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THE FUTURE OF MOBILE INFORMATION AND COMMUNICATION TECHNOLOGY IN AUSTERE ENVIRONMENTS: A COMMAND AND CONTROL TECHNOLOGY INTEGRATION PERSPECTIVE

THESIS

James W. Harker, MSgt, USAF

AFIT-ENV-13-M-10

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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THE FUTURE OF MOBILE INFORMATION AND COMMUNICATION TECHNOLOGY IN AUSTERE ENVIRONMENTS: A COMMAND AND CONTROL TECHNOLOGY INTEGRATION PERSPECTIVE

THESIS

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In Partial Fulfillment of the Requirements for the

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James W. Harker, BS

Master Sergeant, USAF

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James W. Harker, BS

Master Sergeant, USAF

Approved:

_____   _____
Dr. Alan R. Heminger (Chairman)   Date

_____   _____
John M. Emmert, Col, USAF (Member)   Date

_____   _____
Brent T. Langhals, Lt Col, USAF (Member)   Date

AFIT-ENV-13-M-10

Abstract

The information and communications technology (ICT) field is undergoing a period of tremendous and rapid change. As ICT develops more rapidly, the United States Air Force needs to remain responsive and adaptive to maintain military advantages. The need to integrate ICT developments sooner than our adversaries prompted an assessment of guidelines evaluating how well the AF is doctrinally positioned from a Command and Control perspective to support integration of emerging ICT. A Delphi Study was commissioned by the 689th CCW to forecast the future of mobile Information and Communication Technology (ICT) in austere environments. Using the ICT forecast data as a basis, the panel provided inputs on the integration concerns the forecasted trends invoked and the effects of the forecast on the Measures of Effectiveness outlined in AF doctrine.

Acknowledgments

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James W. Harker

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THE FUTURE OF MOBILE INFORMATION AND COMMUNICATION TECHNOLOGY IN AUSTERE ENVIRONMENTS: A COMMAND AND CONTROL TECHNOLOGY INTEGRATION PERSPECTIVE

I. Introduction

The mission of the United States Air Force (USAF) is to *fly, fight* and *win*...in air, space and cyberspace (www.af.mil). In order to achieve mission success the Air Force (AF) recently enumerated its core duties, distinctive capabilities, and responsibilities. The AF then streamlined them into twelve core functions. According to AF Doctrine Document 1 "These core functions express the ways in which the Air Force is particularly and appropriately suited to contribute to national security…".

Each of these core functions are comprised of unique personnel, equipment, and infrastructure thus requiring Information and Communication Technology (ICT) to operate seamlessly amongst one another. The Command and Control (C2) function supports AF core functions and the AF mission: "effective C2 of forces is woven throughout each level of conflict and is accepted as a necessity for successful military operations" (AFDD6-0, 2011). Therefore ICT developments realized in this core function have the potential to affect the efficiency of C2 thus affecting a substantial portion of AF operations. This thesis explores the effect of forecasted changes in ICT on C2 technology integration.

Background

ICT is a term used to represent the merging of Telecommunications and Information Technology and is defined throughout the literature as, *a catch –all phrase used by the international community to describe a range of technologies for gathering,*

storing, retrieving, processing, analyzing, and transmitting information (Kramer et al, 2007; Wentz et al, 2008; Bakari, 2007; FR, 2007). With a common understanding of how ICT is defined and what it is composed of, one may consider how ICT developments contribute to the C2 core function.

Attempting to forecast ICT development trends is not a revolutionary idea. For example, Gordon Moore described Integrated Circuit (IC) development trends creating Moore's Law which outlines that transistors on ICs double approximately every 18 months (Moore, 1965; B. Nagy et al, 2011). Moore's Law has since been revised numerous times and extrapolated to many performance metrics for ICT hardware (B. Nagy et al, 2011). Assuming these extrapolations of Moore's Law are valid, ICT hardware capabilities will develop at an exponential rate. This rapid rate of development may have ramifications for the use of ICT in C2.

The inclusion of devices or components into an already functioning system requires planning to avoid potential negative effects on functionality. Each sub-net or autonomous C2 communication system must be able to communicate with others via a common backbone. Integrating these devices and systems is promoted through the use of the C2 Measures of Effectiveness (MoEs) explained below.

<u>Command and Control ICT Measures of Effectiveness</u>

1. <u>Flexible</u>: 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. <u>Responsive</u>: The C2 system must be responsive to user needs. The response should be instantaneous, reliable, redundant, and timely (AFDD6-0, 2011).

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

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

5. <u>Survivable</u>: 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. <u>Sustainable:</u> For a system to be sustainable it must remain interoperable, affordable, and ultimately usable.

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

Figure 1. Measures of Effectiveness (AFDD6-0, 2011)

Problem Statement

As ICT capabilities increase, the AF faces significant integration challenges. To fulfill the core functions charged to the AF, the best C2 ICT should be integrated for utilization. Forecasting mobile ICT in austere locations and evaluating the appropriateness of the current MoEs compared to the forecast should encourage this integration.

RESEARCH QUESTION 1:

What is the future of mobile ICT in austere locations in 5-10 years, 10-20 years and 20 plus years?

The forecast data obtained from the panel is intended to provide an insight as to what ICT is coming down the pipe for use in the AF. This insight can be useful in determining how well our doctrine outlines the integration requirements imposed on new ICT. More specifically, the MoEs will be evaluated in an effort to determine if all projected concerns are encompassed within them and what changes should be implemented.

RESEARCH QUESTION 2:

Based on a forecast for ICT development, will the Measures of Effectiveness be met and should they be modified based the on forecasted trends?

Problem Approach

A Delphi Study will be used to create a forecast of ICT development and to assess the impact of that forecast on the MoEs. Futurists and communication technology experts will be selected to serve on the Delphi panel.

Research Scope

The study will be conducted utilizing non-military futurists and ICT experts from within the United States.

Thesis Outline

This first chapter introduced readers to the topics and provided a brief background. Chapter 2 contains a review of the Delphi Method, C2 MoEs, and ICT Forecasting literature. Chapter 3 describes the Delphi Method and explains how it will be implemented. Chapter 4 contains a summary of results from the Delphi Panel

responses. Chapter 5 presents a discussion of the findings including recommendations,

conclusions, and recommendations for future research.

II. Literature Review

As the AF evolves so do the technologies associated with day-to-day operations. The ICT infrastructure that has been built up at static bases directly contributes to mission success. Additionally, current portable ICT systems strive to transfer these static base capabilities to mobile warfighters. Up to the present, this has been done rather effectively. However, as ICT development trends suggest, new developments are being introduced at an increasingly rapid rate. Resulting in static base ICT struggling to keep abreast with the advancements and leaving the mobile ICT sector even more overwhelmed. This literature review begins by briefly discussing the Delphi Technique and its four components. A brief description of Command and Control, its associated technologies, and technological Measures of Effectiveness will follow. Finally, ICT forecasting will be introduced.

The Delphi Method

Delphi Origination

The RAND Corporation is a global policy think tank that began as a subsidiary of Douglas Aircraft Company in 1946 researching the long range planning of future weapons systems. In an effort to avoid conflicting interests, RAND separated from Douglas Aircraft Company in 1948 as an independent non-profit organization (Wikipedia, 2012). Soon after, in the 1950s, RAND workers Olaf Helmer , Norman Dalkey, Ted Gordon and associates began working on a USAF project and while doing so created the Delphi Technique (Dalkey & Helmer, 1963; Hsu & Sandford, 2007; Linstone & Turoff, 2011).

Delphi Technique

       The Delphi technique is a group communication process used to elicit the

knowledge and opinions of experts on real-world matters (Dalkey & Helmer, 1963;

Dalkey, 1969; Linstone & Turoff, 1975; Lindman, 1981; Martino, 1983; Hsu &

Sandford, 2007). It is an appropriate method for forecasting subjects in which

information is scarce or non-existent and the value of expert opinion is amplified (Rowe

& Wright, 2001; Oliver et al, 2002). The most common use of this technique is in the

futures sector forecasting timeframes of specific events and repercussions of current

actions (Rowe & Wright, 2001). More specifically, the Delphi technique has been

identified as an effective method for IT-related studies (Mishra et al, 2002). The four

pillars of the Delphi Technique are anonymity of experts, iteration of research instrument

questions, controlled feedback to experts, and aggregation of expert responses (Rowe &

Wright, 2001; Helmer, 1972). The sequence of a generic Classic Delphi study begins

first by selecting the expert panel. A panel size of 5-20 is generally sufficient, however if

the topic requires in-depth feedback from experts, a smaller panel size may suffice (Rowe

& Wright, 2001; Armstrong, 1985). Next, an unstructured questionnaire is administered

to the panel. The research team analyzes the responses and aggregates them. From this

the team creates a structured questionnaire and feedback document for the next sampling

iteration. This process continues generally for 3 to 5 rounds (Gustafson et al, 1975;

Ludwig, 1994; Hsu & Sandford, 2007). Consensus is often the researcher's goal in a

Delphi study but divergent responses also provide value evident by Olaf Helmer's (1967)

statement "… use considerable caution in deriving from their various opinions a single

combined position." One may postulate that Helmer's concern of compromising the

experts' responses to arrive at a single vision may subsequently detract from the accuracy and validity of the Delphi technique. The four characteristics and their significance to the Delphi technique are further described below.

Anonymity

The Delphi technique incorporates anonymity of expert panelist to avoid the weaknesses associated with other face-to-face group methods (Rowe & Wright, 2001; Helmer, 1972). The panelists will not be biased by the perceived authority or level of knowledge of the other panelists nor will a domineering and/or boisterousness participant skew responses; additionally participants will not suffer from the band-wagon effect or the stubbornness associated with changing one's mind after publically stating one's position on an issue (Helmer & Rescher, 1959; Oh, 1974; Adams, 2001; Dalkey, 1976; Hsu & Sandford, 2007).

Iteration

Iteration of sampling questions allows the participants to recount their answers, review the thoughts and replies of other participants, and ultimately reinforce or modify their responses (Rowe & Wright, 2001; Helmer, 1972).

Feedback

Feedback is aggregated into the initial model from the first round of responses. This initial model is fed back to the panel for assessment. This sets the stage for the panel to provide anonymous group collaboration on the issues (Rowe & Wright, 2001; Helmer, 1972).

Aggregation

The aggregation of the panel's responses need not be in the form of a consensus as this is not the only intent of the Delphi technique (Linstone & Turoff, 1975; Linstone & Turoff, 2011; Coates, 1975). Much can be learned from divergent responses shedding light on the complexity of the problem at hand (Coates, 1975).

Command and Control (C2)

Joint Publication (JP) 1-02, Department of Defense (DOD) Dictionary of Military and Associated Terms define C2 as

> *"The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. 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."*

The definition 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 (AFDD6-0, 2011).

C2 Technology

C2 Technology includes "equipment, facilities, hardware, software, infrastructure, materiel, systems, and a whole host of other elements" (AFDD6-0, 2011). AFDD6-0 outlines the purpose of C2 communication systems "…to ensure commanders receive mission-essential information, make informed and timely decisions, and communicate appropriate commands to subordinates throughout the operation." Currently, the standard C2 communication systems are expected to provide voice and data exchange capabilities within the C2 center and among select entities within the Global information Grid (GiG) (AFDD6-0, 2011). JP 1-02 describes the GiG:

> *The GIG is the globally interconnected, end-to-end set of information capabilities, associated processes and personnel for collecting, processing, storing, disseminating, and managing information on demand to warfighters, policy makers, and support personnel. The GIG includes all owned and leased communications and computing systems and services, software (including applications), data, security services, and other 19 associated services necessary to achieve information superiority. The GIG supports all DOD, national security, and related intelligence community missions and functions (strategic, operational, tactical, and business), across the full range of military operations. The GIG provides capabilities from all operating locations (bases, posts, camps, stations, facilities, mobile platforms, and deployed sites). The GIG provides interfaces to coalition, allied, and non-DOD users and systems.*

A set of guidelines were developed and published for assessing systems suitability for inclusion to the C2 ICT realm.

C2 Technology Measurements of Effectiveness (MoE)

MoEs are a set of guidelines based on characteristics published in AFDD6-0 designed to ensure the proper functioning of C2 ICT. They are used to evaluate a system's suitability for inclusion to the C2 ICT. The MoEs consist of seven measures: Flexible, Responsive, Mobile, Disciplined, Survivable, Sustainable, and Interoperable.

Flexible

"Flexibility is the key to airpower" - Gen Giulio Douhet. While the General likely did not directly mean that flexibility in C2 communication systems is the key to airpower, his remarkably accurate statement is fitting to the situation. The C2 communication systems incorporated throughout the AF and DoD should remain 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. This should be accomplished with minimal downtime (AFDD6-0, 2011).

Responsive

The C2 system must be responsive to user needs. The response should be instantaneous, reliable, redundant, and timely (AFDD6-0, 2011). Responsiveness differs from flexibility in that the responsiveness indicates more of what is expected performance wise rather than capability wise. For instance, it is the system's flexibility that allows it to access one's email; however, how quickly that email opens and the attachments download are the system's responsiveness.

Mobile

Mobile C2 technology is an ambiguous term requiring contextual definition. "Must be as mobile as the forces, elements, or organizations they support without degraded information quality or flow" (AFDD6-0, 2011). Expounding on this definition one may confidently assert that the technology implemented must be scaled appropriately for use and thus the mobility of the system is somewhat contingent on the users or group of users. For example, an entire Air Expeditionary Wing (AEW) has a C2 communication system that requires a fleet of aircraft to transport while a smaller contingent may be able to carry their C2 system in a single backpack.

Disciplined

AFFD6-0 describes the C2 system's discipline: *The C2 infrastructure must be focused, balanced, and based on predetermined needs for critical information.* The discipline of a system can be interpreted through an efficiency point of view. For instance, the list of required capabilities is given to the engineers who in turn develop solutions. The solution chosen should accommodate the MoEs, but not be so advanced that it detracts from intended purposes. In other words, the engineers should consider future capabilities of the system but not forgo current abilities striving to attain new ones.

Survivable

Also somewhat of an elusive term, national policy dictates the survivability of national command centers and the communications systems through which decisions are transmitted to forces (AFDD6-0, 2011). 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. For example, a network configured around a single server would not be considered survivable. If that one server fails, the entire network is rendered inoperable and thus, for a lack of a better term, dead.

Sustainable

The sustainability requirements mandate that a system must provide continuous support during any type and length of operations (AFDD6-0, 2011). This implies that the system be economically designed and employed. For a system to be sustainable it must remain interoperable, affordable, and ultimately usable. For instance, as AF legacy systems continue to age, their sustainability decreases congruently. This is due to antiquated support components akin to vacuum transistors being taken out of production. Subsequently, AF legacy systems that require vacuum transistors face a finite lifespan as the replacement items in reserve dwindle.

Interoperable

AFDD6-0 explains C2 communication systems "should be able to operate with key joint and coalition C2 systems." Once again referring to the explanation of the GiG, interoperability of a system supports its ability to exchange data.

ICT Forecasting

"A hiatus exists between inventors who know what they could invent, if they only knew what was wanted, and the soldiers who know, or ought to know, what they want, and would ask for it if they only knew how much science could do for them." (Churchill, 1920).

In order for the USAF to achieve a distinct advantage over current and potential adversaries, long range technological visions are developed identifying future capabilities (AFDD1, pg10).

Technological Forecasting (TF) was first officially documented in 1935 when the New Deal's National Resource Commission tasked a committee to look into the future of 13 major inventions and predict the impacts (Coates et al, 2001). In the context of this study, because ICT encompasses technology, TF is synonymous with ICT forecasting.

TF Methods

Mitroff and Turoff present the adage "philosophy is the most basic of all of man's creations." One's philosophy is their decision-making foundation which guides their responses to the inherent philosophical concerns posed in TF:

What permits us to extrapolate from the past or present to the future? What guarantees that the future will behave like the present or past? What firm insurance or what sure guarantee do we have that the future will behave as our projections of it forecast? (Mitroff & Turoff, 1973).

The answers to the questions above guide researchers toward various data collection methods and theoretical foundations, the merit which arguably corresponds to its accuracy (Mitroff & Turoff, 1973; Wise, 1976).

TF methods

The two fundamental types of TF approaches are normative and exploratory. Exploratory approaches of TF are coined as relatively simple schemes used when trying to predict the technology of the future. Exploratory TFs generally use the knowledge and opinions of groups of experts or some kind of simple trend-line approach (Roberts, 1969). Normative approaches are commonly used in economic predictions using multivariate systems analysis and cause-effect models to derive predictions. An exploratory approach, specifically the Delphi technique was chosen for this study.

Conclusion

This chapter explored the literature on the Delphi Technique, C2, C2 associated technologies, MoEs, and ICT forecasting. Evaluating ICT integration concerns for AF C2 requires first, that one have a forecast of emerging ICT. Then, the MoEs can be assessed based on the ICT forecast. The Delphi Technique is the TF method that will be used for this study.

III. Methodology

The Delphi Technique was chosen as the methodology for this study because it has become a fundamental tool in technological forecasting (Linstone & Turoff, 2002). Additionally, Linstone and Turoff suggest the technique provides value as a system for assessing policy questions (2002). This will be useful for assessing the MoEs . Therefore, a Delphi Study will be used to provide ICT forecast and an assessment of C2 MoEs.

Overview of implementation

The Delphi Technique will be used for its technological forecasting merits in eliciting inputs from an expert panel to form a forecast of mobile ICT in austere locations. This forecast will then be fed back to the panelists as a reference to see how well the current set of MoEs promotes integration of the forecasted equipment and capabilities. The study will begin by creating the panel of ICT industry experts. Next, the data collection phase will begin. During this phase, the researchers will gather panelist inputs using research instruments. The inputs will be analyzed and aggregated forming the feedback portion of the next iteration research instrument. The iterative process will continue until the responses seem to stabilize. The last round of inputs will be used to form the final aggregated forecast of mobile ICT and the panelists' collective thoughts on the appropriateness of the MoEs for integrating the forecasts. Creating the panel of experts is the first step of implementing the Delphi Technique.

Knowledge Areas

To get an accurate representation of the ICT industry as a whole, the Delphi Panel should include individuals with expertise in specific knowledge areas. These knowledge areas need to capture the entirety of the ICT field, yet have sufficient focus to provide justification of expertise for inclusion in the Delphi panel. Obtaining this focus is complicated by the enormity of the ICT field. Additionally, it seems impractical to have representative experts from every conceivable segment of the ICT industry as it was defined in chapter 1. It is even more unlikely the research team will be able to elicit the participation of an expert who transcends all disciplines. As such, the research team will extract specific skill sets and synthesize five over-arching Knowledge Areas (KAs). Developing these KAs requires creation of a logic model depicting how the KAs will be structured and related throughout the chronological process of developing a capability. The Defense Acquisition Management System Model served as the basis. It consists of 5 acquisition states that can be adapted to knowledge areas. For example, the Materiel Solution Analysis state in figure 2 was changed to the Concept KA in figure 3.
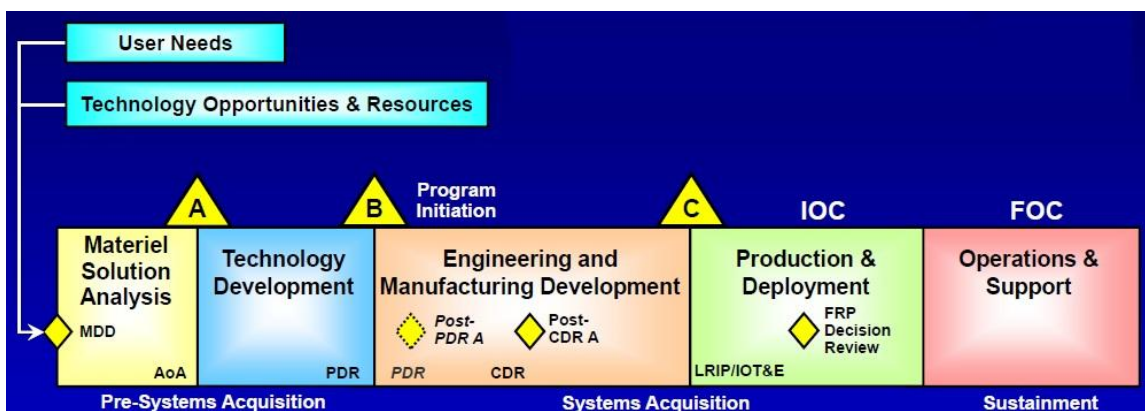

Figure 2. Defense Acquisition Management System Model

```
┌──────────┐
│ Concept  │──┐
└──────────┘  │
          ┌───▼──────────┐
          │ Intellectual │──┐
          └──────────────┘  │
                    ┌───────▼────────┐
                    │   Technology   │──┐
                    └────────────────┘  │
                              ┌─────────▼─────────┐
                              │   Application     │──┐
                              └───────────────────┘  │
                                        ┌────────────▼──────────┐
                                        │     Employment        │
                                        └───────────────────────┘
```
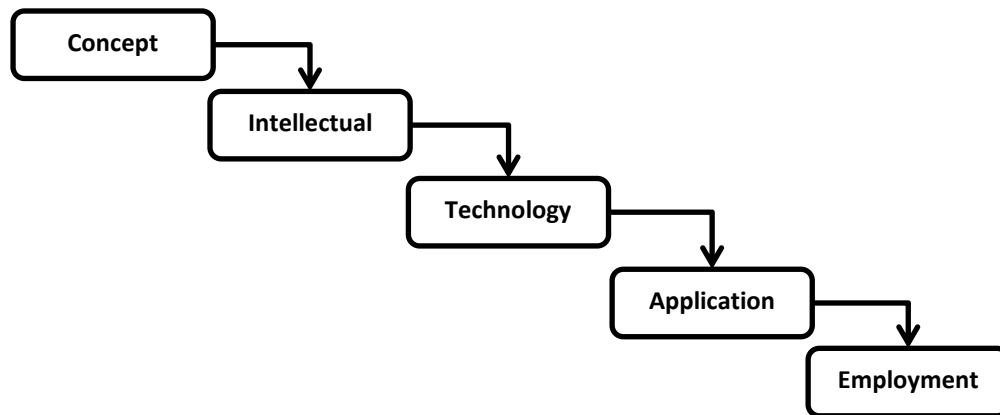
Figure 3. The ICT Interactive Capability Creation Model

These five knowledge areas represent a spectrum of expert perspectives within the mobile ICT industry which captures the multiple disciplines needed to field a capability. Using this construct, technologies and capabilities are developed primarily in a logical fashion beginning with "Concept Design and Demand" ultimately ending with "Employment". However, the order of development may change based on needs. As an example, warfighters utilized chat room capabilities in combat air operations centers 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).

Concept Design and Demand

This construct focuses on what ICT consumers want or expect from the devices provided or what forward thinkers imagine. As the first step in the interactive creation process, new ideas are formulated or imagined. At this point there are unlimited possibilities without bounds of physical or monetary restraints. Potential sources of representatives from this KA include experts from fields and specialties that monitor, influence, predict, and respond to changes in ICT and societal demands. Potential

sources of representatives from this KA include marketing professionals, consumer reporters, futurists, science fiction, and product testers.

Intellectual and Research

This construct focuses on the academics and theorists specializing in the ICT sector. As the second step in the interactive creation process research is conducted and solutions are presented for the ideas generated in the first step. At this point there may or may not be multiple possibilities depending on both physical and monetary restraints. The Delphi panel may include experts from fields and specialties that conduct basic research, applied research and generate innovative ideas. Potential representatives from this KA include experts from academia and think tanks.

Technology

This construct includes the physical components of the communications technology such as cable, telephone, television and radio manufacturing, cellular phones, and computer network hardware. As the third step in the interactive creation process, research is applied and solutions are implemented for the ideas generated in the first step. At this point, a particular device or solution has been built or chosen for possible implementation. The Delphi panel may include experts from fields and specialties that are on the forefront of technology innovation, specifically professionals within the Research and Development sections of various ICT manufacturing sectors. The potential sources of these professionals include telecommunications, networking, and hardware producers.

Application

This construct focuses on the development of new ICT device interfaces. As the fourth step in the interactive creation process, the ICT device has been chosen for a task and can be implemented, configured or programmed for use. At this point, the device interface for a particular device or solution is created allowing the ICT device to function according to the user requirements. The Delphi panel may include experts from fields and specialties that develop new ICT interfaces. Potential representatives from this KA may include experts that develop interface solutions between devices and individual users such as webpage designers, application developers, and software engineers.

Employment

This construct is a customer focus area that concentrates on how ICT is employed to accomplish a goal or mission. As the fifth and final step in the interactive creation process, the device has reached maturation and is available for use. At this point the ICT device has been created and produced; how the device is employed determines both its functionality and usefulness in the ICT realm. The Delphi panel may include experts from fields and specialties that utilize cutting-edge ICT in diverse environments and circumstances. To accomplish complex tasks involving many individual users requires continuous connectivity within an organization. Potential sources of representatives from this KA include international corporations, humanitarian organizations, news and information groups, municipalities, and sporting event organizers.

Expert criteria

Though the Delphi method has no specific criteria as to what makes an individual an expert, multiple sources indicate that the individual should have at least 5 consecutive

years of specific experience in the field of focus (Mitchell, 1991; Rowe and Wright, 1999; Dawson & Brucker, 2001). For the purposes of this effort, the researchers defined an ICT expert as a professional with at least five years of specific experience in one or more relevant KAs, though potential panelists exceed this requirement by a considerable margin.

Research Instruments

The research instruments created for this study will be designed to perform two functions. First, these instruments will collect data used to form the mobile ICT in austere locations forecast. Secondly, the instruments will be used to gather opinion concerning the assessment of current AF MoEs in light of the forecast.

Collection of mobile ICT forecast data

All iterations of questionnaires will solicit responses from the panelists about mobile ICT development. The responses to the first round will provide the data to create an initial aggregated forecast. This first round forecast will be fed back to the panelists for comment and revision and also as a reference for MoE assessment.

Collection of AF MoE assessment data

All iterations after the first round will solicit responses concerning MoEs in reference to the forecasted technologies. Once C2 MoE data collection begins in the second round it will occur in the same fashion as mobile ICT data collection.

The data collection will occur iteratively until the researchers feel as though the responses have stabilized usually within three to five rounds (Linstone & Turoff, 2002).

After all data has been collected, the final aggregated forecast and assessment will be presented in Chapter 4.

Conclusion

This chapter explained the chosen methodology and how it was implemented. The researchers' decomposition of ICT and ICT industry then set the stage for panel selection. Once the panel composition was created, the purpose and outline of the research instruments were presented. Summing up Chapter 3 into one sentence, The Delphi Technique was chosen as the methodology for this study and this is how it will be implemented.

IV. Results

This chapter presents the Delphi panel, ICT forecasts, and C2 MoE analysis. The Delphi study was completed using three rounds of questions and feedback. The research instruments used to gather data are included in appendices A-C.

Creating the Panel

The Delphi Panel was created using the list of experts provided by students in an Information Resource Management program capstone course. The final deliverable from that course was a list of approximately 100 panel candidates to represent Concept, Intellectual, Technology, Application, and Employment Knowledge Areas (KAs):. The candidates were divided into KA groups and ranked within that group. Literature suggests that a panel of experts should consist of 5 to 20 members; yet, due to the expertise of panel candidates and the in-depth feedback desired, fewer panelists seemed appropriate (Armstrong, 1985; Rowe & Wright, 2011). The panel target size was set at ten to twelve. The top 25 candidates were contacted with the expectation that less than 50% would accept. Positive responses were received from 11. Round 1 attrition left us with 8 panelists that participated throughout the entire study. Those that dropped out did so before providing any input to the study thus did not affect the group's forecasts. Figure 1 contains pertinent information about the panelists and shows an even distribution with emphasis on the Application and Employment KAs as requested by the research sponsor.

Panelist Demographic data

Table 1. Panelist Demographics

Knowledge Area Represented	Job Title	Education	Experience
KA: 1 Concept Development & Demand	Lecturer and Executive-in-Residence	PhD	20+ years
KA 2: Intellectual & Research	Program Manager	PhD	40+ years
KA 2: Intellectual & Research	Associate Professor of Systems Engineering, AFIT	PhD	20+ years
KA 3: Technology	Director of Business Development/Sales	MA x 3	20+ years
KA 4: Application	Staff Architect	BS	20+ years
KA 4: Application	Practice Leader	MA	20+ years
KA 5: Employment	Branch Chief- IT/Disaster Emergency Communications	BS	20+ years
KA 5: Employment	Network Consulting Engineer	BA	20+ years

Mobile ICT Forecasts

The forecast narratives are the researchers' analysis based on panelist inputs gathered throughout the three rounds of the Delphi study. The forecasts are presented using a categorical approach. The categories are Personal ICT, Interfaces, Data Storage, Infrastructure, Protocols, Satellite Communications (SATCOM), Security, Power, and Environmental. For each timeframe, 5-10 years, 10-20 years, and 20+ years, the nine categories will be examined. As the forecast categories are presented, the first round summation is presented followed by recommended changes from second round, and ultimately the final category forecast. For categories that were not addressed or did not change throughout the study, a single forecast entry marked as "Final" is presented.

ICT Categories Defined

Personal ICT is defined for use within this study as devices or nodes used by individuals which are normally portable. Examples include smartphones, tablets, and laptop computers.

Interfaces are defined for use within this study as the human to machine interaction method. An example of a computer interface is a keyboard.

Data Storage is defined for use within this study as the method or device that stores data. Examples include memory sticks, hard drives, and Compact Disks.

Infrastructure is defined for use within this study as the support equipment and services required in operating ICT. An example of infrastructure is a cellular tower or satellite uplink.

Protocols are defined for use within this study as procedures or methods of machine level communication. Protocol examples include Hyper Text Transfer and Secure Socket Layer Protocols, HTTP and SSL respectively.

Satellite Communications (SATCOM) is defined for use within this study as the exchange of data, voice, or video via satellite uplinks and/or downlinks.

Security is defined for use within this study as the protection of data from access or manipulation by unauthorized entities. Examples include both physical barriers such as buildings and fences as well as data encryption techniques.

Power is defined for use within this study as the source from which the systems operate, primarily electricity.

Environmental is defined for use within this study as the conditions or availability of natural resources surrounding a system or location. Examples of environmental include an earthquake or hurricane imposing reduced ICT capabilities on a region or the availability of water, gas, and precious metals in a given location.

Mobile ICT Forecast 5-10 Years

Personal ICT

Round 1- ICT used in austere environments will trend towards smaller, faster, and cheaper devices akin to handheld tablets and smart phones.

Round 2 – No changes.

Final - ICT used in austere environments will trend towards smaller, faster, and cheaper devices akin to handheld tablets and smart phones.

Interfaces

Final -The panelists did not provide forecast inputs for this category during this time period.

Data Storage

Round 1 – Increases in cloud computing will enable linkage to global networks.

Round 2 - Panelists suggested removing Cloud Computing from *Data Storage* forecast because it is encompassed by convergence of applications and data services thus was moved to the Infrastructure section..

Final - The panelists did not provide forecast inputs for this category during this time period.

Infrastructure

Round 1 - 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.

Round 2 – Removed the reduction of necessary infrastructure. Panelists asserted that the infrastructure needs may not decrease due to the increased bandwidth demand from device to device communications, unmanned aerial vehicles, robots, sensors, etc.

Final - 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.

Protocols

Round 1 - Everything over Internet Protocol (EoIP) will be the medium of choice for voice, data, and video.

Round 2 – No changes.

Final - EoIP will be the medium of choice for voice, data, and video.

Satellite Communications (SATCOM)

Round 1 - Exponential increases in user demand for bandwidth will drive advances in mobile satellite technologies. In austere environments, SATCOM 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.

Round 2 - Data transport innovations were added to advancements in mobile satellite technologies. SATCOM and alternatives were presented along with the

presumption that satellite use would decrease. SATCOM 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.

      Final – Changes include SATCOM as the recognized infrastructure backbone

with alternatives developed as intermediary links. 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 alternatives may be 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.

Security

Round 1 - Advancements in cyber security will enable low probability of intercept/low probability of detection as well as anti-jamming capabilities.

Round 2 - Changed enabling to promoting security capabilities and introduced security as a continuous concern with human component. 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.

Final - 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.

Power

Round 1 - There will be incremental advancements in remote power generation, including fuel cells, improved solar, and batteries.

Round 2 – Included power storage and distribution as part of the remote power topic and introduced likely technologies. Fuel cells, improved solar capabilities, batteries and other "green" technologies are likely.

Final - Economic influences and development rates introduced as conditions to military use. 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.

Environmental

Final - The panelists did not provide forecast inputs for this category during this time period.

Mobile ICT Forecast 10-20 Years

Personal ICT

Round 1 - Mobile devices will proliferate. Miniature, wearable computing devices may advance to the point where they approximate human mental capabilities. Individual devices become low-power, charged by physical movement, respiration, possibly even using electro-chemical methods such as human blood sugars.

Round 2 – No changes.

Final - Mobile devices will proliferate. Miniature, wearable computing devices may advance to the point in which they approximate human mental capabilities. Device power being derived from the user was moved to the beyond 20 year projection. Panelists felt it was the more appropriate timeframe for the projection.

Interfaces

Human-technology interfaces will progress towards sensory applications (visual, tactile, etc), possibly even biological in nature.

Round 2 – No changes.

Final - Human-technology interfaces will progress towards sensory applications (visual, tactile, etc), possibly even biological in nature.

Data Storage

Final - The panelists did not provide forecast inputs for this category during this time period.

Infrastructure

Round 1 - Infrastructure will include robust global ICT capabilities and further reductions in necessary deployable communications equipment.

Round 2 – Panelists introduce socioeconomic factors and multiple paths for infrastructure development.

Final - 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 economic/social/political 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.

Protocols

Final - The panelists did not provide forecast inputs for this category during this time period.

Satellite Communications

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.

Round 2 –Ad hoc networking was introduced to the forecast. Ad hoc type topologies employing devices as both individual consumers and as inter-networked components of the global network.

Final - Satellite alternative forecasts were moved to the 5-10 year forecast based on panelist inputs. 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.

Security

Final - The panelists did not provide forecast inputs for this category during this time period.

Power

Round 1 - Advancements in remote power generation will include wireless power technology and nuclear batteries.

Round 2 - "Green technologies" such as wind and solar introduced as possibilities for use in austere environments. Wireless power transmission may mature if RF interference and possible adverse health effects are overcome.

Final - 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 still not be used for military operations in austere locations on a large scale within this timeframe. 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.

Environmental

Final - The panelists did not provide forecast inputs for this category during this time period.

Mobile ICT Forecast 20+ Years

Personal ICT

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

Interfaces

Round 1 - Displays will be holographic using physical motion as the keyboard, mouse, and similar technologies have become obsolete.

Round 2 – Removed holographic display from forecasted interfaces. Panelists suggested identifying a specific technology beyond 20 years may not be appropriate. Instead, they proposed the general direction of capabilities.

Final - Computers will interface with users via physical motion in lieu of the keyboard, mouse, and similar technologies which will have become obsolete.

Data Storage

Round 1 - Crystalline storage systems will be developed. Cloud computing will be fully matured.

Round 2 - Panelists suggested identifying a specific technology beyond 20 years may not be appropriate. Instead, they proposed the general direction of capabilities. 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.

Final - 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.

Infrastructure

Round 1 - 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.

Round 2 - Personal satellite uplinks were removed because panelists identified them as infeasible. Global connectivity was solidified as being likely and examples of environments becoming disconnected were introduced.

Final - 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.

Protocols

Final - The panelists did not provide forecast inputs for this category during this time period.

Satellite Communications

Final - The panelists did not provide forecast inputs for this category during this time period.

Security

Round 1 - Networks will be enabled with robust satellite defenses, smart security, and cloud.

Round 2 - Panelists suggested that the satellite defenses, smart security and cloud protection be removed from this section because security is projected to be a continuous

concern progressing in step with ICT. Impacts of security breaches were introduced. Devices will be interconnected, which will require robust security due to the potential for severe negative impacts of compromise

Final - Devices will be interconnected, which will require robust security due to the potential for severe negative impacts of compromise.

Power

Final - The panelists did not provide forecast inputs for this category during this time period.

Environmental

Round 1 - The panelists did not provide forecast inputs for this category during this time period.

Round 2 –Depletion of natural resources such as petroleum and precious metals was identified as a concern for powering manufacturing facilities and as source materials for ICT hardware.

Final - 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.

C2 MoE Data

Using the ICT forecasts as a reference, the panelists were asked to provide inputs in two areas. First, the panelists were asked to state their opinions on how each of the seven MoEs would change in importance. Next, the panel was asked to consider how well the MoEs address C2 ICT integration concerns. The results below are an analysis

and aggregation of the panelist inputs by the researcher during the data collection process. If the panelists did not provide revisions to the initial response summation, a single entry is presented marked as "Final." Alternatively, if revisions were suggested, both summations are included with the "Final" entry providing a statement at the beginning identifying the changes.

Evolution of each MoE's importance

Final – Responses focused on the importance of three MoEs: Flexible, Sustainable, and Interoperable.

Flexible - Unanimously the panelists agreed that this is an important consideration ensuring that during the infrastructure growth process backward compatibility is maintained.

Sustainable - Some asserted that its importance should increase due to shrinking military budgets. The reduction in funds may require that equipment life cycle be extended. Conversely, others stated that as ICT develops at increasingly faster rates, equipment is becoming obsolete during its functional life cycle thus detracting from the importance of Sustainable.

Interoperable - Some stated that interoperability would be more important because as the global network grew so operation within that network becomes more important. Yet, others stated that as the network grew, protocol standardization would increase as well. This would result in most devices being interoperable without specialized configuration.

MoEs address concerns for future C2 ICT

Round 2 - Some members expressed that the MoEs were generalized enough to encompass all relevant aspects of future ICT systems planning. Others suggested adding the following distinct measures: Securable, Bandwidth Consumption, Redundancy, Parallelism, and Auto-Adaption.

Final - Panelists introduced a possible paradigm shift in data exchange hereby termed "Data Usage." As ICT becomes faster and data is shared nearly instantaneously, the actual consumption and processing of the data is more heavily weighted. Rather than focusing on how quickly we can funnel data to users we may need to focus on how quickly that data can be interpreted and applied to decisions. Some members expressed that the MoEs were generalized enough to encompass all relevant aspects of future ICT systems planning. Others suggested adding the following distinct measures: Securable, Bandwidth Consumption, Redundancy, Parallelism, Auto-Adaption, and Data Usage.

This chapter presented the data as interpreted by the researchers. The Mobile ICT forecasts were introduced in a categorical format with inputs from each iteration explained. The C2 MoE data was then presented in a similar categorical fashion.

V. Discussion, Recommendations and Conclusions

This chapter contains a discussion of the ICT forecasts as well as a discussion of

C2 MoEs. Next, researcher recommendations will be presented followed by the

Limitations of the Study, Suggested Future Research, and finally the conclusion.

ICT Discussion

Multiple paths regarding forecasted ICT were suggested based on different

conditions that the panelists felt would stimulate and guide ICT development. The

common themes extracted from these conditions were environmental and socioeconomic

in nature.

Personal ICT

The forecasted proliferation of ICT akin to smartphones seems strongly

influenced by socioeconomic factors. The panelists indicated that market forces would

drive the development of both ICT and ICT infrastructure. As such, in underdeveloped

or impoverished locations, proliferation rates may be lower and infrastructure scarce.

Interfaces

ICT interface development will continue to transform moving away from standard

keyboard and mouse configurations incrementally progressing toward sensory

applications such as visual, tactile, and eventually biological. The rate of interface

development seems to be linked to socioeconomic factors directly and indirectly. Direct

linkage seems evident through basic supply and demand principals. If a demand for

interface evolution exists, it seems safe to assume that manufacturers would direct

attention to fulfilling that demand. Indirect linkage seems predicated again on market

forces. Logically speaking, the devices must be proliferated before a significant demand

is placed

Infrastructure

Bandwidth requirements will continue to grow and evolve increasing

infrastructure demands. However, producing infrastructure and bandwidth expends

resources suggesting that a more prosperous region would have more bandwidth

available and a higher demand. For example, the bandwidth demands such as device to

device connectivity, unmanned aerial vehicles, robots, and sensors should increase in

thriving economies.

Protocols

Protocols will continue to evolve to conform to performance standards as well as

interoperability standards. Therefore, Everything over IP (EoIP) will be refined,

implemented, and matured as the primary protocol for transferring voice, data, and video.

Due to the industry convergence on the IP protocol, it seems likely that this area will be

affected less by socioeconomic factors and more by manufacturer agreements to

standardize equipment. IP or a next generation version of IP is likely to be the industry

standard within five to ten years.

SATCOM

SATCOM currently dominates the market as the backbone to the global network

in both the commercial and military realms. In the commercial sector this probable into

the distant future. Bandwidth capabilities, security, and global coverage should continue

to improve through incremental advances. It seems likely that military will continue to

use SATCOM as the primary long distance backhaul medium. However, intermediate

backhauls mediums may be needed in situations where data exchange from the FOB is ported through a gateway and connected to the GiG via SATCOM. This will prompt development of long range, high performance RF and Optical data exchange systems augmenting SATCOM in austere locations. These new technologies should be available for use within the next ten to twenty years.

Security

Data security will be a concern into the distant future as ICT evolves, so will the malicious attackers. Additionally, as ICT proliferates and becomes less expensive, the pool of potential attackers grows congruently. Therefore we should dedicate significant resources to data security development to maintain a decisive edge over data attackers.

Power

Generating power is an enduring concern that has been largely alleviated in most parts of the world, specifically the developed regions. However this is a significant concern in remote, undeveloped areas and locations affected by natural disasters where power infrastructure has been damaged or destroyed. The use of petroleum fueled electric generators to generate power in austere locations introduces significant limitations such as the logistical footprint. As such, advancements in "green" technologies are probable within the 10-20 year timeframe. Although "green technologies" commonly infer environmental worth, they are important on logistical merit as well. For instance, a bank of petroleum fueled generators requires periodical fuel deliveries and maintenance activities. Solar, wind, or hydro power generation systems may substantially reduce the logistical footprint and support requirements. Therefore, it seems reasonable to invest aggressively in the development of these

technologies in aspirations of reaping the cost savings benefits during future engagements.

C2 MoE Discussion

Responses from the panel provided the following C2 MoE topics of concern: Flexibility, Sustainability, Interoperability, Security, Bandwidth Consumption, Redundancy, Auto-Adaption, and Data Usage.

Flexibility

According to the Delphi panel, the importance of this aspect seems to be growing for a couple of reasons. First, we want our systems to be adaptable enough to perform in a multitude of configurations as described in AFDD6-0. It may be that the rise in importance will be primarily focused on the ability of a projected system to be reconfigured or reprogrammed to utilize different protocols. This ability will directly support the next issue of sustainability.

Sustainability

A system being "sustainable" includes an affordability component. According to AFDD6-0, sustainable "… requires economical design and employment." Current budgetary restraints and looming concerns are placing increased emphasis on affordability which may prompt system planners to do the same.

Interoperability

As mentioned in the previous paragraph, interoperability in an important concern during the system planning phase of ICT. The new system should be capable of

interfacing with applicable ICT systems. This concern will continue to grow in importance well into the future.

Security

Security concerns were voiced multiple times during the study from many panelists. The ability to secure both hardware and the data contained or passed through that hardware is imperative. The current military culture of acquiring many Commercial Off-The-Shelf (COTS) ICT components seems to present avenues of security lapses to potential adversaries. For instance, devices or components engineered, manufactured, or assembled outside of the DoD (which is nearly all of them) may possess unidentified security vulnerabilities that can later be exploited by adversaries. As a result, the importance of security concerns during system planning may increase.

Bandwidth Consumption

Panelists suggested that bandwidth has evolved to the status of a commodity. The demand on bandwidth is projected to continuously increase thus solidifying it as a considerable topic of concern into the future. It may be that current restrictions on DoD bandwidth are primarily due to infrastructure limitations. However, as infrastructure evolves and bandwidth capabilities increase, the restraining factor may become budgetary. If this occurs, the amount of funding provided for bandwidth should become directly proportional to the amount of bandwidth obtained.

Redundancy

One may assert that intuitive communication is vitally important in a C2 environment. This assertion supports the panel's suggestion that the importance of ICT redundancy is increasing. An example is a base network. A communication

enhancement implemented in the 1990's has become a communication requirement in 2013. This increased dependency has created a vulnerability in which a network outage brings the AF at large to a limited operations state. In order to reduce potential vulnerabilities, as our dependency on ICT grows, so should our focus on system redundancy.

Auto-Adaption

Auto adapting hardware would likely increase ease of use and speed of setup however, akin to the COTS concerns discussed in the "security" section, automated processes equate to new potential vulnerabilities. For instance, if the systems or components are obtained from outside the DoD, it may be possible for adversaries to plant vulnerabilities into systems later implemented into C2 applications. Therefore if we begin to seek and accept these auto-adaption or auto-configurable devices the security aspects introduced as a result may warrant increased attention.

Data Usage

Based on panelist inputs, we may be entering an era in which data is exchanged so rapidly that the key differentiator between C2 ICT may morph from hardware capabilities to end user interpretation. As an example one may consider internet search engines. Performing a search in many cases yields numerous results to the user. The user must then interpret the results and select the appropriate data before it can be applied to the task at hand. As panelists suggested in the ICT forecasts, Personal ICT devices will continue to proliferate. One may assert, as these devices disburse and make data more accessible, evolution of data coding and presentation will become increasingly influential

on perceived ICT effectiveness. The coding and presentation will likely lead to increased interpretability of the data.

Recommendations

Based on inputs from the Delphi panel, the future of MoEs and their continued suitability is centered on elasticity in the form of frequent revisions. The topics discussed above may or may not be addressed by current MoEs depending on whom you ask, which presents perhaps the largest weakness. Such important considerations should not be left to chance. Those empowered to make C2 ICT integration decisions are assumed to have a suitable knowledge base to consider all relevant issues prior to acceptance. As a result, the MoEs seem purposely generalized providing significant flexibility and adaptability. However, as ICT development reaches exponential rates, if unchanged, the generalized MoEs may not remain a strong enough guide for integration decisions because the emerging capabilities and subsequent integration concerns may be missed. It seems naive to believe non-codified concerns will be applied consistently to future C2 ICT equipment. Therefore my recommended actions are as follows:

- Assemble a C2 integration board composed of ICT and C2 experts. Convene the board annually to review MoEs and provide revisions when appropriate.
- Enumerate all known concerns as either stand-alone MoEs or sub-MoEs to ensure consistent evaluation of C2 ICT.

Limitations of the Study

The study was limited by the knowledge of panelists and the time at which they participated. Composing a panel of different members may bring different insights and

forecasts. Additionally, the same questions asked at a later time would likely produce answers that benefit from future knowledge.

Recommendation for Future Research

The study limitations may be addressed by repeating this study with different participants after waiting a period of time, such as 2-5 years.

Conclusion

This chapter began with a discussion of C2 MoE topics of concern identified by the panel of experts. Then the recommended action list was presented. The limitations were then described followed by the suggestions for future research. Future warfare will not be conducted traditionally especially as ICT developments prompt new operational capabilities and demands. Accordingly, we should attempt to envision how these capabilities will be integrated into existing C2 systems to improve operations. We can apply the trends from the forecasts in chapter 4 not as specified plan of action, but as a tool designed to prepare our AF for impending changes.

"By failing to prepare, you are preparing to fail."

— Benjamin Franklin

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   MSgt James Harker
2054 Turnbull Rd   5579 Hickam Dr
Beavercreek, OH 45431   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.

Part 1: Basic Demographics

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?

Part 2: Please answer and elaborate on the following:

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

Note: Part II of this research instrument has been removed. It was used for a separate topic not covered within this thesis.

 Part I: Round 1 Feedback

Part 1 is a narrative derived from the responses received from round 1 of this study. Do you agree with this prediction? 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 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.

<u>Command and Control ICT Measures of Effectiveness</u>

1. <u>Flexible</u>: 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. <u>Responsive</u>: The C2 system must be responsive to user needs. The response should be instantaneous, reliable, redundant, and timely (AFDD6-0, 2011).

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

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

5. <u>Survivable</u> 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. <u>Sustainable</u> For a system to be sustainable it must remain interoperable, affordable, and ultimately usable.

7. <u>Interoperable</u> 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, predictions were mapped to the MoE(s) it seemed to support or fulfill creating the table below. Please review this table and provide comments.

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

Note: Part II of this research instrument has been removed. It was used for a separate topic not covered within this thesis.

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>

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, it should be cautioned that though greatly expanded local connectivity may provide a level of military utility, security concerns stemming from persistent social/political/economic 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.

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?

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 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, predictions 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 prediction 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?

<u>Command and Control ICT Measures of Effectiveness</u>

1. <u>Flexible</u>: 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).

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

Table of Predictions mapped to MoEs

Prediction	MoE
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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

Bibliography

Adams, S. J. (2001). Projecting the next decade in safety management: A Delphi technique study. *Professional Safety, 46* (10), 26-29.

Air Force Doctrine Document 1 (AFDD1) (2011). *Air Force Basic Doctrine, Organization, and Command,* 14 October 2011, accessed 1 October 2012 at http://www.e-publishing .af.mil.

Air Force Doctrine Document 6-0 (AFDD6-0) (2012). *Command and Control,* 28 July 2011, accessed 1 October 2012 at http://www.e-publishing .af.mil.

Armstrong, J.S. (1985). Long Range Forecasting From Crystal Ball to Computer, *2nd ed., New York, John Wiley & Sons Inc., 1985.*

Bakari, Jabiri Kuwe. (2007). A Holistic Approach for Managing ICT Security in Non-Commercial Organisations: A Case Study in a Developing Country. *Stockholm University Department of Computer Systems Sciences.*

Churchill, Winston Sir (1920). *The Great War. Vol 4.* Home Book Co. London

Coates, Vary et al. (2001). On the Future of Technological Forecasting. *Technological Forecasting and Social Change* 67, 1–17 (2001). Elsevier Science Inc.

Coates, J.F. (1975). In Defense of Delphi: A Review of Delphi Assessment: Expert Opinion, Forecasting, and Group Process by H. Sackman, *Technological Forecasting Social Change* 7 (1975) 193–194.

Dalkey, Norman, Helmer, Olaf (1963). An Experimental Application of the Delphi Method to the Use of Experts, *Informs. Management Science (1963).*

Dalkey, Norman C. (1976). An Elementary Cross-Impact Model. *TFSC 3,* No. 3 (1972).

Dalkey, Norman C. (1969). An Experimental Study of Group Opinion: The Delphic Method. *FUTURES* 2, No.3 (September 1969).

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

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

Final Report, Information and Communications Technology Industry (FR). (2010). *The Industrial College of the Armed Forces.* Fort McNair, Washington, DC: NDU

Press.

Gustafson, D.H., Delbecq, A.L. , Van de Ven, A.H. (1975). Group techniques for program planning, A Guide to Nominal Group and Delphi Processes. *Scott, Foresman and Company*, Glenview, IL, 1975.

Helmer, Olaf (1972). Cross-Impact Gaming. *Futures*, June 1972.

Helmer, O., & Rescher, N. (1959). On the epistemology of the inexact science. *Management Science, 6*, 25-53.

Helmer-Hirschberg, Olaf (1967). Analysis of the Future: The Delphi Method. Santa Monica, CA: RAND Corporation, http://www.rand.org/pubs/papers/P3558. Also available in print form.

Hsu, Chia-Chein, Sandford, Brian A. (2007). The Delphi Technique: Making Sense of Consensus. *Practical Assessment, Research & Evaluation.* Volume 12, Number 10, August 2007

Joint Publication 1-02 (JP1-02) (2012), *Department of Defense Dictionary of Military and Associated Terms,* 15 Aug 2012, accessed 1 October 2012 at http://www.dtic.mil.

Kramer, F., Starr, S., Wentz, L. (2007). Information Communications Technology Support to Reconstruction and Development: Some Observations from Afghanistan. *National Defense University.*

Linstone Harold A., Turoff, Murray (2011). Delphi: A brief look backward and forward. *Technological Forecasting & Social Change* 78 (2011) 1712–1719

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

Linstone, H. A., & Turoff, M. (1975). Introduction. In H. A. Linstone, & M. Turoff (Eds.). *The Delphi method: Techniques and applications* (pp. 3-12). Reading, MA: Addison-Wesley Publishing Company.

Ludwig, B. G. (1994). Internationalizing Extension: An exploration of the characteristics evident in a state university Extension system that achieves internationalization. *Unpublished doctoral dissertation, The Ohio State University, Columbus*.

Martino, J. P. (1983). Technological forecasting for decision making. *New York*: North-Holland.

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.

Mitroff, Ian I., Turoff, Murray. (1973). Technological Forecasting and Assessment: Science and/or Mythology? *Technological Forecasting and Social Change 5,* 113-134. American Elsevier Publishing Company, Inc.

Moore, Gordon (1965). *Cramming More Components onto Integrated Circuits.* PROCEEDINGS OF THE IEEE, VOL. 86, NO. 1, JANUARY 1998

Nagy, B. et al. (2011). *Superexponential long-term trends in information technology.* Technological Forecasting & Social Change. Vol 78 (2011) 1356-1364

Oh, K. H. (1974). Forecasting through hierarchical Delphi. *Unpublished doctoral dissertation, The Ohio State University, Columbus*.

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

Roberts, Edward B. (1969). Exploratory and Normative Technological Forecasting: A Critical Appraisal*. *Technological Forecasting* 1 (1969). American Elsevier Publishing Company, Inc.

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 J. Armstrong (Ed.). Principles of Forecasting* (pp. 125-144). Boston: Kluwer Academic.

Wentz, L., Kramer, F., Starr, S. (2008). Information Communications Technologies for Reconstruction and Development: Afghanistan Challenges and Opportunities. *Center for Technology and National Security Policy National Defense University.*

Wikipedia. (2012). RAND Corporation, accessed 1 October 2012 at http://en.wikipedia.org/wiki/ RAND_Corporation.

Wise, George. (1976). The Accuracy of Technological Forecasts, 1890-1940. *Futures*. (October 1976).

Curriculum Vita

James W. Harker, MSgt, USAF

Vita last updated: 24 January 2013

<u>ACADEMIC ACHIEVEMENTS</u>

B.S.   New York Institute of Technology, New York, NY, 2005.
          Major: Interdisciplinary Studies
A.A.S.   Community College of the Air Force, Maxwell AFB, AL, 2005.
          Major: Electronic Systems Technology

<u>RESEARCH INTERESTS</u>

Communications	Computer Science
Innovation	Smartphones
Future Technologies	Database Design

<u>CAREER HISTORY</u>

Student – Air Force Institute of Technology, Dayton, OH
(August 2011 – Present)
- Earning MS in Information Resource Management

Section Chief– Air Education and Training Command – 98 FTS, Air Force Academy, CO
(February 2008 – August 2011)
- Developed Airmanship course lesson plans, syllabi, and student guides
- Taught multiple airmanship lessons and courses

Visual Imagery and Intrusion Detection Systems Assistant NCOIC – AF Space Command – 90th Missile Maintenance Squadron, F.E. Warren AFB, WY
(July 2006 – February 2008)
- Led team maintaining security system guarding priority A assets

Broadcast Maintenance Technician / NCOIC – USAFE – AF News, Aviano AB, Italy
(July 2003 – July 2006)
- Engineered, installed, upgraded and maintained news and radio studio equipment.

Maintenance Support Evaluator, USAFE – 39th Communications Squadron, Incirlik AB, Turkey
(July 2000 – July 2003)
- Inspected communications equipment and the maintenance actions of the personnel.

*Television Intrusion Detection Systems Maintenance Apprentice – AF Space Command –
90th Communications Squadron, F.E. Warren AFB, WY*
(December 1997 – July 2000)
- Assisted with the maintenance of the security system providing protection to nuclear assets.

PROFESSIONAL EDUCATION

Basic Military Training – 1997
Airman Leadership School – 2001
Non-Commissioned Officer (NCO) Academy – 2006
Senior NCO Academy (Non-residence) - 2010

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14. ABSTRACT The information and communications technology (ICT) field is undergoing a period of tremendous and rapid change. As ICT develops more rapidly, the United States Air Force needs to remain responsive and adaptive to maintain military advantages. The need to integrate ICT developments sooner than our adversaries prompted an assessment of guidelines evaluating how well the AF is doctrinally positioned from a Command and Control perspective to support integration of emerging ICT. A Delphi Study was commissioned by the 689th CCW to forecast the future of mobile Information and Communication Technology (ICT) in austere environments. Using the ICT forecast data as a basis, the panel provided inputs on the integration concerns the forecasted trends invoked and the effects of the forecast on the Measures of Effectiveness outlined in AF doctrine.					
15. SUBJECT TERMS ICT Forecasting, Future of Communications, Delphi Study, Command and Control Technology, Integration					

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