely confidential, and your identity will only be used by the researchers during the data gathering and interpretation phase of the research. No individual data will be reported; only data in aggregate will be made public. Data will be kept in a secure, locked

cabinet to which only the researchers will have access. If you have any questions or concerns about your participation in this study, please contact:

ALAN R. HEMINGER, Ph.D.
Associate Professor of Management Information Systems
Graduate School of Engineering and Management
Air Force Institute of Technology, Wright-Patterson AFB, OH
Voice: 937-255-3636 (785-3636 DSN) ext 7405

Privacy Act of 1974 and AFI 33-332

The Material / Information contained herein falls within the purview of the Privacy Act of 1974 and will be safeguarded in accordance with the applicable system of records notice and AFI 33-332. This study is anonymous. No attempt to identify you or your organization will be made unless information indicates a credible or potential threat. By participating in this research, you acknowledge that the information you provide, including the open text comments, may be viewed and released in accordance with the Freedom of Information Act. Do not include personal identifying information.

Operational Security (OPSEC), AFI 10-701

Do not provide OPSEC information. OPSEC is a process of identifying, analyzing and controlling critical information indicating friendly actions associated with military operations and other activities such as: 1) Identify those actions that can be observed by adversary intelligence systems. 2) Determine what specific indications could be collected, analyzed, and interpreted to derive critical information in time to be useful to adversaries. and 3) Select and execute measures that eliminate or reduce to an acceptable level the vulnerabilities of friendly actions to adversary exploitation. Comply with all OPSEC measures outlined in AFI 10-701. Do not provide critical information or indicators.

Please respond to this request for your assessment **electronically** and return it to: andrew.soine@afit.edu or james.harker@afit.edu. If you have questions, Capt Soine can also be reached at (478) 918-4269 or MSgt Harker at (307) 221-5577. Written correspondence can be addressed to:

Capt Andrew T. Soine
2054 Turnbull Rd
Beavercreek, OH 45431

MSgt James Harker
5579 Hickam Dr
Dayton, OH 45431

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. YOUR SIGNATURE INDICATES THAT YOU HAVE DECIDED TO PARTICIPATE HAVING READ THE INFORMATION PROVIDED ABOVE.

Volunteer Signature____Date_______________

Volunteer Name (printed)____

This round has five questions. The instrument is "non-attribution", so please elaborate fully on your answers. Please do not collaborate with other individuals in providing your answers. Once all responses are received, you will be given the opportunity to revise your initial responses to part 2. Subsequent rounds will be announced as needed and all research will conclude by 1 January 2013.

<u>Part 1: Basic Demographics</u>

1. Personal information (please circle or fill-in your answers below)
   a. Level of education
      HS AA BA MA PhD
   b. Primary area of expertise
      ____
   c. Years practicing Primary expertise
      1-5 5-10 10-15 15-20 20+

2. What is your current job title?

3. Considering your primary expertise, in what capacities have you dealt with information and communication technology?

<u>Part 2: Please answer and elaborate on the following:</u>

4. What is the future of mobile, deployable communications technology in austere environments?

   *In the context of this study, "mobile" can be defined as the capability of being moved from place to place. Technology that can be considered mobile can be as small as a smart phone or fit into a backpack, or as large as something which can

be loaded onto a pallet. All aspects of ICT should be considered such as interfaces, any supporting services, etc.
**In the context of this study, an austere environment can be defined as one with little or no existing infrastructure, or one where infrastructure has been significantly degraded.

5. Considering your responses to question #4, which technologies will be mature and available for use in:
   a. 5-10 years
   b. 10-20 years
   c. Beyond 20 years?

*In the context of this study, a mature technology is at the point where performance can be reasonably bounded as a new, separate system or part of another system (AFDD1, 2011).

Appendix B: Round 2 Research Instrument

Part 1: Round 1 Feedback

Part 1 is a narrative derived from the responses received from round 1 of this study. Do you agree with this forecast? In what ways do you disagree, if any? Does it suggest to you any other issues which may need to be considered? (For example, power generation was not considered while developing the first questionnaire, but we received some interesting input.)

5-10 years*:*

> In 5-10 years, ICT used in austere environments will trend towards smaller, faster, and cheaper devices akin to handheld tablets and smart phones. Technology convergence and the increased use of applications and data services will reduce the size and amount of dedicated communication equipment and lessen the logistical footprint and overall necessary infrastructure. Infrastructure will be significantly more modular, self-configuring, adaptable, and self-healing. Drop-in, self contained "network-in-a-box" technologies will be developed.
>
> Everything over IP (EoIP) will be the medium of choice for voice, data, and video. Exponential increases in user demand for bandwidth will drive advances in mobile satellite technologies. In austere environments, satellite communications will be the backbone infrastructure of choice, though linked drones may offer a viable alternative. Increases in satellite bandwidth and cloud computing will enable linkage to global networks. Advancements in cyber security will enable low probability of intercept/low probability of detection as well as anti-jamming capabilities. There will be incremental advancements in remote power generation, including fuel cells, improved solar, and batteries.

10-20 years*:*

> In 10-20 years, mobile devices will proliferate. Miniature, wearable computing devices may advance to the point where they approximate human mental capabilities. Human-technology interfaces will progress towards sensory applications (visual, tactile, etc), possibly even biological in nature.
>
> Infrastructure will include robust global ICT capabilities and further reductions in necessary deployable communications equipment. Commercial entities will provide communication mediums with much broader global coverage, driven largely by market forces and demand for technology by local populations in austere locations where such technology is currently unavailable. Satellite

technology will continue to progress allowing for constant network connectivity and very high data rates. There will be advancements in specialized communication mediums, including optical communications, space, underwater, underground, foliated canopy, and GPS-denied territories.

Advancements in remote power generation will include wireless power technology and nuclear batteries. For individual technologies, devices become low-power, charged by physical movement, respiration, possibly even using electro-chemical methods such as human blood sugars.

Beyond 20 years:

Sensory integration of small ICT devices will be mature technology, possibly even implanted. Displays will be holographic using physical motion as the keyboard, mouse, and similar technologies have become obsolete. Crystalline storage systems will be developed.

The global environment will have few locations which will be considered to be austere from an ICT perspective. Specialized communications disciplines such as combat communications may be eliminated as network connectivity will be global and mobility therefore becomes transparent. Users will have personal satellite uplinks. Networks will be enabled with robust satellite defenses, smart security, and cloud protection.

Part II: An Acquisitions & Procurement Perspective

Part II of this study will ask four short-answer questions regarding the narrative from round 1.

Background:

The DoD utilizes the Joint Capabilities Integration Development System (JCIDS) to verify and validate a warfighter need which has been submitted by a sponsoring agency before it can become a formal acquisitions program. It has been shown that this process alone can take as long as two years for a warfighter need to become a valid requirement before it can enter into the formal acquisitions process. Furthermore, it has been shown that the formal acquisitions process can take as many as six years to field a basic capability, assuming the program is not technically complex, low visibility, and has programmed funding.

1. Given what you know about accelerating advancements in the ICT field, what would be a reasonable target timeframe to develop a new technology to a fielded capability in order to stay up to date with regards to technology used in austere environments in the next 5-10 years? 10-20 years? Beyond 20 years?
2. Considering the length of time it can take to validate a warfighter requirement and organically develop a new capability, it can be argued that it won't be long before defense acquisitions can no longer keep up with the rate of technological advancement in mobile ICT without a significant reduction of its development time, assuming that this is not already the case. Do you agree? Can you foresee a time when the defense acquisitions community will be required to rely almost exclusively upon technology developed commercially to stay current with technology trends?
3. Many responses indicated that ICT in austere environments is trending towards small, networked, individually-based technologies akin to tablets or smart phones using data services and applications. Rather than developing dedicated equipment for a specific function or capability, imagine an acquisitions model similar to the app stores currently in use in the private sector, where programmers can create apps and upload them to an online repository which can be vetted and approved by the Department of Defense. This could enable a new acquisitions model with two possibilities. First, in a more traditional sense, users would have the capability to express a desired capability, then producers could develop an app to meet that need, and the user can choose apps as mission requirements dictate. Alternatively, programmers could create new apps offering new, innovative capabilities towards users who may not even be aware of a particular need or solution to a problem until they see it. Is this model feasible, and if so, what is a practical timeframe?

4. Many panelists did not offer an input for the 10-20 year and 20+ year timeframes. Is it still practical for a large organization to expend significant resources to plan and budget beyond 5-10 years? If so, what challenges would senior leaders need to overcome in order to be more proactive? If not, would it be more practical to focus on developing the organization flexibility to adapt to technologies as they emerge?

Part III: A Command & Control (C2) Technology Perspective

Part III of this study will ask three short-answer questions regarding the narrative developed from round 1.

Background:

C2 was chosen for analysis because of the overarching effect on AF missions at the Strategic, Operational, and Tactical levels. C2 functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission. This description points to three distinct sectors forming C2: personnel, technology, and processes. The C2 technology component often receives the most attention due to advanced technology characterizing American warfare (Air Force Doctrine Document (AFDD) 6-0, 2011).

C2 Technology includes "equipment, facilities, hardware, software, infrastructure, materiel, systems, and a whole host of other elements" (AFDD6-0, 2011). Its purpose is to "ensure commanders receive mission-essential information, make informed and timely decisions, and communicate appropriate commands to subordinates throughout the operation" (AFDD6-0, 2011). New theatres of operation or temporary engagements such as humanitarian relief efforts drive the creation of geographically separated C2 "sub-nets". The inclusion of these new devices or sub-systems into an already functioning system has the potential to negatively affect functionality. With that in mind, the 7 Measures of Effectiveness (MoEs) describing desired attributes of C2 technology as explained in AFDD6-0 are summarized below.

Command and Control ICT Measures of Effectiveness

1. Flexible: functionally able to adapt to different operating requirements such as tropical, desert and frigid weather and possess the capability to be reconfigured for different applications and protocols (AFDD6-0, 2011).

2. Responsive: The C2 system must be responsive to user needs. The response should be instantaneous, reliable, redundant, and timely (AFDD6-0, 2011).

3. Mobile "Must be as mobile as the forces, elements, or organizations they support without degraded information quality or flow" (AFDD6-0, 2011).

4. Disciplined AFFD6-0 describes the C2 system's discipline: *The C2 infrastructure must be focused, balanced, and based on predetermined needs for critical information.*

5. Survivable For use in this context a system can be considered survivable when complete functionality is not focused entirely on one node or subnet within the system.

6. Sustainable For a system to be sustainable it must remain interoperable, affordable, and ultimately usable.

7. Interoperable AFDD6-0 explains C2 communication systems "should be able to operate with key joint and coalition C2 systems."

Questions:

1. Please explain your thoughts regarding the MoEs positive or negative effect on AF C2 Technology adoption. *For example, you may believe that the 'Disciplined' MoE may be too restrictive in that it only considers the known data transfer requirements and does not consider the potential unexpected challenges.*

2. Considering projections from the first round, how do you envision the evolution of each MoEs importance? *For example, you may believe that mobility may become far less important as global infrastructure grows. On the other hand, you may envision interoperability increasing in importance to ensure everyone connected to a network can communicate within it.*

3. Do you feel as though the current set of MoEs covers the entire spectrum of concerns for future C2 ICT? If not, what concerns should be addressed?

4. As the first round responses were analyzed, forecasts were mapped to the MoE(s) it seemed to support or fulfill creating the table below. Please review this table and provide comments.

Table of Forecasts mapped to MoEs

Prediction	MoE
ICT 5-10yr Predictions	**Fulfilled**
Satellites launched and Satellite bandwidth increase and drone augmentation	1,2,5,6,7
Application, frequency, security, and service convergence optimization	1,2,5,6,7
Network-in-a-box	1,3,4,7
Remote power solutions	1,2,3,4,7
Wearable computing	1,2,3
ICT Interoperable via common platform such as IP	1,2,3,5,6,7
COTS end items primarily faster, lighter, and cheaper versions of current devices	1,2,3,5,7
ICT 10-20yr Predictions	
Global Networks and data banks	1,2,3,7
Electro-chemical, wireless, and nuclear power	1,2,3
Device AI performing to approximately human mental capabilities	1,2,3
Biological interfaces, devices attached or embedded into humans	3
Elective human enhancement procedures	2,4
Satellite stealth and repulsion of foreign objects	5
ICT 20+yr Predictions	
Personal satellite uplinks	1,2,3,7
3 dimension sensory interfaces	1,2
Crystalline data storage and holographic displays	2
Fully networked globe	1,2,3,4,5,6,7
Satellite defense mechanisms	4,5

Appendix C: Round 3 Research Instrument

Part I: The Future of ICT Deployed In Austere Environments

Part I of this round is a revised narrative integrating panelist feedback on the narrative from round 2. Please review the narrative and provide any comments below.

Precursor:

The panelist responses to the narrative presented from the first round seemed to be rooted in four distinct areas: Security, Satellite Communications (SATCOM) or alternatives, power, and environmental/ political/ socioeconomic issues.

1. *Security* concerns included notions of an entirely connected world being vulnerable to cyber-attacks with devastating global consequences.
2. *SATCOM* was portrayed by some panelists as a critical technology to future ICT development, whereas others depicted it as a technology approaching the end of its military usefulness with regards to ICT in austere environments due to physical limitations. Both are depicted as possible future scenarios.
3. *Power generation* was solidified as an important realm of development.
4. The *environmental/ political/ socioeconomic* theme portrayed the concern of available natural resources required to build ICT and their environmental impacts, military-specific concerns influencing development in austere locations, and market forces being the primary driver of commercial ICT development.

10 years*:*

In 5-10 years, ICT used in austere environments will trend towards smaller, faster, and cheaper devices akin to handheld tablets and smart phones. Technology convergence and the increased use of applications and data services will reduce the size and amount of dedicated communication equipment and lessen the logistical footprint. However, the infrastructure needs may not decrease congruently primarily due to the increased bandwidth demand due to device to device communications, unmanned aerial vehicles, robots, sensors, etc. Infrastructure will likely become significantly more modular, self-configuring, adaptable to its operating environment, and self-diagnosing/healing. Drop-in, self-contained network technologies will be developed.

Everything over IP (EoIP) will be the medium of choice for voice, data, and video. Exponential increases in user/device demand for bandwidth will drive advances in mobile satellite technologies and data transport innovations. Satellite communications will continue to be a useful option for the backbone infrastructure in austere environments. However, some identified disadvantages such as bandwidth and vulnerability to jamming by peer nations will necessitate the development of alternatives such as linked drones, optical, and VHF technologies. If viable alternatives are developed, SATCOM utilization may remain as a niche capability for military use but largely taper off as a legacy system.

Advancements in ICT will promote development in low probability of intercept/low probability of detection as well as anti-jamming capabilities. However, cyber security, data-intercept and anti-jamming capabilities will remain a concern well into the future because of the human component. Tactics used by adversaries can be expected to advance as well so in effect the threat may remain constant over time. There will be incremental advancements in remote power generation, storage, and distribution. Fuel cells, improved solar capabilities, batteries and other “green” technologies are likely.

<u>To what extent do you agree with this revised narrative? Do you believe we have captured a reasonable forecast for this timeframe? Are there any additional issues which may need to be considered?</u>

<u>10-20 years</u>*:*

In 10-20 years, mobile devices will proliferate. Miniature, wearable computing devices may advance to the point where they approximate human mental capabilities. Human-technology interfaces will progress towards sensory applications (visual, tactile, etc), possibly even biological in nature. Global infrastructure will continue to grow and evolve in attempts to sustain global ICT capabilities. Required deployable communications equipment may not necessarily diminish. Alternatively, it will change in size, capability, and purpose.

Commercial entities will provide communication mediums with much broader global coverage, driven largely by market forces. Demand for technology by local populations in austere locations where such technology is currently unavailable will increase and many locations currently considered austere will become much less so from an ICT perspective. However, it should be cautioned that though greatly expanded local connectivity may provide a level of military utility, security concerns stemming from persistent social/political/economical instability may make local access by military units an area of concern as a primary source of connectivity. Furthermore, despite the increase in demand some of these areas may remain un-served by the commercial sector due to poor projected profits. Satellite technology will continue to evolve concurrently while new methods are developed. Alternatives to satellite include advancements in specialized communication mediums, including optical communications, space, underwater, underground, foliated canopy, and GPS-denied territories. Constant network connectivity and very high data rates may be obtained through ad hoc type topologies employing devices as both individual consumers and as inter-networked components of the global network.

Many responses indicate advancements in remote power generation, storage, and distribution will focus on fuel cells and "green technologies" such as wind and solar for use in austere environments. Alternative technological advancements may include nuclear batteries and wireless power transmission if RF interference and possible adverse health effects are overcome. Individual devices may draw sufficiently low amounts of power that physical movement, respiration, possibly even electro-chemical methods may be viable.

<u>To what extent do you agree with this revised narrative? Do you believe we have captured a reasonable forecast for this timeframe? Are there any additional issues which may need to be considered?</u>

Beyond 20 years*:*

Sensory integration of small ICT devices will be mature technology, possibly even implanted. Devices will be interconnected, which will require robust security due to the potential for severe negative impacts of compromise. Computers will interface with users via physical motion in lieu of the keyboard, mouse, and similar technologies which will have become obsolete. Data archival technologies will be multiple generations beyond current capabilities allowing users to securely store and retrieve data with an accessible lifespan of 50-100 years. New materials crucial to ICT manufacturing will need to be explored due to their possible scarcity of precious metals and environmental impacts from mining and the continued use of petroleum products for their manufacture and disposal.

Austerity as it pertains to mobile ICT will be due more to an occurrence of an event within an environment rather than characteristic of the location as mobility will have become transparent. Events such as natural disasters, power grid failures, war, etc. are potential situations which may render an otherwise “developed” area austere.

To what extent do you agree with this revised narrative? Do you believe we have captured a reasonable forecast for this timeframe? Are there any additional issues which may need to be considered?

Part II: An Acquisitions & Procurement Perspective

Part II of this round contains narratives derived from the responses from the Part II questions from round 2. Please review the narratives and provide any comments below.

Background:

The DoD utilizes the Joint Capabilities Integration Development System (JCIDS) to verify and validate a warfighter need which has been submitted by a sponsoring agency before it can become a formal acquisitions program.   It has been shown that this process alone can take as long as two years for a warfighter need to become a valid requirement before it can enter into the formal acquisitions process. Furthermore, it has been shown that the formal acquisitions process can take as many as six years to field a basic capability, assuming the program is not technically complex, low visibility, and has programmed funding.

5. Given what you know about accelerating advancements in the ICT field, what would be a reasonable target timeframe to develop a new technology to a fielded capability in order to stay up to date with regards to technology used in austere environments in the next 5-10 years? 10-20 years? Beyond 20 years?

   Responses diverged into two main categories. First, several indicated that it is difficult to make a forecast as to an appropriate timeframe. This is due to the fact that there are many variables involved such as the level of urgency, and the specific type of technology being developed. Alternatively, differing development timelines suggested were as early as 3 months to 3-4 years to keep up with the rate of technology change.

   Regardless of the timeline offered, traditional Government methodologies are inadequate in the arena of ICT given the rate of change and efforts to streamline current practices are unlikely to result in significant benefit. Rather than trying to keep up, the Government may adopt trends in private sector practices such as rapid prototyping, extreme programming, and shifting research and development efforts toward development or re-engineering of existing technologies rather than organically developed capabilities.

To what extent do you agree with this narrative? If you disagree, in what ways do you see differently? Are there any additional issues which may need to be considered?

6. Considering the length of time it can take to validate a warfighter requirement and organically develop a new capability, it can be argued that it won't be long before defense acquisitions can no longer keep up with the rate of technological advancement in mobile ICT without a significant reduction of its development time, assuming that this is not already the case. Do you agree? Can you foresee a time when the defense acquisitions community will be required to rely almost exclusively upon technology developed commercially to stay current with technology trends?

   Responses indicated that this is foreseeable, if it is not already the case. The Government is already heavily dependent upon the private sector for mobile ICT capabilities and no longer does significant development of ICT. However, it is likely that there will always be an intrinsic need for some level of technology development for military applications when commercial technologies are inappropriate or unacceptable. The ability to quickly re-engineer or adapt existing commercial technologies will likely be more important than organic development in the future.

<u>To what extent do you agree with this narrative? If you disagree, in what ways do you see differently? Are there any additional issues which may need to be considered?</u>

7. Many responses indicated that ICT in austere environments is trending towards small, networked, individually-based technologies akin to tablets or smart phones using data services and applications. Rather than developing dedicated equipment for a specific function or capability, imagine an acquisitions model similar to the app stores currently in use in the private sector, where programmers can create apps and upload them to an online repository which can be vetted and approved by the Department of Defense. This could enable a new acquisitions model with two possibilities. First, in a more traditional sense, users would have the capability to express a desired capability, then producers could develop an app to meet that need, and the user can choose apps as mission requirements dictate. Alternatively, programmers could create new apps offering new, innovative capabilities towards users who may not even be aware of a particular need or solution to a problem until they see it. Is this model feasible, and if so, what is a practical timeframe?

   Responses indicated that this approach is feasible. This model is already in use in the private sector, not just for consumer applications but at the corporate level as well. The collective efforts in the inter-connected marketplace have proven to be able to bring solutions to the user more quickly than individual development efforts. First, there must be a formalized process to ensure security and military-specific requirements are met and maintained in order for this to become a practical model for defense acquisitions. A motivated development effort may make this model ready for use in as few as 1-2 years once resources to execute are in place. Once the infrastructure and processes have been finalized, the creation of new capabilities may be completed in as few as 1-3 months.

<u>To what extent do you agree with this narrative? If you disagree, in what ways do you see differently? Are there any additional issues which may need to be considered?</u>

8. Many panelists did not offer a forecast for the 10-20 year and 20+ year timeframes. Is it still practical for a large organization to expend significant resources to plan and budget beyond 5-10 years? If so, what challenges would senior leaders need to overcome in order to be more proactive? If not, would it be more practical to focus on developing the organization flexibility to adapt to technologies as they emerge?

Responses diverged into several categories. First, it is in fact practical to expend resources beyond 10-20 years. However, resourcing efforts should be focused upon maintaining awareness of trends in technology, scenario planning, and developing the organizational flexibility to adapt to new ICT trends. Development efforts will trend towards smaller scale, incremental developments or upgrades rather than large, expensive development programs. However, there will still be a need for some level of long-range resource planning for uniquely large and complex developments for military-unique requirements in austere environments.

Alternatively, it will not be practical to expend significant resources beyond 5 years for development efforts. The Department of Defense does not show support for large, expensive development efforts of this kind but will rather focus on emerging urgent needs. The defense acquisitions community will still need to develop the flexibility to adapt to new ICT trends.

To what extent do you agree with this narrative? If you disagree, in what ways do you see differently? Are there any additional issues which may need to be considered?

Part III: A Command & Control (C2) Technology Perspective

Part III of this round contains narratives derived from the responses from the Part III questions from round 2. Please review the narratives and provide any comments below.

1. Please explain your thoughts regarding the MoEs positive or negative effect on AF C2 Technology adoption.

   The group theme seemed to portray that MoEs are positive considerations during system planning. However, two distinct viewpoints were expressed. First, some asserted that the MoEs are still applicable and flexible enough to guide the AF in future ICT endeavors. Conversely, others stressed that the MoEs are strictly focused on current issues thereby committing users to a system or approach omitting emerging needs and slowing new capability creation.

   To what extent do you agree with this narrative? If you disagree, in what ways do you see differently? Are there any additional issues which may need to be considered?

2. Considering projections from the first round, how do you envision the evolution of each MoE's importance?

   The group responses focused on the importance of three MoEs. First, flexibility was an important consideration to ensuring that during the infrastructure growth process backward compatibility is maintained. Sustainable was a contested MoE. Some asserted that its importance should increase as military budgets are decreasing and as a result, equipment life cycle may be extended. However, others stated that as ICT develops at increasingly faster rates, equipment becoming obsolete during its functional life cycle is now a certainty rather than a possibility thus detracting from the importance of Sustainable. Finally, Interoperable was also a double edged sword. Some stated that interoperability would be more important because as the global network grew it would allow those connected to interact. Yet, others contested that assumingly everyone connecting to the network was already interoperable therefore the importance would decrease.

To what extent do you agree with this narrative? If you disagree, in what ways do you see differently? Are there any additional issues which may need to be considered?

3. Do you feel as though the current set of MoEs covers the entire spectrum of concerns for future C2 ICT?

   Some members expressed that the MoEs were vague enough to encompass all relevant aspects of future ICT systems planning. However, others suggested adding distinct measures for areas including Securable, Bandwidth Consumption, Redundancy, Parallelism, and Auto-Adaption.

   To what extent do you agree with this narrative? If you disagree, in what ways do you see differently? Are there any additional issues which may need to be considered?

4. As the first round responses were analyzed, inputs were mapped to the MoE(s) it seemed to support or fulfill creating the table below. Please review this table and provide comments.

   This question yielded the most divergent results among the group. Some stated that due to the interrelated nature of the MoEs, an ICT system or ICT system component must fulfill all of the MoEs for inclusion into a system of systems. Some asserted that the mapping provided in the table looked appropriate. Finally, others commented on the forecast validity and timeframe rather than the MoE in which it likely supports. The MoEs and table are included below for reference.

To what extent do you agree with this narrative? If you disagree, in what ways do you see differently? Are there any additional issues which may need to be considered?

Command and Control ICT Measures of Effectiveness

8. Flexible: functionally able to adapt to different operating requirements such as tropical, desert and frigid weather and possess the capability to be reconfigured for different applications and protocols (AFDD6-0, 2011).

9. Responsive: The C2 system must be responsive to user needs. The response should be instantaneous, reliable, redundant, and timely (AFDD6-0, 2011).

10. Mobile "Must be as mobile as the forces, elements, or organizations they support without degraded information quality or flow" (AFDD6-0, 2011).

11. Disciplined AFFD6-0 describes the C2 system's discipline: *The C2 infrastructure must be focused, balanced, and based on predetermined needs for critical information.*

12. Survivable For use in this context a system can be considered survivable when complete functionality is not focused entirely on one node or subnet within the system.

13. Sustainable For a system to be sustainable it must remain interoperable, affordable, and ultimately usable.

14. Interoperable AFDD6-0 explains C2 communication systems "should be able to operate with key joint and coalition C2 systems."

Table of Forecasts mapped to MoEs

Prediction	MoE
ICT 5-10yr Predictions	**Fulfilled**
Satellites launched and Satellite bandwidth increase and drone augmentation	1,2,5,6,7
Application, frequency, security, and service convergence optimization	1,2,5,6,7
Network-in-a-box	1,3,4,7
Remote power solutions	1,2,3,4,7
Wearable computing	1,2,3
ICT Interoperable via common platform such as IP	1,2,3,5,6,7
COTS end items primarily faster, lighter, and cheaper versions of current devices	1,2,3,5,7
ICT 10-20yr Predictions	
Global Networks and data banks	1,2,3,7
Electro-chemical, wireless, and nuclear power	1,2,3
Device AI performing to approximately human mental capabilities	1,2,3
Biological interfaces, devices attached or embedded into humans	3
Elective human enhancement procedures	2,4
Satellite stealth and repulsion of foreign objects	5
ICT 20+yr Predictions	
Personal satellite uplinks	1,2,3,7
3 dimension sensory interfaces	1,2
Crystalline data storage and holographic displays	2
Fully networked globe	1,2,3,4,5,6,7
Satellite defense mechanisms	4,5

Appendix D: Final Prediction

10 years*:*

In 5-10 years, ICT used in austere environments will trend towards smaller, faster, and cheaper devices akin to handheld tablets and smart phones. Technology convergence and the increased use of applications and data services will reduce the size and amount of dedicated communication equipment and lessen the logistical footprint. Bandwidth demands will accelerate exponentially due to increased usage of device to device communications, unmanned aerial vehicles, robots, sensors, etc. Infrastructure will become increasingly complex as more devices and platforms converge on the network. However, the subnets or gateways will become more modular, adaptable, and autonomous.

Everything over IP (EoIP) will be the medium of choice for voice, data, and video. Exponential increases in user/device demand for bandwidth will drive advances in mobile satellite technologies and data transport innovations. Satellite communications will continue to be a primary option for the backbone infrastructure in austere environments assuming advancements in bandwidth are sufficient to meet expected increases in bandwidth demands. However, perceived vulnerabilities, bandwidth, and connection limitations in some austere locations such as foliated canopies, inside buildings and underwater will prompt development of alternatives such as linked drones, optical, and VHRF communication technologies. Some of these may be heavily reliant upon US government funding as opposed to market forces. Therefore, if funding continues these alternatives are probable. If funding is insufficient, it is probable that SATCOM capabilities will remain as the primary austere environment infrastructure backbone. In both scenarios SATCOM will continue to evolve in capability through hardware advancements, data coding, and data compression techniques.

Advancements in ICT will promote development in low probability of intercept/low probability of detection as well as anti-jamming capabilities. Satellite connectivity will become increasingly accessible via the internet which will increase overall user capability and connectivity, though it may also provide seemingly low-cost opportunities for non-kinetic and cyber type attacks. As such, cyber security, data-intercept and anti-jamming capabilities will remain a concern well into the future because of the human component. Tactics used by adversaries can be expected to advance as well so in effect the threat may remain constant over time. ..

There will be incremental advancements in remote power generation, storage, and distribution. Assuming economic stability, fuel cells, improved solar capabilities, batteries, hydroelectric, and wind technologies are likely. However, if this technology displays a slower, incremental rate of advancement it may limit its potential to present a distinct military advantage over adversaries resulting in continued reliance upon more traditional methods.

10-20 years*:*

In 10-20 years, mobile devices will proliferate. Miniature, wearable computing devices may advance to the point where they approximate human mental capabilities. Human-technology interfaces will progress towards sensory applications (visual, tactile, etc), possibly even biological in nature. Global infrastructure will continue to grow and evolve in attempts to sustain global ICT capabilities. Required deployable communications equipment may not necessarily diminish. Alternatively, it will change in size, capability, and purpose.

Commercial entities will provide communication mediums with much broader global coverage, driven largely by market forces. Demand for technology by local populations in austere locations where such technology is currently unavailable will increase and many locations currently considered austere will become much less so from an ICT perspective. However, some point out that the socioeconomic factors within a region may limit the amount, reliability, and quality of ICT services available to the DoD. Therefore, local access as a primary source of connectivity for military units is an area of concern. Furthermore, despite the increase in demand some of these areas may remain un-served by the commercial sector due to poor projected profits. Satellite technology will continue to evolve. Constant network connectivity and very high data rates may be obtained through ad hoc type topologies employing devices as both individual users and as inter-networked components of the global network.

Many responses indicate advancements in remote power generation, storage, and distribution will focus on fuel cells and "green technologies" such as wind and solar for use in austere environments. However, the logistical footprint required to employ these green technologies suggests they will not be used in austere locations on a large scale within the next 20 years. Alternative technological advancements may include thorium-based nuclear energy and batteries as well as wireless power transmission if RF interference and possible adverse health effects are overcome.

Beyond 20 years*:*

Sensory integration of small ICT devices will be mature technology, possibly even implanted. The individual devices may draw sufficiently low amounts of power that physical movement, respiration, possibly even electro-chemical methods other than batteries may be viable. Devices will be interconnected, which will require robust security due to the potential for severe negative impacts of compromise. Computers will interface with users via physical motion in lieu of the keyboard, mouse, and similar technologies which will have become obsolete. Data archival technologies will be multiple generations beyond current capabilities allowing users to securely store and retrieve data with an accessible lifespan of 50-100 years. New materials crucial to ICT manufacturing will need to be explored due to their possible scarcity of precious metals and environmental impacts from mining and the continued use of petroleum products for their manufacture and disposal.

Austerity as it pertains to mobile ICT will be due more to an occurrence of an event within an environment rather than characteristic of the location as mobility will have become transparent. Events such as natural disasters, power grid failures, war, etc. are potential situations which may render an otherwise "developed" area austere.

Bibliography

Akyildiz, I., Jornet, J. (2010). The Internet of Nano-Things. *IEEE Wireless Communications*, 16(6), 58-63.

Albright, R. (2002). What Can Past Technology Forecasts Tell Us About the Future? *Technological Forecasting & Social Change*, 69 (5), 443-464.

Bergmann, W. (1996). Military Specifications (MILSPEC) Reform: Change is Underway in the Way We Write and Apply Standards Prescribing Management and Manufacturing Practices. *Defense Acquisitions University Publications*. Retrieved November 5, 2012 at http://www.dau.mil/pubscats/PubsCats/PM/articles96/bergmann.pdf.

Bishop P., Hines A., Collins T. (2007). The Current State of Scenario Development: An Overview of Techniques. *Foresight – The Journal of Future Studies, Strategic Thinking and Policy*, 9(1), 5-15.

Boje, D., Murnighan, J. (1994). Assessing the Quality of Expert Judgment: Issues and Analysis. *Decision Support Systems*, 11(1), 1-24.

Brockhoff, K. (1975). The Performance of Forecasting Groups in Computer Dialogue and Face to Face Discussions. In: Linstone, H., Turoff, M. (Eds.), The Delphi Method: Techniques and Applications, Addison-Wesley, London.

Chairman of the Joint Chiefs of Staff. Joi*nt Capabilities Integration and Development System*. CJCSI 3170.01H. Washgington: GPO, 10 January 2012.

Chan, A., Yung, E., Lam, P. (2001). Application of Delphi Method in Selection of Procurement Systems for Construction Projects. Construction Management and Economics, 19(2), 699-718.

Cherry, D. (2010). *Making JCIDS Work for the Warfighter*. U.S. Army War College Strategy Research Project, U.S. Army War College, Carlisle Barracks, PA, February, 2010.

Chou, C. (2002). Developing the e-Delphi System: A Web-based Forecasting Tool for Educational Research. *British Journal of Educational Forecasting*, 33(2), 233-326.

Chyma, T. (2010). *Rapid Acquisition*. Civilian Research Paper. U.S. Army War College, Carlisle Barracks, PA, February, 2010.

Clayton, Mark J. "Re-engineering Delphi: A Technique to Harness Expert Opinion," *Educational Psychology*, Dec 1997.

Dawson, M., Brucker, P. (2001). The Utility of the Delphi Method in MFT Research. *The American Journal of Family Therapy*, 29(2), 125-140.

Department of Defense. (2000). DoD 4120.24-M: *Defense Standardization Program, Policies and Procedures.* Retrieved November 26, 2012 from http://www.dtic.mil/whs/directives/corres/pdf/412024m.pdf.

Department of Defense. (2011). *Defense Standardization Program: Policies and Responsibilities.* Retrieved November 26, 2012 from http://www.dsp.dla.mil/APP_UIL/policy.aspx?action=content&accounttype=displaypolicy&contentid=33.

Department of Defense. (2011) *Quadrennial Defense Review*. Retrieved July 16, 2012 from www.defense.gov/qdr/

Des Marchais, J. (1999). A Delphi Technique to Identify and Evaluate Criteria for Construction of PBL Problems. *Medical Education*, 33(7) 504-508.

Devezas, T., Linstone, H., Santos, H. (2005). The Growth Dynamics of the Internet and the Long Wave Theory. *Technological Forecasting and Social Change*, 72, 913-935.

Erffmeyer, R., Erffmeyer, E., Lane, I. (1986). Quality of Group Judgment. Psychological Bulletin, 84, 120-128

Expert. (2012). Retrieved August 9, 2012 from http://www.merriam-webster.com/dictionary/expert?show=1&t=1344358997

Exponential Growth. (July, 2012). In Wikipedia. Retrieved July 26, 2012, from http://en.wikipedia.org/wiki/Exponential_growth.

Exponential. (February, 2013). Retrieved February 8, 2013, from http://www.merriam-webster.com/dictionary/exponential.

Final Report, Information and Communications Technology Industry. (2007). *The Industrial College of the Armed Forces.* Fort McNair, Washington, DC: NDU Press.

Fortuna, C., Mohorcic, M. (2009). Trends in the Development of Communication Networks: Cognitive Networks. *Computer Networks*, 53, 1354-1376.

Gorcin, A., Arslan, H. (2008). Public Safety and Emergency Case Communications: Opportunities from the Aspect of Cognitive Radio. *3rd IEEE Symposium on New Frontiers in Dynamic Spectrum Access Networks*. 1-10.

Government Accountability Office. (2008). *DOD's Requirements Determination Process Has Not Been Effective in Prioritizing Joint Capabilities*. Washington, DC: U.S. Government Printing Office.

Hasson, F., Keeney, S., McKenna, H. (2000). Research Guidelines for the Delphi Survey Technique. *Journal of Advanced Nursing*, 32(4), 1008-1015.

Hasson, F., Keeney, S. (2011). Enhancing Rigour in the Delphi Technique Research. *Technological Forecasting and Social Change*, 78, 1695-1704.

Hacklin, F., Marxt, C., Fahrni, F. (2009). Coevolutionary Cycles of Convergence: An Extrapolation from the ICT Industry. *Technological Forecasting and Social Change*, 76, 723-736.

Kahn H., Wiener, A. (1967). The Year 2000. *A Framework For Speculation on the Next Thirty Three Years.* Macmillan, New York, 1967.

Klemmer, E. E. T. (1972). Measurement of time spent communicating. *Journal of Communication*, 22(2), 142-15.

Koh, H., Magee, C. (2006). A Functional Approach for Studying Technological Progress: Application to Information Technology. *Technological Forecasting and Social Change*, 73(9), 1061-1083.

Kundra, v. (2011). *Federal Cloud Computing Strategy*. Washington, DC: U.S. Government Printing Office.

Kurzweil, R. (2001). *The Law of Accelerating Returns*. Retrieved June 5, 2012, from http://www.kurzweilai.net/the-law-of-accelerating-returns

Larkowski, M. (2003). *The Cyberspace Development Dogfight: Tightening the Acquisitions Turn Cycle*. MS Thesis, AFIT/ICW/ENG/09-03. School of Engineering and Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, June 2009.

Linstone, H., Turoff, M. (2002). *The Delphi Method: Techniques and Applications*. Retrieved from is.njit.edu/pubs/delphibook/delphibook.pdf.

Linstone, H., Turoff, M. (2011). Delphi: A Brief Look Backward and Forward. *Technological Forecasting & Social Change*. 78(9), 1712-1719.

Ludwig, B. (1997). Predicting the Future: Have You Considered Using the Delphi Methodology? *Journal of Extension*, 35(5).

Lunkwill. (2005). *Exponential.svg*. Retrieved July 26, 2012, from http://en.wikipedia.org/wiki/Exponential_growth

Lysenko, V., Desouza, K. (2012). Moldova's Internet Revolution: Analyzing the Role of Technologies in Various Phases of the Confrontation. *Technological Forecasting and Social Change*, 79, 341-361.

Magee, C. & Devezas, T. (2011). How Many Singularities Are Near and How Will They Disrupt Human History? *Technological Forecasting & Social Change*, 78, 1365-1378.

McKenna, H., Keeney, S. (2008). Delphi Studies, in R. Watson, H.P. McKenna, S. Cowman, J. Keady. *Nursing Research: Design and Methods*, 251-260.

Miranda, L., Lima, C. (2011). Trends and Cycles of the Internet Evolution and Worldwide Impacts. *Technological Forecasting and Social Change*, 79, 744-765.

Mishra, S., Deshmukh, S., & Vrat, P. (2002). Matching of Technological Forecasting Technique to a Technology. *Technological Forecasting & Social Change*, 69, 1-27.

Mitchell, V. (1991). The Delphi Technique: An Exposition and Application. *Technology Analysis & Strategic Management*, 3(4), 333-358.

Mlot, S. (2012). Army to Deploy Android Smartphones in Oct. Retrieved December 18, 2012, from http://www.pcmag.com/article2/0,2817,2406530,00.asp.

Moore, G. (1965). Cramming More Components Onto Integrated Circuits. *Electronics*, 38(8), 114-117.

Nagy, B., Farmer, J., Trancik, J., & Gonzales, J. (2011). Super-exponential Long-term Trends in Information Technology. *Technological Forecasting & Social Change*, 78, 1356-1364.

National Institute of Standards and Technology. (2010). NIST Cloud Computing Program. Retrieved February 8, 2013 at http://www.nist.gov/itl/cloud/.

Neal, M. (2004). *Establishing a Foundation to Capture the Cost of Oversight for a Major Defense Program Within the Information Technology (IT) Acquisition Community*. MS Thesis. AFIT/GCA/ENV/04M-07. School of Engineering and Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, March 2004.

Nelson, C., Steckler, B., Stamberger, J. (2011). The Evolution of Hastily Formed Networks for Disaster Response. *2011 IEEE Global Humanitarian Technology Conference*. 467-475.

Patten, M. (2009). *Understanding Research Methods: An Overview of the Essentials*. Glendale, CA: Pyrczak Publishing.

Oliver, R., Balko, B., Seraphin, A., Calhoun, A. (2002, November). Survey of Long-Term Technology Forecasting Methodologies. Retrieved from http://www.dtic.mil/dtic/tr/fulltext/u2/a410179.pdf.

Ramanathan, R., Redi, J. (2002). A Brief Overview of Ad Hoc Networks: Challenges and Directions. *IEEE Communications Magazine, 50th Anniversary Commemorative Issue*. 20-22.

Rowe, G., Wright, G. (1999). The Delphi Technique as a Forecasting Tool: Issues and Analysis. *International Journal of Forecasting*, 15(4), 353-375.

Rowe, G., Wright, G. (2001). Expert opinions in forecasting: The role of the Delphi technique. In Armstron, J. (Ed), *Principles of Forecasting: A Handbook for Researchers and Practitioner* (pp 125-144). New York, NY: Springer Sciences + Business Media, Inc.

Saunders, G. (2001). Milspec Reform: Completed. Retrieved November 5, 2012 from http://www.astm.org/SNEWS/NOVEMBER_2001/saunders_nov01.html

Smura, T., Sorri, A. (2009). Future Scenarios for Local Area Access: Industry Structure and Access Fragmentation. *Proceedings of the 8th International Conference on Mobile Business*. 57-63. IEEE Press.

Tague, J., Beheshti, J., & Rees-Potter, L. (1981). Retrieved July 17, 2012, from https://www.ideals.illinois.edu/bitstream/handle/2142/7189/librarytrendsv30i1_opt.pdf?sequence=3#page=130

Tegart, G. (2003). Nanotechnology: The Technology for the 21st Century. The APEC Center for Technology Foresight, National Science and Technology Development Agency. Bangkok, Thailand.

The Delphi Method. (2004). Retrieved August 22, 2012, from http://cobhomepages.cob.isu.edu/jeffstreet/mgt329/The%20Delphi%20Method.pdf

Williams, P., Webb, C. (1994). The Delphi Technique: A Methodological Discussion. *Journal of Advanced Nursing*, 19(1), 180-186.

Wilson, K. *Determining Communication Shortfalls for Homeland Defense*. MS Thesis, Naval Postgraduate School, Monterey, CA, December 2007.

Woudenberg, F. (1991). An Evaluation of Delphi. *Technological Forecasting & Social Change*, 40, 131-150.

Wyld, D. (2010). The Cloudy Future of Government IT: Cloud Computing and the Public Sector Around the World. *International Journal of Web & Semantic Technology*, 1(1), 1-20.

Zhu, D., Porter A. (2002). Development of New Technology Forecasting Algorithm: Hybrid Approach for Morphology Analysis and Conjoint Analysis of Patent Information. *Technological Forecasting and Societal Change*, 69(5), 495-506.

Zolingen, S., Klaassen, C. (2003). Selection Processes in a Delphi Study About Key Qualifications in Senior Secondary Vocational Education. *Technological Forecasting and Social Change*, 40(4), 317-340.

Vita

Capt Andrew Soine was born in Minneapolis, Minnesota. He grew up in Mandeville, Louisiana and graduated from Fontainebleau High School in 1998. In 2002, he graduated from Louisiana Tech University. In 2004, he was commissioned to active duty through the Air Force Officer Training Schools at Maxwell AFB, Alabama.

Capt Soine began his career at Robins AFB, Georgia where he was assigned to the 542d Combat Sustainment Wing as a program manager for the ALQ-161 electronic countermeasures suite for the B-1B. After 18 months, he was re-assigned to the 330th Aircraft Sustainment Wing as executive officer for one year in the 580th Aircraft Sustainment Group which is responsible for the sustainment of all Air Force Special Operations Forces/Combat Search and Rescue fixed and rotary wing aircraft. Then, he was assigned as program manager for the Tanker Flight performing sustainment on the HC-130P/N fleet. While in the Tanker Flight, Capt Soine participated for six months on the High Velocity Maintenance project.

In 2008, Capt Soine was assigned to the Space Development and Test Directorate (SMC/SD), Kirtland AFB, New Mexico as a program manager for the Multi-Mission Satellite Operations Center (MMSOC). In 2009, Capt Soine was deployed to Kabul, Afghanistan as Movement Officer in Charge with the US Army Corps of Engineers. Upon his return in 2010 to SD, he returned to the MMSOC program as deputy branch chief where he oversaw the first launch on the new ground system. Capt Soine enrolled in the Air Force Institute of Technology in August, 2011. Upon graduation, Capt Soine will be assigned to the Air Force Research Laboratory at Wright Patterson AFB.

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 074-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From – To)*
21-03-2013	Master's Thesis	August 2012 – March 2013

TITLE AND SUBTITLE

Needed Actions within Defense Acquisitions Based on a Forecast of Future Mobile Information and Communications Technologies Deployed in Austere Environments

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Soine, Andrew T., Captain, USAF

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)

Air Force Institute of Technology
Graduate School of Engineering and Management (AFIT/ENV)
2950 Hobson Way, Building 640
WPAFB OH 45433-8865

8. PERFORMING ORGANIZATION REPORT NUMBER

AFIT-ENV-13-M-28

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

USAF/AFSPC/24AF/689CCW
689th Combat Communications Wing
575 Tenth St
Robins AFB, GA 31098
DSN 472-8689, 689ccw.cce.exec@robins.af.mil
"Fear the Beast" Joseph.Scherrer@ROBINS.AF.MIL

10. SPONSOR/MONITOR'S ACRONYM(S)
USAF/AFSPC

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A: APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The purpose of this research was twofold. First, it developed a forecast of future mobile information and communications technologies (ICT) suitable for use by military forces in austere environments in 5-10, 10-20, and beyond 20 years. Secondly, it explored whether or not current acquisitions practices will be adequate to meet the needs of warfighters who depend on mobile ICT. These questions were explored by conducting utilization of the Delphi technique. Eight panelists from within the private sector conducted three rounds of iterative feedback. This research resulted in a technology forecast for the three timeframes aforementioned, and the potential impacts to the defense acquisitions community. First, current acquisitions practices are unlikely to meet the needs of warfighters dependent upon mobile ICT and streamlining efforts are not likely to result in sufficient lessening of development timelines to maintain technological currency. Secondly, it is foreseeable that military forces will become increasingly dependent upon technologies developed by the private sector. An acquisitions model which exploits technological advances in the form of smart phones and tablets and a secure repository for approved applications and data services is feasible and may help defense acquisitions to maintain technological currency as they replace dedicated, single-purpose equipment. Finally, it suggested that developing the organizational flexibility to adapt to emerging technological trends will become more important than detailed planning and budgeting beyond 10 years.

15. SUBJECT TERMS

Acquisitions, Mobile, Austere, Information and Communication Technology, Forecast, Delphi

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Dr. Alan Heminger
U	U	U	UU	116	**19b. TELEPHONE NUMBER** *(Include area code)* (937) 255-3636 x7405, alan.heminger@afit.edu

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18