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Development of a Theoretical Framework of Distributed Cognition Phenomena in Control Centers During Crisis Conditions

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DEVELOPMENT OF A THEORETICAL FRAMEWORK OF DISTRIBUTED COGNITION PHENOMENA IN CONTROL CENTERS DURING CRISIS CONDITIONS

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ABSTRACT

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The purpose of this research is to develop and partially validate a theoretical framework describing distributed cognition phenomena occurring in organizational control centers functioning in crisis environments. Using a systems approach, the work synthesizes existing constructs relating to distributed cognition then supplements this knowledge with review of crisis management literature. The goal of this effort is the development of a framework for understanding the impact of crisis conditions on such phenomena occurring within the specified setting. An exploratory case study approach was used to partially validate and refine the framework by gauging its ability to interpret the impact of crisis conditions on control center performance.

The researcher identifies a gap in crisis management literature relating to the study of distributed cognition within organizational control centers. The prevalence of and importance of institutionalized control centers to large organizations expecting to experience environments requiring more rapid processing of information and expedient reaction than usual is recognized within crisis management literature. A primary purpose of such control centers is to facilitate distributed cognition. Frameworks describing such phenomena in more

general organizational settings can be found within distributed cognition literature, organizational learning literature, and in military science. In some cases the specific setting of control centers is addressed but not to the extent of conceptually framing or applying a framework to the more specific setting.

The basic research questions explored are: (1) what are the key constructs and interrelationships that structurally frame distributed cognition phenomena within control centers? and (2) what are the structural impacts of crisis conditions on the phenomena in such settings?

Results of this research could, (1) aid in the implementation of new strategies, designs, training plans, methodologies, and technologies in crisis control centers for complex, technically oriented organizations, (2) improve the systemic design of and confidence in the assessment of mechanisms and subsystems designed to facilitate distributed cognition within organizations, (3) improve the general understanding of how distributed cognition takes place within organizational control centers, and (4) lead to a better understanding of the systemic effects crisis conditions have on the structures within control centers designed to facilitate distributed cognition.

This dissertation is dedicated to my beloved new wife, Beth. Conducting this research and drafting this document was an arduous, extended process that did not come easily and I am profoundly grateful for that fact; had I finished this work within planned time constraints, I never would have met her. Without her love, support, and help, I would never have finished this process. She is the love of my life.

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There are many people who have contributed to the successful completion of this dissertation.

First is the United States Air Force. They funded me to attend Old Dominion University and pursue this degree, to conduct this research, and then granted me access to the units that were the subjects of the case studies at the heart of this work. I will always be proud to be a member of this fine organization of men and women.

Second, I must mention Dr. Rafael Landaeta and my committee members. I was Dr. Landaeta's first dissertation student and I count myself fortunate. His hours of guidance pushed me through the tough periods and his comments were, without exception, always substantive and correct and they greatly improved this work. Similarly, the advice of the remaining committee members also made this work a better product. Without them this research would not have been possible. I thank them all for their help, their patience, and their flexibility.

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CHAPTER I

INTRODUCTION

The establishment, development, and institutionalization of control centers are natural responses by large, diverse organizations and bureaucracies to facilitate the expeditious comprehension of and response to fluid, dynamic, sometimes unexpected environments. The ability of these control centers to fulfill their purpose is challenged even more as crisis conditions emerge in the outside environment. Developing an in-depth, systemic perspective of how cognition occurs within the specific setting of control centers functioning during crisis periods, (1) could aid in the implementation of new strategies, designs, training plans, methodologies, and technologies in crisis control centers for complex, technically oriented organizations, (2) could improve the systemic design of and confidence in the assessment of mechanisms and subsystems designed to facilitate distributed cognition within organizations, (3) could improve the general understanding of how distributed cognition takes place within organizational control centers, and (4) could lead to a better understanding of the systemic effects crisis conditions have on the structures within control centers designed to facilitate distributed cognition. Additionally, (5) the framework may be transferable to other distributed cognition systems in a variety of organizational settings engaged in crisis management or response and may provide similar benefits accordingly. These potential benefits motivate the rigorous definition of the concepts involved as well as the construction of the

suggested framework to answer the central questions of this research. Table 1.1 captures these potential benefits and will serve as a foundation for building the remainder of this research process.

Table 1.1: Research Benefits
Overall Research Goal: Developing an in-depth, systemic perspective of how cognition occurs within the specific setting of control centers functioning during crisis periods

Potential Benefit	Description
PB1	Provide a basis for better development of implementation strategies for adapting new methodologies and technologies to support such centers
PB2	Provide a more comprehensive, holistic assessments of the performance of such centers, enhance the confidence placed in such assessments, and subsequently enhance training and practice regimes thereby enhancing control center performance during times of crisis
PB3	Provide for further understanding of the distributed cognition phenomena seen emerging from individuals and subsystems involved in managing, and running control centers
PB4	Provide a better understanding of the systemic effects crisis conditions have on the structures within control centers designed to facilitate distributed cognition
PB5	The framework may be transferable to other distributed cognition systems in a variety of organizational settings engaged in crisis management or response and may provide similar benefits accordingly

Crisis Environments and Control Centers

Many large organizations usually operate within environments with some level of predictability and develop their internal structure, processes, and methodologies as well as posture their resources and personnel accordingly. Many such organizations understand, both at leadership levels and throughout

their functional sub-units, that they must also be postured for more unpredictable, transitory sets of events significantly impacting their operations and requiring more intensive, extensive, and timely study and reaction than normal daily operations. Such sets of events constitute *crisis environments* that will be more rigorously defined later in this proposal. Crisis management is essentially defined as the preparation for, planning for, functioning within, and learning during and after such sets of events (Hermann 1963, Mitroff 1994, Coombs 1999, Loosemore 1998, Unzucker 2002, Lagadec 1990). Over the years, especially since Hermann's (1963) work, a large body of popular management literature and a smaller body of academic organizational research literature has developed around the topic of crisis management.

Much is written from an experiential basis describing specific lessons learned from a variety of historical crises and developing and generalizing conclusions for future implementation (Borins 2002, McConnell and Stark 2002, Nudell and Anotkoll 1998; Lagadec 1990; Mayrs and Holusha 1996, White 2001, Nelson and French 2002, Hooper 1999). Much is also written about the subject from a prescriptive, "how-to" approach in which authors lay out an organizational structure, hierarchy, systematic methodology, or implementation strategy for various technological aids designed to provide an organization with a means to provide oversight in a crisis situation (Johansenn et al. 2001, Loosemore 1998a, 1998b, 2001, Lee 1999, National Research Council 1996, Schrodt 1999, Coombs 1999, Ogrizek 1997, Mitroff 2000; Unzucker 2002).

Many organizations that frequently expect to experience crises of somewhat less predictable natures institutionalize their efforts to manage these crises through the establishment of what can generally be called control centers (Coombs 1999). Generally speaking, these control centers are usually postured with batteries of specialized, trained personnel, communications devices, and a large variety of plans, checklists, status boards, data management technologies and other such artifacts. Crisis management literature has focused significantly over recent years proposing that a primary function of institutionalized organizational control centers is to facilitate the collective organizational understanding of how to react to non-typical, fluid, dynamic environments or crises (Coombs 1999, Vidaillet 2001, Lagadec 1990). However, the existing body of knowledge within crisis management research has not yet yielded systemic frameworks tailored to facilitate understanding the learning processes that occur in the specific case of control centers. Additionally, the current body of knowledge has not focused on developing a similar systemic understanding of the impact of crisis conditions on control centers.

A systems approach is stressed here because within the crisis management literature detailed above, a variety of disparate constructs are proposed and researched but a holistic, comprehensive framework detailing the interrelationships of these elements is lacking. Complex problems involving a variety of observers' and participants' interpretations are suited to a systems approach of setting boundaries, specifying interrelationships, and understanding emergent phenomena (Flood and Carson 1993, Checkland 1981).

Key to initially bounding this work's efforts is development of what constitutes a crises environment. Figure 1.1 provides an overview of an initial literature investigation in pursuit of such a definition.

Figure 1.1: Definitions of Crisis

"a turning point for better or worse" – Fink (1986)

"A situation characterized by surprise, high threat to important values, and short decision time." Hermann, (1963).

"a major occurrence with potential negative outcome affecting an organization, company, or industry. As well as its publics, products, services, or good name." Fearn-Banks (1996)

"a major unpredictable event that has potentially negative results. The event and its aftermath may significantly damage an organization and its employees, products, services, financial condition, and reputation." – Barton (1993).

"an event that is an unpredictable, major threat that can have a negative effect on the organization, industry, or stakeholders, if handled improperly." – Coombs (1999).

"Extreme events that cause disruption and put lives and property at risk. These require an immediate response and application of resources beyond regular application." - National Research Council (1996).

"a Hippocratic concept: all illnesses reach a turning point. From here some are fatal, some go on to recovery, all others develop to another form, and take on a different constitution." Dab (1993).

"a fit of uncertainty, and distress where everything is in suspense in anticipation of imminent resolution of the illness." Bolzinger (1982).

"Crisis: a situation in which numerous organizations are faced with critical problems, experience both sharp external pressure and internal tensions, and are then brutally and for an extended period thrust to the center stage and hurled against one another, all in a society of mass communication, in other words in direct contact with the certainty of being at the top of the news on radio and television and in the press for a long time." Lagadec, (1990)

Three general themes emerge out of these definitions. First, crisis events are considerably more significant and negative to organizations than normal events in terms of their impact on organizational survival in its current state. Second, they may have components of surprise, unpredictability, and difficulty relative to the normal events organizations are ideally postured for. This notion can be thought of as crisis environments being composed of a level of complexity for which the organization is not ideally prepared. Third and finally, these authors all point to the internal organizational and emotional stress caused by crises.

At this point by bringing these themes together a working definition can be proposed: *crisis environments are those (a) with potential for significant negative organizational outcomes and (b) of a significantly greater level of complexity than organizations are usually prepared for and as a result of either or both of these elements (c) can cause significant internal organizational stress.*

A well-developed understanding of what constitutes a crisis environment is a necessary basis for building a framework to understand the impact of such an environment on organizational control centers. Given the proposition that facilitating more rapid conceptualization and reacting processes is a primary purpose of such entities, this aim itself also needs to be approached systemically.

The Concept of Distributed Cognition

Before describing the concept of distributed cognition, some basic, and at this point initial, definitions of its conceptual underpinnings, as used for purposes

of this work, is in order. First, distinction must be made between what constitutes data, information, knowledge, and perhaps intelligence. Ackoff (1989) develops a hierarchy of these concepts: *data* is nothing more than raw symbols differentiating various states of the universe; *information* is data processed into a useful form with some level of meaning answering the basic questions "who", "what", "when," and "where"; *knowledge* represents information applied to begin answering "how". Ackoff goes on to define *understanding* as the appreciation of knowledge when one begins answering "why" and compares the distinction between knowledge and understanding to the distinction between memorizing and learning. Finally, Ackoff defines *wisdom* separately from the other four concepts, which are focused upon the past. Wisdom is the ability to project understanding for predictive purposes.

Moving on to the concepts of learning and cognition, Boisot and Canals (2004) describe an agent's act of *perception* as the transition between outside stimuli and the creation of data; *conceptualization* as the transition between data and information; and finally the *processing of mental representations* as the act of using information to create knowledge. Boisot and Canals cite Clark (1997) and Damasio (1999) for describing the agents "tuning" of such transition "filters" as being driven by "cognitive" expectations. Rogers (1997) specifically describes cognition as the act of modifying representations.

This systematic moving up between levels of mental usefulness is echoed with analogous terms in the various frameworks, to be discussed later in this proposal, describing organizational learning and distributed cognition. For

purposes of this work no distinction will be made between learning and cognition other than the understanding that cognition tends to be the favored term within psychological, anthropological, and cognitive sciences while learning tends to be used more prevalently in organizational research and management circles. Furthermore learning and cognition will be accepted to constitute the whole iterative process of converting data to higher forms of mental usefulness and then moving beyond that to the point of acting and evaluating actions over time to further improve usefulness. The higher forms described as wisdom and understanding may also be used interchangeably with the notion of intelligence.

Perhaps the notion of learning occurring at more than just the level of the individual first arose out of psychological, sociological, and anthropological research circles. Dewey (1938), focusing on the means by which knowledge is gained, stated,

> "Experience does not simply go on inside a person. We live from birth to death in a world of persons and things which is in large measure what it is because of what has been done and transmitted from previous human activities" (p. 39).

Other early authors similarly focused on the merits of understanding individual behavior through the concept that one's knowledge, thoughts, and actions are rooted inside a system of existing knowledge and cultural artifacts and processes (Vygotsky, 1929; Wundt, 1921; Allport, 1924). Roberts' (1964) suggestion that social organization reflects an architecture of cognition at the community level seems to capture the essence of the perspectives.

Within organizational management circles a general notion of collective learning perhaps first began to arise when March and Simon (1958) commented that the focus of their work is on "the flow of information within organizations that instructs, informs, and supports decision making processes." Weick's work (1979) focused on organizational psychology and embraced the organic perspective of learning by focusing on the fact that knowledge is gained and retained within organizational structures despite personnel turnover. Argyris and Schon (1978) crystallize this stream of thought by describing organizational learning as occurring when individuals,

> "...experience a surprising mismatch between expected and actual results...and respond through a process of thought and further actions that lends them to modify their images of organization or their understandings of organizational phenomena and to restructure their activities so as to bring outcomes and expectations into line, thereby changing organizational theory in use. In order to become organizational the learning that results from *organizational* inquiry must become embedded in the images of organization held in its member's minds and/or [its] epistemological artifacts (maps, memories, and programs) embedded in the organizational environment" (p.16).

Within cognitive science, psychology, and anthropology, many authors (Rogers and Scaife 1997, Magnus 2004, Giere 2001) point to Hutchins' works in the 1980's and 1990's with a variety of his partners (Hollan 1984, Pea 1996, Kirsch 1998, Palen 1997, and Norman 1985) as first bringing the term distributed cognition to the fore. These case studies, documenting the processing of mental representations over time by groups of individuals, are cited for their development of the perspective that distributed cognition is a distinct phenomena composed of the processes by which collectives learn about and act within their

environment. Hutchins (1995) cites Hinton and Becker's (1992) construction of models showing how two visual modules are able to share a representation of a visual world in such a way that through their interaction they can recover depth, something that neither can sense alone. The analogy is that differing components of a collective can work together to achieve, maintain, and adjust a representation of the outside environment.

Argyris and Schon's focus on the embedding of images in organizational artifacts mirrors these same ideas. By bringing together their work and that of Hutchins and other authors, (Rogers and Scaife 1997, Magnus 2004, Giere 2001 Pea 1996) the following three basic themes seem to be repeatedly cited:

1) As opposed to cognitive science in general, the phenomenon of distributed cognition is not limited to the boundary of the individual person. The boundary can be repeatedly redrawn around a variety of subunits or groupings of personnel and materials that accomplish cognition for the purposes of the collective group

2) Again, as opposed to general cognitive science which focuses on the mental representations of the environment which individuals use, maintain, and adjust, distributed cognition focuses not only on such representations used by groups but also on the interactions amongst group members, artifacts, and the environment as mechanisms for accomplishing cognition.

3) The boundary of events relating to cognition extends broadly over time not just encompassing any single *chapter* or single adjustment to a given set of mental representations of the environment. Past events, artifacts, and

knowledge bases of personnel within subunits experiencing significant turnover over time may significantly influence the ability of a collective group to learn about its environment.

By synthesizing these themes from the literature for purposes of this work, distributed cognition can be defined as: *the ongoing accumulation, distribution, and synthesis of knowledge across time, amongst personnel and systems, and at all levels within a bounded organization, which leads to the development, adjustment, and sometimes tearing down of shared mental representations of the outside world within which the organization is trying to pursue its goals.* More rigorous, detailed development of the concept of distributed cognition follows in the literature review chapter that will (1) provide a firm basis within cognitive science and organizational learning literature and (2) develop a listing of authors' themes and characterizations of the phenomena and (3) provide a detailed description of the resulting frameworks they have constructed to describe it.

Overview of Existing Distributed Cognition Conceptual Frameworks

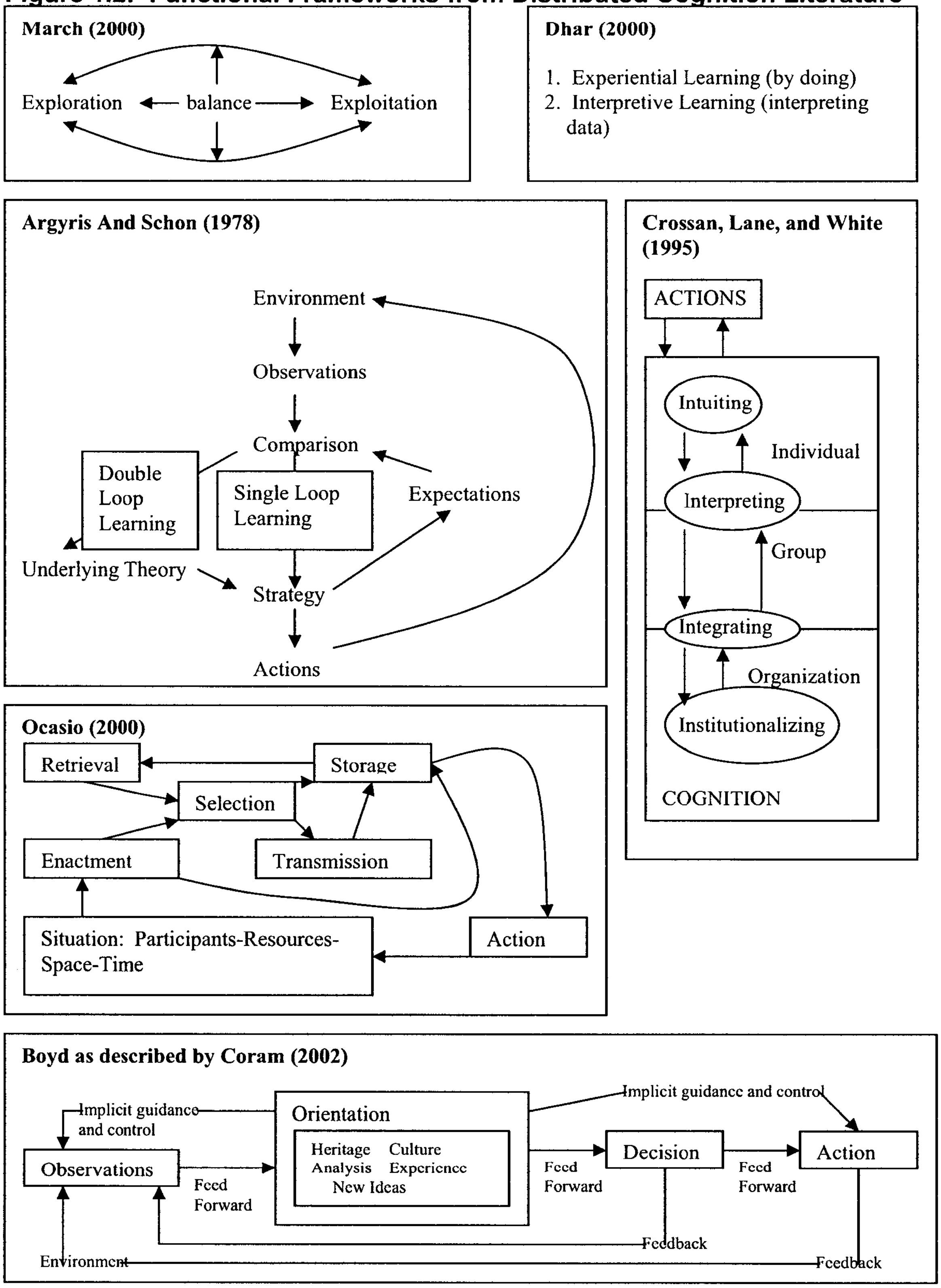
A variety of characterizations, conceptual models, and resulting propositions describing distributed cognition processes have been developed within the literature (March 2000, Dhar 2000, Crossan et al 1995, Argyris and Schon 1978, Ocasio 2000, Boyd in Coram 2000). A central theme lying at the foundation of these frameworks is the idea that cognition is essentially the emergent, manifest development, adjustment, and propagation of representations of the outside environment across an organization as it attempts

to use them to influence that environment (Hutchins 1995, Wright 2000, Walsh 1995, Ocasio 2001, Waern 1999, Rogers 1997, Vidaillet 2001, Argyris 1996). Figure 2.1 provides a brief overview of some of the more structured conceptual frameworks and models.

This basic, defining element of cognition, the processing of representations, then serves as a foundation for the development of a variety of approaches to understand various aspects of the idea of distributed cognition within organizations. Crossan, Lane, and White's (1999) 4-I theory of organizational learning identifies the key processes of intuiting, interpreting, integrating, and institutionalizing and focuses on their occurrence at and linking between the three primary institutional levels at which such learning takes place: the individual level, the group level, and the organizational level. Argyris and Schon (1978) identify 1) a surface type of learning that takes place within an organization as it processes data within an institutionalized perspective of reality and 2) a secondary, deeper learning that occurs when such perspectives are questioned and altered at a more basic level. Rulke and Zaheer (2000) develop an approach based on the dichotomy of *self-knowledge*, that knowledge contained within a single organizational unit, and *resource-knowledge*, the organizational unit knowing it doesn't have the knowledge in question but knowing where it can be gained. They then cross these characterizations with the notions of *purposive learning channels*, for example, formal institutionalized training such as classes and *relational learning channels*, for example, informal person-person discussion of situations in order to capture the differing impacts of

these forms of cognition within the organization. Ocasio (2001) proposes his SERTS (selection-enactment-retrieval-transmission- storage) model, developed from empirical study, as a way of understanding how information is processed in an organization. Lastly, the decision making process perspective of "observation-orientation-decision-action" processing, so called OODA loops, formally developed by John Boyd (in Coram 2000) is used as a recurring framework within military circles (Fadok 1995, Cramer 1996, Plehn 2000) and is very much analogous to the other frameworks discussed in describing the learning process. Though, developed primarily with a protagonist versus intelligent opponent's or enemy's point of view, the OODA loop process has application within settings where the protagonist is merely trying to come to grips with the pace of an external environment via looping through the OODA process at sufficient speed.

Figure 1.2: Functional Frameworks from Distributed Cognition Literature



The use of these characterizations definitely informs and frames the distributed cognition process and begins to approach a systems perspective. A more rigorous, systemically developed, holistic framework would ensure comprehensiveness as well as provide for a means to understand the impact of crisis conditions on the specific case of organizational control centers.

Filling the Literature Gap, Research Goals and Questions

The goal of this research is to use a systems approach to develop, validate, and adjust a conceptual framework, using constructs from distributed cognition literature tailored to the specific case of control centers functioning during periods of crisis. The validated framework could then be used as a basis for the development of more rigorous control center performance assessment criteria and the development of implementations strategies for introducing new technologies and procedures into control centers. The four primary motivations or potential benefits cited in the introduction to this chapter motivate the primary research questions of the proposed research and subsequently the proposed development of the Distributed Cognition in Crisis Control Centers (DC5) framework. The primary research questions that would be explored in this research are: (1) what are the key constructs that structurally frame the phenomena of distributed cognition within control centers and how are they interrelated? and (2) what are the structural impacts of the onset and development of crisis conditions on the distributed cognition systems in such settings?

Flowing from these general questions are more focused *objective* questions that will serve to guide the research. It should be noted, as shown in figure 1.3, that the development of these interim objectives was part of an iterative process involving the proposed literature review and the proposed DC5 construction process itself. These interim objective questions are:

1) To develop a set of general themes and characterizations relating to distributed cognition and to understand how these in turn are developed into existing conceptual frameworks and models.

2) To determine the general themes and characterizations within crisis management literature relating to the impact crisis conditions have on organizations.

3) To develop a conceptual framework capturing the impact of crisis conditions on distributed cognition phenomena within control centers.

4) To develop and use an exploratory case study methodology in conjunction with the developed framework to determine if it aids in describing and understanding the functions and interactions of subsystems within a distributed cognition system functioning in periods of crisis.

5) To partially validate the framework by using as a means for assessing an initial fitness characterization of a distributed cognition system.

6) To partially validate the framework by developing a testing a training plan designed to improve the performance of a distributed cognition system functioning within a variety of crisis environments.

Table 1.2 details the focused objectives and their interrelationship with both the primary research questions and the potential benefits, previously detailed in Table 1.1 of the research.

Table 1.2: Focused Objective Questions
Overall Research Goal: Developing an in-depth, systemic perspective of how cognition occurs within the specific setting of control centers functioning during crisis periods.
Primary Research Question 1 (PG1): What are the key constructs that structurally frame the phenomena of distributed cognition within control centers and how are they interrelated?
Primary Research Question 2 (PG2): What are the structural impacts of the onset and development of crisis conditions on the distributed cognition systems in such settings?

Focused Objectives	Description	Primary Research Questions Addressed	Potential Benefits of Research Addressed (see Table 1.1)
FO1	To develop a set of general themes and characterizations relating to distributed cognition and to understand how these in turn are developed into existing conceptual frameworks and models.	PG1	PB1, PB2, PB3, PB5
FO2	To determine the general themes and characterizations within crisis management literature relating to the impact crisis conditions have on organizations	PG2	PB1, PB2, PB4, PB5
FO3	To develop a conceptual framework capturing the impact of crisis conditions on distributed cognition phenomena within control centers	PG1, PG2	PB1, PB2, PB3, PB4, PB5
FO4	To develop and use an exploratory case study methodology in conjunction with the developed framework to determine if it aids in describing and understanding the functions and interactions of subsystems within a distributed cognition system functioning in periods of crisis.	PG1, PG2	PB3, PB4, PB5
F05	To partially validate the framework by using it to initially assess a distributed cognition system's fitness characterization and subsequently using it to design a training plan to improve performance.	PG1, PG2	PB1, PB2, PB3, PB4
F06	To implement the training plan in FO5 and assess the improvement in performance of the distributed cognition system.	PG1, PG2	PB1, PB2, PB3, PB4

Organization of Research Proposal

One final area of required research is examining the methodologies for qualitative, case study oriented methods to support the collection of information to validate and further adjust and develop the conceptual framework. As will be detailed in Chapter III of this proposal, exploratory case study methodology is most suited to both the research objectives as well as the data being analyzed.

Case studies will be based on Air Force Unit Control Centers (UCC) preparing for Operational Readiness Inspections via iterative exercises with multiple units of analysis, the systemic functions of the UCCs themselves. The developed methodology will be applied to support the objective of discovering the applicability of the developed conceptual framework to training and equipping UCCs for formal inspection. Case data will be systematically obtained and analyzed through a developed case research strategy based upon the developed conceptual framework and resulting in the population of a case database. This database will compile multiple sources of evidence including transcribed event logs, descriptions of the UCCs during the OREs, semi-structured interviews with SCC personnel prior to exercises, the formal post exercise assessment reports themselves, and follow-up validation interviews with case participants.

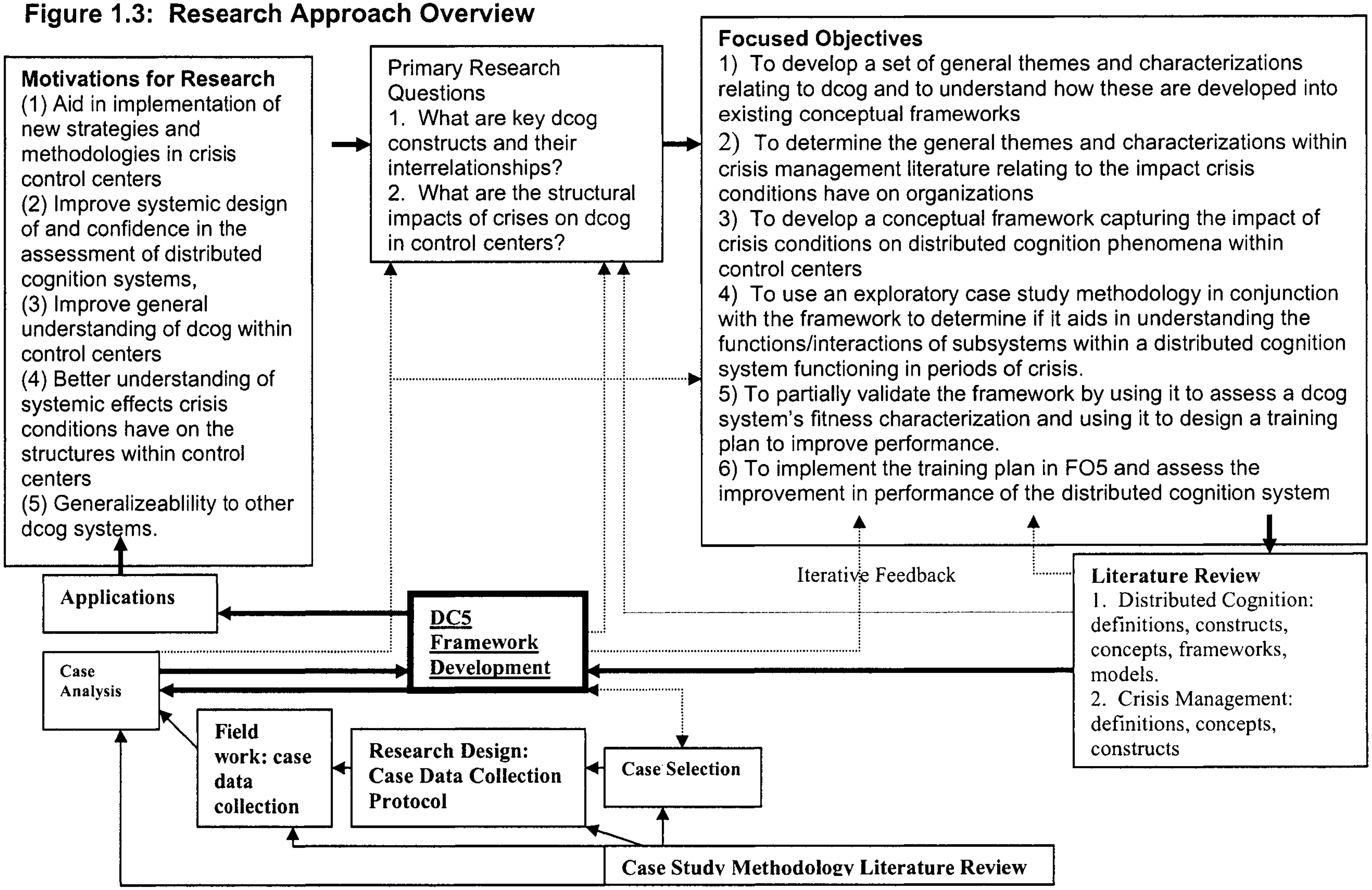
Figure 3.1 is a general overview of the entire research approach including literature review, framework development methodology, and case validation research design. Within the Literature Review chapter of the anticipated proposal, first a general review of the development of the concept of distributed cognition and resulting frameworks authors have developed will be undertaken. Second, a general overview of crisis management literature will be provided focusing on capturing crisis management characteristics specific to the case of crisis control centers. Third, a detailed background of the type of case's proposed for study will be provided. Fourth, this knowledge base will then be synthesized into the proposed DC5 framework.

Within the Methodology chapter of the anticipated proposal, case study research design literature is reviewed to support the development of a detailed design for the specific purpose of validating the proposed conceptual framework and resulting propositions. The development and defense of the case study methodology will be presented. Case selection strategy as well as overarching guidance for case data collection protocol will be developed.

Within the Research Design chapter of the anticipated proposal, detailed data collection protocols and instruments will be developed to support the goals, objectives, of the research and the study of the selected cases

Only after the approval of the research proposal, will the actual case study fieldwork be undertaken. Results from fieldwork will then be reviewed and analyzed to support the validation and adjustment of the proposed conceptual framework. The resulting validated framework can then be used as a basis for the development of control center performance criteria and the development of strategic guidelines for deploying and implementing new technologies and procedures into control centers. Additionally, further development and refinement of the proposed framework providing better explanatory understanding of distributed cognition phenomena in crisis situations can be accomplished under the auspices of future research.

Figure 1.3: Research Approach Overview



Potential Benefits of Research to the Air Force and to the Academic Field of Engineering Management

The means by which control centers gather, process, present, and orient information into knowledge in order develop, implement, and adjust response alternatives is captured by the definition of distributed cognition. The central effort of the research is to develop a systemic, conceptual framework for describing these phenomena as it takes place within an SCC and then to use it as a structural basis for assessing and improving SCC performance. Hopefully, the understanding guided by use of the proposed framework will lead to improved performance to be confirmed when the unit being trained is formally inspected by the ACC/IG team and thus the framework will receive an initial form of validation. By developing a qualitative means of mining the data characterizing a squadron's SCC before and during an ORE such propositions and the overall model itself can be validated and adjusted. Results could aid in the implementation of new strategies, methodologies, and technologies in crisis control centers, could improve the quality of the systemic comprehensiveness of and confidence in evaluation and assessment processes, and could improve in the general understanding of how organizational cognition takes place within control centers operating in crisis conditions.

The proposed research will have three primary benefits within the academic field of Engineering Management crossing the various components making up this area of study. Firstly, the application of system engineering approaches, central to the academic field itself, in order to comprehend, analyze, and frame the complex system to be investigated will demonstrate the suitability

of such methodologies to crisis management and organizational management issues. Secondly, the framework produced as result of this research will supplement the body of knowledge relating to (a) crisis management, (b) business policy and strategy, (c) managerial and organizational cognition, (d) social issues in management, and (e) conflict management, providing a new framework for understanding problems relating to distributed cognition within large organizations in crisis situations. Finally, the large and complex nature of an Air Force flying wing, organizationally and technologically, operating within a crisis environment is typical of problems faced by Engineering Managers. As a result of this typicality and the proposed framework applications including the development of performance assessment criteria and new technology/procedure implementation strategy guidelines, the research is expected to have value crossing over to similar sized and similarly complex organization.

CHAPTER II

LITERATURE REVIEW

Purpose, Objectives, and Organization of Literature Review

The primary purpose of this literature review will be threefold in reaching toward the overall goals of this research. First, academic literature relating to distributed cognition and organizational learning will be reviewed, critiqued, and synthesized in order to gain perspective on the general definitions, characterizations, and themes relating to these fields of study. Second, and similarly, crisis management literature will also be reviewed to support the development of an understanding of the topic and to develop specific characterizations of crisis environments and their impact on organizations and their control centers. Finally, Air Force organizational literature relating to the function of fielded squadron control centers will be reviewed to gain an understanding of official, organizational perspectives relating to these organizational entities.

In Chapter III, two additional minor literature reviews will be conducted to support the goals of this research. First, as was described in the previous chapter, information developed in this literature review will be synthesized using systems analysis methodologies to support the goal of developing a systemic, conceptual framework for understanding the process of distributed cognition within crisis control centers. A review of literature relating to systems analysis methodologies suited to the nature of such problems will be accomplished as will

the actual discussion leading to the development of the suggested framework. Second, a review of case study analysis techniques will be accomplished in to support the subsequent development of a plan for validating the suggested framework.

Returning to the objective of this chapter, the efforts in the first area of focus, distributed cognition, will be accomplished by presenting a review of the academic literature relating to the field with the interim objectives, along the way to supporting the framework development of Chapter III, of: 1) developing a formalized working definition of distributed cognition, 2) developing a listing and an understanding of the themes within the literature relating to the study of distributed cognition, and 3) understanding existing frameworks others have used to support a comprehensive, holistic understanding of distributed cognition.

Crisis Management literature will be summarized to support meeting the interim goals of: 1) developing an overarching characterization of exactly what constitutes a crisis environment, which will in turn lead to 2) developing a further, more specific, listing of detailed characterizations of a crisis environment which can then, in Chapter III, be used in conjunction with the body of knowledge gained in the area of distributed cognition to develop the proposed conceptual framework.

In order to support the focused efforts on the specific case of fielded UCCs functioning in wartime environments, a summarization of the existing Air Force literature relating to the staffing, equipping, operational functions, assessment, and interaction with units outside, of an SCC will be undertaken with

the interim objective of developing a further listing of specific characterizations of the cases to be studied.

Figure 2.1, Literature Review: Purpose, Objectives, and Organization, captures the organization, interim objectives, and overall purpose of this literature review. Figure 2.2, Literature Review Map: Coverage Areas and Gaps, captures the key subject matter areas of the literature review and their intersections which form the literature gaps this work is attempting to fill. Table 2.1, Literature Review Summary, at the end of the chapter will refer to Figure 2.2 as it summarizes the content of the literature review and specifies the researcher's opinion of where gaps in the existing literature exist.

Figure 2.1: Literature Review: Purpose, Objectives, and Organization

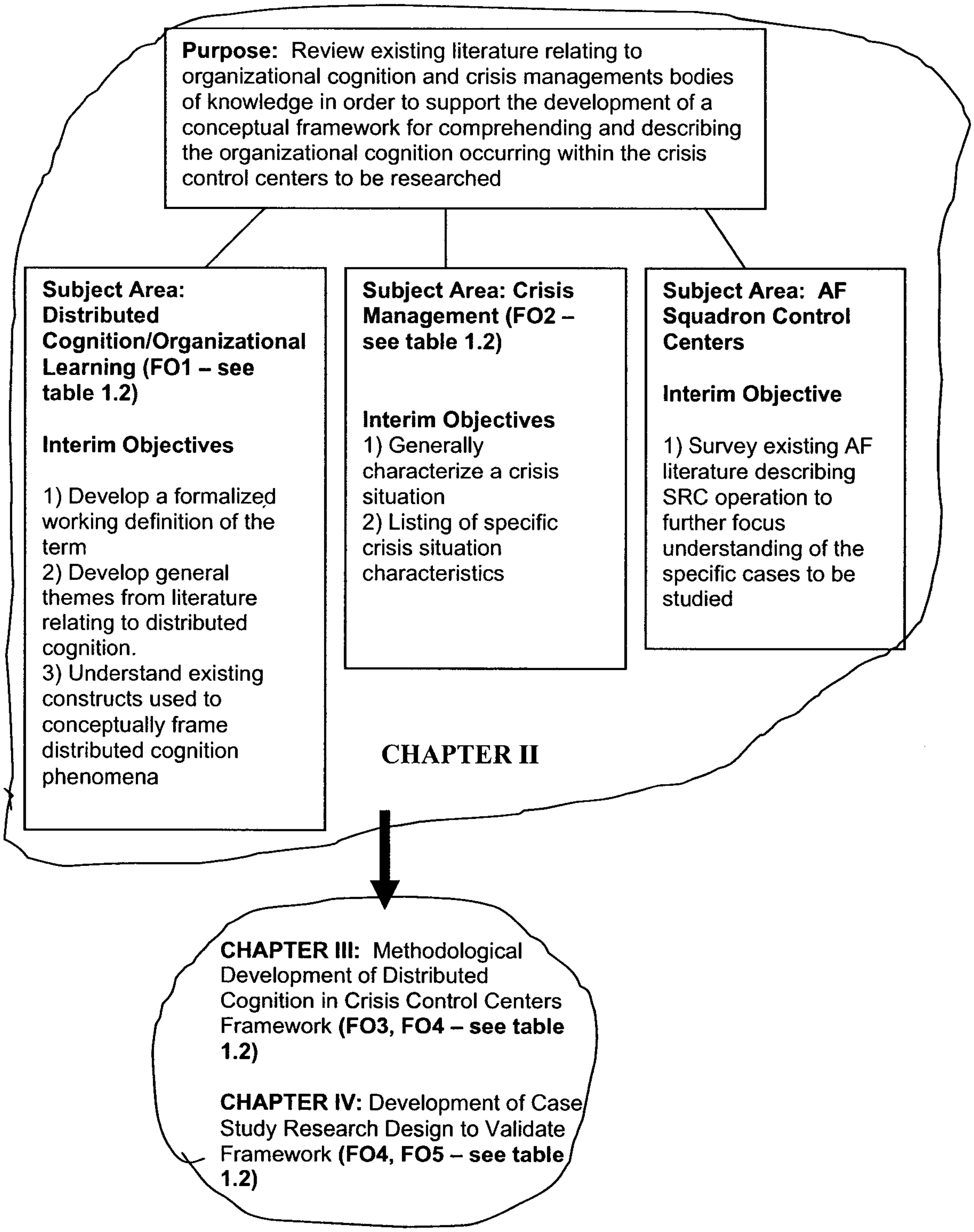
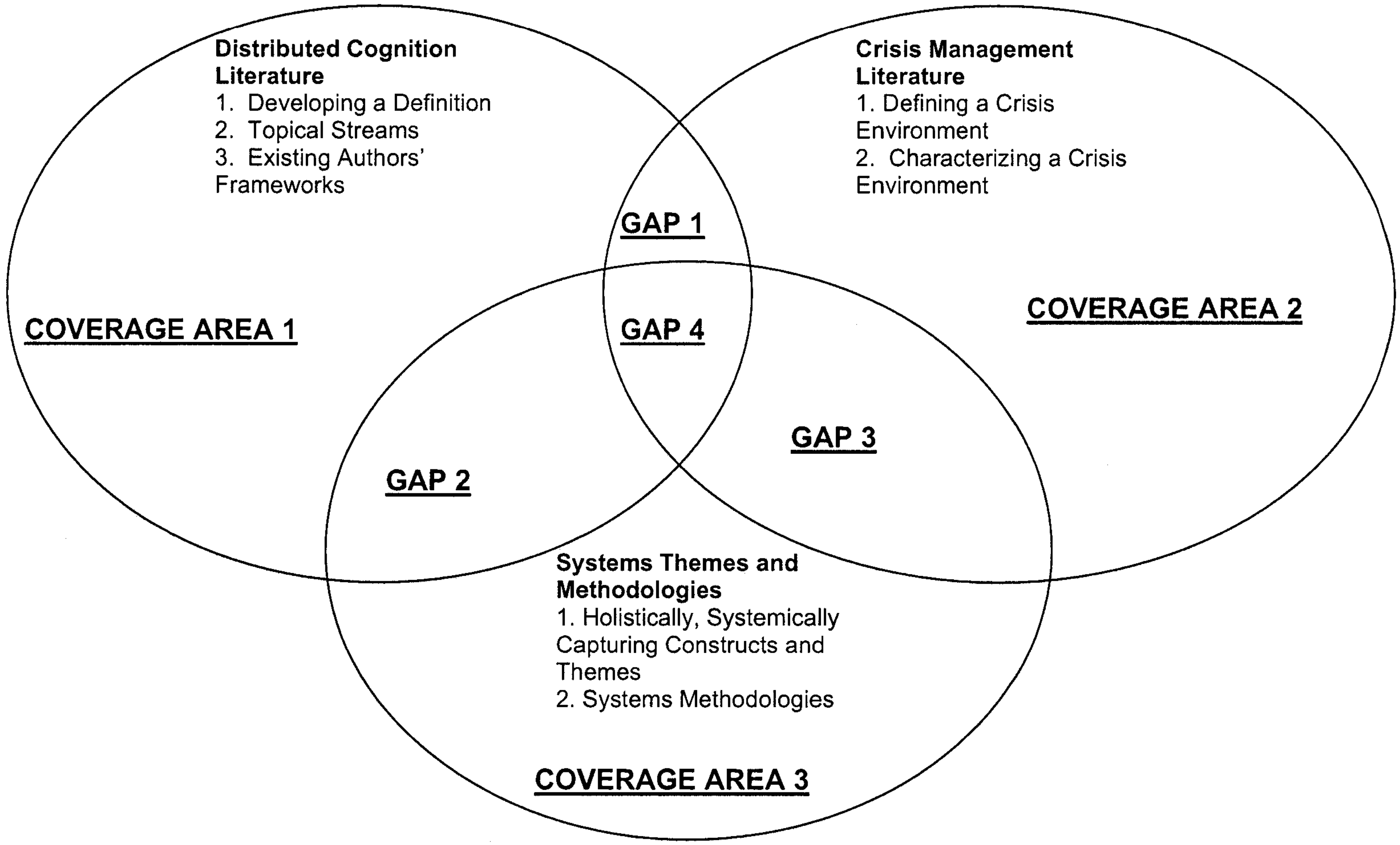


Figure 2.2: Literature Review Map: Coverage Areas and Gaps



Towards Defining Distributed Cognition: Roots of the Concept

Argyris and Schon (1996) argue that a term such as organizational learning require specification in each particular context in which it may appear. Given that the concept of distributed cognition is both central to this research and, as discussed, that a gap in the literature exists relating to the lack of a formal systems engineering application of the concept to crisis management control centers, a concise working definition is needed. This definition would serve to provide clarity and specificity to the term, distributed cognition itself, which flows from and is used somewhat interchangeably throughout the literature with other terms including distributed cognition, collective reasoning, collective mind, and organizational learning. Additionally, a working definition derived here specifically to serve the goals of this research will serve to enhance focus specifically on the cases, crisis management control centers, to be studied.

Perhaps the notion of learning occurring at more than just the level of the individual first arose out of psychological, sociological, and anthropological research circles. Dewey (1938), focusing on the means by which knowledge is gained, that is experience and education, stated,

> "Experience does not simply go on inside a person. We live from birth to death in a world of persons and things which is in large measure what it is because of what has been done and transmitted from previous human activities" (p. 39).

Other early authors similarly focused on the merits of understanding individual behavior through the concept that one's knowledge, thoughts, and actions are rooted inside a system of existing knowledge and cultural artifacts

and processes (Vygotsky, 1929; Wundt, 1921; Allport, 1924). Roberts' (1964) suggestion that social organization reflects an architecture of cognition at the community level seems to capture the essence of the perspectives.

Within organizational management circles a general notion of collective learning perhaps first began to arise when March and Simon (1958) in their seminal work within the field, *Organizations,* commented that the focus of their work is on "the flow of information within organizations that instructs, informs, and supports decision making processes." Weick's work (1979) focused on organizational psychology and embraced the organic or collective perspective of learning by focusing on the fact that knowledge is gained and retained within organizational structures despite personnel turnover. Argyris and Schon (1978, 1996) crystallize this stream of thought by describing organizational learning as occurring when individuals,

> "...experience a surprising mismatch between expected and actual results...and respond through a process of thought and further actions that lends them to modify their images of organization or their understandings of organizational phenomena and to restructure their activities so as to bring outcomes and expectations into line, thereby changing organizational theory in use. In order to become organizational the learning that results from organizational inquiry must become embedded in the images of organization held in its member's minds and/or [its] epistemological artifacts (maps, memories, and programs) embedded in the organizational environment" (p.16).

While Argyris and Schon focus on an organization learning lessons, in both specific incremented time periods and more continuously, with broad strategies on how to facilitate its occurrence and then develop a means of understanding the depth, so-called "single loop" vs. "double loop," of learning,

other authors have begun to focus not just on the collective nature of learning phenomena and its resulting implications but on the actual basic mechanisms by which such organizational learning occurs. This narrower focus, arising out of cognitive science interests as opposed to organizational behavior circles, is upon the more organic, surface action of collective cognition versus the more generalized process of organizational learning and its benefits to the organization.

Amongst this group of authors, many (Rogers and Scaife 1997, Magnus 2004, Giere 2001, Rogers 1997), point to Hutchins' work in the 1980's and 1990's as first bringing the term distributed cognition to the fore and his work in conjunction with other authors, Hollan (1984), Pea (1996), Weitzmann (1984), Kirsch (1998), Palen (1997) , and Norman (1985) as laying the groundwork for the development of distributed cognition as a framework for understanding the processes which collectives use to learn about and act within their environment. Hutchins (2000) himself provides a most concise review of the historical development of the field drawing from its roots in the research of authors from psychological, anthropological, and organizational science. In defending the notion that cognition does not have to be confined within the "skin or skull" (p.1) of the individual and in attempting to explain the concept of distribution between disparate system subunits being necessary for cognition, Hutchins (1995) cites Hinton and Becker's (1992) construction of models showing how two visual modules are able to share a representation of a visual world in such a way that through their interaction they can recover depth, something that neither can

sense alone. The analogy is that differing components of a collective can work together to achieve, maintain, and adjust a representation of the outside environment.

Defining Distributed Cognition and Organizational Distributed Systems

Synthesizing the work of Hutchins (2000) and the descriptions of that work cited by other authors, Rogers and Scaife 1997, Magnus 2004, Giere 2001 Hollan (1984), Pea (1996), Weitzmann (1984), Kirsch (1998), Palen (1997), and Norman (1985), the following three basic themes seem to be repeatedly cited:

1) As opposed to the regular science of cognition in general, the phenomena of distributed cognition is not limited to the boundary of the individual person, rather the boundary can be repeatedly redrawn around a variety of subunits or groupings of personnel and materials that accomplish cognition for the purposes of the collective group.

2) Again as opposed to the general cognitive science which focuses on the mental representations of the environment which individuals use, maintain, and adjust, distributed cognition focuses not only on representations used, maintained, and adjusted by groups but also on the interactions amongst group members, materials, and the environment as mechanisms for accomplishing cognition.

3) The boundary of events relating to cognition extends broadly over time not just encompassing any single chapter or single adjustment to mental representations of the environment. Past events, artifacts, and knowledge

bases of personnel within subunits experiencing significant turnover over time may significantly influence the ability of a collective group to learn about its environment.

Before using these aspects of *distributed* cognition drawn from the literature to provide a working definition for purposes of this research, an explanation is in order regarding the terms *distributed* cognition and *organizational* cognition. While the terms are used somewhat interchangeably throughout the literature, the researcher generally takes *organizational cognition* to be a subset of the broader general term *distributed cognition,* the distinction being that while distributed cognition occurs on a general level across many boundaries of sub-units within some broader collective human grouping, *organizational cognition* describes the distributed learning occurring within a specific bounded sub-unit; i.e., for purposes of this research the boundary of interest will be drawn around the SCC organization. The researcher sees the distinction as minor and finds throughout the literature that the themes and constructs of either term are generalizable to the other themes thus while the terms may be used interchangeably for purposes of this work, distributed cognition will be preferred.

Using the cited themes of the literature, distributed cognition can be defined as: *the ongoing collective accumulation, distribution, and synthesis of knowledge across time amongst personnel and systems at all levels within a bounded organization which leads to the development, adjustment, and sometimes tearing down then redevelopment of both tacit and explicit mental*

representations of the outside world within which the organization is trying to pursue its goals.

Even further refinement of this definition is needed for the requirements of this work. Specifically, defining a *distributed cognition system* as *a system designed or used by organizations for the intended purpose of facilitating distributed cognition as described above* is necessary. The importance of this additional step of specification will be seen in Chapter III as it is used to facilitate Beer's (1984) system of interest specification in applying his Viable System Model to the focus of this work.

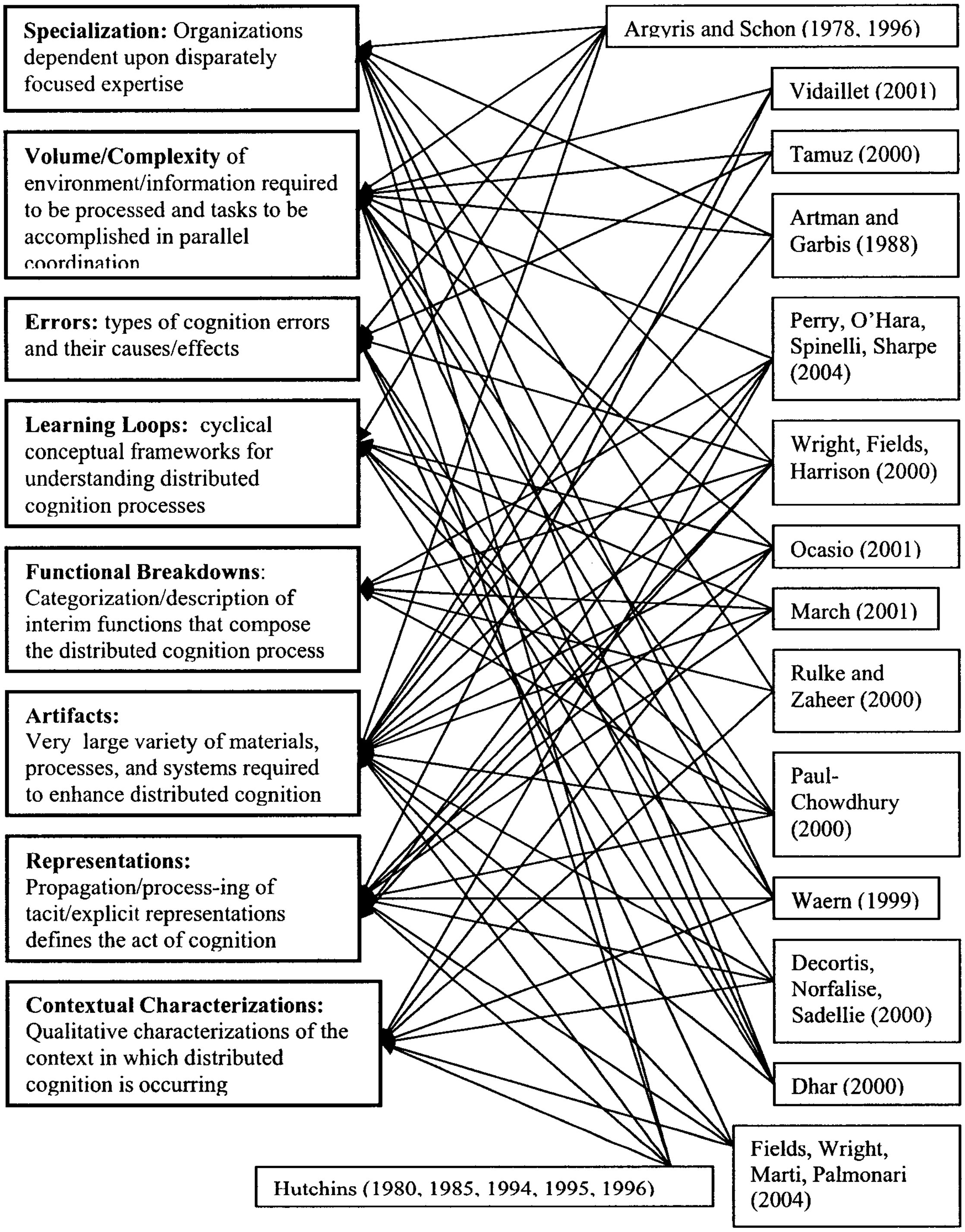
While the pursuit of a working definition of distributed cognition specific to purposes of this research served to introduce the concept and facilitate the initial literature review into the field, a more detailed review is required to provide a listing of authors' themes and characterizations of the phenomena and to provide a description of the resulting frameworks they have constructed to describe it.

Topical Streams of Distributed Cognition Literature

An extended general review of the academic literature relating to the phenomena of distributed cognition and organizational learning literature, led to the identification of several separate themes that repeatedly arise. Initial reviews led to the identification, clustering and categorization of these themes while in depth follow-up facilitated the development of a literature map tracking the ideas of specific authors to the developed themes. Figure 2.3, Distributed Cognition Literature Tracking Map: Emergent Themes of Authors, demonstrates the

recurrence of these themes within literature relating to distributed cognition and organizational learning. It should be noted that the listing of authors here is by no means exhaustive but rather it is somewhat of a generalized representative sampling of a larger set and its purpose here is to demonstrate the recurrence of eight dominant emergent themes to be detailed in the following order: 1) the complexity of the environment and the volume of information being processed by such systems, 2) the integration of specialized expertise's as a key function of distributed cognition, 3) the occurrence and impact of errors within learning systems, 4) a focus on the material, process, institutional, and technological artifacts which develop within organizations to facilitate distributed cognition, 5) the various key characterizations of the context within which the organizational cognition is occurring that are judged to significantly impact the cognition process, 6) the focus on and tracking of the propagation of representations through an organization–the fundamental act of cognition, 7) the breaking down, categorization, or description of the interaction of various structural functions of learning organizations, and lastly, 8) the detailing of a variety of frameworks sharing a cyclical theme describing the processes which must be looped through in order for organizations to learn.

Figure 2.3: Distributed Cognition Literature Tracking Map: Emergent Themes of Authors



Complexity: The Nature of the Environmental Information Being Processed

The first recurrent theme noted in the literature, complexity of the environment stands apart from the other prevalent themes in that the others relate to the process of distributed cognition itself. The environmental complexity in which distributed cognition systems exist is repeatedly cited by authors as a motivator or cause for the development of the system itself. Cognition has to necessarily become a distributed act because environmental complexity encourages it to arise. The initial grounding requirement motivating the rise of distributed cognition within organizations is the complexity and challenging nature of the environment in which organizations are functioning. Authors researching distributed cognition break down this environmental characterization into a variety of descriptive, thematic adjectives: problematically complex, ambiguous, techno-centric, time constrained or dynamic, and demanding of parallel and dissimilar tasks.

Complex environments are a primary driver of distributed cognition within organizations and are repeatedly cited within distributed cognition literature. Hutchins (1994) describes environments requiring a "weaving" of both a variety of observations and a variety of knowledge bases in order to be understood. Artman and Garbis (1988) describe the demands of environments requiring different, disparate "domain" knowledge bases and information resources. Perry et al (1998) note the volume of detail that must be processed, tracked, and remembered in order to understand such environments. The difficulty of understanding such complexity motivates organizations to posture themselves

and assemble systems composed of requisite knowledge bases and capability so that they can be understood.

If we extend complexity a step further, one must ask what indeed can be knowable versus what may not be knowable. March (2001) describes ambiguity as an "elementary problem" which organizations must overcome if they are to become intelligent about their environment; correlation and causality between events is difficult to ascertain and motivates intensive exploration of the environment. Dhar (2001) notes that complex environments may be discontinuous or non-linear; elements of the environment may have numerous interactions that arise and diffuse, complicating the knowability of the environment. Murphy et al (2001) notes that such ambiguity and diversity motivates the setting of goals by organizations in order to begin breaking down what must be understood and what can be ignored. Argyris and Schon (1996) note that the search for causality within ambiguous events is a central aim of both organizations. The ambiguity organizations perceive in operating environments motivates the construction of systems designed to remove such ambiguity.

Perhaps just an extension of the complexity of such environments, the concept of a techno-centricity motivating distributed cognition is repeatedly found within the research literature. As discussed previously when seeking to provide an working definition of distributed cognition, boundary setting is key to defining the system actually accomplishing the cognition; techno-centrism can arise both in the environment outside of the organization in question or, if arbitrary bounding

occurs, the influence of technologies within an organization can necessitate the rise of distributed cognition. Artman and Garbis (1988) note that a techno centric collection of communication devices may be viewed as the boundary line itself between an organization and its environment, placing additional cognitive burdens upon the organization to understand the technologies it uses to accomplish such interface. Perry et al (1998) note that the complexity of the world in which organizations operate is enhanced by the complexity of the technologies existing today. Wright et al (2000) note that the capabilities provided by technology internal to the organization for purposes of facilitating distributed cognition require an understanding of their existence and capabilities in the outside environment first. Complex technologies existing in the environment in which organizations operate add to the complexity of that environment itself and further require organizations to adapt themselves to deal with such complexity.

Dynamic environments further complicate the organization's task of comprehension. Dhar (2001) describes the difficulties associated with complex environments by noting that they are frequently and painfully either quick to respond or slow to respond to outside stimuli, or characterized by infrequently occurring phenomena, and further cites technology (computers, instrumentation, etc.) as a means for systemically enhancing cognitive capabilities in such environments. Vidaillet (2001) notes that organizations can quickly be overcome by events because the timely development and processing of representations in order to understand them cannot keep up with their pace. Wright et al (2000)

focus on the artifacts organizations develop to be able to respond to time constrained events, but such cognitive artifacts themselves exist because of the nature of environments anticipated by organizations. The dynamic nature of environments in which organizations operate requires urgency in developing understandings and responses; distributed cognition systems are constructed to meet this requirement.

Time constrained and complex environments require organizations to accomplish different tasks simultaneously or to distribute them across the organization. Artman and Garbis (1988) note that time constraints require parallel and disparate, non-alike task lists and thus require organizations to field and integrate a variety of expertises. Hutchins' (1994) discussion of intersubjectivity, an understanding or appreciation of another's task to be discussed in more detail later in this review, as a key characterization of the internal context within which distributed cognition occurs assumes that a variety of different tasks are having to be accomplished simultaneously. Waern et al (1999) as well as Wright et al (2000) describe the "co-ordination", to also be discussed in more detail later in this review, of representations flowing from different organizational elements as the primary function of distributed cognition systems; necessarily inherent in such descriptions is the idea that a breadth of expertise cannot be maintained within individual humans but must be distributed across several sub-systems in order to comprehend, act, and meet the demands of such an environment.

This characterization of the environment in which distributed cognition systems arise, flows from repeated themes cited in the literature. These themes,

problematic complexity, ambiguity, techno-centricity, dynamic environments, and demands for accomplishment of parallel and dissimilar tasks, are repeatedly cited by authors as motivating factors leading to the development of distributed cognition systems. Without such requisite characteristics in environments, it is possible to see simplistic cognition within a single individual or simple systems as being all that is required of an organization, but if and as these characterizations begin to become true of an environment the phenomena of distributed cognition within organizations begins to occur. Analogous to these themes, which exist outside a bounded organization in its environment, are the contextual characterizations authors draw of the nature of events and processes within the organization.

Specialization and Integration

The complexity inherent in environments which leads to the rise of distributed cognition systems within organizations also leads to the formation of analogous, specialized subsystems designed to enhance the organization's ability to understand and react to specific aspects of a diverse environment. As a result of the specialization, which develops to deal more efficiently with environmental complexity, organizations must also integrate the data being synthesized by the disparately equipped and trained specialized subsystems. This integration, also referred to as co-ordination within the literature (Waern 1999, Wright 2000) of synthesized representations is where the idea of

distributed cognition begins to separate from the mere collective sum of the cognitive parts of the specialized expert systems.

As stated, many of the same characterizations of environmental complexity from the literature described previously are also used by the same authors to describe the reflective development of specialization within the bounded distributed cognition system being studied. Rather than reciting each author that made these characterizations and going over them once more, perhaps a better way to illustrate this point is to review some of the actual studied specialized subsystems whose expertise, recommendations, and conclusions had to be organizationally integrated in order for the researcher to reach conclusions about the nature of the distributed cognition phenomena which was occurring. This review will also serve to summarize existing studies on the phenomena of distributed cognition in fielded situations.

In perhaps the seminal modern work, repeatedly cited throughout the literature, on the topic of distributed cognition, Hutchins (1980, 1990, and 1994) makes the essential case that cognition exists at a systemic level within the navigational functions of a US Navy ship at sea. Essentially, initial disparate measurements of various external environmental items (visible geographic points, celestial objects, time, satellite receptions, etc.) are made by a variety of specialized subsystems, tools, and personnel and are turned into representations further refined by other systems to produce fix, bearing, and speed. Citing the general recognition that human cognition is the development, maintenance, and adaptation of mental models or representations, Hutchins meticulously tracks

such representations as they are born and mature through the ship's navigation function.

Later in other work with Klausen (1996, 2000), Hutchins also studies the function of air traffic control from the perspective of an airplane cockpit again tracking the processing of representations and information from ground controller through the three officers on board and through the systems they use ultimately into the control surfaces of the plane. Fields et al (1999) also study air traffic control but focus on ground control rooms and the subsystems arrayed there to process representations from radar returns into instructions to aircraft. No one person or subsystem accomplishes the task itself, but an integration of these specialized parts leads to the final goal.

Thagard's (1993), (Giere's (2001) and Magnus' (2004) works are focused primarily on making the argument that Science, in general, has evolved into a large distributed cognition system, the intended goal of which is the search for truth or causal explanation of observed phenomena. In advancing their argument they cite specialized scientists themselves, instrumentation, models, visual representations, academic journalism, academic certification processes, award and reward systems, in addition to other functional systems all working integrally together hopefully to achieve the goal of finding scientific truth. The fact that such specialized subsystems exist and do work through an evolved system of interrelationships suggests that Science is indeed a system of distributed cognition.

In focusing on an objective similar to the one selected for this work, Artman and Garbis (1988) initially and in later work with Waern (1999), study the integration or co-ordination of disparately developed representations through an urban emergency phone call center. They cite the training, jargon, rules and procedures, and systems available to the telephone operator receiving incoming calls as separate systems which the operator and higher level controllers must integrate to organize a response specific to the needs of the incoming call. The diversity, variety, and complexity of potential calls require the development of these specialized subsystems and their subsequent integration in order to meet the center's goals.

With a goal somewhat similar to that of this work, Wright et al (2000) focus on developing a framework or model specifically designed for understanding human-computer-interaction (HCI). Central to their Resources Model are six abstract information structures informing the HCI process: plans, goals, affordances, history, action-effect, and current state. Without describing these in detail here or seeking to differentiate the framework that is the goal of this research, which will be accomplished in Chapter III, it suffices that again these represent sub-categorizations or specializations that a system synthesizes and then uses to accomplish its specific goal, in this case understanding HCI.

Other authors prefer to focus on the nature of specific subsystems common to distributed cognition systems and how they may specifically effect the overall goals of the larger system. Murphy et al (2000) focus on the relationship between personnel performance feedback systems within organizations and the

development and adjustment of overall organizational goals, arguing that the tension between these subsystems impacts the ability of the organization to understand and act within its environment. Tamuz (2000) and Vidiallet (2000) both focus on how the institutionalized rules for categorizing aircraft accidents and hazardous waste accidents respectively impact the ability of their communities to learn from the accidents themselves. These more narrowly focused studies of distributed cognition phenomena concentrate on specific specialized subsystems that have developed within organizations overtime and how they impact the overall process of learning itself, but the point for purposes in this context is that such specialization of subsystems exists and is a pre-requisite for distributed cognition to occur.

Specialization and the development of focused subsystems of people, materials, and artifacts arises because an organization is seeking to operate efficiently within an environment so complex that it exceeds the cognitive ability of collectives of mere well-rounded individuals and simple sub-systems. As a direct result of this specialization of subsystems, integration of their resultant conclusions, recommendations, responses, representations must occur for the organization to meet its goals. This initial process of integrating specialized efforts is where cognition begins to become a distributed act and not merely the sum of the collective learning efforts of each specialized subsystem. Merely integrating such representations, however does not fully describe the distributed nature of the cognition or learning; a further distributed step occurs when organizations must deal with errors made by themselves and their subsystems.

The Impact of Errors within Distributed Cognition Systems

A topic repeatedly discussed within distributed cognition and organizational learning literature is that of errors and their prevention, their impact, and their processing within cognition systems. This focus on errors within distributed cognition systems can be further divided into two primary levels.

First, on the surface, as researchers attempt to determine what leads to success within cognition systems they identify numerous artifacts and contextual qualities found in such systems that develop over time in part to prevent, detect, and mitigate errors and their subsequent system impacts. A listing of such artifacts would include visual representational systems, computational offloading systems, communications systems, meetings, memory and tracking systems, institutionalized procedures, rules, and heuristics, purposive learning systems, instrumentation systems. Similarly a listing of error preventing, detecting, and mitigating contextual qualities descriptive of the setting within which a cognitive system is functioning would include, horizon of observation, redundancy in communications, redundancy in information storage, clarity in communications, intersubjectivity amongst personnel and subsystems, and experience and competence of personnel. As each of these individual topics is the subject of much focus within the literature, they will be presented in greater detail with distinctive citations to respective authors later in this review; the point to be made here is that control of errors within distributed cognition systems is a fundamental

driver of many of the emergent qualities of distributed cognition systems. Environmental complexity coupled with the frailty of systems and personnel necessitates that error processing be planned for and structured for accordingly.

A second focus on errors is on a deeper level, in that they drive the actual learning or cognition occurring in organizations that is the more significant adjustment of representations. Dhar (2000) focuses on the distinction between so called Type I errors, the selection of bad alternatives, which are self correcting and Type II errors, the rejection of good alternatives, which are only addressed when participants within systems step aside and re-examine events, expectations, and causal relationships. Hutchins (1994) discusses the impact of integrating secondary, personnel on-the-job training goals into actual shipboard navigation systems, in which overseeing personnel quietly allow some errors as they occur to propagate through the system in order that junior personnel may see the impact of the error, learn the various points where the error can be detected and corrected, and gain an appreciation for why institutionalized structure exists. Boyd, as described by Coram (2002) noted that an iteration of decision or selection of alternative, within his OODA loop involved a feeding forward set of expectations. After deploying the selected alternative and observing outcomes, the orientation phase of his process involved determining why expectations were not reached. Argyris and Schon (1996) define errors as simply the tension existing between expectations and observations. Most of these are caught by system functions and are corrected at an almost passive level. Occasionally, however they are not caught until system wide impact

begins to occur or an active, deeper learning takes place in which organizational personnel question and adjust the structure of their system itself:

> "Organizational learning occurs when individuals within an organization experience a problematic situation...They experience a surprising mismatch between expected and actual results of action and respond to that mismatch through a process of thought and further action that leads them to modify their images of organization...and to restructure their activities so as to bring outcomes and expectations in line...In order to become *organizational* the learning that results...must become embedded in the images of the organization held in its members minds and/or the epistemological artifacts...embedded in the organizational environment."

Errors are a primary focus within the literature because they can inhibit the performance of distributed cognition systems and as a result, such systems are motivated to develop artifacts and contextual qualities to enhance their ability to detect, assess, and mitigate errors as they occur. On a deeper level, errors may be manifestations directly related to previous organizational actions or experiences that no longer agree with accumulating data, motivating a more fundamental reassessment of the existing environmental understanding and organizational structure and function which lead to the error.

The Artifacts of Distributed Cognition

A primary focus of distributed cognition literature is on proving that cognition is indeed occurring on a systemic level and not merely within the minds of collectives of individuals. The suggestion is made that the creation and adjustment of representations of the outside world being studied is being

accomplished by individuals working in concert with a host of artifacts or subsystems which are just as integral to the process as the individuals themselves. The tracking of changes in representations through these artifacts in the form of inputs and outputs is a recurring methodological basis for research. An overview of categorizations of prevalent distributed cognition system artifacts found in the literature is provided here to provide a flavor for what may be considered an artifact of distributed cognition.

Visual representational systems are those that allow information to be directly perceived without explicit formulation and that externalize, make explicit, and system- orient the tacit representations existing within the minds of individuals (Decortis et al 2000, Wright et al 2000, Walsh 1995, Paul-Chowdhury 2000, Fields et al 1999, Artman and Garbis 1988). Perhaps the most readily recognizable example of a visual representation is a geographic or system wide status map. Other forms include physical models of the outside environment, graphic displays, charts, status boards, photographs, and a variety of other types of displays.

Tracking and memory systems may or may not take a visual form providing the perception benefits detailed above but they fulfill another core purpose of curing the requisite attention deficit which may exist in groups of individuals given the variety in their environment (Decortis et al 2000, Wright et al 2000, Hutchins 1995, Perry et al 1998, Dhar 2000, Paul-Chowdhury 2000, Fields et al 1999, Tamuz 2000, Argyris and Schon 1996). Examples include once again status boards and maps as well as event logs, computerized databases,

checklists, maintenance histories, plans, personnel and materials listings, accounting records, and even reminder notes.

Computational offloading systems are those that free other systems and individuals to focus efforts elsewhere by absorbing the detailed, tedious, and time consuming tasks of accomplishing computation (Perry et al 1998, Wright et al 2000, Ocasio 2000, Paul- Chowdhury 2000, Fields et al 2000, Hutchins 1990, 1994, 1996, Tamuz 2000). Examples include the obvious computer software and calculators as well as graphing tools, data-mining tools, mathematical instruments, and presentation building tools.

Communications systems seem to be at the heart of a variety of distributed cognition studies. Their primary purpose is to enhance the process of gathering, and distributing data and messages into and through the system being studied (Perry et al 1998, Wright et al 2000, Ocasio 2000, Waern et al 1999, Johanssen 2001, Giere 2001, Paul- Chowdhury 2000, Fields et al 2000, Hutchins 1990, 1996). Examples include the common telephone, as well as computer networks, fax machines, radios, message boards, academic journals, chat rooms, and even human runners.

Institutionalized processes is a catch-all of somewhat disparate artifacts composed of resources and procedures that become part of the structure of cognition systems themselves and can serve to meet several of the goals being described here. Examples include plans, goals, mission statements, heuristics, rules, categorization methodologies, clustering methodologies, simulation and gaming techniques, jargon, prioritization listings, and other procedures. While it

is difficult to align these artifacts into any one particular category, the idea that they are a part of the structure of cognition systems is prevalent in the literature (Perry et al 1998, Ocasio 2000, Waern et al 1999, March 2000, Johanssen 2001, Giere 2001, Paul-Chowdhury 2000, Fields et al 2000, Hutchins 1996).

Purposive learning systems or training programs themselves are artifacts designed to improve the performance of individuals and systems within cognition systems. Hutchins (1996), Rulke and Zaheer (2000), and Argyris and Schon (1996) in particular note the positive impact of designing training goals into and considering training as part and parcel of cognition systems on the long-term performance of those systems. Such systems include classes, books, manuals, exercises, inspections, read-files, and academic journals.

Instrumentation systems are those which allow individuals to accurately and precisely measure variability that would otherwise be beyond their capability and in so doing amplify the system's ability to detect and thus attempt to control change in the outside environment (Wright et al 2000, Hutchins 1994, 1996, Decortis et al, Dhar 2000, Fields et al 2000, Giere 2001, Magnus 2004). Types of instrumentation are numerous and sometimes specific to the environment being studied but include atmospheric condition monitors, sensors, tracking devices, and sampling and testing devices.

This listing of the types of artifacts that may be found within distributed cognition systems is provided here to give a flavor for exactly what these artifacts are. They serve the purpose of aiding the individual and systems within an organization to develop an understanding of the outside environment. While they

represent physical manifestations of a cognition system attempting to achieve their intended purposes other non-physical qualities of such systems also emerge as key to enhancing distributed cognition.

Contextual Properties Impacting Cognition

In addition to identifying and describing a broad range of artifacts that may be found within distributed cognition systems, authors also focus on several emergent, contextual properties of the settings in which such systems operate that can significantly impact system performance. Such qualities found in this literature review include staff competence, leadership, intersubjectivity, horizon of information visibility, flexibility, and redundancy. These qualities are identified and defined here to provide a flavor for the contextual system properties researchers have found to impact system performance.

While it may seem directly obvious that the competence of the personnel within a distributed cognition system has a direct bearing on performance, it is such directness that calls for it to be defined first as an important contextual property. Hutchins (1996) notes that on-the-job training is woven into US Naval shipboard navigation systems to improve the competence of personnel. Drills, practices, and tests are done to train personnel and thereby improve system performance. Wright et al (2000) note that personnel "competency traps" seem to be a recurring cause of incorrect or halted representational propagation through cognition systems. Paul-Chowdhury (2000) notes that personnel motivation, reliability, absorptive capacity, and retention capacity are significant

hindrances to knowledge transfer within organizations. Rulke and Zaheer (2000) correlate both the self-knowledge and resource knowledge, not having expertise on a given subject but knowing where it may be found, of managers to the performance metrics of grocery stores. Staff competence is an obvious first choice in selecting contextual properties of cognition systems that may have a direct bearing on performance.

Somewhat related to staff competence but somewhat lightly addressed within the reviewed literature is the idea of leadership within an organization influencing cognition performance. Perhaps because it is a highly subjective term and difficult to apply quantitative measure to, and perhaps because it can be included under the overarching heading of staff competence, many authors do not directly cite it as a property influencing performance, but it does seem obvious that good organizational leadership would directly impact performance. Without explicitly mentioning the overarching concept of leadership, Hutchins (2000) in tracking mental representations through an airline cockpit crew, does describe the impact of a decisive action and communication by the Captain to the crew on quickly bringing system performance back to within an accepted norm. Boyd as described by Coram (2002) noted that in making hard decisions a leader had to convey their gravity to his subordinates as they acted upon them. Argyris and Schon (1996) cite Schein's (1992) definition of leadership as being "the attitude and motivation to manage organizational culture" (p374). They propose that,

> "A learning leader must assess the adequacy of his organization's culture, detect its dysfunctionality, and promote its transformation

> by...promoting [his] assumptions [regarding learning] within the culture of his organization...Leaders can foster a learning culture by envisioning it and communicating the vision..."

Quality of leadership within an organization is a contextual property that must be suspected of having a direct bearing on cognition system performance.

Hutchins (2000) cites Rommetvelt and Blakar (1979) and Wertsch (1985) in defining intersubjectivity as the ability to put oneself in another's shoes in order to develop a shared understanding of a situation. His example in the case of the airline cockpit is that of a First Officer sensing his Captain's sudden need for a specific bit of information quickly and providing it without being asked because the First Officer also has some experience at accomplishing the Captain's task load. Similarly because the Captain knew that the First Officer had such an intersubjective understanding of his tasks he correctly anticipated that the help would be provided without asking. Other authors discuss the impact of intersubjectivity on system performance by noting how the capability to appreciate another player's place within the system resolves errors quickly and distributes assistance quickly, allowing representations to be sharpened and actions to be coordinated (Decortis et al 2000, Vidaillet 2000). For intersubjectivity to play a role in influencing the propagation of representations through a distributed cognition system, potential sympathetic players must be in a position to know what is occurring to other players.

Decortis et al (2000) define a horizon of visibility as "the functional workspace that each participant can monitor in addition to its own task" (p.3). Hutchins (1994) argues that the size of this space impacts error detection and

correction because it allows or limits monitoring by other system players. By making information flow visible to many players with intersubjective understandings of one another, representations can be molded and adjusted quicker and with less iteration. Fields et al (1999) refer to this concept as *accessibility of representations* and note how artifacts play a key role in broadening the sharing of information. Johannsen (2001) notes how monitoring the background chatter within a control room plays a significant role in constructing accurate representations. Perry et al (1998) refer to the visibility of other perspectives facilitating the synthesis of ideas. In addition to a spatial horizon of visibility a time horizon also exists; information must be processed and transmitted by systems in a timely manner if it is to be used by system actors (Artman and Garbis 1988, Hutchins 1994, Vidaillet 2000, Fields et al 1999). Each of these authors is addressing the same idea; that is that distributed cognition systems must develop or have designed into them architectures which facilitate increasing the horizon of observation of individual system players.

Two additional contextual properties that obviously would be suspected of impacting system performance are redundancy and integratability. Redundancy in communications, information storage, computational ability, visual representations, observations, and in other subsystems is cited by numerous authors as increasing a system's ability to detect errors and calibrate responses (Hutchins 1994, 1996, Decortis et al 2000, Fields et al 1999, Tamuz 2000). Similarly, subsystems must accept, process, and produce representations in such a manner that they can be used and understood by other subsystems and

players. Integratability or flexibility is key if representations are to propagate accurately across subsystems and must be designed into distributed cognition systems (Hutchins 1994, 1996, Fields et al 1999).

A variety of contextual qualities or emergent properties of distributed cognition systems have a direct bearing on system performance. Staff competence, leadership, intersubjectivity, horizon of information visibility, flexibility, and redundancy were presented here to provide a flavor for the manifest properties repeatedly cited within the literature and for their ability to influence a cognitive system's performance in fulfilling its intended purpose, developing, adjusting, and processing representations of the outside environment.

The Propagation of Representations - The Heart of Cognition

Within anthropological and psychological research into individual human thinking and learning, the act of cognition is routinely defined as a mapping of one kind of information to another through the selection and transformation of representations (Marr 1982, Thagard 1996, Norman 1993, Vera and Simon 1993, Hutchins 1995). In order for an organism to come to conclusions about its environment, it must *develop* mental representations of that environment and *imagine* what impacts its actions or the actions of others may have on that environment. After acting or observing others' actions and the ensuing environmental changes, the organism can make judgments about causality, interrelationships, and the accuracy of its conceived representations then

iteratively adjust them accordingly. This process is the fundamental act of cognition and learning.

Because this process traditionally has been thought to take place within the brain of the individual organism or human, the study of cognition, that is the processing of representations, has been confined to anthropological and psychological circles. When the ideas of collective mind and distributed thinking began to arise, as was discussed in the introduction to this literature review, and organizations came to be thought of as thinking organisms, tacit, internal, mental representations could be to some extent explicitly defined as they had to be to be transferred between humans and between subsystems. Thus the major focus of distributed cognition research, as has been discussed in detail previously, is in making explicit these mental models being used within organizations and tracking their development and processing over time (Wright et al 2000, Hutchins 1994, 1996, Decortis et al, Dhar 2000, Fields et al 2000, Giere 2001, Magnus 2004, Paul-Chowdhury 2000, Perry et al 1998, Ocasio 2000, March 2000, Rulke and Zaheer 2000, Waern et al 1999, Rogers 1996, Tamuz 2000, Vidaillet 2000). Additionally, what once was the province of anthropologists and psychologists also began to draw the interest of the organizational and management science. One might suspect some common themes to emerge from amongst this research into the tracking of representational propagation and indeed as has been seen thus far some have, but one might also expect there to be some common functionality to the processes whereby such representations are developed and processed.

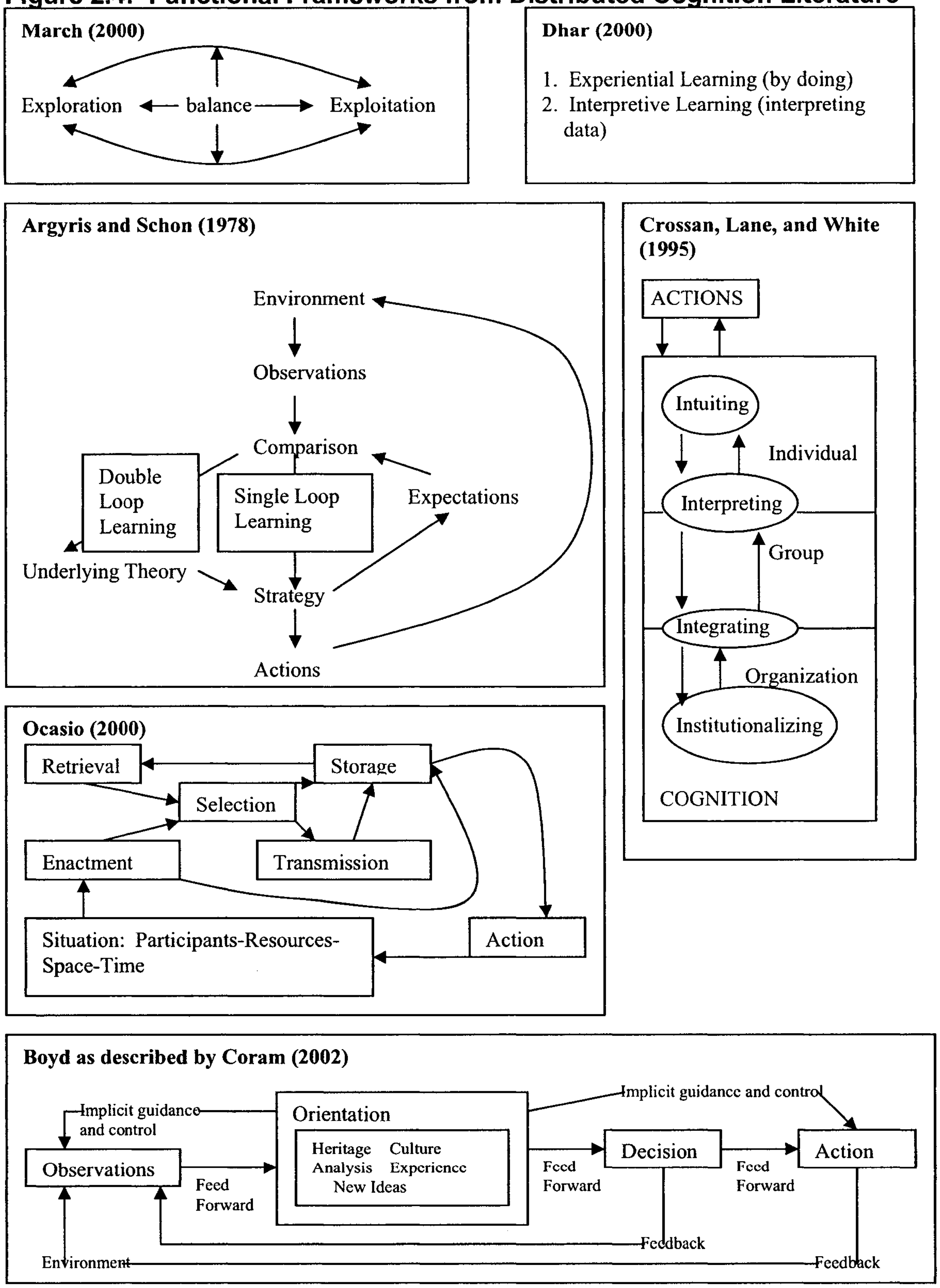
Common Structural Functions and the Emergence of Cognitive Cycles within Distributed Cognition Literature

The purpose of the section of this literature review on specialization is to describe how, in response to environmental pressures and the desire to operate more efficiently given those pressures, organizations are motivated to develop or evolve specialized subsystems which can employ their respective expert knowledge bases in concert against the complexity of the environment. This emergent organizational structure tends to be specific to the type of organization and type of environment, i.e. businesses develop marketing, accounting, production, and research divisions while cities develop transportation, law enforcement, tax assessment, and building code divisions. From the distributed cognition researcher's perspective a goal may then be to understand how the work of these disparately focused subsystems is synthesized into a collective understanding of these environments.

Rather than looking at each organization individually, researchers have developed some basic frameworks for understanding distributed cognition systems in general by identifying functional commonalities to all such learning systems. The purpose of this portion of the literature review is to first summarize the works of other authors in identifying and describing some of the basic functions of distributed cognition systems and second to highlight a recurrent theme in many of these frameworks, that is the concept that learning involves a repetitive, iterative cycling through of these suggested functions in pursuit of

developing accurate representations of outside environments. Figure 2.4, Functional Frameworks from Distributed Cognition Literature, presents a simplified outline of the functional frameworks suggested within the reviewed literature.

Figure 2.4: Functional Frameworks from Distributed Cognition Literature



March (1991, 1998, 2000) identifies the two fundamental problems of the organizational-environmental learning challenge as being ignorance and ambiguity; ignorance simply being the lack of knowledge about the environment and ambiguity being the lack of knowing how to change the environment. From this basis, he then suggests that the two fundamental functions of learning organizations are exploration, to gain knowledge and reduce ignorance, and exploitation, in deciding upon and pursuing goals by using gained knowledge thus removing the ambiguity of understanding the organizations place within the environment. March then goes on to describe the balance that organizations must maintain between these two functions; too much exploration and not enough exploitation results in little productive activity and the organization cannot sustain itself while the reverse results in an organization that never discovers new alternatives and is prone to Type II errors that eventually finds itself no longer adaptable to a changing environment.

Dhar (2000) reviews March's work and extends his own two primary means of organizational learning: learning by doing and learning through interpretation. Learning by doing or experiential learning reduced to its core is merely initiating or repeating actions that have worked successfully in the past without much contemplation for why they work-an "if it works then do it again" mentality. Not much is really learned other than that a correlation between a particular action and a result exists; exploration is de-emphasized. Reduced to its simplistic core, learning by interpretation is simply reaching conclusions about interrelationships based on past historical data. In its extreme this form of

learning is prone to errors due to small sample size and interpretations being applied to non-analogous environmental situations. By defining learning using extreme notions, Dhar is implicitly suggesting that both of his suggested forms complement the other.

Argyris and Schon (1978, 1996), as previously discussed, cite errors or the differences between expectations and outcomes as the driving force behind learning. If errors are to be corrected organizations must ask themselves why the discrepancies occurred and must make changes to prevent recurrences. They identify a surface type of feedback loop, single loop learning, in which the difference between expected outcomes and actual outcomes of previous actions and strategies results in changes and adaptations to the strategy being deployed. They then further identify a deeper form of learning feedback loop in which an organization questions and adjusts the underlying theory supporting the implemented strategy.

Argyris and Schon developed their framework from an organizational science perspective and before cognitive science had really developed the concept of distributed cognition within organizations, thus for purposes of this research, some effort needs to be made to interpret their perspective in the language of distributed cognition. A cognitive scientist would view single loop learning as a minor adjustment or recalibration of an accepted representation or a refinement of understanding how organizational actions impact the accepted representation. Such changes to representations developed over time would be in terms of minor changes in size or scale while double loop learning would be

viewed as a major adjustment or change in the actual structure of the representation of the environment and its interrelationships with the organization itself. One further noteworthy attribute of Argyris and Schon's explicitly defined organizational learning framework is that it is one of the original ones that view the learning process as being composed of a series of iterative feedback loops, a concept at the core of other frameworks.

Crossan, Lane, and White's (1995) 4-I theory of organizational learning rests on their identification of four basic functions: intuiting, interpreting, integrating, and institutionalizing. Intuiting is the act of an individual recognizing patterns or possibilities in the environment. Interpreting is the act of explaining such ideas to oneself and/or crossing the individual's boundary and explaining it to a group of other individuals. Integrating is that group developing a shared understanding based on the interpretations of several. Finally, institutionalizing is when organizations formally act on the integrated concepts of such groups. By focusing on the levels at which each suggested basic function is occurring, the authors are implicitly suggesting that learning is indeed a distributed function. They further suggest that these steps work in both directions as representations are built from the bottom-up or feeding forward as they describe it, then institutionalized and fed back down to individuals as they become the basis for implicit action.

Crossan et al then go on to suggest four basic propositions relating to their framework. First, a tension exists between assimilating new learning and using existing learning, analogous to March's balance between exploration and

exploitation and Argyris and Schon's single and double loops. Second, learning occurs at multi-levels, personal, group, and organizational within an organization, i.e. organizational learning is a distributed act. Third, processes link these levels; again learning is an emergent, systemic, distributed act. Fourth and finally, cognition affects action and vice versa, suggesting an iterative relationship exists between the two.

Ocasio (2000) building on Weick's (1979) work suggests his SERSTS model based on the following functions composing the organizational processing of representations: situation, enactment, retrieval, selection, transmission, and storage, all of which are analogous to other frameworks already described. Ocasio's situation is essentially analogous to the outside environment used in other frameworks. Enactment, a concept borrowed from Weick is essentially the initial creation from scratch of different representations of a situation. Retrieval refers to representations not necessarily created on the fly but supplemented with existing representations of similar situations already developed by an organization; again one notes the tension between exploration and exploitation. Selection is the actual work of picking representations or combining them, analogous to Crossan et al's integrating phase. Transmission is the act of propagating the representation through the various portions of an organization for both refinement and action. Finally, storage is analogous to the institutionalization of the given representation for purposes of future retrieval and incorporation into action strategies. Implicit in Ocasio's model, first, is the idea that the cognitive action his functions compose has the purpose of leading to

action to change the situation for the organization's benefit and second, that information and representations flow through an organization to such ends in a continuous manner.

While developed somewhat separately from cognitive and organizational sciences, Boyd's conceptual framework of OODA loops, described by Coram (2002), for purposes of explaining the actions of protagonists in military conflicts is functionally analogous to the learning frameworks already discussed. Indeed, Coram (2002) describes the objective of the framework as being a means "to get inside the mind and the decision cycle of an adversary" (p. 335). As stated before in this work, Boyd's looping of information is composed of four distinct phases: observation, orientation, decision, and action. Figure 2.4 provides a detailed diagram used by Boyd himself (Coram 2002) as he briefed his concept throughout the US military establishment in the 70's and 80's.

There are three issues of particular noteworthiness in Boyd's framework developed outside of other sciences dedicated to understanding the thinking process. First, the idea he suggests of implicit feedback from the orientation phase of his process to the action phase is suggestive of Argyris and Schon's single loop learning, March's exploitation, and Dhar's experiential learning. Second, the feedback loop flowing from the decision phase to the observation phase is suggestive of Argyris and Schon's expectations being part of strategy selection and being a means of measuring representation accuracy via the existence of errors. Finally third, Boyd attempts to capture both culture and context by citing their influences on the orientation phase of the process. And

overarching all these points is again the iterative, meta-loop cited by other authors of the learning process.

The purpose of this review was to provide a flavor for the existing frameworks that can be found within the literature and to develop common themes that exist across these frameworks. These themes include the notions that cognition is an iterative, repetitive looping process, that it occurs on surface levels and deeper levels relating to the degree to which representations are adjusted, that natural tensions exist between using existing representations repeatedly and adjusting them or developing new ones, and that the basic functions of cognition consist of compiling environmental observations, searching for and recognizing patterns within those observations that in turn can be developed into conceptual representations of the environment, settling on a representation as the basis of developing strategies of action and expectations, and then implementing those strategies, observing results, and repeating the process.

Summary of Literature Themes and identification of Literature Gaps

The purpose of this portion of the literature review is to develop an understanding of the concepts of distributed cognition and organizational learning and to detail the recurrent themes found across the literature. By integrating the work of several authors, a working definition is developed particular to the nature of this work for a more specific concept of distributed cognition: the ongoing collective accumulation, distribution, and synthesis of knowledge across time

amongst personnel and systems at all levels within a bounded organization which leads to the development, adjustment, and sometimes tearing down then redevelopment of both tacit and explicit mental representations of the outside world within which the organization is trying to pursue its goals.

Additionally by structured review and clustering of like issues, the following major themes relating to the study of distributed cognition and organizational learning are identified: 1) the complexity of the environment and the volume of information being processed by such systems, 2) the integration of specialized expertise's as a key function of distributed cognition, 3) the occurrence and impact of errors within learning systems, 4) a focus on the material, process, institutional, and technological artifacts which develop within organizations to facilitate distributed cognition, 5) the various key characterizations of the context within which the organizational cognition is occurring that are judged to significantly impact the cognition process, 6) the focus on and tracking of the propagation of representations through an organization–the fundamental act of cognition, 7) the breaking down, categorization, or description of the interaction of various structural functions of learning organizations, and lastly, 8) the detailing of a variety of frameworks sharing a cyclical theme describing the processes which must be looped through in order for organizations to learn.

Given that the focus of this work is on the development of a systemic, conceptual framework for understanding the organizational cognition occurring in crisis control centers, the difficulty one would find in applying the large and disparately varied existing literary constructs to the specified case is indicative of

gaps existing in organizational literature. First, construction of systemic functional, structural frameworks for description of cognitive functions within the specific case of crisis control centers is lacking. Johanssen et al (2001), Hutchins (1994, 1996), and Waern et al (1999) all provide detailed insight into the function of what can be considered control centers functioning in environments of varying degrees of complexity and Vidaillet (2000) provides a case review empirically identifying themes arising out of a crisis situation in which control centers played a key role. The objective of these authors, however, is not to develop and test conceptual frameworks in such settings and furthermore their objectives are not to detail the impacts of crisis situations on the phenomena of cognition within these settings.

Second, while some systems analysis concepts are prevalent in some of the reviewed frameworks, Boyd's seeming to holistically incorporate more than the others, it is difficult to tell how, methodologically, these frameworks are developed as the authors merely develop and present them based on ranging literature reviews as was done here or develop them empirically out of specific cases. A systems scientist would suspect that by formally and explicitly applying the techniques of system analysis to the problem of constructing such frameworks, a more holistic, comprehensive approach could be developed and confidence in its ability to provide a more complete means for understanding cognition phenomena in specified settings would be increased. Such an effort will be undertaken in Chapter III of this work for the specific case in focus, crisis

control centers, but first a review of literature relating to the setting of that focus must be accomplished.

A Review of Crisis Management Literature – Purpose and Objectives

The purpose of this portion of the literature review is to develop an understanding of how the onset of crisis conditions might impact cognitive phenomena within organizational control centers. To that end a survey of crisis management literature is undertaken with two objectives in mind: first, to distill an working definition of what constitutes a "crisis" from an organizational perspective, and second, to develop a listing of themes prevalent in the literature that characterize crises in general. Chapter III will then use a systems analysis methodology to integrate ideas from the two major focus areas of this literature review, distributed cognition and crisis management, into the proposed conceptual framework at the center of this work. A review of crisis management literature can lead one to broadly categorize works into two categories: first, declarative "how-to" popular management literature describing experiences and developing prescriptive approaches to dealing with crises situations, with a prevalent focus on organizational public and media relations, and second, literature focused on development of overarching frameworks for describing and rigorously understanding a crisis situation. Many of the reviewed works mention the need for control centers and describe cases involving organizational control centers during periods of crises but the general perspective is to provide organizational leaders with guidance and not as is the focus of this work to focus

intently on the control centers themselves. Nevertheless, they still do provide fertile ground for meeting the specified objectives here.

Prescriptive Approaches to Crisis Management

The term crisis management is a bit of a "buzzword" in today's popular management literature as organizations deal with the uncertainty of modern environments. Perhaps as a result, a variety of works exist marketed to managers who have to face such situations. Generally speaking, such works focus on descriptive story telling to illustrate knowledge gained from experience. A brief review of such works provides a flavor for the nature of most crisis management literature.

Meyers et al (1986) in the dramatically titled When It Hits the Fan describe nine types of modern business crises including sudden market shifts, product failures, cash crises, and labor relations by retelling various stories then listing points or lessons learned within the story. In many cases the stories are summed in catch phrases. For example, after citing numerous case stories relating to product failures the reader is instructed briefly to "redesign it or retire it." Similarly, Lerbringer (1997) presents six general types of crises organizations may have to confront: natural, technological, confrontation, malevolence, management, deception, and misconduct and then describes examples of each citing areas where mistakes occurred and improvements could be made. Unzucker (2002) distills crisis response into five general areas: investigation, restoration of normal operations, preparation for litigation, restoration of staff and

public confidence, and reduction of political impact; then goes on to identify the seven personality traits of good crisis managers: being stable under pressure and public exposure, being firmly anchored in company and corporate position, being believable as company spokesman, being able to handle ad hoc assignments well, being a team player, and being able to deal with uncertainty. Bernstein (2003) identifies eight general public relations mistakes made by organizations: playing ostrich or not addressing a growing crisis, waiting to respond to a crisis only after it has gone public, assuming a good reputation will speak for you, treating the media like an enemy, remaining trapped in a reactionary mode, over-relying on technical jargon in media communications, assuming the truth will triumph, and ignoring personnel's emotions.

The point of these citations is to provide a general flavor for the approach most works on the subject take towards crisis management; they provide a review of crisis cases citing lessons learned followed by a declaration of a set of steps or principles that can be used by organizations responding to crises. Lessons learned and typologies of crisis cases are doubtless very useful in developing a knowledge base for organizational managers but for purposes of developing a holistic view of crises, they provide little more than a background on which to further develop more rigorous concepts.

Developing a Working Definition of a Crisis Environment

In more conceptually rigorous approaches to the subject matter of crisis management, a variety of authors begin by distilling out of their cases a

generalized definition of what a crisis is and what crisis management is. Figure 2.5, Definitions of Crisis and Crisis Management, provides a review of theses definitions.

Figure 2.5: Definitions of Crisis and Crisis Management

Crisis

"a turning point for better or worse" – Fink (1986)

"A situation characterized by surprise, high threat to important values, and short decision time." Hermann, (1971).

"a major occurrence with potential negative outcome affecting an organization, company, or industry. As well as its publics, products, services, or good name." Fearn-Banks (1996)

"a major unpredictable event that has potentially negative results. The event and its aftermath may significantly damage an organization and its employees, products, services, financial condition, and reputation." – Barton (1993).

"an event that is an unpredictable, major threat that can have a negative effect on the organization, industry, or stakeholders, if handled improperly." – Coombs (1999).

"Extreme events that cause disruption and put lives and property at risk. These Require an immediate response and application of resources beyond regular application." - National Research Council (1996).

Originally a medical idea: "a Hippocratic concept: all illnesses reach a turning point. From here some are fatal, some go on to recovery, all others develop to another form, and take on a different constitution." Dab (1993).

"a fit of uncertainty, and distress where everything is in suspense in anticipation of imminent resolution of the illness." Bolzinger (1982).

"Crisis: a situation in which numerous organizations are faced with critical problems, experience both sharp external pressure and internal tensions, and are then brutally and for an extended period thrust to the center stage and hurled against one another, all in a society of mass communication, in other words in direct contact with the certainty of being at the top of the news on radio and television and in the press for a long time." Lagadec (1984)

Crisis Management

"Set of factors designed to combat crises and lessen the actual effects of the crises. Put another way, cm seeks to prevent or lessen the negative outcomes of a crisis and thereby protect the organization, stakeholders, and/or industry from damage. (Coombs 1999)

"The set of concepts, principles, analysis, and working methods, that apply specifically to the very particular situation known as a crisis." (Ogrizek, Guillery 1999).

Three general themes emerge out of these definitions. First, crisis events are considerably more significant and negative to organizations than normal events in terms of their impact on organizational survival in its current state. Second, they may have components of surprise, unpredictability, and difficulty relative to the normal events organizations are ideally postured for. In light of the prior discussion of a key theme from distributed cognition and organizational learning literature, environmental complexity, this notion can be thought of as crisis environments being composed of a level of complexity for which the organization is not ideally prepared. Third and finally, these authors all point to the internal organizational and emotional stress caused by crises.

Bringing these themes together an working definition can be proposed: *crisis environments are those with potential for significantly more negative organizational outcomes and of a significantly greater level of complexity than organizations are usually prepared for and in turn cause significant internal organizational stress.* While a definition such as this one lays the foundation for gaining a conceptual understanding of a crisis environment, further review is necessary to more completely characterize that environment.

Characterizations of the Crisis Environment – Emergent Literature Themes and an Operational Specification of Complexity

In reviewing crisis management literature three general approaches of characterizing crisis environments emerged: developing typologies of crises, describing varieties of complexity associated with crises, and developing characterizations of various periods of the life of a crisis within an organization.

Discussion of the first two of these themes leads to the idea that they can be merged into the general idea of characterizing the nature of a crisis's complexity while discussion of the latter stresses the importance of understanding the dimension of time as it relates to conceptualizing crisis environments.

As was previously discussed, Meyer et al (1986) identified ten types of crises affecting business enterprises: these include crises in labor relations, public perception, market shifts, product failures, management succession, cash flow, organizational relationships, hostile takeovers, adverse international events, and governmental regulation. Similarly, Nudell and French (1988) propose five types of crises typically occurring within governmental and political circles: natural disasters, accidents, terrorism, criminal acts, and disruptive actions, i.e. strikes, boycotts, and protests. Lerbringer (1997) identifies seven slightly more general types of crises with which organizations may find themselves confronted: natural, technological, confrontation, malevolence, skewed values, deception, and management misconduct. Given the definition proposed earlier, each of these types of environmental events constitute crises for organizations because they meet the specified criteria, they pose significantly negative consequences for the organization and their complexity is of a nature for which the organization is not usually prepared.

These typologies spring from those underlying complexities. Natural disasters present a volume of requirements outside the normal range for governments. Technological crises may require larger or different knowledge bases than organizations previously had. Criminal acts may be outside the

normal plans of organizations. Each of these types of crises represents an underlying degree or nature of complexity with which the organization must come to deal. In terms of conceptualizing crisis environments then it is this underlying nature of the crisis's complexity that first drives the organization's stress and not the emergent typology itself.

Some authors address this underlying nature of the complexity within crisis environments. The National Research Counsel (author unidentified 1996) cites five characteristics of crisis environments: 1) magnitude or the sheer volume of information, events, and demanded responses, 2) dynamic urgency or the short time period required for understanding and action, 3) infrequency and unpredictability of events, 4) credibility of sources, and 5) multidimensionality or the breadth of differing ways in which events impact the organization. Lerbringer (1997) focusing on the time dimension of crises cites suddenness, uncertainty, and urgency. Meyer et al (1986) cite multidimensionality, ability to control, and urgency.

Because *complexity* fills a key portion of the developed working definition of a crisis environment for purposes of this work, its own further operational specification is required. In general terms *"level of complexity"* can be expanded to encompass as Carlisle and Rebentisch (2003) suggest 1) the amount of novelty introduced by the environment into to the control center, 2) the demands of the environment on the control center in terms of the amount of dependence between specialized sources of knowledge required to develop successful responses, and 3) the demands of the environment on the control center in terms

of the amount or type of specialization required to successfully respond. This characterization of complexity and its demand on organizational learning entities is reflective of the discussions of specialization, integration, horizon of visibility, and intersubjectivity discussed in the literature review. The novelty side of complexity itself can further be characterized by the sheer number of entities involved, the pace of events, and high degrees of uncertainty (Jackson, 1991; Beer, 1979).

In meeting the objective of this work, developing a conceptual framework for understanding distributed cognition phenomena within organizations, it will be important to define these underlying aspects of crisis environments in terms of the perspective of the proposed framework. For example, Boyd may view a crisis situation's urgency in terms of a challenge to his organizations ability to observe, or sample, and orient itself to a changing environment fast enough to make decisions and act. Similarly, Ocasio may view crisis magnitude as a challenge to organization's ability to enact a large enough representation to encompass the volume of detail necessary to act within such an environment. Also importantly, such a framework must provide a means of understanding the impact of crises on its systemic structure as it passes through times of normalcy, crisis, and return to normalcy.

Several authors approach the problem of framing crisis situations from the perspective of time, that is, breaking down the life of an organization functioning through times of crisis into separate phases. Taking the organization's perspective the National Research Council (1997) identifies four main phases of

time during a crisis: preparation, avoidance, response, and recovery. Fink, as cited by Coombs (1999) use a medical illness metaphor as a means to frame the life of an organization in a crisis situation: the prodromal period, when clues that a crisis exists begin to emerge; the breakout period, a triggering event with attendant damage; the chronic period, when lingering effects must be addressed; and the resolution period, when the crisis issue is no longer a concern. Mitroff (1994) characterizes the issue thusly; a period of signal detection, one of probing and prevention, one of damage containment, and one of recovery, followed by one of learning. Coombs (1999) attempts to simplify these ideas suggesting that crisis management is composed of times of prevention, preparation, performance, and then learning. The fact that a variety of authors choose to focus on the timelines of crisis situations suggests their importance to framing crisis problems. These characterizations of crisis situation phasing will be synthesized and used in Chapter III of this work to ground the proposed framework in the time dimension as well as to provide a means to understanding the impact a crisis has, as it initially develops, exists, and fades, on learning phenomena within organizations.

Summary of Literature Review relating to Crisis Management

Reviewing and integrating the work of several authors, the view of crisis environments as those "with potential for significantly more negative organizational outcomes and of a significantly greater level of complexity than organizations are usually prepared for and in turn cause significant internal

organizational stress," lays the foundation for developing a conceptual understanding for the impacts of such environments on organizational learning systems. Similarly such a framework must also capture the various characterizations of the natures of complexity within crisis environment and their impact on an organization. Finally, the emergent and recurrent focus within the literature on the time phases in the life of crisis situations suggests the importance of incorporating such phases into any constructed conceptual framework which has the purpose of providing a means of understanding the impact of crisis on an organization's learning systems. Figure 2.6, Crisis Management Literature Review Summarization, provides a summary of the literature review relating to crisis management.

Figure 2.6 - Crisis Management Literature Review Summarization

Crisis Environment Defined:

Environments and events with potential for significantly more negative organizational outcomes and of a significantly greater level of complexity than organizations are usually prepared for and in turn cause significant internal organizational stress

Dominant Literature Themes Characterizing Crisis Environment

Crisis Typologies

Natural Disasters, Accidents, Terrorism, Criminal Acts, Disruptive Actions (strikes, boycotts, protests). (Nudell and French 1988)

Public Perception, Market Shift, Product Failure, Management Succession, Cash, Relationships, Hostile Takeover, Adverse Int'l events, Regulation/Deregulation (Meyer 1986)

Natural, Technological, Confrontation, Malevolence, Skewed Values, Deception, Management Misconduct.

Characteristics of Crisis Complexity

Magnitude, Urgency, Infrequency/Unpredictability, Credibility Of Info/Resources, Information Demand, Multidimensionality, Context. (National Research Council 1996).

Suddenness, Uncertainty, Time Compression, (Lerbringer 1997).

Dimension, Control, Time options. (Meyers 1986).

Crisis Phases

Preparedness (planning and training), Avoidance, Response, and Recovery. (National Research Council, 1996).

Illness Metaphor: Prodromal, Breakout, Chronic, Resolution Fink (1988).

Signal Detection, Probing And Prevention, Damage Containment, Recovery, Learning. (Mitroff, 1994).

Prevention, Preparation, Performance, And Learning. (Coombs, 99)

The Purpose of Control Centers in Times of Crisis

Control centers in various forms have been the focus of many studies relating to distributed cognition (Johanssen et al 2001, Fields et al 1999, Artman and Garbis 1988), the underlying reason for which is that the primary focus of such centers is to serve as the central nerve-center or "brain" of larger organizational groups, collecting observations from the outside world, interpreting them, and developing responses. Indeed it can be said that the implicit purpose of such control centers is primarily to facilitate an organization's distributed cognition (Artman and Garbis 1988). When one thinks of the existing organizational learning frameworks from the literature discussed thus far one can picture all the functions occurring in the control centers.

This commonality between the working definition of an organizational cognition system and a crisis control center represents an intersection of the two areas of focus in this literature review. Specifically it allows for the, for purposes of this work, definition of a crisis control center as *an organization's centralized establishment for facilitating distributed cognition in the event the organization encounters a crisis environment*.

Having identified one of the two main areas of gaps in the reviewed literature as a lack of a systemic understanding of the impact of crisis conditions on distributed cognition control centers and the other being the lack of use of systems engineering methodologies in constructing distributed cognition frameworks in general, it is important to ensure that the control centers to be studied and to serve as the object of focus for the proposed framework are

indeed functioning in crisis environments. Specifically, as a matter of condition in the proposed definition of a crisis environment it is required that such "environments and events" have "potential for significantly more negative organizational outcomes and...significantly greater level of complexity than organizations are usually prepared for and in turn cause significant internal organizational stress". The question to be answered is "does the posturing of an organization in fielding a control center, sometimes complete with contingency plans, emergency checklists, myriads of communication systems, and other such artifacts constitute being 'prepared for' and thereby eliminate the ability to claim a crisis environment exists?" The answer lies primarily in the word "usually" in the proposed definition. The organization, not the control center, is postured for some sort of daily set of expected occurrences. The fact that organizations take steps to mitigate crisis environments does not mean crises can still not occur in terms of degree of complexity and in terms of the internal stress they may cause. A normal 911 call reporting an individual's heart attack to a city's emergency call center would not constitute a crisis for the city; however a mass casualty event, such as plane crash, would most certainly still qualify as a crisis even though its control center might have a contingency plan for such an event.

Air Force Unit Control Centers

The study of control centers functioning in such crisis environments and the impacts of those environments, relative to ones for which the organizations are usually prepared, on the distributed cognition phenomena within such control

centers are the focus of this work. Air Force Wing Unit Control Centers functioning during simulated wartime operational readiness exercises and inspections meet the requirement of functioning in crisis conditions. The specific cases used validate and adjust the proposed framework will be Air Force Squadron Control Centers participating in operational readiness exercises simulating wartime conditions in preparation for formal Operational Readiness Inspections being conducted by the Air Force's Air Combat Command's Inspector General team.

One of the many internal functions of The United States Air Force's Air Combat Command (ACC), headquartered at Langley Air Force Base, Virginia and comprised of 18 active duty and over 50 reserve component reporting installations located mostly in the continental United States, is that of its Inspector General's (IG) directorate. One of the responsibilities of the IG, and his or her team of about 150 officer and senior enlisted personnel, is to conduct Operational Readiness Inspections (ORI) in order to provide senior ACC leadership with a measure of a subordinate unit's capability to accomplish its wartime mission. ORIs, in their usual form, involve the IG team with augmenting inspectors traveling to the installation to be inspected and conducting round-the-clock, basewide-oriented, scripted scenarios for about eight days. Generally, the first three days of inspection, Phase I of the ORI, focus on the installation's ability to mobilize, or prepare and package, personnel and equipment for expedient travel to a forward location. During Phase II, the remainder of the inspection and the focus of this research, the entire installation is simulated to be at a forward

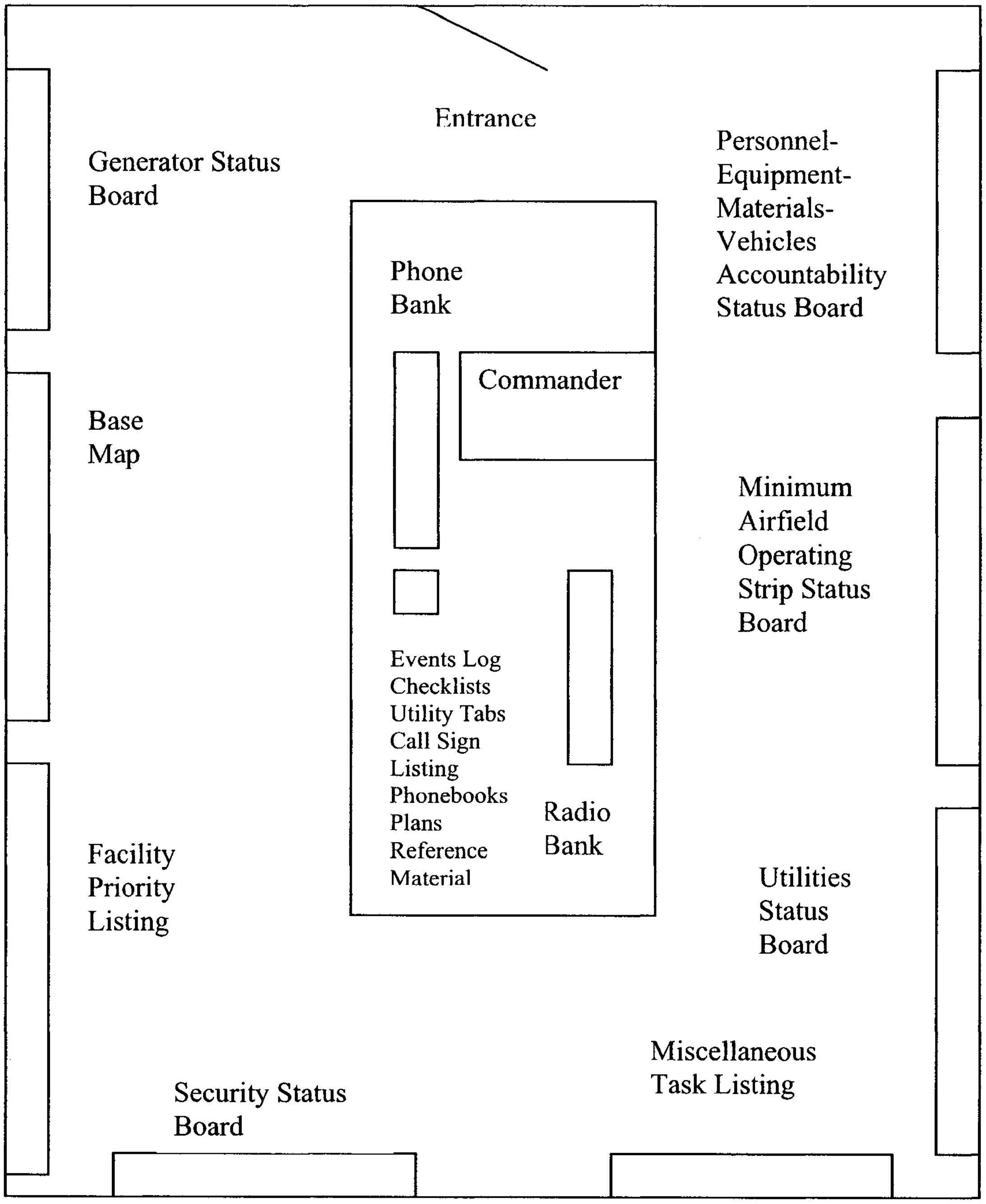
location from which units are conducting offensive and defensive wartime operations.

Over many years a rigorous set of criteria, ACC Supplement 1 to AFI 90-201, *Operational Readiness Inspection Criteria*, has developed and evolved to evaluate the common fighter or bomber wings within ACC (ACC 2002). The Phase II portion of this criteria is broken down into three major graded areas; the Employment and Mission Support criteria evaluate the flying mission, aircraft maintenance, and base functions pretty much along hierarchical organization lines with a few sections of criteria dedicated to evaluating systemic processes such as communication security and command and control; the Ability to Survive and Operate (ATSO) portion of the criteria breaks down and evaluates the emergent behavior of the wing in response to conventional and chemical attacks upon the base, mass casualties, and a variety of other negative occurrences expected to occur during wartime. Falling within the Mission Support portion of this criteria organization is the installation's Civil Engineering function, usually of squadron strength, approximately 100 to 400 personnel and accompanying vehicle, equipment, and material, responsible for maintaining the base's facilities and infrastructure. Civil Engineering squadrons for purposes of readiness exercises and inspections are composed of smaller elements, or flights, responsible for accomplishing engineering design, environmental management of base activities, resource management of materials, and general operations including road, airfield, and earthwork, interior and exterior electrical-systems work, interior and exterior water, gas, and sewage utilities work, carpentry and

structural work, entomological work, contingency generator maintenance and servicing, and heating, ventilation, and air condition systems work. In total Civil Engineering Squadrons are large, complex organizations of diversely skilled experts responsible for maintaining the technologically intensive systems required to support a modern Air Force wing in times of war.

A central portion of the inspection criteria (see Appendix 1) related to evaluating a base's Civil Engineering function in an ORI is dedicated to the Squadron's Control Center (SCC), the central nerve center responsible for processing incoming data relating to facility and infrastructure conditions from all the various units on base, developing an understanding of events, developing solutions and presenting them to Squadron leadership for review and decision making, then relaying and coordinating response actions with field units. The SCC, housed in a fielded control center or contingency headquarters facility type of setting, is composed of personnel representing the various sub-organizational flights within a Civil Engineering Squadron. Typically each of these individuals is accompanied with two or more means of communication with their field counterparts dispersed across the base. SCC layouts themselves involve banks of phones, status boards, and workstations centralized around a single SCC director, the squadron's senior leadership. Figure 2.7, Sample Floor Plan of an AF Unit Control Center, is a typical floor plan for an Engineering SCC.

Figure 2.7: Sample Floor Plan of an AF Unit Control Center



During the ORI, *inputs* in the form of scripted actions performed by actors (inspector personnel or assistants), input cards, or material and equipment placements are *dropped* or enacted at various locations around the base. As units in the field respond to inputs such as chemical agent detection, ground intruder alerts, mortar blasts, fires, craters and building damage, information is channeled to the SCC for repair efforts to be prioritized and responsive strategies decided upon and implemented. For the engineering function of an Air Force Wing, the SCC is the squadron's crisis control center.

ORIs are high-pressure events hopefully mirroring the pressures of wartime. Most wings train anywhere from a year to six months for an ORI, by conducting in-house Operational Readiness *Exercises* (ORE) if they know an impending for ORI is scheduled. Grades for all sections of the criteria are given on a five-point scale (Outstanding, Excellent, Satisfactory, Marginal and Unsatisfactory) and superior performers and teams are specifically identified. Individual, squadron, functional, and overall wing success will almost definitely find its way into personnel appraisals. On occasion, poor performance does result in reassignment of personnel. At the conclusion of the ORI the inspection team, usually composed of 50-100 functional air force experts and led by a team chief with the rank of colonel, will spend two days writing its report, according to a rigorous specified format based on established criteria (ACC 2002). Before departing the installation, the IG team chief will be the primary speaker at a mass briefing to the base populace, usually in the base theater and televised to other large facilities, in which the various sub-section performance assessment ratings

are revealed, via high-tech slideshow with music and action pictures for all to see, and "rolled-up" into the ratings for the major graded areas after which the final overall wing grade is revealed.

Air Force Wing Engineering Squadron Control Centers functioning during operational readiness exercises and inspections exist to facilitate the expedited recovery of continued function of wing facilities and infrastructure. In order to accomplish their mission these centers must by definition facilitate the distributed cognition of a host of players including personnel and subsystems responsible for airfield and navigation systems, back up generator systems, utility systems, squadron security and personnel-equipment-vehicles-materials accountability, tracking of chemical agent exposure, tracking of damage, and facility repair. Making their task even more difficult is the crisis environments in which they are asked to perform: environments full of potential adverse outcomes relating to personnel and system survival, and full of foreseen and unforeseen complexity sometimes exceeding the capability of the centers to fully and adequately process and act within.

Summary of Literature Review

Table 2.1, Summary of Literature Review uses Figure 2.2, Literature Coverage Areas and Gaps, introduced at the beginning of this chapter, as a basis for summarizing the location of gaps in the subject matter of the existing literature that this work is attempting to fill.

Table 2.1: Summary of Literature Review (based on Figure 2.2, Literature Map)

	Coverage Area 1: Distributed Cognition Literature	Coverage Area 2: Crisis Management Literature
Non-Intersecting Subject Matter from Literature Review	- Literature Themes (see Fig 2.3): Learning Loops Functional Breakdowns, Artifacts, Representations - Existing Frameworks (see Fig. 2.4): March (2000), Dhar (2000), Argyris and Schon (1978), Crossan, Lane, and White (1995)	- Anecdotal Summaries and Prescriptive Approaches - Frameworks: Crisis Typologies, Characteristics of Crisis Complexity, Crisis Phases.
Gap 1: Distributed Cognition and Crisis Management	PARTIALLY FILLED - Literature Themes (see Fig 2.3): Specialization, Volume/Complexity, Errors, Contextual Characterizations - Existing Frameworks (See Fig. 2.4): Boyd (2002)	PARTIALLY FILLED - Characterizations describing uncertainty and unknowability
Gap 2: Distributed Cognition Literature Using Systemic Approaches	PARTIALLY FILLED - Existing Frameworks (See Fig. 2.4): Ocasio (2000) and Boyd (2002) to greater extent	No Intersection
Gap 3: Crisis Management Literature Using Systemic Approaches	No Intersection	UNFILLED
Gap 4: Systemically Framing Distributed Cognition Phenomena in Crisis Environments	PARTIALLY FILLED: Existing Frameworks (See Fig. 2.4): Boyd (2002) begins to approach	UNFILLED

The primary purpose of this literature review was threefold in reaching toward the overall goals of this research. First, academic literature relating to distributed cognition and organizational learning was reviewed and synthesized in order to gain perspective on the general definitions, characterizations, and themes relating to these fields of study. Second and similarly, crisis management literature was also reviewed to support the development of an understanding of the topic and to develop specific characterizations of crisis environments and their impact on organizations and their control centers. Finally, Air Force organizational literature relating to the function of fielded

squadron control centers was reviewed to gain an understanding of official, organizational perspectives relating to these organizational entities.

Specifically within the first area of focus, distributed cognition, review of the academic literature relating to the field was accomplished with the interim objectives, along the way to supporting the framework development of Chapter III, of: 1) developing a formalized working definition of organizational cognition, 2) developing a listing and an understanding of the themes within the literature relating to the study of distributed cognition, and 3) understanding existing frameworks others have used to support a comprehensive, holistic understanding of distributed cognition.

Crisis Management literature was summarized to support meeting the interim objectives of: 1) developing an overarching characterization of exactly what constitutes a crisis situation, which in turn lead to 2) developing a further, more specific, listing of detailed characterizations of a crisis situation which will then be used in conjunction with the body of knowledge gained in the area of organization cognition to develop the proposed conceptual framework in Chapter III.

The researcher identifies six main gaps in the literature reviewed thus far. First, addressing Gap 1 in Figure 2.2, in terms of distributed cognition literature little exists on attempting to capture the impacts of a crisis environment on the phenomena. The notion is hinted at in discussion of certain literature themes: 1) specialized expertise being inadequate to the task at hand, 2) volume and complexity and the challenges they place on cognition, 3) sources of errors made

in learning processes and 4) contextual characterization discussed in this chapter which limit cognition. Boyd (Coram, 2002) begins to systemically approach ways to create crises to confound an opponent's learning process. The specific goal of understanding crisis impacts upon distributed cognition phenomena is not the focused objective of the frameworks and themes existing in the literature though. Second, addressing Figure 2.2's Gap 2, within crisis management literature, little is found that focuses on learning in general or distributed cognition specifically. The subject matter is approached obliquely in discussions of unknowability and uncertainty in the environment but not with the specific goal of looking at organizational cognitive processes.

Third, the construction of the existing cognitive frameworks reviewed, seems to be based on the authors' raw synthesis of literature and experience. Boyd (Coram, 2002) and Ocasio (2000) begin to approach a systems view of the phenomena by capturing the interaction of constructs but they don't set out with a systemic methodology in mind to develop their work. Fourth, and as a result Boyd's (Coram, 2002) work also begins to approach a systems view of a crisis environment's impacts on learning, but it remains difficult to actually track the systemic impact of differing crisis characteristics on learning phenomena. Fifth and alternatively, within crisis management literature, the researcher could find no work even reaching the point of capturing interrelationships between constructs to capture crisis impacts on a given set of phenomena. Sixth and finally, the author similarly could find no crisis management literature attempting

to systemically frame the impact of a crisis environment on distributed cognition phenomena.

Separately from this discussion, in order to support the focused efforts on the specific case of fielded UCCs functioning in wartime environments, a summarization of the existing Air Force literature relating to the staffing, equipping, operational functions, assessment, and interaction with units outside, of an SCC was undertaken with the interim objective of developing an understanding of specific characterizations of the cases to be studied.

Not found in depth in this discussion is the researcher's view that a systemic structural view of the subject matter would yield substantial benefit in understanding the phenomena in the setting in question. This notion is developed and addressed in the next chapter.

CHAPTER III

METHODOLOGY

Purpose and Organization of Chapter

The purpose of this chapter is three-fold. First, using a systems approach, a theoretical framework will be developed that will 1) synthesize the information developed in the literature review, 2) describe the systemic structure of distributed cognition occurring in control centers, and 3) capture the effects of changing crisis intensity on the distributed cognition occurring in control centers. Second, the appropriateness and suitability of using exploratory case study methodology to validate a portion of the constructed framework will be discussed in detail: 1) a general critique of case study methods will be presented followed by 2) a discussion of the challenges associated with integrating qualitative and quantitative data gained from case analysis to be followed then by 3) further discussion of the limits of statistical approaches for the given research material and lastly 4) discussion of the challenges for the case researcher who is *close* to the cases being studied. Finally, some discussion is presented to explain why the term "theoretical framework" is used to describe the central product that is presented in this chapter and that is to be validated using the research design in the next chapter. Chapter IV, Research Design, will then follow where the specific design of the case study protocols and database will be made explicit.

Why a Systems Analysis Methodology is Needed

One of the main points of this work is the suggestion that the problem of understanding the impact crisis environments have on control centers is naturally suited to a systems approach. While a systems thinking approach has many strengths, this proposition that the focus of this work is especially suited to it, stems from the idea that the problem has the following four attributes characteristic of those for which systems analysis has a lot of promise: 1) as seen from the literature review the problem is inherently complex, driven by the complexity of the crisis environment as well as the contextual, technological, and specialization demands placed on control center systems: 2) successful distributed cognition necessarily calls for multi-disciplinarity amongst control center participants and sub-systems: 3) the complexity inherent in the problem as well as the diverse views, perspectives, and constructs of both crisis management and distributed cognition cited in the literature view suggest that any proposed theoretical framework addressing the problem must take a holistic approach to ensure all relevant ideas and constructs are captured and accounted for: 4) finally and more specifically, the focus of this work is on capturing the impacts of a changing crisis environment on the phenomena of distributed cognition occurring in control rooms, thus a systemic structural approach is needed to capture interrelationships between the outside environment and subsystem constructs. Checkland (1981) captures the strength of systems thinking in his definition,

> "Systems thinking is an epistemology which when applied to human activity is based upon the four basic ideas: emergence, hierarchy, communication, and control as characteristics of systems. When applied to natural or designed systems the crucial characteristic is the emergent properties of the whole" (p. 318).

The inherent complexity associated with distributed cognition systems cited above and in the literature review coupled with the challenge of understanding the impacts of complex crisis environments on such systems implies that a simplistic, one-track reductionist approach by itself will not work (Flood and Carson, 1993). The approach must be one that looks for emergent properties and constructs arising out of the complexity. Systems analysis methods are based on the understanding that knowability is inherently limited in analyzing complex systems and proceed accordingly to focus on emergent properties (Checkland, 1981).

Another key principle of a systems analysis approach to a problem is one of complementarity. Systems thinking recognizes that multiple perspectives of a problem will provide different knowledge about the problem and this knowledge will not be entirely independent or in congruence (Clemson, 1984). The principle of complementarity applies to this work in two ways: 1) the multiplicity of existing perspectives relating to the topics of distributed cognition and crisis management cited in the literature review and 2) the inherent multiplicity of views that must be synthesized to develop and adjust representations within distributed cognition systems. A theoretical framework attempting to describe such processes must be constructed using a method that takes such complementarities into account.

Closely tied to the first two motivations discussed for using a systems approach in the work is the overarching goal of developing a holistic view of the situation. Systems thinking recognizes that the whole of a system is greater than the sum of its parts. Reductionist approaches must be accompanied by ones accounting for this holism (Flood and Carson, 1991). Keating (2000) suggests that

> "the primary strength of the systemic perspective for structural analysis is the holistic perspective, which examines the entirety of the structure within its operational context. As such a holistic approach examines formal and informal relationships between entities, as well as emerging patterns" (p. 181).

In attempting to capture a description of distributed cognition in control centers in times of crisis an approach that accounts for both the whole of existing knowledge as well as describes the whole of the actual process must be used if the theoretical framework is to have sufficient breadth.

As will be discussed in greater detail in the next section, a key focus of this work is on capturing the effects of a changing crisis environment upon distributed cognition phenomena. Most of the constructed representations of distributed cognition phenomena discussed in the literature review acknowledge the environment in which the system they have bounded exists. Some address the environment as interacting with the distributed cognition system along a single transitional phase. While continuous interaction with subsystems may be implied, not much depth is provided on how such interaction occurs and what its emergent impacts are on the system as a whole. In order to gain this ability a systems analysis method must be chosen which accounts for

understanding the structure of the system in question and the impact of a changing environment upon that structure.

Beer's Viable Systems Model

The focus of this work is on developing a means for understanding the impact of crisis environments on distributed cognition phenomena in control centers. To accomplish this goal with any rigor a means of describing the impacts of environmental influences on the *structure* of the system under study must be achieved. As was previously discussed, the proposed structures analyzed in the literature review do not facilitate tracing environmental changes into the sub-elements or structure of the distributed cognition phenomena occurring in a control center. For example, a simple but sudden increase in the pace of events might represent the onset of or an increase in intensity of a crisis situation that a control center must attempt to manage. With the existing structures discussed in the literature review it is difficult to articulate directly how such an event pace increase will impact the distributed cognition system other than to point out that the system must simply respond faster itself. Systems thinking though suggests that sub-systems making up the whole distributed cognition system may be impacted differently or not in parallel. Subsequent interactions with other subsystems may feedback positively or negatively leading to emergent properties the existing proposed structures might not predict. The level of simplicity of the existing proposed structures does not inform the understanding of the cognitive processes in the system.

An approach that is both focused on the systems structure and facilitates the understanding of outside environmental structural impacts on sub-systems is Beer's (1979, 1984) Viable Systems Model (VSM). Developed by Beer based on an organic perspective of systems as well as the view that such system structure is recursively seen repeatedly at different levels of hierarchy within systems, the VSM is, "…flexible and robust – both prerequisites in fast-changing environments" (Espejo et al, 1996). Keating states that the VSM offers "a comprehensive systems perspective of structure (Keating 2002) and further offers that it can be used as a "template against which operational structures can be 'diagnosed'" (Keating 2000). Espejo et al. cites the VSMs substantial use in companies and non-profit organization as means for understanding organizations (Espejo, 1996).

As Beer's Viable System Model serves is key to the framework central to this research, scholarly criticism of the VSM must be reviewed and discussed in terms of its practical impacts in this context. Addressing such criticism as well as delineating the extent to which Beer's themes are incorporated in the framework follows later in this chapter after the framework is developed.

Beer identifies five basic functional or structural subsystems required if any system is to remain viable. Presented here and in Figure 3.3, The Viable System Model, as developed by Beer (1979, 1984), Espejo (1996), and Keating (2000), these five systems are:

System 1 – *operations:* produces the products or services that are the essence of the operation. The primary function of System 1 is to implement the organization's will as it performs task in the outside environment. A variety of System 1's or autonomous may exist within an organization focused on implementation a particular purposeful, sub-specialty of the organization.

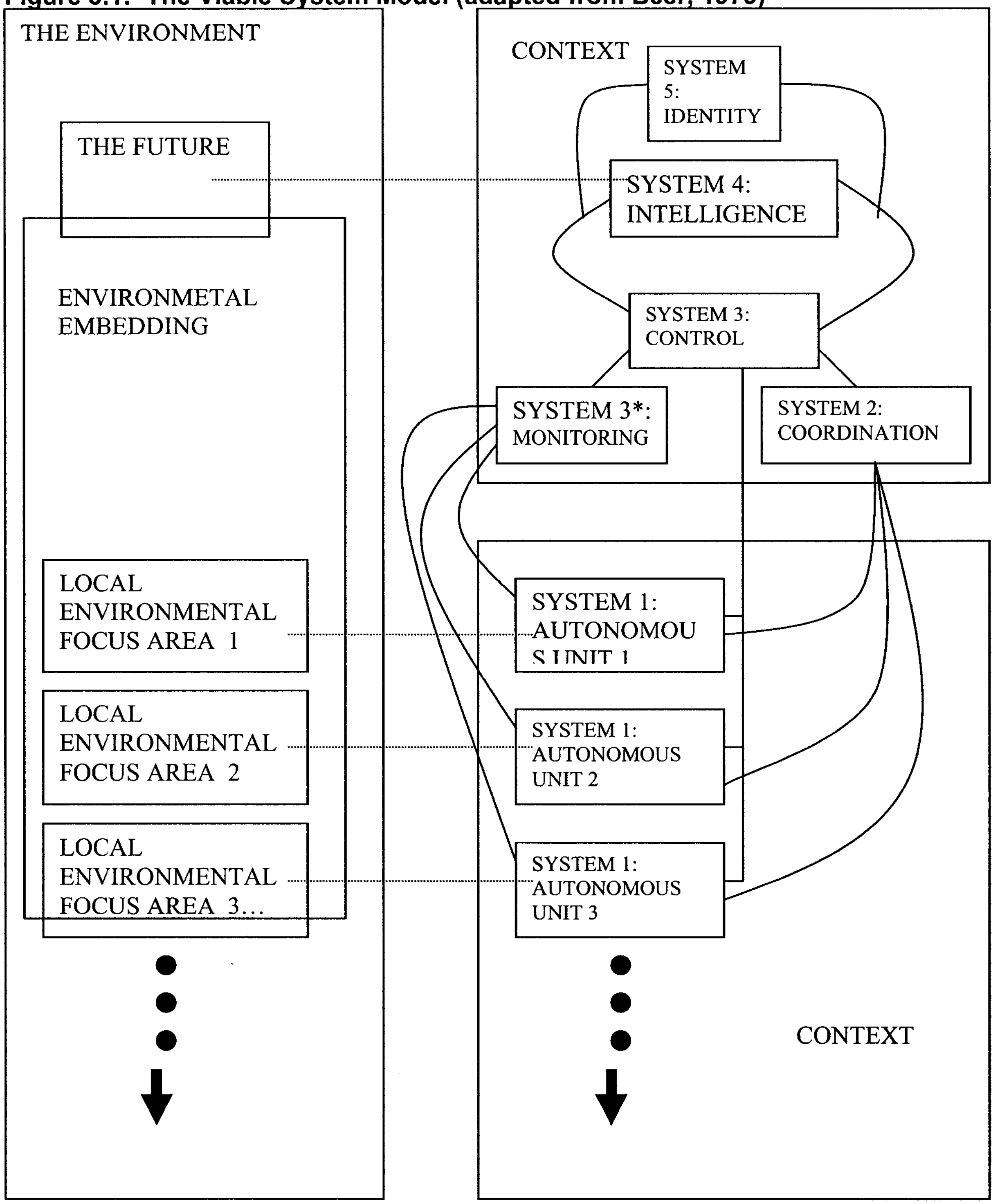
System 2 – *co-ordination*: the primary function of this system is to provide for system stability by synchronizing the System 1's within the organization, preventing unnecessary oscillation between the other systems and promoting integrated responses and actions.

System 3 – *control/monitoring:* maintains operational performance on a daily basis, by focusing internally on executing policy, distributing resources, and ensuring accountability. Beer identifies a separate function of System 3, so-called "System 3*" focused exclusively on monitoring the state of operations by routine or sporadic audits.

System 4 – *intelligence:* the primary function of this system is to capture information about the external environment and assess it's meaning for future implications. A natural tension exists between System's 3 and 4 as they focus on their individual functions and generate demands upon each other.

System 5 – *policy/identity*: this system is responsible for the strategic, broad decisions and direction associated with the very identity of the overall system itself. Also this system monitors and seeks to maintain balance between the inward focus of System 3 and the outward focus of System 4.

Figure 3.1: The Viable System Model (adapted from Beer, 1979)



A Methodology for Implementing VSM

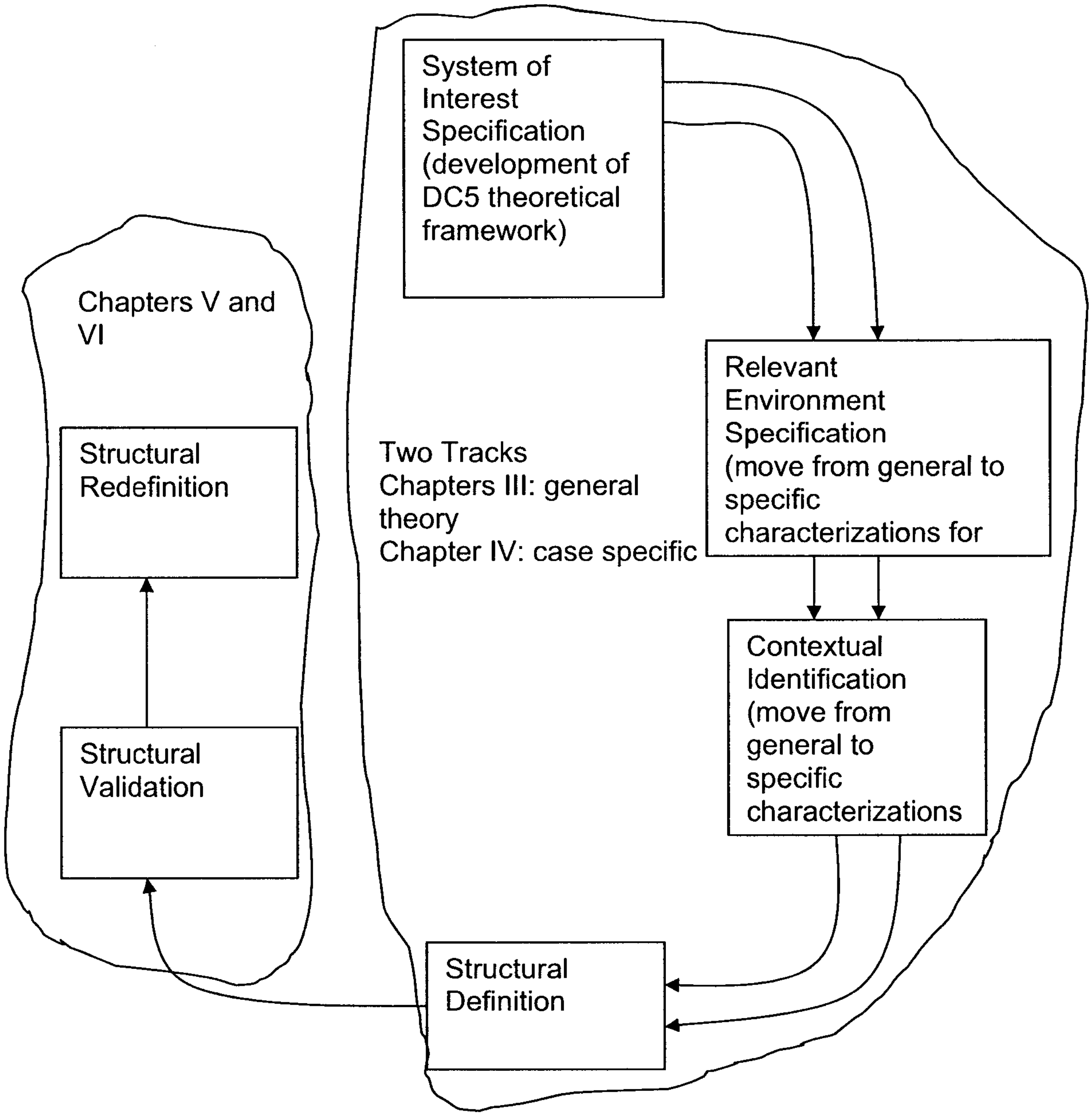
In applying the ideas of the VSM to the initial development of a theoretical framework for understanding the structure of distributed cognition phenomena in control centers operating in crisis environments a systems-based methodology, stemming from Keating's (2002) and Checkland's (1981) approaches was used as is detailed in Figure 3.4, Viable System Model Application Methodology.

First, the actual focus area of this work, the system of interest, as has been described before, must be specified concisely and delineated accordingly. This function serves to bound the area of investigation. Second, the relevant environment must be specified; a key function in this work as the focus is on specific environmental impacts upon the system of interest. This work will be in two steps: 1) a generalized approach to defining a crisis environment in this chapter and 2) a specific delineation of the crisis environments expected to be observed in the selected case studies in Chapter IV. Third, the structure to be studied must operate within a specified context that enables and constrains the structure of the system of interest. In order to rigorously specify this context, again a general approach discussing contextual elements developed in the literature review will be used followed by a detailing of contextual elements specific to the cases to be studied. Fourth, using the knowledge and understanding developed through the specification process above a general and case specific definition of the structure of the system of interest will be

developed. Discussion will also follow of the interrelationships between system structural elements themselves as well as with the outside environment.

Fifth, in later chapters, in order to remain within the scope of this investigation portions of the developed structural definition will be selected for validation by developing protocol for selecting and studying specific cases of control centers functioning within crisis environments. Sixth and finally the understanding gained from the case analysis will be applied, iteratively, to update the theoretical framework as its being developed. The resulting framework can then be used to support future study, analysis, tools, assessment methods, doctrines, and implementation methodologies relating to control centers functioning in crisis environments: the original motivation for this research.

Figure 3.2: Viable System Model Application Methodology



DC5 Development: System of Interest General Specification

In general the system of interest for this research is the system established within an organizational control center to facilitate cognition of the outside environment. As described in Chapters I and II, control centers functioning in dynamic, complex environments necessarily are characterized by diverse, specialized personnel, leadership personnel, technological subsystems, and other artifacts making the cognitive process a distributed one. In terms of providing a general physical bounding, the facility housing the control center could be thought of as serving the purpose. Examples of such control centers include aircraft cockpits, 911 call centers, fire department alarm rooms, military control centers, shipboard navigational control centers, and mobile incident response centers. Given advances in information technology perhaps some organizations would attempt to disperse or to allow dispersal of the personnel and subsystems composing the essential functions of the control center. Considerations of advantages and disadvantages to such setups aside, a topic to be discussed in system contextual specification, the bounding by facility skin becomes less useful in such situations. In these cases it would simply involve those involved in centralizing information flow, constructing organizational representational understanding, decision-making, and action planning. The bounding is presented here in general terms because a central assumption of this work is that the basic concepts involved in describing and framing distributed cognition in control centers is generally universal with analogous constructs in a variety of settings. As such, understanding gained in one setting is assumed, if

contextual and environmental factors are appropriately accounted for, to have external validity or transferability to other settings. A rigorous specification of the settings of the specific cases to be studied will be provided in Chapter IV.

DC5 Development: Crisis Environment Specification

Before proceeding with a general specification of the relevant environment for this research a general reservation should be noted. Keating (2000) suggests that the,

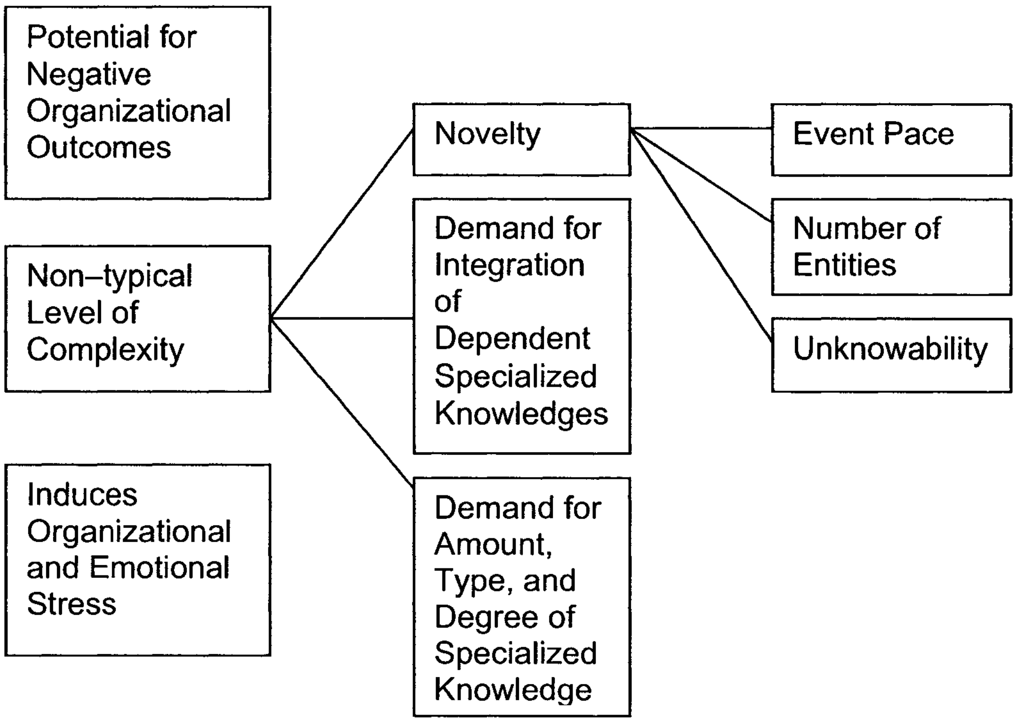
> "linkage between the system structure and environment is in constant flux. Therefore it is unrealistic, particularly where environments are complex and turbulent to assume that the environment will remain stable once identified. Throughout the analysis as new discoveries and understanding of the environment emerge, the environmental 'model' must be constantly updated" (p. 188).

With this in mind the following specification is approached with the understanding 1) that it must capture the complexity and dynamism of the expected crisis environment and 2) that as part of this research effort an iterative process of updating the environmental specification must be undertaken.

As developed in the Literature Review, a crisis environment can be defined those, (a) with potential for significant negative organizational outcomes (note: from a pessimistic perspective, crisis outcomes, even those that may be potentially tremendously positive, can be thought of as negative, a dominant theme in the literature review, because such outcomes represent great opportunities that might be missed, i.e. failing to get a new product to market on time and capturing the subsequent market share and financial windfall) and (b) of

a significantly greater level of complexity than organizations are usually prepared for and as a result of either or both of these elements (c) can cause significant internal organizational stress. In general terms "level of complexity" can be expanded to encompass as Carlisle and Rebentisch (2003) suggest 1) the amount of novelty introduced by the environment into to the control center, 2) the demands of the environment on the control center in terms of the amount of dependence between specialized sources of knowledge required to develop successful responses, and 3) the demands of the environment on the control center in terms of the amount or type of specialization required to successfully respond. This characterization of complexity and its demand on organizational learning entities is reflective of the discussions of specialization, integration, horizon of visibility, and intersubjectivity discussed in the literature review. The novelty side of complexity itself can further be characterized by the sheer number of entities involved, the pace of events, and high degrees of uncertainty (Jackson, 1991; Beer, 1979). Figure 3.3 captures this general specification of the crisis environment. Once a contextual specification of the system of interest and its structural definition is completed, this relevant environment specification can be used to inform a discussion of the impacts of a crisis environment on control center distributed cognition phenomena. As before, a case specific relevant environment specification will be undertaken in the next chapter.

Figure 3.3: General Specification of the Crisis Environment



DC5 Development: Contextual Identification

Contextual identification, perhaps more than the other portions of this methodology, is the most highly setting-dependent factor for consideration. Specific local enabling and constraining contextual factors have the potential to have significant impact positively or negatively on the performance of control centers and their cognition processes. Furthermore the variety of such contextual factors represents a challenge to the transferability of this research to control center settings different than those cases selected for actual analysis in Chapters IV and V. Therefore it is imperative that setting specific contextual factors be made explicit so that they may be taken into account when generalizing about results.

The literature review however, did identify several general characterizations of factors influencing distributed cognition phenomena that would be considered contextual rather than structural. Such emergent properties that can significantly impact control center system performance include staff competence, leadership, intersubjectivity, horizon of information visibility, flexibility, and redundancy. Any investigation into control center performance must take the competence of the personnel and their ability to function as a team into account. As documented in the literature review several authors cite this contextual factor key analyzing control center performance. Somewhat related to staff competence but somewhat lightly addressed within the reviewed literature is the idea of leadership within an organization influencing cognition performance.

Perhaps because it is a highly subjective term and difficult to apply quantitative measure to, and perhaps because it can be included under the overarching heading of staff competence, many authors do not directly cite it as a property influencing performance, but it does seem obvious that good organizational leadership would directly impact performance. Quality of leadership within an organization is a contextual property that must be suspected of having a direct bearing on cognition system performance and as a minimum on some level a subjective characterization must be attempted in order to at least document it as confounding factor impacting other analyses.

A variety of authors discussed the impact of intersubjectivity on system performance by noting how the capability to appreciate another players place within the system resolves errors quickly and distributes assistance quickly, allowing representations to be sharpened and actions to be coordinated (Decortis et al 2000, Vidaillet 2000,). For intersubjectivity to play a role in influencing the propagation of representations through a distributed cognition system, potential sympathetic players must be in a position to know what is occurring to other players. In general terms an investigatory approach into distributed cognition must attempt to capture the level of intersubjectivity at which the sub-systems and players within a control center are operating.

Similarly horizon of visibility is also a defining contextual characteristic of a control center. By making information flow visible to many players with intersubjective understandings of one another, representations can be molded and adjusted quicker and with less iteration. A variety of authors in the literature

review identified horizon of visibility as playing a large role in performance. Intersubjectivity and horizon of visibility correspond directly to the nature of the complexity within a crisis environment discussed in the previous section, in that they directly impact the organization's ability to meet the demands of integrating the knowledge of specialized subsystems in interdependent situations to construct and adjust cognitive representations. A research design must attempt to capture and detail a characterization of these contextual elements in order to understand their impact on control center cognitive performance.

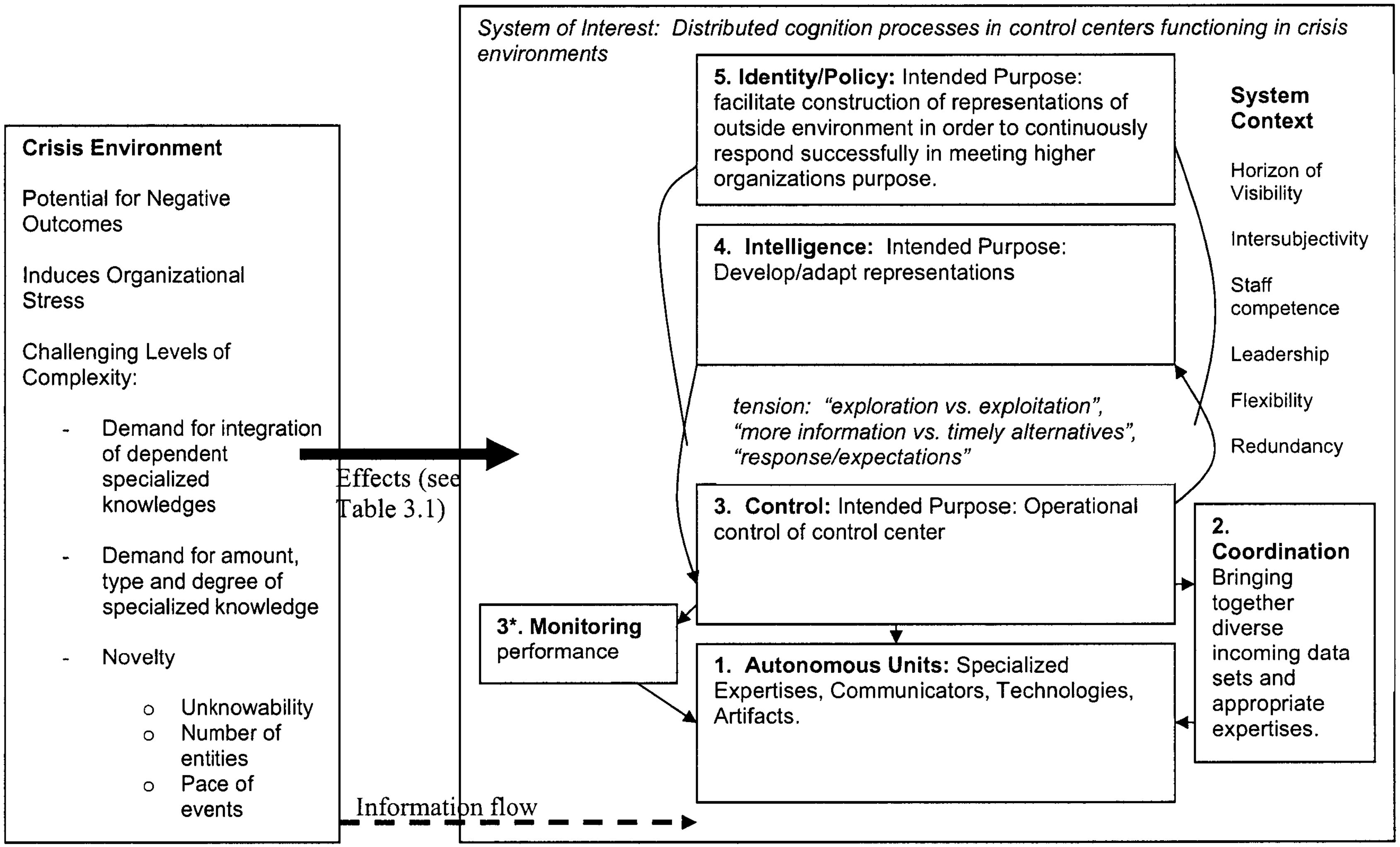
Two additional contextual properties that obviously would be suspected of impacting system performance are redundancy and integratability. Redundancy in communications, information storage, computational ability, visual representations, observations, and in other subsystems is cited by numerous authors as increasing a system's ability to detect errors and calibrate responses (Hutchins 1994, 1996, Decortis et al 2000, Fields et al 1999, Tamuz 2000). Similarly, subsystems must accept, process, and produce representations in such a manner that they can be used and understood by other subsystems and players. Integrateability or flexibility is key if representations are to propagate accurately across subsystems and must be designed into distributed cognition systems (Hutchins 1994, 1996, Fields et al 1999). These characterizations similarly directly impact the ability of control centers to respond to complex environments demanding the integration of specialized knowledge bases to support successful response.

These general contextual characterizations of control center cognition will be integrated directly into the actual structural definition of the process in the following section.

DC5 Development: Structural Definition

The purpose of this portion of the methodology is to use the VSM in conjunction with the knowledge gained in the literature review, to develop a theoretical, conceptual framework of the distributed cognition phenomena occurring within crisis control centers. Again, the major motivations for using the VSM are 1) to provide a more rigorous description of the structure of the phenomena specific to the setting of control centers than present frameworks and 2) to provide a means of identifying relationships between a crisis environment and the developed structural framework. Figure 3.4, DC5 Theoretical Framework, attempts to capture 1) the existing proposed structures discussed in the literature review within a VSM framework, 2) contextual elements influencing distributed cognition processes, and 3) the relationship of environmental complexity to the cognition structure.

Figure 3.4: DC5 Theoretical Framework



Discussion of Internal DC5 Structure

System 1: Autonomous Units

System 1 in the internal structure of the DC5 structure is composed of the individual autonomous sub-systems making up the control center's distributed cognition system. Such systems would include the personnel and systems responsible for receiving inputs from the outside environment and transmitting that information around the control center accordingly, the experts representing a variety of specialized knowledge bases, and sub-system artifacts responsible for storing, retrieving, and presenting data and representation. While each of these units has its own specialized purpose, the general base level functions of observing, storing, presenting, retrieving, and transmitting information as discussed in the literature review occur here (Boyd from Coram, 2002; Argyris and Schon, 1996; Ocasio, 2000; Crossan et al. 1995). The autonomous units are controlled and monitored by System 3 to regulate performance.

System 2: Coordination

System 2 plays a very important role in the DC5 framework. As a key characterization of the crisis environment is the integration of dependent specialized knowledge bases to construct and maintain representations leading to continued successful responses, coordination of such expertises is vital. This function of the system is controlled by System 3 when it instructs specialized subsystems to work together to generate knowledge. Close coordination is key

in these respects to ensure that the entire system does not oscillate back and forth as cycles through the process of learning lead to actions and subsequent reactions based on serial uncoordinated knowledge creation, decision, and action (Carlisle, 2003). Boyd's (in Coram, 2002) constructs of feed forward expectations and implicit guidance represent the systems instruction to its autonomous units of what to expect from a set of actions based on the present representation of the outside environment. On a simplistic level an example of coordination in an aircraft cockpit would be a pilot discussing a loss of power with a first officer monitoring instruments indicating loss of fuel pressure to an engine. Working together they are able to create a picture of the trouble with the aircraft.

System 3: Control and System 3*: Monitoring

The control system within the DC5 framework corresponds to 1) the continuous operational control of the center itself as well as 2) basic single loop (Argyris and Schon, 1996) or experiential learning. The basic control functions of monitoring and auditing subsystem performance are the same as in other systems not specific to distributed cognition; additionally, the control function in this respect takes care of basic planning, equipping, and training as well as implementing actions based on representations, decisions, and policies flowing from the remainder of the system. Crossan's (1995) "institutionalization" of learning is the ground responsibility of the control function. Base level learning, what Argyris and Schon (1996) describe as single loop learning and Dhar (2000) describes as experiential learning are placed here because they generally are

composed of the system acting on a given representation that is not being adjusted or is not perceived to need to be adjusted; the system is reacting based on its internal picture of the outside environment, gaining experience, but not having to adjust its perspective.

System 4: Intelligence

While System 2, Coordination, is responsible for ensuring the right specialized sub-systems are brought together and work in concert to develop and adjust representations, the actual act of creating new knowledge is structural function of Intelligence. This is where observed information, converted from data by autonomous units, is brought together and oriented (Boyd in Coram 2002), compared to existing representations (Argyris and Schon, 1996), interpreted (Dhar, 2000), information converted into knowledge (Ackoff, 1989), and representations selected or enacted (Ocasio, 2000; Weick, 1979).

Similarly expectations of response acts are developed based on constructed representations (Argyris and Schon, 1996). These are compared with information flowing back to the control center after responses have been implemented and representations iteratively adjusted accordingly. The natural tension Beer (1984) describes between the Control system and Intelligence System is reflective of 1) March's (2000) suggested balance a learning system must maintain between exploitation and more exploration and Argyris and Schon's (1996) comparison between observations and expectations. Double loop learning occurs when the tension between these systems reveals a gap in the

implemented responses and the forecasted expectations and subsequently representations are adjusted accordingly.

A couple notes revisiting the process of system of interest specification and definition are necessary here. First, it can be pointed out that the VSM intelligence function of a control center could be thought of from two perspectives. One being the functional act of creating knowledge from incoming information as discussed here and the other being that this functional subsystem represents the collective intelligence of the control center itself as it tries to forecast and plan only for the control center's continuing operations in the outside environment, rather than that of assembling and adjusting representations and plans of action for the outside organization as a whole. The literature on this work implicitly assumes that such a function of creating knowledge and courses of action is part of cognition. Thus for purposes of this work this intelligence function within the DC5 framework will be assumed to cover both functions: 1) the primary job of creating knowledge for actionable response for the outside organization as well as 2) the additional job of focusing on the future job of the distributed cognition system of the control center itself. As will be seen in the discussion of System 5, an analogous issue with specification and definition also exists.

A second issue of fine specification and definition must be discussed with regard to the difference between coordination and intelligence as it applies specifically to a distributed cognition system. As was seen in the literature review a key aspect of *distributed* cognition systems is that they require the integration

of diverse specialized expert knowledge bases in order to create knowledge from the information flowing into the system; i.e. it may easy to blur the actual creation of knowledge across both Systems 2 and 4. For purposes of this work *coordination* will be viewed as the work of bringing the right expert subsystems together at the right time given a set of inflowing data and the actual creation of knowledge or representations once those expert subsystems are together is the act of *intelligence*.

System 5: Identity

The identity of the DC5 system is bound up in its intended purpose to facilitate distributed cognition for the organization. Closely tied to this identity is the overall purpose of the organization (i.e. putting out fires for the fire department alarm room or successfully flying the aircraft for an aircraft cockpit). Some mention here should be made of system thinking with regards to system purpose, which can be thought of as irrelevant to intended purpose. Expressed simply a system's purpose "is what it does" (Beer, 1979); the system can only accomplish what its structure allows it to accomplish; to the extent the structure is inadequate the system for the environment in which it functions the system will not accomplish its intended purpose. System 5 is where the heart of learning takes place when broad strategic decisions (Boyd in Coram, 2002; Argyris and Schon, 1996) based on constructed representations are made. In addition to occurring at the ground level within System 3, Crossan's (1995) institutionalizing of representations begins at this policy level. This function also monitors the

natural tension between Systems 3 and 4 ensuring, providing guidance, and breaking ties between demands for more exploration and more action.

As was discussed with regard to System 4, System 5 also recursive set of perspectives to address. The identity of the distributed cognition system of a control center may be viewed as referring to the identity, policy level, or senior leadership of the outside organization the control center supports as well as the identity of the control center itself. Again, using the dominant paradigm developed in the literature review, this work will take the primary function of System 5 to be the central identity of the outside organization the control center is supporting while recognizing that secondarily it also represents that of the control center itself. As was discussed in the literature review crisis environments tend to directly impact the heart of an organization driving these functions into convergence as crisis intensity increases.

Discussion of Interactions between the Crisis Environment and the Internal DC5 Framework

The purpose of using the VSM to capture the structure of distributed cognition processes in control centers was to be able to identify and systemically understand how various characteristics of a crisis environment structurally impact those processes. Table 3.1 and the following discussion detail the interrelationships identified in the DC5 framework.

Table 3.1: Crisis Environment Effects on DC5 Subsystem Performance

	S1. Autonomous Units	S2. Coordination	S3. Control	S3*. Monitoring	S4. Intelligence	S5. Identity	Context
Real Crisis Pressure (Potential for adverse organization outcomes + inducement of stress)	- System self-doubt might increase - Sensitivities to stimulus increased -Focus changes	- Differences amplified - Acquiesce to consensus - May not seek consensus	- Pressure S1 to provide more information and S2 to process more information - Increase demands on S4 for implementable solution	- Must determine if S1's are handling pressure appropriately	- Demand more information to get representation right	- Seek more confidence in representation before selecting alternatives - Selection/ decision/action goes to the organization core so balance is less routine	- Increase focus/ pressure may cause HOV to be ignored - Increase pressure on individual systems may cause loss of IS with other systems - Staff competence directly impacted - Leadership directly impacted
Complexity: Demand For High Levels Of Specialized Expertise	- Ability to correctly inquire about data increasingly challenged	- Possible increased demand between systems	- Must ascertain when S1 has become overwhelmed	- Must ascertain when S1 is no longer up to environmental demands	- Ability to interpret data increasingly challenged	- Required to ad-just decision making approach based on known lack of knowledge	- Staff competence up to the task - Leadership increasing S1 performance
Complexity: Demand for Integrated Expertise	- Ability to correctly inquire about data increasingly challenged	- Challenged with knowing who needs to be involved in processing information	- Must ensure coordination is functional	- Must ascertain if S2 is no longer capable of meeting requirements	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- HOV and IS crucial - SC and Leadership also important
Complexity-Novelty Unknow-ability	- Ability to correctly inquire about data increasingly challenged		- Can recognize when more data collection is fruitless		- Can recognize when more data collection is fruitless	- Required to adjust decision making approach based on known lack of knowledge	
Complexity-Novelty-Number of entities	- Ability to track and process data challenged because of volume	- Ability to coordinate/assimilate data challenged because of volume	- Can recognize when systems becoming overwhelmed	- Must ascertain if S1's and S2 up to task/ replaceable	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- Flexibility key - Redundancy may prevent processing errors
Complexity-Novelty Pace of events	- Ability to receive and process data challenged	- Ability to process data challenged	- Increase demand for a timely plan of action	- Must ascertain if S1's and S2 up to task/ replaceable	- Ability to interpret data increasingly challenged	- Senses need to act quickly	- Redundancy may prevent processing errors

General System Wide Impact of Crisis Pressure

Two of the three portions of the crisis environment definition developed in the literature review have system wide effects on the framework, impacting every one of the structural subsystems in the framework, impacting the identity of the system, and impacting the general context in which the overall system operates. In order for an environment to fulfill the definition developed in the literature review for a crisis, it must have potential for negative organizational outcomes. As human beings in the organization become aware of this potential, stress is induced as the gravity of the situation begins to weigh on the actions of those personnel. This organizational stress can lead to poor performance as task focus is distracted by thoughts of the negative outcomes.

Because crises have the potential for significant negative organizational consequences they strike at the heart, System 5, of any organizational system. For distributed cognition systems this can occur in three ways: the overarching strategies the system employs to facilitate the construction of representations and responses come under more pressure, the pressure to successfully manage the tension between Systems 3 and 4 is increased, and the actual decisions themselves also come under greater pressure. First, in order to comprehend the outside environment distributed systems are constructed to receive information and construct meaning. The methods used to accomplish this task represent strategic deployments of assets and capabilities for distributed cognition systems. The responsibility for successfully adapting these strategies over time to a dynamic crisis environment weighs heavier because of that environment

itself. Second, as the negativity of potential outcomes of a crisis rises, it is expected that System 3 will demand increasingly more accurate and timely updates of representations, expectations, and alternatives for implementation from System 4. Similarly, System 4 will demand that System 3 generate more data and information from the autonomous units. This tension can be expected to grow as the pressure of a crisis environment rises on the human beings functioning in such systems; System 5 bears the responsibility of managing this tension and balancing the need for more understanding with the need for timely, implementable, actionable alternatives. Third and finally, the nature of the actual decision-making-the decisions themselves carry more weight in terms of organizational outcomes.

As was discussed above, the pressure of a crisis situation impacts the tension between Systems 3 and 4, but it also strikes at the specific internal functions of all the DC5 subsystems. System 4 has the responsibility to generate and maintain representations that become increasingly crucial to the future viability of the organization and the DC5 system itself. System 3 has the responsibility of generating accurate and precise data and information on the outside environment so that System 4 can fulfill its function. System 3 also must ensure information is transmitted around the control room, presented, stored, and retrieved successfully. The impact of errors in these functions is heightened by the pressure of the crisis situation. System 3 also bears the responsibility for monitoring the performance of the human beings and sub-systems functioning in the crisis situation and deciding when action must be taken if performance does

not meet standards. System 1, autonomous units, namely functional specialized expert human beings, will fill the pressure of the crisis as they bear the individual responsibility for applying their expertise to get data and information and provide initial alternatives. Because an inherent aspect of crisis complexity may involve the need for coordinated interpretation of information, System 2 will also bear the weight of bringing the right subsystems together to generate understanding; crisis pressure will impact system accordingly.

Because it strikes at the functional responsibilities of all DC5 subsystems, crisis pressure may be thought of as being inherently contextual. Additionally, however, the pressure of a crisis environment impacts some of the general contextual characterizations developed in the literature review. Staff competence and leadership play a key role in responding to the pressure of a crisis situation. The difference in level of performance between inexperienced, poorly trained, less competent, or poorly led personnel and their opposites can be expected to increase as the pressure of a crisis environment is increased. Error and failure rates can be expected to rise accordingly. System artifacts being used by such personnel to facilitate the control centers distributed cognition processes will become less useful as the personnel begin to fail.

The potential for negative outcomes and the awareness of that potential raise the pressure on the human beings making up a DC5 system. As such all subsystems of the DC5 system, the heart of the DC5 system, and some contextual characterizations of the DC5 system are impacted.

The General System Wide Impact of Crisis Complexity

Similar to the potential for negative outcomes and in a general way, complexity can also raise the pressure on all DC5 subsystems. The knowledge that the relevant environment is complex, difficult, hard to predict, or unknowable stresses the human beings involved in attempting to understand it. As such the pressure for performance on all DC5 subsystems is raised. Complexity when broken down as in the literature review also has specific impacts on various individual DC5 subsystems and contextual characterizations.

The Specific Challenges of Complexity for the DC5 Framework: Integrating Specialized Knowledge Bases

Complex environments may demand the integration of more than one or perhaps several diverse specialized expert knowledge bases in order for actionable, accurate representations to be constructed by a distributed cognition system (Carlisle, 2003). This aspect of complexity impacts the subsystems of the DC5 framework in specific ways: coordination, System 2, becomes the key in developing an understanding of the environment and as actual understanding is pursued by coordinated work, intelligence, System 4 is impacted as meaningful representations are successfully or unsuccessfully formed. Complex environments may require diverse expertises to be both understood and successfully acted within. As such it becomes imperative that the right personnel, subsystems, and artifacts are brought together to develop representations and actionable alternatives. The intuition to look at initial information and make and educated guess about what knowledge is necessary

to apply to the information to create understanding is a function of System 4, intelligence. Maintaining the specialized knowledge bases and the systems required to bring them together to create understanding is the province of System 3. Once knowledge is created by coordinated expert systems, System 4 is fulfilling its intended system purpose.

In addition, to the DC5 subsystems impacted by the demands for integration of specialized knowledge bases, contextual characterizations of the control center play a key role in responding to such demands. The extent of the horizon of visibility within a distributed condition system and the degree of intersubjectivity amongst personnel and subsystems play a key role in constraining or enabling the diverse coordination of specialized knowledge bases. If the information flowing in, through, and out of a control center has a high degree of visibility to personnel and subsystems within the center, then the likelihood of timely coordination of knowledge assets is increased. The ability to monitor the chatter of other players doing their functional jobs, status boards and maps, slide presentations, read files and reports, and access to databases are examples of such visibility enablers. To the extent they are used and monitored they increase the likelihood of successful coordination. If personnel within a control center operate in hushed tones, are stationed so they do not look at each other or interact, do not access stored data, or have it easily presented then the coordinating ability is inherently constrained. Similarly, intersubjectivity is a key contextual enabler or constrainer in coordinating knowledge bases. To the extent that personnel within a control center are familiar with each other, have

practiced their functions together as a team with little turnover and know enough of each other's function and knowledge base to empathize with their portion of the organizational mission then the likelihood of successful coordination is enabled. If control centers are assembled with players who have not worked together before and have little knowledge or appreciation for each other's specialty area then the likelihood of successful coordination is constrained.

The Specific Challenges of Complexity for the DC5 Framework: The Specialized Knowledge Bases Themselves

A crisis environment may challenge a distributed cognition system by demanding a degree, amount, or type of specialized knowledge base to which the existing system would be challenged to meet internally (Carlisle, 2003). As such autonomous units, System 1, would be pushed near or perhaps beyond their abilities to derive meaning from inflowing information. In such cases the purposeful learning, as defined by Rulke and Zaheer (2000) accomplished prior to crisis by the autonomous specialized expert becomes of lesser value and relational learning, that is knowing where information can be obtained becomes more important. The knowledge base of the specialized expert autonomous unit must be conceived to encompass such relational knowledge. As will be discussed in a later section, pace of events may significantly inhibit the ability to retrieve knowledge outside of expertise housed within the control center.

System 3 is also impacted by this potential characteristic of crisis complexity as it holds the responsibility for staffing personnel and maintaining systems housing such knowledge. A crisis environment can quickly exceed the

ability of System 3 to perform these functions. Additionally System 4 is impacted because the ability to create representations is inhibited by the constraints of the lack of expertise of the autonomous units. Finally in terms of contextual interrelationships, staff competence captures the degree of ability of the autonomous units to do their job. Crisis demands for specialized knowledge impact distributed cognition systems directly and simply because they demand, or can create requirements for, knowledge that does not exist within the distributed cognition system or is beyond the ability of the system to provide.

The Specific Challenges of Complexity for the DC5 Framework: Novelty

Carlisle (2003) develops three aspects of the *novelty* of complexity, separate from the two aspects of complexity and their relationships to the DC5 structure already discussed, which challenge organizational learning: the unknowability of complex environments, the number of entities involved in complex environments, and the pace of events. These aspects are novel in that they represent changes from the norm for which the organization is postured. To some extent the organizations DC5 systems can be postured for increased degrees of novelty in these areas but these too can be exceeded.

Distinct from the sheer requirement for a greater extent of specialized knowledge than a DC5 system can provide, is the *unknowability* of a complex environment. Unknowability refers to the idea that the environment may simply be unpredictable or even if the relational knowledge sourced could be reached in a timely manner to raise knowledge levels, the effort would still be fruitless. As

such, unknowability impacts the autonomous specialized expert within a distributed cognition system because he may be rendered helpless to develop representations and work with others. Coordination is limited to the extent unknowable aspects of a problem cannot be used to help augment knowable aspects into actionable representations, thus Intelligence, System 4's ability to create representations, is impacted. In unpredictable environments System 4 is unable to provide System 3 with alternatives or future expectations. System 5 must posture itself for the fact that such environments do exist and seek to develop strategies of action, and representation construction that allow the unknowable portions of problems to be isolated so that action alternatives can be developed leveraging the knowable portion of the environment and hedging the unknowable portion.

The contextual descriptors that interplay with unknowability are the flexibility of the subsystems within the distributed cognition system and the staff competence and leadership of the personnel in the control center. To the extent that the subsystems and personnel composing a control center can handle new, unforeseen environments, deal with the fact that portions of the problem will be unknowable, and isolate them accordingly, then cognitive performance can still be increased in the face of the tremendous challenges of unknowable complexity.

Autonomous specialized expert units individually or in coordination with each other may have it within their knowledge base to construct an actionable representation of an environment and generate alternative response; however,

the sheer number of entities or scale of the problem may exceed their ability to process the information and produce required products. The scale of incoming information may lead to errors in the basic control functions of receiving, transmitting, storing, retrieving, tracking, and presenting information. As autonomous units become overwhelmed in the deluge of information the ability to monitor all their actions and performance may also be impaired. Contextually, the horizon of visibility subsystems have on the information flow through the control system may become cluttered with the abundance of information. Also in a contextual sense, redundant systems for tracking, storing, and retrieving information may serve to help catch and reduce errors caused by the scale of inflowing information.

In a similar way to the scale of complexity in terms of the number of entities that must be understood in order to develop accurate actionable representations, the pace of events can also overwhelm the subsystems of the DC5 framework. Autonomous units, coordination of those units, control of operations, and the ability to generate representations rising from these foundations may well be within the capability of a distributed cognition system in developing an understanding of a single event. If, however, the pace of events begins to increase, autonomous units can be overwhelmed, availability for coordinated work will not be timely and system stability will be compromised, representations will not be timely, and System 3 will be demanding better understanding and forecasts and not getting them, raising the tension between

System 3 and System 4. System 5 will be forced to impose strategic limits to what they system can adequately handle and performance will be degraded.

Contextually, staff competence, leadership, horizon of visibility and intersubjectivity can all be harnessed to enable faster processing of inflowing information. Additionally, redundant systems can reduce errors or mitigate their impact.

Criticism of Viable System Model and Its Use in this Context

As Beer's Viable System Model serves is key to the framework central to this research, scholarly criticism of the VSM must be reviewed and discussed in terms of its practical impacts in this context. The criticism reviewed by the researcher seems to coalesce around three main themes: 1) a supposed, hierarchical rigidity implicit to the VSM, 2) a supposed implicit assumption in the VSM of unity of effort, particularly in the area of information flows, amongst the individuals bounded within a system of interest, and 3) it is difficult for some practitioners to understand and apply. These topic areas will be discussed first, in terms of the substance of the criticism, and second, in terms of the practical implication it has on this research context. Additionally, some of Beer's consistent themes present in his development of the VSM are less prevalent in use in this work; this lack of complete intersection must also be delineated. Specifically, these themes include, 4) Beer's focus on recursion as central to his perception of systemic functional structure, and 5) Beer's description of environmental interaction with system structure. These themes will be presented

and complemented with a discussion of how they are subsumed within in the DC5 framework.

The first major theme of criticism of the VSM noted by the researcher is the notion that model implies a hierarchy amongst its functional components, i.e. the autonomous sub-units, S1, are controlled by S3, led by S4 by being provided with intelligence and environmental expectations, and in turn S3 and S4 and the tension between the two are managed by S5 the identity of the organization most likely embodied by its senior leadership (Jackson, 1986; McEwan, 2001). As a result, some organizations, that may exist without any explicit or implicit hierarchy established, may prove difficult for applying VSM to as a tool (Andersson, 1998).

Beer's response to such criticism would be two fold. Superficially, Beer would argue that over the longer-term time all systems develop some form of hierarchy driven by the need for concentration of responsibility (Beer, 1984). More deeply though, this criticism may represent a misunderstanding in applying the VSM to an organization as practitioners may simply try to fit VSM functional components to hierarchical organizational charts. This is not Beer's intention (Beer, 1984; Espejo, 1996; Keating 2002). Beer would point out that over the long term organizations develop an identity and institute policies to govern their actions. They also necessarily must control and coordinate their processes in order to exist or be viable in the outside environment. Any individual or sub-grouping in an organization may serve as an autonomous unit, a controlling unit, a coordinating unit, may develop environmental intelligence, a my draft or implement policy. The key is in understanding that the VSM is a structural

breakdown of the functions of a system, not necessarily a guide for organizing a particular system.

For purposes of this work the criticism does not apply on the superficial basis because the system being observed has been established, it has matured, and it exists within the hierarchical context of a military control room; i.e. the system of interest is hierarchical in nature so such critics could not argue that the VSM would not be applicable. On the deeper level, in developing and applying a framework for observing, describing, and critiquing control center performance it is understood such actions must be interpreted on functional system basis and not necessarily on a charted organizational basis.

The second major noted area of criticism stems from the notion that because the VSM is derived from set theory and intended to specify the functional structure of any system occurring in nature, biological, machine, organizational, etc. that it implicitly assumes that all functional sub-elements work in unity toward system goals (Checkland, 1980; McEwan, 2001). As a result, the fact that individuals may act in their own self-interest, disrupting processes and information flows, rather than in the interests of the system, is difficult to contemplate using VSM constructs. Beer would argue that his 'S3' control function implicitly acknowledges incorrect sub-element action outside of system interest and works to counter it and would further counter that even within biological systems, sub-structures require regulation; tired muscles screaming for rest are still used to accomplish an athlete's goals and cancerous cells may be attacked by immunity systems. Implicit in Beer's Viable System Model is the

coercive power of systems over sub-elements to act with system interests in mind. In the crisis control center setting being researched in this work, the example of stressed personnel acting to relieve their own stress rather than focusing on mission requirements springs readily to mind. This criticism provides a deeper understanding for the VSM practitioner who must understand the idea of diverse motivations, account for them, identify them, and attempt to explain them through the control systems of the VSM. Any framework and methodology built on VSM must be cognizant of such potential.

The third major area of criticism of the VSM reviewed in the literature focuses on its difficult nature to comprehend and understand. Such critics point out that Beer's use of set theory, cybernetics language, and systems knowledge make it difficult to understand and apply (Checkland, 1980, 1981; Andersson, 1998; Malik, 2002; Keating 2002). One must first understand systemic ideas of recursiveness, minimum critical specification, variety, requisite variety, and holism, homeostasis, and complexity to understand VSM and, as discussed above, the practitioner must be careful to avoid the pitfall of overlaying the VSM onto the organizational chart.

In the researcher's view this is a valid criticism of the VSM. For the immediate purposes of this work it does not present a problem, as the researcher is thoroughly familiar with both Beer's work and its critics. For longer term however if the proposed DC5 framework is to serve as a basis for developing organizational wide approaches to assessment and design then individuals in

those organizations will need to be educated accordingly. Without such knowledge the benefits of using DC5 would be limited.

Beer (1984) points out that in addition to considering interactions between the system in focus and the exterior environment, the VSM practitioner should also consider that viable systems are inherently recursive; that is, they reside within larger viable systems and are composed of smaller viable systems. Beer suggests that the practitioner must consider and comprehend the setting of the viable system of interest by understanding where it resides within, at least, one level of recursion greater than itself and one level of recursion less than itself, in other words, the viable systems of which it is composed. In the case of the system of interest of this work, the Air Force control center, this viable system resides within the larger Air Force unit being observed, an Air Force Wing survival recovery center functioning within the larger context of the entire Wing. The survival recovery center primarily exists to control the defensive, ground-response operations of the wing and to lesser extent to facilitate coordination between outside wing functions, to monitor performance of those functions, and in some cases to house and express the identity of the wing as contained in its senior leadership. Similarly, going down one layer of recursion, the center is composed of the individual humans staffing the center, each his or her own viable system interacting with the same environment. Also the center is composed of sets of individuals and artifacts serving functional purposes, for example the processing of casualties by communications systems, medical systems, and personnel systems. In term of distributed cognition, the cognitive

functions of each of these bounded systems, the Air Force Wing, the human individuals in the control center, and the sub-functions of the control center are also recursively in play processing incoming information and being impacted by crisis elements at their own respective levels. This recursion described here is not made explicit in the diagrams and tables specifying the DC5 development that follows, as they are limited to the system level of interest, but the researcher tacitly acknowledges there existence.

Beer (1984) also develops the connections between the outside environment and the operational, non-management structure of a viable system. Specifically, he highlights the fact, that viable systems are structured for the *management of complexity* within an external environment. Beers measure of such complexity is the systems concept of variety. Systems deal with the level of variety in their environments by managing it in relation to their own internal capability's limits to manage variety. If they do not have the *requisite variety* internally to interpret data streams flowing from the environment they are forced to *attenuate* the inflowing information into something more manageable. If the inflowing information they are being provided is not specific enough for an acceptable level of regulated response then viable systems attempt to amplify the existing variety and obtain greater detail. In the development that follows the DC5 tacitly captures these notions by characterizing the level of complexity in the crisis environment. In terms of information that must be processed and turned into usable knowledge through distributed cognition such ideas are captured by characterizing the crisis environment by its pace of events, scale of events,

unknowability, demand for high degrees of specialized expertise, and demand for high degrees of integrated expertise. This research is limited by its attempt to broadly conceptualize and frame distributed cognition phenomena as a whole; further study into the specifics by which control centers amplify and attenuate incoming information, based upon this work, could be promising for future research.

Finally Table 3.2, Incorporation of Viable System Model Themes, is a listing of these and other themes from Beer's Viable System Model as condensed from his *Diagnosing the System for Organizations* (1984) coupled with a description of the extent to which the particular theme is reflected in the DC5 framework just developed. The Table is reflective of the detail in the Viable System Model as well as the initial broad generalness of the DC5 framework. Future research could build upon this work to further refine and deepen the DC5 framework.

Table 3.2: Incorporation of Viable System Model Themes

Viable System Model Theme (as presented by Beer, 1984)	**Status of Incorporation In DC5 Framework**
Recursion	Captured in discussion above one level of recursion above and below the system of interest: the control center. Not made explicit in DC5 figures and Tables.
Self Reference	Implicitly captured in discussion of system wide impacts of general crisis pressure and stress. Not explicitly used in DC5 figures and Tables.
Homeostasis- internal system stability	Implicitly captured in describing the internal tension between S4 (DC5 System Intelligence) and S3 (DC5 System Control). Not explicitly used in DC5 figures and Tables.
Invariance	Not used/referenced in DC5 Framework.
Environment, Requisite Variety, Attenuation, and Amplification	Captured in discussion above. Tacitly recognized in characterizing complexity in the crisis environment. Not directly used in DC5 Figures and Tables.
Channel Capacity	Implicitly captured in discussion of horizon of visibility, and characterization of complexity.
Transducer	Not used/referenced in DC5 Framework.
Oscillation	Captured in discussion of DC5 Framework System 2
Comparator	Not used/referenced in DC5 framework
Feedback	Captured throughout discussion of DC5 framework
Convergence	Not captured as defined/developed by Beer in the DC5 framework
Autonomous Subsystems	Captured in the S1 systems of the DC5 framework
Algedonic Responses	Captured in discussion of DC5 framework above
Coordination Subsystems	Captured in the S2 systems of the DC5 framework
Metasystems	Captured in discussion of recursion above
Control Subsystems	Captured in the S3 systems of the DC5 framework
Monitoring/Audit Subsystems	Captured in the S3* systems of the DC5 framework
Cohesion	Implicitly captured in discussion of recursion above and in discussion of general crisis pressure/stress in the DC5 framework
Intelligence	Captured in the S4 systems of the DC5 framework
Identity	Captured in the S5 systems of the DC5 framework

In Summary: Usefulness of the DC5 Theoretical Framework: Understanding Capability and Performance

The DC5 framework will be useful because it synthesizes the constructs of other authors covered in the literature review capturing the structure of a distributed cognition system, the structure provides a means to trace the impacts of crisis environments to their effects on distributed cognition systems, it captures contextual enablers and constraints inherent in any control room, and most importantly it provides a systemic means of theoretically framing the problem. If the validity of the framework can be established through study of distributed cognition in actual real-world control centers functioning in crisis environments, then the framework can serve as a foundational doctrine that (1) could aid in the implementation of new strategies, designs, methodologies, and technologies in crisis control centers for complex, technically oriented organizations, (2) could improve the systemic design of and confidence in the assessment of mechanisms and subsystems designed to facilitate distributed cognition within organizations, (3) could improve the general understanding of how distributed cognition takes place within organizational control centers, and (4) could lead to a better understanding of the systemic effects crisis conditions have on the structures within control centers designed to facilitate distributed cognition. Additionally, (5) the framework could also be transferable to distributed cognition systems, other than those of control centers, functioning in crisis environments.

In order to validate the framework it is proposed that a control center described in the literature review be analyzed in context as it functions in a crisis environment, a formal air force exercise or inspection, using exploratory case

study techniques. In order to fit within the scope of this work, the research design and validation effort will focus on an open case study exploration of a control center functioning in three of a specific Air Force Wing's operational readiness exercises as it prepares specifically for a formal outside operational readiness inspection. During the initial exercise the focus of the case study will be on using the developed DC5 framework 1) to generally understand the distributed cognition phenomena occurring in a control center to see if does indeed provide a useable basis for framing issues and 2) to develop a *distributed cognition system fitness assessment.* This assessment will be a detailed descriptive characterization of the strengths and weaknesses of the control center's distributed cognition using the DC5 framework. One of the challenges facing an Air Force Wing preparing itself for a formal operational readiness inspection is to develop scripted scenarios within its preparatory operational readiness exercises that will prepare the various wing organizations to perform at a high level during the inspection. The usefulness and validity of the DC5 framework could be shown if the assessment method described above could then in turn be used to develop specific crisis environments within scripted scenarios designed to suitably stress a control center's distributed cognition system in order to train the individuals and involved subsystems for better performance. The focus of two remaining AF Wing operational readiness exercises will be just that; the deployment of scripted scenarios based on the initial fitness assessment designed to stress and subsequently train the system and improve system performance.

The analogy of a college freshman athlete and a track coach helps explain this second approach which also informs a greater understanding of the framework itself. The coach will typically run his or her new athlete through a battery of tests or trial runs to gain an initial measure or characterization of various attributes of the runner. In the world of track athletes, such attributes may include useable oxygen intake, the ability to process and dispose of lactic acid in the athlete's muscles, the athlete's heart rate, the athlete's stride characteristics, and the athlete's body structure and composition. The coach's job is then to design and implement a training regime to suitably stress these various areas so that improvements can be gained. Certain types of running, training approaches, and even diets induce certain physiological improvements. A key constraint on coaches is that there is only so much time or mileage that runner can actually accomplish before injury or burn out. Thus the coach must optimize the training regimen for a specific upcoming race or track meet. The athlete's performance is a reflection of the coach's training regimen and even the underlying theory used to design it.

Stepping aside from the coach and athlete analogy to put this concept in more rigorous academic terms, the DC5 framework could be used by an observer to characterize a given crisis scenario as it impacts a distributed cognition system. Let [CE], full of descriptions and characterization of the various aspects of the scenario based on the crisis environment specification detailed in the DC5 framework represent the framework's formal capture of a given scenario. Let (DC5F), full of descriptions and characterizations of the

various structural subsystems detailed in the DC5 framework represent the framework's formal capture of the capability or fitness level of a given control center .

The DC5 framework implies that given specific knowledge about a crisis environment and given specific knowledge about a distributed cognition system's fitness [DC5F], predictions can be made as to the systems performance, i.e.

[P] = [CE][DC5F]

If a measure of system performance, [P] can be gained objectively as possible, then an initial measure or characterization of DC5 fitness can be obtained, i.e.

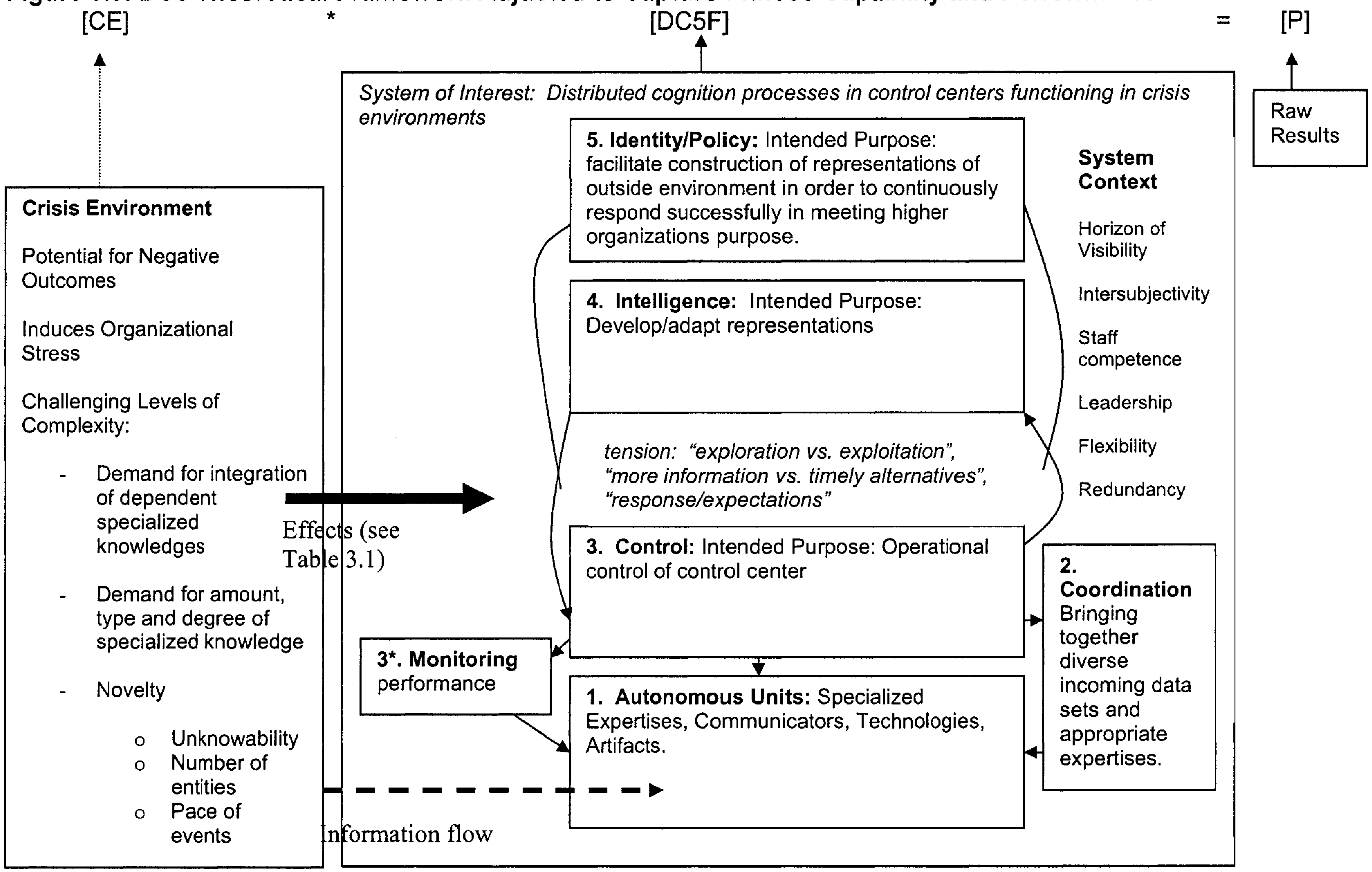
[P]/[CE] = [DC5F]

This initial assessment can the in turn be used to design scenarios, i.e. [CE]'s, to further train the distributed cognition system for other crisis environments it will face.

Returning to the real world, the challenge, to assert that the DC5 framework is useful and has validity, then becomes one of finding a suitable means of measuring, capturing, describing, or characterizing system performance or [P]. Returning to the analogy of the track athlete this performance is captured in a raw form in his or her elapsed time in an event.

The corresponding raw measure of a control center's performance is the rating assigned by evaluating expert judges using long-established criteria. This further discussion and development of this research approach further informs the development of the DC5 framework. Figure 3.5, DC5 Theoretical Framework Adjusted to Capture Fitness Capability and Performance, captures this further refinement of the framework.

Figure 3.5: DC5 Theoretical Framework Adjusted to Capture Fitness Capability and Performance



Second, addressing the idea of the uncertainty principle – that is measuring or assessing any system necessarily also alters the system to some degree; for example, control center systems or members may change their approach if they know they are being measured for such purposes. Also using a crisis scenario as an initial means to capture [DC5F] necessarily trains the system itself, positively or negatively for subsequent scenarios. Third, a training regime is constrained by the amount of scenarios a control center can suitably work through given the constraints of an individual operational readiness exercise itself as well as the limited number or scheduling of exercises a wing may conduct before a formal inspection. Fourth, the idealistic, mathematical conception of,

[P] = [CE][DC5F]

described above and the analogy of the objective measures a track coach may use, i.e. timed events, heart rate, lung capacity, are not realizeable in the complex world of characterizing environments, distributed cognition system fitness, and performance. Thus the researcher is inherently limited to qualitatively attempting to reach such characterizations or assessments. As such qualitative techniques, specifically those of the case study are best suited to such efforts.

The first three of these challenges will be addressed in Chapter IV, research design. The fourth, using qualitative, exploratory, case study

techniques is central to the soundness of this research thus a formal review of such methodologies is undertaken next.

Case Study Research

Due to the initial development of the DC5 theoretical framework in the preceding section as well as its specific focus on both control centers and crisis environments, any investigation into its validity is necessarily initial and exploratory. Yin (1994) suggests case study methodologies are ideally suited for such problems. Before proceeding with the development of an actual case study research design, the actual capabilities and weaknesses of such an approach must be weighed. To inform the process of the actual case study research design to follow in Chapter IV, first a general critique of such methodologies is undertaken; second, because case data is expected to be both quantitative and qualitative in nature the inherent challenges in using differing means of measurement is discussed; third, the limitations of sample space on using inferential statistics in the proposed research design are discussed; and fourth, potential criticisms associated with researcher closeness to cases researched, a potential are of bias for this research, are discussed.

A Critique of Case Study Research

Within the study of organizational behavior, case study is just one of many general methods for accomplishing research. Surveys, histories, grounded theory, simulation, and controlled experimentation are other approaches. When

selecting a general approach as a research basis for subsequent development into a methodology, researchers 1) must determine which approach is best suited to the subject matter being investigated and 2) must develop a thorough, sophisticated, scholarly understanding of that approach in order to ensure the soundness of the research. The goal of this section is to present just such a scholarly critique of case study research which can then eventually be used to 1) defend its selection as a research approach for certain topics as well as to 2) establish it as a basis for developing a specific detailed, methodological research design.

To meet this goal, (1) the philosophical and "canons of science" underpinnings of case study research are presented followed by a (2) description of the types of research inquiries it is best suited too as well as those to which it is not. This description is then amplified by (3) pointing out the important distinctions between case study research and other research designs accompanied by a (4) detailing of the strengths weaknesses, assumptions, and limitations of case study research. (5) The scholarly criticisms most prevalent in literature and most likely to be encountered by case study researchers are then detailed. (6) These criticisms are then traced into four goals relating to the nature of validity and reliability specific to case study design and strategies and safeguards for addressing these design goals are discussed.

The Philosophical and Scientific Foundations for Case Study Research

The variety of methodologies available to the researcher focusing on a particular topic or set of research questions can be divided into two primary categorizations: quantitative approaches and qualitative approaches (Creswell, 1994; Yin, 2003). The dichotomy that exists between these typologies is driven by the underlying paradigm or operational worldview of the researcher with regard to his or her topic (Patton, 1991; Creswell, 1994). These paradigms spring from general philosophical perspectives the researcher holds of the topic area that can be characterized by the basic ontological, epistemological, and methodological assumptions made by the researcher (Guba, 1990). As a basis for critiquing case study research, generally a qualitative approach to research although it may also contain quantitative elements, its ontological and epistemological underpinnings should be contrasted with those of strictly quantitative approaches. Additionally, the methodological means by which case study research approaches and addresses accepted canons of scientific inquiry must also be understood.

Ontology is concerned with the question of what is the nature of what exists (Guba, 1990; Patton, 1991; Potter, 1996). The quantitative approaches dominant in the natural sciences assume that the fundamental reality of the world consists of physical objects and processes that exist independent of the observer. Also referred to as positivism, this view when applied to the study of human behavior holds that social facts exist in an "objective reality apart from the beliefs of individual persons" (Patton, 1991, pp 390); natural and human processes and outcomes can be reduced and traced to physical, causal

antecedents in a Newtonian fashion. Alternatively, qualitative approaches rest on the ontological view that the world exists within the mental conceptions of individuals and groups (Patton, 1991; Potter, 1996; Bonoma, 1985). This assumption focuses the qualitative researcher on determining what is that people believe and the constructs they apply in their world.

Epistemology is concerned with the question of how do we know what is that we know or how do we arrive at conclusions about our world (Guba, 1990; Patton, 1991; Potter, 1996). For those with a positivistic view of the world, quantitative research approaches ensure that the researcher maintains objectivity and does not interfere with that which is being studied. Theories are developed and compared to observable facts, which are assumed to exist independently, and scientific knowledge is created. Epistemologically, qualitative approaches assume a constructionist view of nature in which meaning is developed by viewing what is "presented and...worked by [the observer] into a re-presentation" (Baldano, 1955 as quoted in Patton, 1991). As a result qualitative researchers select and develop methodologies suited 1) to describing the processes and constructs people use to create meaning in their world as well as 2) to allowing the researchers to actively interpret the world for themselves.

A few caveats and comments are in order on these philosophical underpinnings of the research methodology selection and development process. First, the importance to the researcher of understanding the ontological and epistemological bases of paradigms is that it ensures logical consistency is maintained throughout their work and places logical limits on the conclusions that

can be postulated (Guba, 1990). Case study researchers must acknowledge the subjectivity of the work and the fact that it is limited to the interpretations and mental representations of the humans involved in the research. They must develop their methodologies accordingly to ensure that such limits are acknowledged and addressed. Second, these paradigms of the world are presented here as dichotomously for purpose of explanation. In reality a spectrum of worldviews exists between the two extremes (Potter, 1996; Guba 1990). The case study researcher finds himself more on the relativistic and constructionist side of these philosophical continuums, but acknowledges the need to minimize subjectivity springing from the more positivistic assumptions.

Third, what drives case study researchers to the paradigm of qualitative research are assumptions about human behavior. Where natural scientists may view nature as separate and reducible and can maintain objectivity, social scientists assume that humans are inherently complex; their actions and thoughts are describable but not mechanistically reducible to basic physical laws and causes; their actions can only be understood through the lenses of other humans (Hofstede, Neuijen, Ohayv, and Sanders, 1990). Thus, qualitative methods may be more suited to developing an understanding of certain human behavioral phenomena.

In order for qualitative research, in general, to be methodologically sound it must ensure that the basic canons of scientific investigation are addressed. The traditional canons of science include the concepts of significance, theory-observation compatibility, generalizability, consistency, reproducibility, precision,

and verification (Strauss and Corbin, 1990; Lincoln and Guba, 1985; Douglas, 2004). Significance and theory observation compatibility are applicable to all kinds of research; the research must not merely restate what is obvious to everyone and what is proposed as theory must correlate to what is observed (Weick, 1974).

The remaining canons listed above have become operationalized within the natural sciences into the terms internal validity, external validity, reliability, and objectivity. Because these traditional terms evolved from the positivist view, Lincoln and Guba (1985) have suggested analogous constructs, expounded upon by others (Douglas, 2004; Marshall and Rossman, 1995), specifically to guide qualitative research. 1) Analogous to internal validity, the validity of inferences about the relationship of dependent variables to independent variables, is credibility, the accurate inferring of relationships within the collected case data. 2) Analogous to external validity, the generalizability of the research propositions to other settings and contexts, is transferability, the applicability of the research to similar contexts; Stake (1978) refers to the similar concept of natural generalization and Patton (1991) uses the term extrapolation. Because the qualitative researcher's paradigm of human behavior is not positivistic, it assumes context to be of significant importance in developing an understanding of human behavior, thus the generalizability to other contexts sought after in the natural science is implicitly limited for social science researchers (Yin, 2003; Douglas, 2004). 3) Analogous to reliability, the assurance that if done in the same way and manner multiple repetitions will lead to the same results, is

dependability, the taking into account and detailing of the dynamic conditions inherent to each human situation under study. 4) Lastly, analogous to objectivity, the researcher's goal to remain separate and not influence what is being studied, is confirmability, the idea that another researcher reviewing his data would agree that it was arrived at as proposed. Because the qualitative researcher frontally acknowledges his own human limitations in interacting with his subject matter, objectivity, in the positivist sense is not realizable. Rather, the method such a researcher uses to collect data through interaction if adequately described should be auditable by others.

Because assumptions about human behavior drive a qualitative researcher to a different philosophical paradigm than a natural scientist to his research interest, the methodologies each chooses to accomplish their research must be inherently different. Logical consistency lies at the base of sound research; a thorough understanding of the ontological and epistemological bases for a methodology allows a researcher to understand the advantages and limitations of that methodology and develop logical conclusions. The differing worldviews of the qualitative and quantitative researcher lead them to different understandings of the canons of science. These understandings must be made explicit in order to know the capabilities and limits of the methodology they support. Lastly, 1) more specific discussion of case study research, 2) the nature of its relation to the traditional scientific canon constructs of reliability and validity and 3) techniques for addressing them, will follow later in this critique. First,

though, is a more descriptive characterization of which research questions are suited to case study research.

Appropriate and Inappropriate Research Questions for the Case Study Design

Yin (2003) takes issue with a common view (Isaac and Michael, 1981; Shavelston and Townes, 2002) within social science circles, that case study research is most suited to initial exploratory inquiry into a subject area when little is known about a given behavioral phenomena. This common view supposes that as research into a subject area matures into a descriptive phase, that surveys or histories, become more appropriate, and further investigation into explanatory or causal inquiry is best suited to controlled experimentation. Yin (2003, p 3) questions this hierarchical view of preferred research strategies by citing several famous examples of case studies that were explanatory or descriptive in nature and also points that controlled experiments are readily adaptable to exploratory inquiry. He alternatively argues for a more pluralistic view of research strategy selection based on three other conditions: 1) the type of research question being posed, 2) the extent of control an investigator has over actual events, and 3) the degree of focus on contemporary events.

Research inquiries focused on answering “what” in terms of what may be initially learned about a subject area are indeed asking the exploratory questions that some consider case study research ideally suited for. Whereas questions regarding what outcomes might have occurred as a result of something else may be best suited to surveys or archival research. Similarly questions of “who”,

"where", and "when" in terms of observed outcomes are more suited to experimentation or surveys. If, however, these same questions desire to know "how" or "why" such outcomes occurred then explanation is being sought and a variety of methods may be best suited.

The remaining two of Yin's conditions, extent of control and *contemporariness* of events, further guide the researcher in considering case studies in these instances. If little control exists over the context within which the phenomena is being studied, boundaries between the two are not evident, and events are happening concurrently as they are being studied, then case studies become much more suitable. If the events have already occurred and participants are unavailable then histories are preferred. If some element of control exists and contextual variables can be separated then field or laboratory experimentation is better.

Mintzberg (1979) suggests that the best way to know how a manager spends their time is simply to sit down and talk with them and observe them over time. He cites several examples from literature that managers are poor estimators of time allocation and surveys may be impacted as a result. Douglas (2004, p64) similarly suggests that concerns regarding "complexity, context, opaqueness, interdependencies, time frames…necessitates applying research methods that elucidate interpretive understanding." If these issues can be eliminated then the researcher has other means available, but the "case study method allows investigators to retain the holistic and meaningful characteristics of real life events" (Yin, 2003). The lack of control the researcher has on these

real life events and the fact that they may be occurring concurrently with the research is what suits them to case study research.

Assumptions, Limitations, Strengths and Weaknesses of Case Study Research Designs

The inherent assumptions, limitations, strengths, and weaknesses of case study research can be categorized into the three main theme groups: those relating to the researcher himself, those related to the researcher's perspective of the subject matter, and those related to the data being collected by the case study researcher. Before discussing these in detail a note is in order; practical weaknesses will be presented in this section while more general weaknesses frequently cited in scholarly literature will be discussed in a later section.

Inductive analysis, personal contact and insight, design flexibility, and empathetic neutrality are all general themes relating to qualitative research (Patton 1990) that play particular roles in characterizing case study research because they relate to the researcher himself. Inherent in these themes are the ontological and epistemological assumptions the researcher has about the topic being studied. Further assumptions involved in case study research relate to researcher himself. The case study researcher assumes that he has the skills and knowledge to conduct case research, a frequent mistake according to Yin (1981, 2003) and Mintzberg (1979). The extent of the case study researcher's competency enhances and limits the quality of the research. Case study allows good researchers to bring their familiarity with the case to bear (Yin 2003, Mintzberg, 1979; Eisenhardt 1989). It permits them to conduct inductive

reasoning, allowing them to explore in search of patterns and causes in open analysis; observations can be generalized to underlying causes by the researcher's own expertise as well as the effort he or she puts into soliciting the expertise of those involved in the case (Patton, 1990; Whitt, 1991). Methodologies, case selection, and research focus can adapt and change as the researcher uncovers previously unidentified trails of inquiry (Eisenhardt, 1989; Dyer and Wilkins).

Similarly, case study research is inherently limited by the researcher's qualities. The biases and influences on the case of the researcher inherently limit the quality of the case study (Yin, 2003; Poplin, 1987) if not accounted for and designed for properly (Yin, 2003). The open-endedness of case study research, cited as an advantage above, also can prove a difficulty as there may no "clear-cut rules on how to proceed" (Patton, 1980, p 389) and the researcher is required to use his own judgment and intuition. Yin (2003) cites length of documentation as a frequent and valid complaint about case study research as leads may have to be followed endlessly and accounted for in detail. Poor interviewing, note taking, and data collecting skill also directly limit case study quality (Yin, 2003; Eisenhardt, 1989).

Patton's (1990) general themes of naturalistic inquiry, holistic perspective, case uniqueness, and context sensitivity also relate to the basic ontological assumptions and epistemological assumptions the researcher has about his topic areas. Because the nature of topics may be complex, highly dependent upon and highly inseparable from context, it is assumed that quantitative methods may

not capture these complexities. Case study research does not require the isolation of the laboratory (Mintzberg, 1979). It allows organizations and people to be studied concurrently with ongoing events (Yin, 2003; Patton, 1990). Because case study research can provide thorough documentation of context it provides for generalizability to underlying theory (Eisenhardt, 1990).

The context dependency and uniqueness of individual cases also results in a lack of generalizability frequently complained about (Isaac and Michael, 1981) and provided by other methods. As stated above the richness of detail provided by case studies (Dyer and Wilkins, 1989) also may lead to difficulty with time and length research constraints.

Finally, the theme of qualitative data (Patton, 1990) itself characterizes case study research. As previously stated richness of data has both advantages in terms of capturing context and disadvantages, length and time commitment. The researcher assumes that he can capture data wholly and interpret it accurately to support the soundness of the research. Case studies, in particular, allow for the collection of a variety of data types (Yin, 2003, Dyer and Wilkins, 1989) and allow them to be used together to triangulate and reach conclusions. Yin (2003) also points to the strength of case studies in holistically capturing context in data noting that the method is suited to situations where many more variables exist than data points. Because case data may be highly qualitative or categorical it is not amenable to the objectivity and verifiability of traditional quantitative methods (Kerlinger 1986).

The purpose of this section was to present the practical limitations, strengths, and weaknesses that flow inherently from case study methods and their underlying assumptions. A more thorough discussion of some of the frequent scholarly criticisms and more general weaknesses of case study research will follow but first is a description of what distinguishes case study research from other approaches.

Distinctions from Other Research Designs

Case study research differs from traditional quantitative methods in terms of its overall goal, its assumptions about researcher interaction, and the differing aspects of breadth each form sees as ideal. Case study also differs from other qualitative methods in its focus on contemporaneous research and again on research purpose.

Quantitative methods attempt to bring explanation to observed phenomena by measuring it relative to controllable variables. Case study researchers are interested in developing an understanding of behavior by observing it, capturing and understanding the perspectives of others, and developing their own perspectives (Yin, 2003). Experimenters seek to remove themselves as much as possible from the subject matter under inquiry, so they can claim with confidence that they themselves did not influence the outcomes or supply their own interpretations. Case study researchers believe that the best way of achieving an understanding of human behavior is to get up close with the actual humans; case study researchers accept the limitations associated with

their interaction as a cost of developing such an understanding (Patton, 1990; Lincoln and Guba, 1985). Quantitative researchers seek breadth in terms of sampling logic; if they focus only on specific variables, isolate them, and sample them across a variety of contexts, logically then they can generalize their findings broadly. Case study researchers are focused on issues that may involve many dependent and independent variables, which may not be isolatable from interacting with each other or from surrounding context. As a result, case researchers seek depth within limited cases in order to develop rich understandings of issues and generalize their data to theory. They acknowledge the lack of generalizability to other contexts and strive instead after replicability by thoroughly documenting their efforts.

As Yin (2003) points out, case study distinguishes itself from other qualitative methods in that it can focus on events as they unfold. Histories gain their data from archival research or begin to overlap with case study methods when they focus on more recent or current events. Case study differs from social experimentation and field trials in acknowledging its subject matter's uncontrollability and not attempting to establish such control. Finally, case study differs from ethnography, the goal of which is primarily description, in that it assumes more explanatory value can be created. To the extent case studies seek to be solely descriptive or ethnographies begin to search for causal links the forms begin to overlap (Yin, 2003).

Scholarly Criticisms of Case Study Research Designs

The distinctions of case study from other designs, particularly from traditional quantitative approaches, frequently give rise to a set of scholarly criticisms of the method. These criticisms can generally be grouped into two broad categories: those concerned with the generalizability of scientific research and those concerned with the rigor of scientific research.

Scholars generally complain that case studies are too narrow in focus and therefore not useful or significant (Patton, 1990). They argue that case study results and findings cannot be applied or reproduced in other cases (Shavelson and Townes, 2002) or in other contexts (Isaac and Michael, 1981; Mintzberg, 1979). These criticisms are valid and to the extent case study researchers attempt to promote their achievement in terms of sampling rigor much deserved. The case study researcher must acknowledge this as an inherent limitation of his work. Case study researchers respond to such arguments by questioning whether anything can be learned at all from their study of complex, human, highly contextually dependent cases and answer yes (Mintzberg, 1979; Eisenhardt, 1989; Dyer and Wilkins, 1989; Patton, 1990) citing the many advantages of case study. They point out that generalizability while important is not at the core of explanatory scientific inquiry, but the process of developing and refuting "plausible-rival-hypotheses" is (Campbell in Yin, 2003 p. ix; Poplin, 1987). As has been previously discussed, to address these valid criticisms some (Lincoln and Guba, 1985; Yin 2003) have sought to redefine the traditional scientific canon of generalizability by stressing replication logic as an alternative construct or by pointing out that generalizability to theory by adding weight to accepted

propositions is still possible. These concepts as they are operationalized into case study design will be discussed in greater depth in a later section. In final summary though, the generalizability a quantitative researcher gains through sampling rigor cannot be matched by case study methods.

Remaining scholarly criticism of case studies seems to fall into the category of discomfort with the lack of scientific rigor assumed to be inherent in the method. Quantitative variables, on some scale whether it be categorical, ordinal, rational, can be assigned numeric value removing subjectivity by opening up the statistical tool box (Kerlinger, 1986). Qualitative constructs do not have this advantage, although even quantitative methods of coding and measure imply some level of subjectivity too. Scholars point out that the removal of numerical methods opens the research up to the bias of the researcher; divergent data sets can easily be twisted, perhaps subconsciously, by the researcher (Whitt, 1991) to fit preconceptions. The required judgment of the researcher for case study cannot but introduce subjectivity into the process (Yin, 2003; Stake, 1978). The response given by case researchers to these criticisms of lack of rigor is that while these concerns do have merit and must be acknowledged, their downsides can be mitigated by effective case research design.

Case Study Research Design Strategies and Safeguards

As was previously discussed, some of the traditional canons of science have been operationalized within quantitative research into objectivity, internal validity, external validity, and reliability. Additionally, as has been discussed,

qualitative researchers have proposed analogous alternatives to these terms specifically to guide their specific efforts (Lincoln and Guba, 1985; Strauss and Corbin, 1990). This focus on definition has led to specific design goals for those developing case study methodologies. These goals in turn have led to specific strategies and safeguards that should be incorporated into case study designs to ensure such objectives are met. Table 1, Validity and Reliability in Case Studies, synthesizes the work of Lincoln and Guba (1987) and Yin (2003) in detailing these goals and the respective tactics a researcher may employ to meet them.

Table 3.3: Validity and Reliability in Case Studies (Lincoln and Guba 1985, Yin 2003)

Traditional Research Goal	**Qualitative Research Goal**	**Case Study Design Tactics**
Construct Validity (also referred to as objectivity)	Confirmability	- Detail Researcher Background - Detail Access Requirements - Triangulate - Establish Chain of Evidence - Informant Review
Internal Validity	Credibility	- Pattern Matching - Explanation Building - Address Rival Explanations - Use Logic Models - Multiple Reviewers
External Validity	Transferability	- Generalize to Theory - Seek Replication
Reliability	Dependability	- Develop and Use Case Protocol - Develop and Maintain Case Database

Construct validity refers to the idea that the quantitative researcher should attempt to be objective with regard to the variables in question (Lincoln and Guba, 1985; Yin, 2003; Voss, Tsikriktsis, and Frolich, 2002). The means by which he measures variables should be as accurate and precise as possible. Scholarly criticism with regard to case studies stresses the bias, subjectivity, and weaknesses of the human researcher. Case study researchers acknowledge this as a potential pitfall and attempt to mitigate its effects by 1) thoroughly detailing the background, demographic and experiential, of the researcher so that the audience can assess his potential biases as well as familiarity with case issues, 2) thoroughly detailing the means by which access to case data sources was gained, again for the purpose of allowing reviewers to assess potential biases 3) triangulating data and conclusions by seeking confirmation from multiple sources of evidence within the case, 4) establishing a chain of evidence that a reviewer can follow to determine what support a given finding had, and 5) having the actual informants review the descriptions and conclusions of the researcher (Yin, 2003; Eisenhardt ,1989; Patton, 1990; Creswell, 1994, Marshall and Rossman, 1995). These steps allow the researcher to provide the audience with a means of confirming the work's findings and conclusions.

Internal validity is the notion that the quantitative researcher should be separate from the variables being studied in order that his interaction does not create unintended effects. Additionally, the variables should be isolated from their surrounding context and their interactions with other variable minimized so that the logic supporting inferences regarding interrelationships is not misguided.

Scholarly criticism of case studied points to the interaction of the researcher with the subject matter and the inability to remove context from the situation. Case study researchers acknowledge the potential weakness and try to address it by 1) identifying recurring patterns within cases to trace causality, 2) using their expertise and that of their informants to build explanations for observations, 3) identifying, detailing, and addressing rival explanations for observations, 4) using logic models or attempting to fit collected data to proposed rival cause-event chains (Yin 2003, Patton 1990) and 5) using multiple reviewers or case analysts to confirm each others work and conclusions. These efforts allow the researcher to ensure his findings are credibly based on the data collected.

External validity is the notion within quantitative research methods that the research is significant because it is generalizable to a broad set of contexts outside that of the existing study. As previously discussed, towards this criticism, case studies do not have a valid answer. Case study researchers must acknowledge that sampling logic is outside of their grasp given the contextual depth of their work on small numbers of cases. Rather it has been proposed that case study findings can be generalized to existing theory (Yin 2003; Eisenhardt, 1989). Additional case studies may allow for replication of the findings to add weight to theoretical propositions (Yin, 2003). The findings of the case study should be transferable to other similar contexts.

Finally, reliability refers to the notion within traditional quantitative research that experiments may be followed and repeated and results should be reproducible. Again because of the dependence of case studies on contextual

depth they're inherently limited in their ability to be reproduced in other settings. This too is acknowledged by the case study researcher who offers in return the ability to audit his results by developing and using a rigorous case protocol and maintaining a case database so that other researchers can agree that had they done the research the same findings would have been reached (Yin, 2003; Eisenhardt, 1989). In this sense the case study becomes dependable from an academic research point of view (Lincoln and Guba, 1987).

The traditional scholarly criticisms of case study research flow from the operationalized notions of the traditional canons of good scientific inquiry. With one exception, case study researchers can acknowledge these criticisms and attempt to address these concerns through a variety of strategies and establish rigor in their designs. Generalizability outside of case context to broader samples is not a feature of case study research; however, for inquiries into context-rich, contemporary, real-world environments involving humans and highly interactive variable sets, case study may be the method most suited to the problem.

Critique Conclusion

The goal of this section was to present a scholarly critique of case study research which can then eventually be used to defend its selection as a research approach for certain topics as well as to establish it as a basis for developing a specific detailed, methodological research design. Understanding the philosophical underpinnings of case study research, its basis in the canons of science, its inherent strengths and weaknesses, what distinguishes it from other

research methods, and its means for addressing the frequent scholarly criticisms it encounters, allows the case study researcher to develop his design from an informed perspective and helps to ensure the soundness of his research.

Integrating Qualitative and Quantitative Data in Case Study Research

One of the advantages of case study research is that it allows the researcher to use both quantitative and qualitative measures to assemble data (Yin, 1981, 2003; Eisenhardt, 1989). This characteristic open-endedness of the method enables the corroboration of observations and findings and thus supports construct validity (Yin, 2003; Eisenhardt, 1989; Patton, 1990; Creswell, 1994, Marshall and Rossman, 1995; Sieber, 1973). Yet integrating qualitative and quantitative measures also brings a set of challenges to the data analysis effort. The purpose of this section is to detail the data analysis implications associated with using different scales of measurement and to describe methods available to the researcher to address these challenges.

<u>Implications of Integrating Quantitative and Qualitative Methods</u>

Mintzberg capture's the motivation of the researcher who decides to mix both qualitative and quantitative methods in his research design:

> "Theory building seems to require rich description, the richness that comes from anecdote. We uncover all kinds of relationships in our "hard" data, but it is only through the use of this "soft" data that we are able to explain them, and explanation is, of course, the purpose of research" (1979, p 587).

Rossman and Wilson (1985) present three primary reasons for endeavoring to capture both types of data: corroboration, elaboration, and initiation. Corroboration refers to the triangulation of findings by relying on more than one method. Elaboration focuses on establishing greater depth to findings developed primarily from another data set. Using another form of data also prompts initiation, which allows the researcher to develop new explanations for observations or to counter existing explanations adding rigor and comprehensiveness to the research. Similarly, in their review of 57 mixed-method research designs, Greene, Caracelli, and Graham (1989) distilled five major purposes behind mixing qualitative and quantitative analysis: 1) triangulation, 2) complementarity, analogous to elaboration, 3) development, the iterative use of one design after another to develop and test theory, 4) initiation, and 5) expansion, seeking to extend the breadth and range of existing inquiry. Hofstede, Neuijen, Ohayv, and Sanders (1990) used in depth interviews to "get a qualitative feel for the gestalt of [an organization's] culture," then used that information to follow with successive phases of surveys to continue developing and demonstrating their conclusions.

The additional validity gained by using both qualitative and quantitative data within a research design enhances the completeness and soundness of the research; however, incorporating both types of data comes with challenges to the researcher also. These challenges include 1) the fact that research approaches are driven by different philosophical underpinnings or paradigms (Creswell, 1994; Rossman and Wilson, 1985) 2) the practical constraints of time, funds, and

researcher ability limitations to take on the additional burdens of analyzing more than one type of data (Creswell, 1994, Morse, 1991) and 3) the practical problems arising with analyzing different data sets.

Rossman and Wilson (1985) describe three perspectives with regard to mixing qualitative and quantitative approaches in a research design. Purists focus on the differences and paradigms supporting the research approaches and argue that using mixed designs is logically inconsistent. Situationalists, tolerate the use of both approaches in a study, but believe that certain situations call for certain methods. Neither of these first two perspectives "foster" (Rossman and Wilson 1985, p.85) the integration of methods; however, a pragmatic perspective also exists. These researchers choose not to focus on the "false dichotomies" (Denzin, 1970, p 119) of the different types of research but choose instead to attempt to capture the strengths of each approach; that is because these differences are based on strongly held philosophical differences, that are in essence a given for scholars reviewing their work, the pragmatic researcher can do little to assuage such concerns other than to understand them and recognize the limits they place on the research.

On the practical side numerous authors, (Yin, 2003; Eisenhardt, 1989; Patton, 1990; Creswell, 1994, Marshall and Rossman, 1995; Sieber, 1973), point out that adding a different methodology to a research design also adds work. Mixed designs require the researcher to become adept at both methodologies, thus the impact of the researcher's own abilities weighs on the design (Sieber, 1973; Greene et al 1989; Yin, 2003). The study can be expected to take longer

as both designs must be implemented and both data sets analyzed according to different regimes (Sieber, 1973; Greene et al 1989; Yin, 2003, Creswell, 1994). Finally adding a methodology also adds cost; the researcher must be both funded and given the access to accomplish both portions of the design (Mitchell, 1986; Morse, 1991). Again, to these implications, the researcher has little response other than be sure he has the capabilities and assets to accomplish the design he develops. Sieber (1973) and Greene et al (1989) suggest that researchers attempting to implement mixed-method designs have limited numbers of cases that are well-bounded, with manageable amounts of participants.

A final area, and focus of the remaining of this section, is the practical side of analyzing the multiple data sets generated by mixed designs. Once a researcher has collected both sets of data he is faced with integrating his analysis of them. Frequent problems cited within the literature include: 1) the difficulty of merging numeric and textual data, 2) the interpretation of divergent results, 3) the lack of delineation, or oppositely, the incorrect merging together of concepts and 4) the weighing of information from different data sources in reaching conclusions (Mitchell, 1986). The researcher must recognize these pitfalls and develop his research design accordingly.

<u>Addressing Data Analysis Challenges through Research Design</u>

To the problem of combining textual and numeric data, two alternatives are available to mixed-design researcher, both relating to converting one type

into the other (Mitchell, 1986). In order to give raw text numeric meaning the researcher is left with development of coding and frequency techniques (Mitchell 1986, Denzin 1970). Statistically, then the problem becomes one of applying multivariate statistical analysis techniques including multiple regression, cross-classification analysis, and multiple analysis of variance (Mitchell, 1986) to the larger, combined data sets; the researcher must ensure, in this case, that the variables in question are rigorously delineated and their intercorrelation is not significant.

Alternatively, the researcher can attempt to conceptually integrate all available data in a confirmatory approach. Such an approach involves searching for logical causal trails, building explanations, and pattern matching in an attempt to develop a richer conceptual understanding of the subject matter (Yin, 2003; Mitchell, 1986; Morse, 1991; Sieber 1973). Tactics that support this analysis strategy include constructing displays of data that facilitate the researcher's ability to detect patterns and links. Such displays include event sequences, arrays based on dimensions suggested by informants or literature, critical incident charts tracing causes, networks detailing linkages between informants and systems, taxonomies, and time ordered matrices tracking information flow (Miles and Huberman, 1994; Yin, 2003; Voss, Tsikritsis, and Frolich, 2002). Each of these tactics can incorporate both qualitative and quantitative data. The objective is to become familiar with the case as it stands alone and to allow its patterns to emerge to support the development of findings and conclusions (Eisenhardt, 1989).

Mitchell's (1986) problems of divergent results and overlapping of constructs are not so much problems of combined research designs as they are problems with the underlying theoretical framework which are now being highlighted by the combined design. To the extent that divergent results exist the researcher must attempt to rationalize them or change or discard the underlying theoretical constructs, assumptions, and propositions, or reconstruct and more accurately delineate variables and propositions. Greene et al (1989) cite such divergence as a strength encouraging the initiation of new conceptual constructs and relationships.

Lastly, the weighing of importance of data sources, as opposed to confronting divergent results, in reaching conclusions is a fact of mixed designs and a point of valid criticism. To this problem the researcher is left only with the hard work of interpreting findings within the context of present knowledge;

> "...it is not accomplished using a mathematical formula to weigh the findings from each method, rather it is an informed thought process, involving judgment, wisdom, creativity, and insight and includes the privilege of creating or modifying theory. It is an exciting part of every research project..." (Morse, 1991, p122).

The researcher must be aware of these limitations and the opening to criticism in this area. Some guidance for the weighing of results is given within the literature.

Greene et al (1989) use the five purposes they identified in the their study of mixed-designs to develop corresponding design objectives. If the primary purpose of pursuing a mixed design was to gain triangulation of observations and

findings, methods should be should be different from one another in terms of their biases: methods designed to uncover or discover patterns and trends should be countered by those seeking to disprove such correlation or logical relation. Then the methods should b applied to the same research questions. Applying them to different sets of research questions does nothing to enhance triangulation. In this case it is suggested the qualitative and quantitative portions of the research are weighed equally (Greene et al, 1989; Creswell, 1994; Sieber, 1973, Rossman and Wilson, 1985).

If the pursuit of a mixed design is motivated by an attempt to enhance complementarity, then some overlap of the methods to examine different facets of a single phenomenon is in order (Green et al, 1989; Rossman and Wilson, 1985). It is further suggested that the two research methods be accomplished simultaneously rather than in sequence so that results are more truly complementary and not gained through prior bias (Green et al, 1989; Creswell, 1994).

The primary design guidance flowing from the motivation to pursue development is the sequential implementation of the different methods (Greene et al, 1989; Creswell, 1994). This was precisely the goal of Hofstede et al (1990) in conducting long interviews to develop a feel for understanding organizational culture constructs and people's perspectives before incorporating their results into successive surveying phases. As with triangulating designs, methods should be dissimilar and of equal weight (Greene et al, 1989).

The aim of designing for initiation is uncover paradox and divergence. Contradiction is valuable in that it can produce learning by motivating the rejection of misguided conceptualizations, the development of a means to explain divergence, or the suggestion for further analysis. In this case research based on stricter positivist paradigms, controlled experiment, should be pursued to counter stricter relativist paradigm bases and produce conflicts (Greene et al, 1989; Rossman and Wilson, 1985).

Mixed method research designs seeking to provide expansion on existing theory and constructs tend to be more wide open in terms of weighting and type of method. In many cases the researcher is attempting to add comprehensiveness or breadth to his work and supplementing a dominant method with a less dominant one (Greene et al, 1989; Creswell, 1994). Green et al (1989) also found that expansion was frequently one of multiple design goals usually complementing attempts to achieve triangulation or complementarity.

Conclusion

The open-endedness of case study research provides the researcher with a means to incorporate multiple research methodologies in pursuit of improving the validity and soundness of his work. Mixed method designs do come with a variety of challenges associated with criticism of using different philosophical paradigms, practical additional workload constraints, and practical data analysis challenges. The researcher selecting such methods must be aware of their

inherent limitations and the problems associated with data analysis and then develop his research design accordingly.

The Limits of Statistical Approaches for this Research Setting

Researchers seeking to develop an understanding of how an institutionalized organizational control center expediently learns about and acts within in its environment, may find that research methods similar to that of the case study are well-suited to the constraints of the subject matter (Johannsen, Artman, and Waern 2001; Coombs 1999; and Vidaillet, 2001). If one seeks to further understand the relationships between 1) conceptual learning constructs based on academic literature and 2) performance measures of control centers within specified crisis environments, the strengths of case study method may be even more attractive. Such strengths include 1) the likelihood of building novel theory as the researcher must capture and analyze the various perspectives of participant informants in comparison with conceptions based on literature, 2) the capability of developing and following up on emergent theory patterns as they may reveal itself during the data collection process, and 3) the inherent theory building process in case-study methods driven by the researcher's search for patterns, linkages, and causality, and 4) the capability to holistically capture the richness of contextual information (Eisenhardt, 1989; Yin 2003; Creswell, 1994; Dyer and Wilkins, 1989; Mintzberg, 1979).

The case study researcher may seek to add breadth, comprehensiveness, and additional rigor to the work by augmenting the qualitative data collected with

quantitative data and with quantitative analysis (Greene, Carricelli, and Graham, 1989; Creswell, 1994). Relating control center performance variables, that is the likely dependent variables in such a study, statistically to constructs developed from the literature, the likely independent variables in the study, within the confines of a small number of individual cases also has an inherent set of problems. The contextual focus of case study work, seen as a strength to researcher, also holds within it the potential effects of a large number of potential independent variables that may or may not be captured by the researcher. The purpose of this section is to discuss such problems, discuss the statistical approaches available to the researcher to uncover the relationships between such variables, and to discuss the implications such approaches may have on the selection of cases for study.

Before proceeding with this discussion, it is important for the researcher to explicitly call attention to a key practical underlying assumption regarding the nature and limitations of the subject matter proposed for study by the researcher. In the cases proposed for study, control centers functioning in crisis environments, the specific control centers in question are typically composed of no more than 10 personnel on a given time shift; this is in congruence with control centers studied thus far in the literature (Johannsen, Artman, and Waern 2001; Coombs 1999; and Vidaillet, 2001). Completely surveying both night and day shifts and possibly overseeing commanders and even possibly formal organizational evaluators will lead to a sample size no greater than 30 respondents, even assuming 100% response. Furthermore the number of cases

to be studied is expected to range somewhere between two and seven at the absolute extremes. For both within-case and cross-case analysis this inherent sample size limitation, in terms of number of respondents and cases respectively, has profound ramifications on the type of statistical approaches, descriptive versus inferential, suitable for analytic use. These ramifications apply particularly to establishing relationships between independent variables and formally assessed measures of what is essentially team performance. This issue will be discussed further in the section that follows. It should be said at this point that there still remain key methodological design objectives that can be drawn from traditional quantitative statistical perspectives to guide the process of case selection; this issue will also be addressed in the discussion that follows.

Challenges Associated with Extracting Information from Case Studies

The problems associated with extracting information from the specific case studies in question to determine the effects of independent variables on dependent variables can be grouped into three main categories: 1) problems associated with sample size requirements for quantitative statistical inference, and 2) problems associated with the expected large number of potential independent, contextual, and interacting variables on qualitative inference and 3) the resulting problems arising from subjectivity inherent in coding qualitative data from the cases.

Quantitative statistical analysis offers a variety of tools that the analyst can use to infer relationships between variables. In order to quantitatively draw

statistical inference about the effects of independent variables on dependent variables, particularly in cases with potential large numbers of independent variables, requisite sample sizes are in order. Widely used rules of thumb include: 1) for surveys in general 51 respondents plus the number of variables specified in the model being researched, 2) for exploratory factor analysis at least 150 data points are required 3) and for confirmatory factor analysis at least 200 are required (Guadagnoli and Velicer, 1988; Hoelter, 1983). Similarly, small samples impact the measures of confidence, measures of fit and measures of interaction involved in other multivariate analysis techniques including correlation, regression, and analysis of variance (Kachigan, 1991, Nachmias and Nachmias, 1976). As previously described and also encountered in similar research (McFadden, 2000) such inferential statistical methods cannot be applied to case study approaches involving limited numbers of participants or limited numbers of cases themselves.

With specific regard to an organization's formal performance assessments of its control centers during an operational exercise and inspection scenario, the resulting metrics will be limited to a few characterizations of that performance rolled up into a single data point. This operational conflict, between the sample sizes involved in case study research and the use of inferential statistical methods to determine relationships between variables, is reflective of conceptual paradigms supporting the suitability of case study methods to qualitatively induce patterns and linkages within case data. This discussion however does not preclude the use of descriptive statistics to enhance the qualitative portion of the

research design in a dominant-less dominant mixed method design (Creswell, 1994; Greene et al, 1989).

A second problem for the researcher involved in a highly, contextually dependent case study is the large potential of independent variables that could influence other variables of interest. Traditional quantitative statistics captures this notion by classifying four types of variables, 1) the explanatory variables, those dependent and independent variables in which the researcher wishes to find relationship, 2) extraneous controlled variables, those which the researcher seeks to control in order to limit their effects on the dependent variables 3) extraneous uncontrolled variables which may confound relationships between explanatory variables, and 4) extraneous uncontrollable variables or noise, the effects of which the researcher attempts to control through random sampling of sufficient size (Kish, 1959; Creswell, 1994). Additionally, the researcher may also expect interaction between any and all of these variable types (Kish, 1959; Cresswell, 1994). The subjectivity involved 1) in the qualitative definition of constructs in terms of construct validity and 2) in qualitative inference in terms of internal validity is another problem associated with the high volume of expected independent variables in a contextually rich case. While inferential statistics may not be applicable to some qualitative inquiries, the basis of quantitative methods can aid in understanding and addressing the problems of ascertaining relationships between variables. This application shall be discussed in a later section.

Approaches from Quantitative Statistical Analysis for Analyzing Effects of Independent Variables on Dependent Variables

While the transformation of qualitative data into quantitative forms for purposes of using inferential statistical methods is inhibited by sample size constraints, descriptive statistics can be used to supplement the qualitative development of constructs as well as the qualitative development of inferences of relationships between variables. Such methods include the familiar mean, median, standard deviation, and range. These can be used to augment qualitative data regarding informants' perspectives and for characterizing informants experientially and demographically. Additionally, frequency counts associated with words spoken in control centers and artifacts repetitively used in control centers can provide valuable quantitative data.

Perhaps an even greater strength associated with using statistical methods is the sharpening of constructs involved in the coding of qualitative data into quantitative information. This conversion process can address some of the concerns relating to the interaction of variable types that was cited as a problem in the previous section. Mixed method researchers (Mitchell, 1986; Morse, 1991) suggest that delineation of separate concepts, and oppositely, the merging of concepts is a significant challenge of the work. Focusing on the types of pitfalls specified by the definitions of variable types, as detailed in the previous section, will help to force the researcher to enhance construct and internal validity. This enhancement will come from expecting the interaction of variable types as coding is accomplished. Use of textual coding methods and Likert scale survey methodologies will provide more precision in definition of constructs, as well as

the development of ordinal levels for quantifying constructs (Nachmias and Nachmias, 1976). The quantification of qualitative data can serve to enhance construct validity; the use of descriptive statistics can augment the qualitative inference of variable relationships. Additionally, the researcher familiar with quantitative approaches can be wary of the pitfalls associated with interacting variables and develop his constructs accordingly. The traditional perspective of quantitative statistical approaches also has implications in case selection for the qualitative researcher.

Implications of Statistical Approaches on Case Selection

The approach statistical analysis takes with regard to understanding variable types can guide the case study researcher in his case selection process. In reviewing the literature and developing frameworks and constructs, the researcher should be cognizant of the variety of variable types that may be encountered. Accordingly, type 2 or so called "extraneous but controllable" variables (Kish, 1959, p 329; Creswell 1994, p 63) should be identified by the researcher prior to data collection. To the extent case selection can eliminate or mitigate the impact of such variables on the work it should be done (Pettigrew, 1988), for example, a control center that for one reason or another will experience a high degree of personnel turnover just prior to data collection efforts may introduce confounding factors into the work. As such the researcher may want to eliminate such a case from consideration. Alternatively, a specific case's characteristics may present an opportunity to observe a key variation in a

explanatory independent variable or perhaps an interaction in explanatory independent variables (Pettigrew, 1988). Such cases represent a chance at initiating the further development of existing conceptualizations or the construction of new ones (Greene et al, 1989; Eisenhardt, 1989).

Conclusion

Quantitative approaches can be useful in designing approaches for case studies involving smaller amounts of participants as well as limited numbers of cases. While the small sample size of participants and cases involved in studying crisis control centers precludes the use of inferential statistics, descriptive statistics can serve to augment the qualitative measurement of constructs and the qualitative inference of relationships. The perspective of traditional statistics with regard to defining variable types can also guide the case researcher in these areas as well as in case selection.

Addressing the Challenge of Researcher Closeness

One of the advantages of case study research is that it allows the researcher to bring his personal expertise and familiarity to the subject matter (Yin 2003; Creswell, 1994; Hofstede, 1990; Dalton 1959). Such researchers may have years of experience in working in their case settings, may be familiar with the jargon in use, may themselves have previously studied such settings, may have unique access for collecting case data, and may be familiar with the dominant aspects of organizational history and culture in such settings. Such

assets may enhance the researcher's ability to develop and test propositions and hypotheses. This degree of closeness to the phenomena under study, however, opens the case researcher to a variety of scholarly criticisms. The purpose of this section is to detail the scholarly criticisms associated with such familiarity as well as to describe methodological design strategies that can be employed to address such criticisms.

Scholarly Criticisms Associated With Researcher Closeness to Subject Matter

Scholarly criticisms focused on the researcher tend to be concerned with the validity and reliability of the work. The traditional canons of science include the concepts of significance, theory-observation compatibility, generalizability, consistency, reproducibility, precision, and verification (Strauss and Corbin, 1990; Lincoln and Guba, 1985; Douglas, 2004). Significance and theory observation compatibility are applicable to all kinds of research; the research must not merely restate what is obvious to everyone and what is proposed as theory must correlate to what is observed (Weick, 1974). In pursuit of incorporating rigor into scientific research, the remaining canons have become operationalized into constructs of validity and reliability (Lincoln and Guba, 1985; Douglas, 2004; Marshall and Rossman, 1995). When the researcher is very close to the material and human behavior being studied as was described in the introductory paragraph to this section they should be prepared for scholarly criticisms to stem from these bases.

Criticism towards a researcher that is close to inquiry subject matter springs from the notions of construct validity, internal validity, and reliability, Construct validity refers to the notion that a sufficient operational set of measuring tools must be employed to ensure subjective judgments are not being made during data collection (Yin, 2003; Lincoln and Guba, 1985; Voss, Tsikriktsis, and Frolich, 2002). Criticisms in this area tend to be of researcher bias in collecting data; the "close" researcher has preconceived notions of the nature of the subject matter and may consciously or unconsciously impose his subjective judgment in collecting and interpreting data. Furthermore the data collection process may be skewed because the researcher has had to gain access to the case participants and material; such access may result in participants telling the researcher what he wants to hear (Cresswell, 1994).

Internal validity refers to the notion that relationships that researcher concludes exist within collected data are correctly inferred (Yin, 2003; Lincoln and Guba, 1985; Voss, Tsikriktsis, and Frolich; 2002 Marshall and Rossman, 1995). Again, scholarly criticism stemming from this underlying basis, focuses on the inherent bias of the researcher that may be too familiar with his subject matter. Biased researchers may consciously or unconsciously reach conclusions based on their preconceived notions. They may assign more weight to data confirming their conclusions and less or none to data not confirming their conclusions. They may choose to ignore altogether or not seek out disconfirming evidence. Because they have not conceived of other types of causal

explanations they may not structure their research designs to uncover such explanations (Yin, 2003; Creswell, 1994).

Lastly, reliability refers to the notion that research results should be reproducible; later researchers should be able to duplicate original findings (Yin, 2003; Lincoln and Guba, 1985; Voss, Tsikriktsis, and Frolich, 2002; Douglas 2004). From this basis of perspective, perhaps the harshest critics maintain that the “close” researcher merely goes through the case data looking for evidence to fit his working, pre-conceived framing of the problem. As a result of such problems stemming from issues of construct and internal validity, the work will not be reproducible by other researchers (Yin, 2003; Creswell, 2004).

Tracing these frequent criticisms to their underlying bases within the traditional canons of science improves the depth of understanding of the criticisms. Furthermore, it allows such a researcher to take such criticisms into account by creating objectives to guide the methodology design process. These objectives in turn lead to the development of specific design strategies to address these problems.

Design Strategies to Address Concerns Regarding Researcher Closeness

First and foremost, the case study researcher who has an intimate familiarity with his cases, must recognize the validity of the criticism regarding closeness to the subject matter. To this extent, the researcher must ensure he has the skills required for good case study. Yin (2003, p 59) describes these as 1) being able to “ask good questions and interpret” the answers in a meaningful

and unbiased manner, 2) being a "good listener and to not be trapped by preconceptions", 3) being "adaptive and flexible so that unexpected observations are seen as opportunities and not threats" and 4) being "unbiased by preconceived notions" that may exist by being "sensitive and responsive to contradictory evidence." To the extent that critics may not be convinced by the altruistic intent of the "close" researcher other tactics exist which can enhance the validity and reliability of the research design.

Qualitative researchers have proposed and expounded on analogous constructs to the traditional notions of validity and reliability (Lincoln and Guba, 1985; Douglas, 2004; Marshall and Rossman,1995; Voss, Tsikriktsis, and Frolich, 2002; Rubin and Rubin, 1995). To the idea of construct validity they offer the notion of confirmability or transparency (Rubin and Rubin, 1995), the ideas that another researcher reviewing case data would agree that the correct observations were made when the case study process took place. Now as a design objective the researcher can pursue confirmability by 1) using multiple sources of evidence to triangulate observations, 2) establishing chains of evidence to support specified observations, 3) having informants review drafts of case data and case report and documenting their subsequent comments 4) documenting the demographic and experiential background of the researcher so that a reviewer can judge if bias was involved in data collection and 5) documenting the steps required to gain access to the case material and informants again so the reviewer can assess possible biases and 6) commenting about sensitive issues such as confidentiality of data and anonymity of

informants (Yin, 2003; Voss, Tsikriktsis, and Frolich, 2002; Rubin and Rubin, 1995; Creswell, 1994). Incorporating these tactics into research design will allow the researcher to respond to the criticisms of bias in data collection.

With respect to the idea of internal validity, qualitative researchers have offered the analogous notion of credibility, the accurate inferring of relationships within the collected case data (Lincoln and Guba, 1985; Douglas, 2004; Marshall and Rossman,1995; Voss, Tsikriktsis, and Frolich, 2002; Rubin and Rubin, 1995). As a design objective a number of strategies can be employed to enhance credibility within the research: 1) identifying recurring patterns within cases to trace causality, 2) using their expertise and that of their informants to build explanations for observations, 3) identifying, detailing, and addressing rival explanations for observations, 4) using logic models or attempting to fit empirical data to proposed rival cause-event chains and 5) using multiple reviewers or case analysts to confirm each others work and conclusions (Yin 2003, Patton 1990; Voss, Tsikriktsis, and Frolich, 2002; Rubin and Rubin, 1995; Creswell, 1994). Incorporating these measures into research design will provide the researcher who has a close familiarity with the research subject matter to address accusations of bias in the conclusions and findings he reaches from analyzing the case data.

With respect to the idea of reliability, qualitative researchers have offered the analogous notion of dependability, the taking into account and detailing of the dynamic conditions inherent to each human situation so that a reviewer may audit the researcher's work and conclude that had the work been done someone

else the same conclusions would have been reached (Lincoln and Guba, 1985; Douglas, 2004; Marshall and Rossman,1995; Voss, Tsikriktsis, and Frolich, 2002; Rubin and Rubin, 1995). With dependability as a design objective the case study researcher can 1) develop and use a rigorous case protocol and 2) maintain a detailed case database (Yin 2003, Voss, Tsikriktsis, and Frolich, 2002; Creswell, 1994). These tactics will allow the case study researcher to counter criticism that his work is not repeatable because his preconceptions and bias lead him to skew data; the establishment and use of a rigorous case protocol helps in ensuring that credibility and confirmability is maintained, that another researcher can trace conclusions by following the processes developed by the original investigator. Maintaining a case database allows another researcher the opportunity to view the manner in which the protocol was applied in the case.

Conclusion

A researcher who is very familiar with and close to the issues involved in the subject matter of the research and subsequently endeavors to pursue a case study will doubtless be exposed to criticisms focused on his preconceptions and biases regarding those issues. The researcher must acknowledge these criticisms as valid concerns, endeavor not to allow his experiences and preconceptions to influence his work, and design strategies, detailed in the literature, into his research methodology to address these criticisms accordingly.

Framework, Model, or Theory?

A brief discussion is necessary explaining why the term *theoretical framework* is applied to the work at the beginning of this chapter and prepared for partial validation in the next. The selection of the term *theoretical framework* as opposed to others might be considered somewhat arbitrary but some rigor applied to defining this term was fruitful to understanding what DC5 proposes to be. The terms framework, model, and theory, very frequently chosen to be in the titles of research documents from a variety of fields, are used interchangeably and without rigorous definition (Sutton and Straw, 1995; Heals, Jean, and Gibson, 1992; Bacharach, 1989; Adam, 1985). As Sutton and Straw (1989, p 371) put it,

> "There is lack of agreement about whether a model and a theory can be distinguished, whether a typology is properly labeled a theory or not."

Freese (1989, p 189) in seeking to define and describe formal theorizing described,

> "an incredible anarchy of language, conceptions, proposals, interpretations, and results of formal theorizing."

Finally, Homans (in Weick, 1989, p 517) makes the complaint,

> "...much official sociological theory consists of concepts and their definitions: it provides the dictionary of a language that possesses no sentences."

The purpose of this section is to develop some working definitions of the terms framework, model, and theory that can be used to guide the researcher to ensure

that he is speaking in complete "sentences", or at the least is aware of when he is not.

Theories, Models, and Frameworks: Definitions and Distinctions

As suggested by the introduction, common use of the terms framework, model, and theory overlaps significantly, thus any set of definitions should be treated as operational. The motivation for pursuing such working definitions is to guide the researcher in development of methodology for confirming the idea he has developed and to ensure that he does not suggest that the idea is anything more than what he has actually shown.

As each of these terms is focused on the construction of meaning about the world it is informative to understand conceptions about how individuals create meaning within their world. First, distinction must be made between what constitutes data, information, knowledge, and perhaps intelligence. Ackoff (1989) develops a hierarchy of these concepts: *data* is nothing more than raw symbols differentiating various states of the universe; *information* is data processed into a useful form with some level of meaning answering the basic questions "who", "what", "when," and "where"; *knowledge* represents information applied to begin answering "how". Ackoff goes on to define *understanding* as the appreciation of knowledge when one begins answering "why" and compares the distinction between knowledge and understanding to the distinction between memorizing and learning. Finally, Ackoff, defines wisdom separately from the other four

concepts, which are focused upon the past. Wisdom is the ability to project understanding for predictive purposes.

An individual's first act in learning about the world involves perceiving data; the five senses take care of this act. The next step in creating meaning is in defining what it is that has been observed. This is the act of framing the data by asking and answering the key questions of "who", "what", "when," and "where." Heals, Jean, and Gibson (1992) citing Chauncey and Miller suggest that frameworks accomplish such acts by providing their users with language specific to characterizing what has been observed; framing includes the acts of definition and assumption. For purposes of an operational definition, *frameworks are the key definitions a researcher constructs regarding to his subject matter.* For example, Newton had framed his work on the basics of physics by developing the constructs of gravity and force to use in concert with those familiar to humans in general, time, distance, and speed. Frameworks involve the development of constructs for understanding phenomena.

In moving on to higher levels of meaning the next question the individual must ask is "how." In this sense constructs must be linked, describing through abstraction the sequences of events, or the order in which constructs are observed. In order to mentally capture such events for further development, the researcher must limit the amount of constructs he considers and thus bounds his conceptualization of the subject matter. In the classical science sense, Galileo acted in such a manner when he developed what came to be known as the heliocentric model of the solar system describing the orbits of the planets around

the sun; creating a model or perspective in which to view observed constructs. *For purposes of operational definition, models are abstract linkages of observed constructs that describe how a phenomenon is taking place.*

It should be noted within the literature that some make no distinction between models and theory (Whetten, 1989; Dubin, 1976). Descriptive models can be used for predictive purposes and they can identify interactions between constructs. For others (Sutton and Staw 1995; Freese (1980); Eisenhardt, 1989; Creswell, 1994; Yin, 2003; Adam, 1985) the key distinction is that theories explain why relationships exist. Newton advanced the heliocentric model by postulating the theory of gravity.

It should be noted that as constructed here these terms represent a hierarchy of meaning. Researchers must first frame constructs, describe interactions amongst them, and then logically suggest a reason why this interaction is observed. Thus all theories as defined here are both models and frameworks; models are frameworks themselves. Some frameworks, such as taxonomies, and listings of variables are not models or theories and some models such as diagrams and flowcharts, in and of themselves, are not theories (Sutton and Staw, 1995).

A note should be added here about where the subject matter of this work distributed cognition in the specified setting fits in the larger scheme of relatively new field of cognitive engineering. A review of literature relating to cognitive engineering shows that it is focused on developing a variety of disparate systems addressing the various critical processes involved in learning about an outside

environment. In a sense these efforts represent the *engineering* or application of scientific principles, in this case those related to cognition. Engineers proceed with their design based on these principles that are sometimes grouped together into overarching perspectives or frameworks of the outside environment. This work is focused on constructing such a framework of diverse principles. Its intent is to frame the existing science so that future engineered applications can be made while using it.

It should also be mentioned again, that in terms of common usage researchers have used these terms interchangeably. As a result such a construction of these concepts may find dispute. But it does provide the researcher with a means of understanding to what extent he has created meaning with his work. In the case of DC5 the term theoretical was chosen because interrelationships are proposed and described and explanation is given to why they exist. Framework is added because the researcher acknowledges that the DC5 construction was the construction of a perspective for which a complementarity of views may exist. Validating, at least partially, the DC5 theoretical perspective is the focus of the next chapter.

Conclusions on Methodology

This chapter had three main purposes. First, using a systems approach, A theoretical framework was developed that 1) synthesized the information developed in the literature review, 2) described the systemic structure of distributed cognition occurring in control centers, and 3) captured the effects of

changing crisis intensity on the distributed cognition occurring in control centers. Second, the appropriateness and suitability of using exploratory case study methodology to validate a portion of the constructed framework was reviewed in detail. Finally, a brief discussion was presented to explain why the term "theoretical framework" is used to describe the central product that is presented in this chapter and that is to be validated using the research design in the next chapter. Chapter IV, Research Design, will follow where the specific design of the case study protocols and database will be made explicit.

CHAPTER IV

RESEARCH DESIGN

Purpose and Organization of Chapter

The purpose of this chapter is to develop a means for validating the DC5 framework developed in Chapter III. As discussed in Chapter III, this validation will be sought by two general approaches guiding the efforts of this research design. First, cases will be explored to find out the degree to which DC5 indeed does provide a general overall means of framing an understanding of observed distributed cognition phenomena. To this end, collected data will be synthesized to comprehend if the constructs and interactions of the DC5 framework are readily apparent in the data and lead to a deeper understanding of the phenomena. To the extent that the data is readily interpreted by the DC5 framework constructs these portions of the framework will be considered to be partially validated. To the extent that various constructs are not readily identifiable in the data or new constructs may be inferred from the data the framework will be adjusted accordingly on an iterative basis between the three Operational Readiness Exercises and one Operational Readiness Inspection.

The second general approach to seek validation of the framework will be to observe if the framework can serve as a basis for an initial assessment of the fitness of a crisis control center's distributed cognition system and subsequently as a basis for devising and implementing a training plan for a control center. To the extent performance increases in subsequent iterations of action in the case

studied the framework will be considered validated. To the extent performance improvements are slow to be seen or are not seen at all the framework will be adjusted accordingly again on iterative basis between the operational readiness exercises and inspection.

As discussed in Chapter III, four primary challenges are inherent in the general approach described above. First, a sound means of measuring or characterizing control center performance must be developed. Second, similar sound means, using qualitative case study methods, must be employed to characterize the nature of a given scenario within an exercise or inspection in terms of the crisis environment. The characterizations of these constructs and their sub-elements can be no more than categorical or perhaps ordinal in nature and more likely just descriptive. Consequently, convergence from multiple data sources must be sought. The third challenge described previously is to design a training regimen of future exercise scenarios within the constraints that exist that will facilitate the performance improvement of the control center. A fourth challenge also discussed in Chapter III is that of general case study methodological soundness.

To meet these objectives, approaches, and challenges this chapter will develop and discuss a case study protocol guiding the overall case data collection and analysis effort. The protocol itself is presented in outline form in Appendix III where the research design is broken down into its various elements. A significant sub-portion of the case study protocol presented here will be the development of the individual data collection instruments supporting the

subsequent analysis. The functions and objectives of these instruments will be presented in this chapter while the actual instruments themselves are presented in Appendix III. In broad terms, the research will be accomplished over two case data sets. The first case is an Air Force unit conducting two internal operational readiness exercises in preparation for a final formal external operational readiness inspection. This first case involves three data collection opportunities. Additionally, this case presents the chance to intervene, as described previously, by developing a performance assessment from the first iteration and using it to in turn support the development of an exercise script for the second exercise. The second case data set will be collected during a formal operational readiness inspection involving another unit. Figure 4.1 Research Design Approach summarizes the discussion above. Figure 4.2, Iterative Approach, condenses the presentation in Figure 4.1 and stresses the iterative design of the research in which successive updates, after analysis of collected data from each ORE and the ORI, are made to the DC5 framework and if necessary the protocol, data collection instruments, and data analysis approach themselves.

Figure 4.1: Research Design Approach

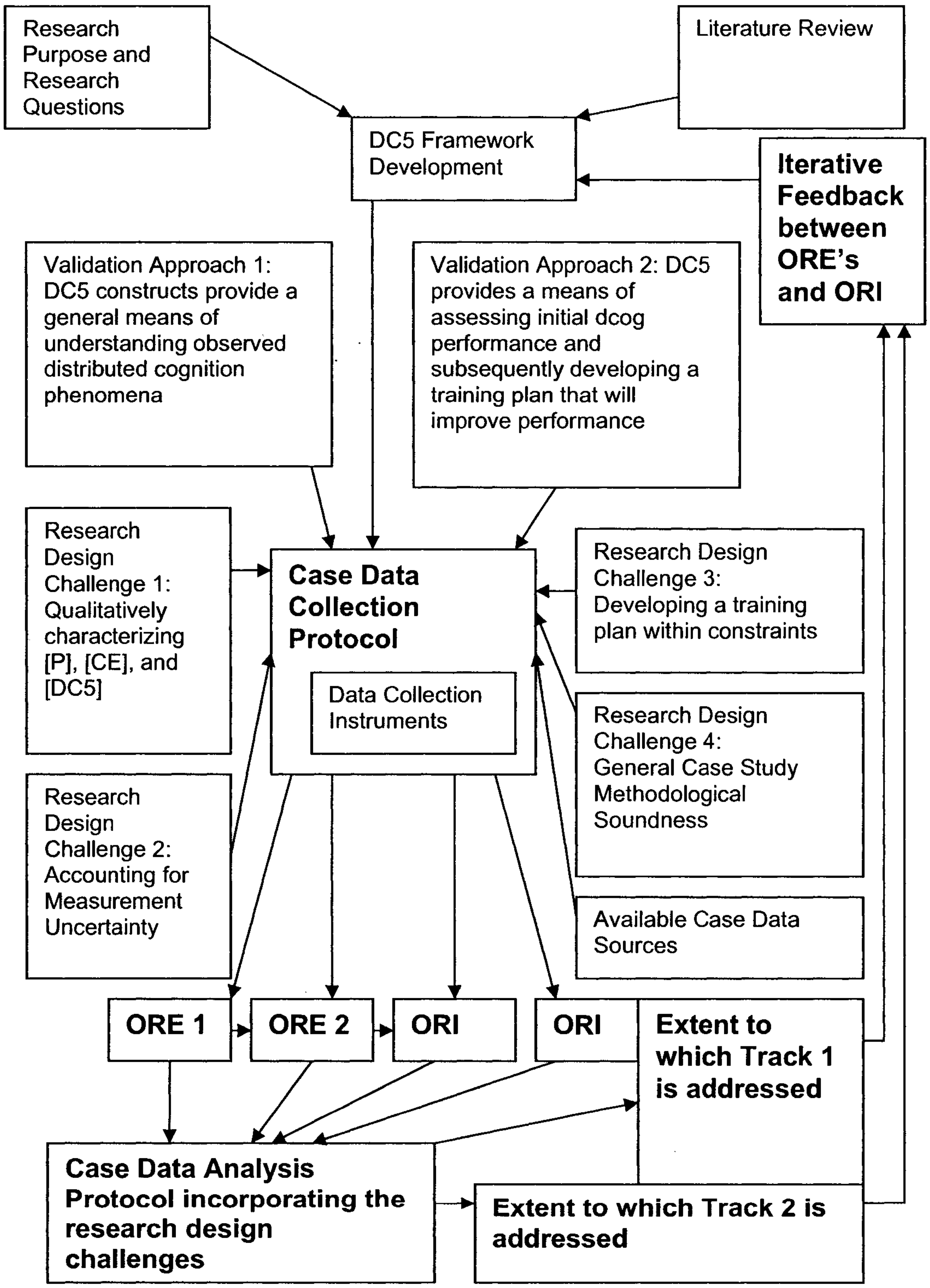
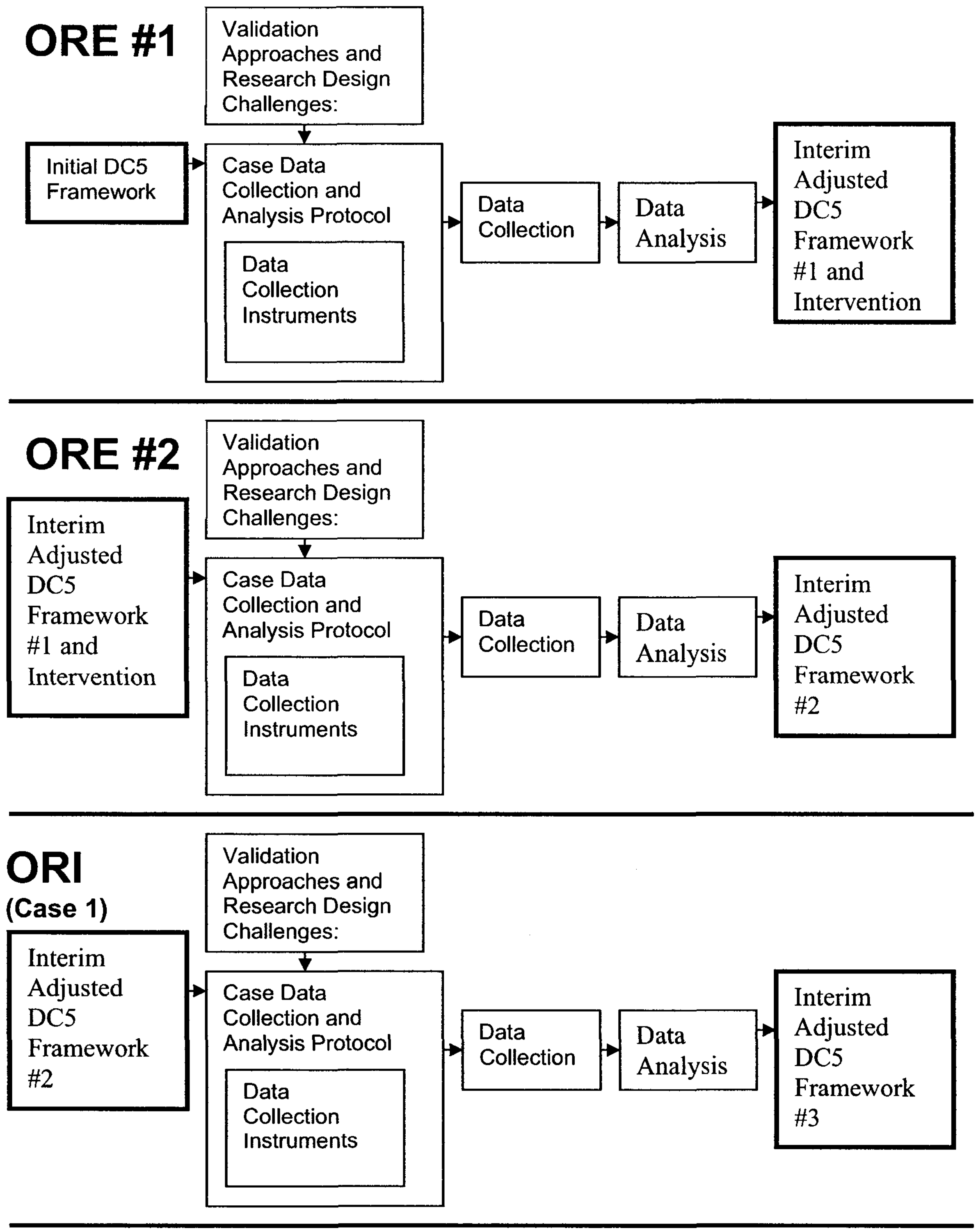
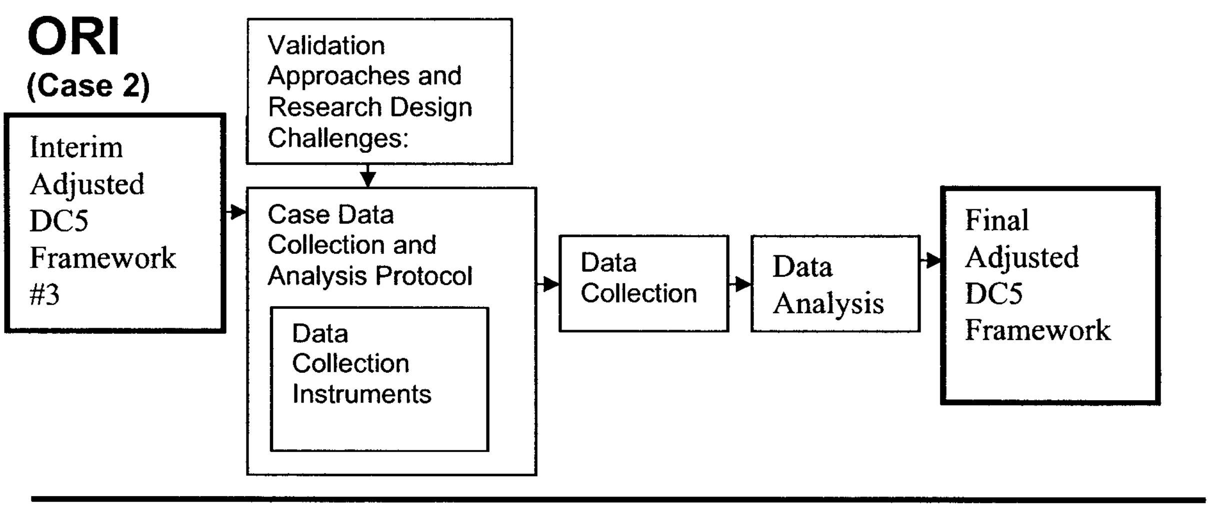


Figure 4.2: Research Design Approach




ORI
(Case 2)
Interim Adjusted DC5 Framework #3
Validation Approaches and Research Design Challenges:
Case Data Collection and Analysis Protocol
Data Collection Instruments
Data Collection
Data Analysis
Final Adjusted DC5 Framework

Organization of Data Collection and Analysis Protocol

Following the prescriptions of Yin (2003) and Creswell (1994) in order to address Research Design Challenge 4, first, general research soundness, and as previously discussed in Chapter III, the general case requirements, suitability, and selection methods must be made explicit. Second, also addressing the same design challenge, general access requirements, availability requirements, and any existing rules of engagement with case data sources requirements must also be made explicit. Third, a general description of the available data sources must be accomplished to serve as a basis for development of the subsequent data collection instruments. Fourth, integrating the described research design challenges with the available case data sources will serve as a basis for design guidance for developing the data collection instruments. Fifth, a discussion of how collected data will be analyzed and employed to validate or adjust the framework will be presented.

Case Requirements, Suitability, and Selection

The two most important general requirements to support framework validation are 1) that the case be that of a control center in which distributed cognition, as has been defined in Chapter II, occurs, and 2) during the period of observation the control center experiences and is challenged by a crisis environment, again as defined in Chapter II. In order to meet the first requirement, control centers 1) must be staffed by people with variety of expertise's, 2) must experience scenarios and environments that sometimes

require these people to integrate their knowledge in order to develop and adjust representations of that external environment, and 3) must be equipped with some variety of artifacts, again as described in Chapter II, which are used to facilitate distributed cognition.

In order to meet the second requirement of a crisis environment, a scripted test or drill is most suited to this type of research. A key component of a crisis environment is unpredictability. Thus researchers trying to ensure they are on site (i.e. control center) to observe a case and collect data in a *real world* situation that fits the developed definition may find that they are waiting interminably for such an ideal crisis to be reported into the control center. To observe a real world situation that fits the developed definition would be desirable from the research point of view of capturing data reflecting the true stresses of such scenarios. Additionally, access to scripted events meeting the developed crisis environment definition, allows the researcher to know what is coming, thus enhancing the ability to capture relevant data in the control center. Furthermore, formalized scripted events, if developed through some institutionalized process, provide some standardization that facilitates comparison across sets of events and across control center cases. Lastly, institutionalized drills are generally followed by formalized, institutionalized processes focused on building an assessment of the performance of the control center based on the opinions of institutional observers and experts. Access to the thoughts, opinions, and discussions of such experts could serve to enhance the analysis of data collected from such cases.

Thus in order to meet the requirements for this research a case must involve a control center staffed by a diverse group of functional experts who have to integrate their knowledge as well as use control center artifacts to construct and maintain representations of the environment and should involve a control center being examined through a formalized test, exercise, or drill simulating a crisis.

Additionally, there are other desirable case attributes that can serve to enhance the research. Control centers developed in order to function in crisis environments generally require and facilitate the rapid flow of information through the use of specialized systems, artifacts, jargon, language, institutionalized processes, methods, and cultures. While familiarity with and closeness to subject matter is an area of concern for the researcher, as discussed in Chapter III, it is essential that the researcher be able to understand and comprehend the flow of information and the construction of the resulting representations, as well as, to keep up with such flows to capture case data for analysis. Thus, cases suitable for research must be ones for which the researcher has the experience and capability to collect and analyze data.

Further desirable characteristics for cases suitable for this research include 1) a documentable, or scripted, variation in crisis intensity that the researcher can access, 2) the scripted variations of the crisis intensity includes a variety of different crisis scenarios that are repeated over time, 3) the case occurs over of a limited amount of time allowing the case data to be processed and analyzed within a suitable amount of time thereafter.

The cases of Unit Control Centers (UCC) functioning during Air Force Operational Readiness Exercises and Inspections (ORE and ORI) described in the literature review in Chapter II meet these requirements and have the described desirable characteristics as well. They are staffed by anywhere from 6 to 15 personnel of a variety of expertise's from various base organizations (for example; engineers, security forces, transportation, medical services, explosive ordnance disposal, flying squadrons, personnel systems, fire department, chemical weapons detection, etc.) who have to integrate their efforts, as well as, utilize their systems and tools to understand and act within their environment. ORIs are rigorous, standardized, institutionalized, scripted events designed to test the unit being inspected against established, institutionalized assessment criteria. The event scripts meet the requirements of implementing crisis conditions as described in the DC5 framework. Additionally, the functional expertise and experience coupled with the inspecting experience of the inspection team provide standardization and rigor to the process. As described previously, the researcher is familiar with the format, jargon, processes, and systems used in such inspections having experienced approximately 20 OREs both as a player and inspector. With the appropriate caveats discussed in the previous chapter regarding researcher closeness to subject matter, these cases are suited to the research in question.

Research Soundness and Data Sources

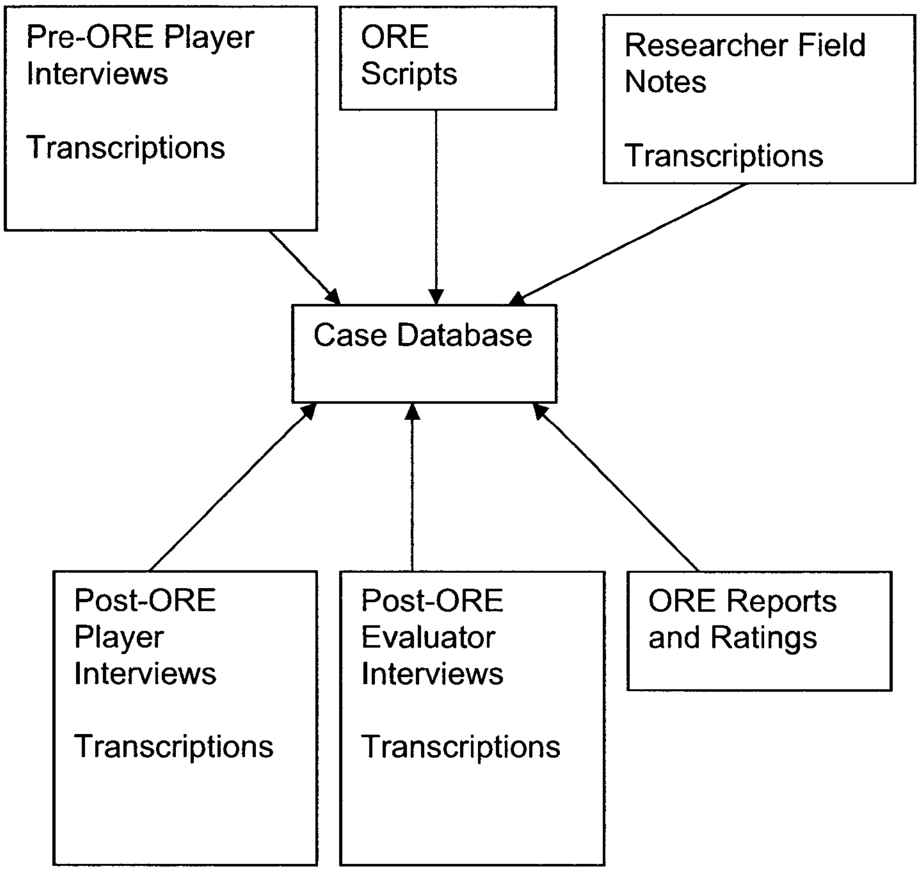
The case study design strategies reviewed in Chapter III (see Table 3.1) serve to guide the development of this protocol as do the research design challenges discussed in the first part of this chapter. The primary objectives of the protocol will be to satisfactorily address the research goals, in terms of rigor, namely: confirmability, credibility, transferability, and dependability. The purpose of the data collection and analysis protocol is to answer the research questions developed in the previous chapters and to confirm the validity of the developed DC5 framework. The protocol accomplishes these tasks by developing specific guidance for selecting, collecting, and analyzing case data. The data types available surrounding a Unit Control Center (UCC) in an Operational Readiness Exercise (ORE) include: 1) pre-ORE interviews with UCC players, 2) ORE scripts that allow the researcher to characterize the crisis nature of the UCC environment, 3) Detailed researcher field notes capturing the unfolding interaction of players and UCC artifacts, 4) Post-ORE interviews with UCC players, 5) Post-ORE interviews with evaluators, and 6) ORE reports and ratings of UCCs inspected.

It should be noted here that the use of surveys was precluded because the number of personnel involved in manning the control centers and evaluating the control centers was small, no more than a dozen total. Thus, it was assumed that a direct capture of any survey questions could be accomplished through the interview process resulting in a higher return rate than the use of surveys. Furthermore, any statistical numeric data captured would necessarily be

descriptive in nature rather than inferential given the small sample space of respondents.

The developed protocol will then serve to guide the process of collecting and assimilating the case data. Figure 4.2, adapted from both the nature of the case to be studied and Yin (1993), captures the multiple data sets available in the case of this research, which can be used to capture and analyze information, as the researcher seeks convergence around common themes and postulates from the framework. The formal iterative analysis discussion leading to successive adjustments to the framework will be accomplished in a prospective Chapter V, Case Analysis, once the data collection and analysis phase of the research begins.

Figure 4.3: Data sets to be used for convergence



Lastly, the goals of achieving research soundness and rigor specific to case study research, as discussed in the literature review, guide the research design development process in terms of data collection and analysis. Table 4.1, Case Study Tactics, adapted from Yin (2003) and Saunders (1998) captures these design strategies.

Table 4.1: Case Study Design Tactics (adapted from Yin, 2003 and Lincoln and Guba, 1985)

Traditional Research Goal	**Qualitative Research Goal**	**Case Study Design Tactics**
Construct Validity or Objectivity	Confirmability	- Detail Researcher Background - Detail Access Requirements - Triangulate - Establish Chain of Evidence - Informant Review
Internal Validity	Credibility	- Pattern Matching - Explanation Building - Address Rival Explanations - Use Logic Models - Multiple Reviewers
External Validity	Transferability	- Generalize to Theory - Seek Replication
Reliability	Dependability	- Develop and Use Case Protocol - Develop and Maintain Case Database

Of these tactics several can be addressed directly. The background of the researcher conducting this investigation can be found in Appendix IV, Supporting Documentation. Access requirements are detailed in the next section. Samples of correspondence relating to gaining case access are also provided in the Appendix IV with the full set of correspondence relating to access and rules of engagement provided in the case database. Samples of informant reviews will be provided in Appendix IV with the full set in the case database. Multiple outside observers and reviewers in addition to the researcher of this investigation were not allowed by the case agency in order to limit footprint on their exercises;

however convergence can be sought on several objectives using the multiple data sources available. Generalization to theory (i.e. to the DC5 framework) is inherent to this research design. Finally, replication is gained by the fact that the research approach involves returning to the same case system three times to gauge improvement of the control center as it prepares through successive exercises.

Availability, Access, and Rules of Engagement

The initial portion of this research protocol is built around meeting the case study design goal of confirmability. Analogous to the traditional research goal of construct validity, the focus of this objective is to remove or mitigate the subjectivity, biases, and weaknesses of the researcher. Case study researchers acknowledge this pitfall and seek its mitigation by 1) thoroughly detailing the background, demographic and experiential, of the researcher so that the audience can assess his potential biases as well as familiarity with case issues, 2) thoroughly detailing the means by which access to case data sources was gained, again for the purpose of allowing reviewers to assess potential biases, and 3) having the actual informants review the descriptions and conclusions of the researcher (Yin, 2003; Eisenhardt ,1989; Patton, 1990; Creswell, 1994, Marshall and Rossman, 1995). These steps allow the researcher to provide the audience with a means of confirming the work's findings and conclusions.

To support these objectives 1) the researcher's military resume is included in the case database along with 2) detailing his experience in working in and

running unit control centers in both operational readiness exercises and inspections, as well as, 3) his experience serving as an inspector on the Air Force's Air Combat Command Inspector General's (ACC/IG) Team evaluating such control centers. Additionally, all the correspondence, mainly email and staffing packages, involved in gaining access to the case data is included in the case database. Essentially in order to gain access to the control centers being evaluated by the ACC/IG team 1) the researcher agreed, as an exchange for the case access, to augment the team as a non-inspector supporting the team's script implementation process on an inspection not used for purposes of this research, 2) the researcher developed a staffing package, provided in the case database, seeking and securing approval from the ACC/IG team leadership detailing the research objectives and approaches to be used, 3) the researcher developed a staffing package, provided in the case database, seeking and securing approval from leadership of the organization being inspected detailing the research objectives and approaches to be used and finally, 4) the researcher and the IG team developed rules of engagement, provided in Appendix IV governing the researchers conduct and interaction with inspectors and players while collecting case data. The ACC/IG team agreed to allow the researcher to conduct this research during four Operational Readiness Exercises and Inspections. This documentation is provided in the case database with samples in Appendix IV.

With regard to this last measure the rules of engagement were designed to support two main goals, 1) ensuring the soundness of the research as

discussed in this section and secondly 2) complying Air Force regulation and policy interpretation regarding the release of inspection information. Essentially these rules of engagement are centered on establishing and maintaining anonymity for units and personnel being inspected, as well as, providing participants a chance to review collected case data, analysis, and conclusions; again both of these efforts are mutually supported by the desire for research soundness and the Air Force's rules for information release.

Data Sources and Research Challenges

A critical task of this investigation is to incorporate these design objectives and constraints into a data collection and analysis protocol that also meets the remaining research design challenges that have been specified in Figure 4.1. The remainder of the protocol with regards to the data sources thus becomes design guidance for developing the data collection instruments themselves, then and analyzing the resulting data. As described previously, the goals of the data collection efforts are, 1) to observe if the DC5 framework provides a means for framing the distributed cognition phenomena occurring in the control center, 2) to observe if the DC5 framework can serve as a basis for providing an initial assessment of distributed cognition fitness, 3) to observe if the DC5 framework can serve as a basis for developing training scenarios for future exercises that will improve performance, 4) to develop a means of characterizing performance of the distributed cognition system, 5) to develop a means of characterizing the

crisis environment of a given scenario within an exercise and 6) to account for measurement influences on distributed cognition system fitness.

Table 4.2 serves to inform the development of the protocol design guidance for the data collection instruments by detailing which data sources can be used to address which research design objective. These subsequent intersections of data source and research design objective can in turn be used to develop specific interview questions as well as guidance to orient the researcher as he observes the UCC in action during exercises and inspections.

Table 4.2: Data Sources vs. Design Objectives = Protocol Guidance for Data Collection Instruments

	Data Sources					
Research Design Objectives	A) Pre-ORE Player Interviews	B) ORE Scripts	C) Researcher Observations	D) Post-ORE Player Interviews	E) Post ORE Evaluator interviews	F) ORE Performance Reports
1) Is DC5 a valid set of constructs for describing distributed cognition phenomena?	A1 - Capture contextual attributes of players - Capture expectations of players, possibly in DC5 terms - Capture preconceptions of players regarding DCOGF, possibly in terms of DC5	B1 - Can scenarios be characterized in terms of DC5, specifically Crisis Environment [CE]?	C1 - Can observations be coded readily into the constructs of DC5? - Is further ordering and understanding of observation gained by using DC5?	D1 - Are failures or successes readily characterized in terms of DC5? - Are scenarios readily characterized in terms of DC5?	E1 - Are failures or successes readily characterized in terms of DC5? - Are scenarios readily characterized in terms of DC5?	F1 - Can formal write-ups be readily captured within DC5 constructs?
2) Can DC5 serve as a basis for providing an initial assessment of distributed cognition fitness?	A2 Not Applicable	B2 - Capturing [CE] in conjunction with Performance [P] is key to using DC5 to assess DCOGF	C2 - Can interpreting observations in terms of [P] and [CE] yield a good characterization of [DCOGF]?	D2 - Asking players for there own assessments of performance in light of crisis conditions. Are their answers readily interpretable in terms of DC5?	E2 - Asking evaluators for their assessments of performance in light of crisis conditions. Are their answers readily interpretable in terms of DC5?	F2 - Can formal write-ups be readily captured within DC5 constructs?
3) Can DC5 serve as a basis for developing training scenarios to facilitate improvement?	A3 - What kind of scenarios do players think they need to work on?	B3 - Use in developing scripts	C3 - What kind of scenarios do observations indicate that require work?	D3 - What kind of scenarios do players think they need to work on?	E3 - What kind of scenarios do evaluators think they need to work on?	F3 - Do formal write-ups lead to scenario development for future training?
4) Can [P] be captured/ characterized?	A4 Not Applicable	B4 Not Applicable	C4 - Describe general feeling of how UCC performed? In light of [CE]	D4 - Capture feelings of how players thought their UCC performed in light of conditions	E4 - Capture feelings of how evaluators thought their UCC performed in light of conditions	F4 - Capture formal write ups Are they interpretable in light of [CE]?
5) Can [CE] be captured/ characterized	A5 Not Applicable	B5 - Characterize scripted scenarios [CE] explicitly in terms of DC5	C5 - Characterize scenarios as they occur [CE] explicitly in terms of DC5	D5 - Capture players view of scenarios	E5 - Capture evaluators view of scenarios	F5 - Capture any formal discussion of scenarios that may exist in report
6) Does resultant DCOGF account for measurement influence	A6 - Seek to determine if research is influencing player's actions	B6 Not applicable	C6 - Seek to determine if researcher presence is influencing actions of players	D6 - Seek to determine if research is influencing player's actions	E6 - Seek to determine if research is influencing evaluator's actions	F6 Not applicable

Additionally, the constructs of the DC5 framework will guide the substantive matter involved in the questionnaires, observation guidance, and evaluation reports review.

It should be noticed at this point that an additional design objective will be discussed and implemented also in Appendix III. The additional design objective is to incorporate practical design guidance relating to long-interview questionnaire development based on the experience of other researchers.

Data Collection and Analysis: Protocol's Development to Support Determination of DC5 Suitability for Distributed Cognition Fitness Assessment

The primary challenge governing the development of the data collection instruments is that each instrument attempts to collect data in such a way that it lends itself to being processed easily into a formal assessment of the fitness of the distributed cognition system. The researcher will have to gauge if indeed the subsequent data collection effort is complete in capturing relevant data to the health of the system. To the extent that data observed does not lend itself to being readily assembled into the constructs of the DC5 framework, the framework will require adjustment. The primary data sources for this effort will be researcher observations, evaluator observations, and formal report write-ups. Additional triangulation, pattern matching, and evidence-chain supply may be found from pre- and post-player interviews by essentially asking them to explain how they think they performed after an exercise. A key facet of the DC5 framework in this case, captured conceptually as [DCOGF] = [P]/[CE] in Chapter III, is interpreting performance in light of the given crisis conditions of a particular scenario. Thus observations will have to be geared for looking for such interpretations as will interview questions. To the extent observations and

answers do not fit readily with this approach, the framework will have to be adjusted.

Data Collection and Analysis: Protocol's Development to Support Determination of DC5 Suitability as a Basis for Developing Training Scenarios

Although data collection instruments, such as the evaluator interviews, player interviews, and researcher observations can be designed with this design objective in mind (i.e., to Support Determination of DC5 Suitability as a Basis for Developing Training Scenarios) , the aim is primarily oriented to the analysis stage of the effort. Specifically, the assessment will identify areas of strengths and weakness within the control center. Scenarios with [CE]'s specific to these attributes can then be developed and scripted for the next operational readiness exercise which will stress the areas needing improvement. Assessments can then be made again to characterize improvement and validate the framework in terms of this objective. Given exercise constraints and limited time, scenarios will have to be prioritized to facilitate optimal performance improvement (i.e., the weak areas will have to be prioritized for training and iterative repetition).

Data Collection and Analysis: Protocol's Development to Support Capturing Performance

This research design objective primarily impacts data collection. Performance is readily captured in report ratings, the interpretations of evaluators and the researcher, and can be triangulated by eliciting the thoughts of the

players after an exercise. Of a practical note here is the 5-tier ordinal, categorical grading construct used in the Air Force: Outstanding, Excellent, Satisfactory, Marginal, and Unsatisfactory. The formal definition of these terms from Air Force regulations is supplied in Appendix I, but because they have been used recurrently for so long, and not just in operational readiness exercise/inspection setting, within the Air Force these terms have become institutional vocabulary. It will not be difficult to elicit responses from evaluators relating to performance. The key will be following up on such pronouncements by having personnel explain their assessments in the context of the crisis environment occurring at the time as DC5 suggests.

An additional and important means of descriptively characterizing performance will be by comparing the representations being used by the UCC over time to the true state of the outside environment, which the researcher will have by virtue of having the exercise script. To the extent that representations, the so-called heart of cognition discussed in the literature review, displayed, discussed, and acted upon deviate from the existing real world environment, performance can be descriptively characterized as degraded. It should be noted that defining performance in this way necessarily scopes out of consideration the decision and action portions of most of the reviewed frameworks. The reason for this scoping in the context of this research is one of simply bounding accomplishable work. Decision analysis and strategy development and implementation are sciences unto themselves and go beyond the scope of this research. Focusing on representations themselves allows for the simpler

definition of performance. To the extent the other constructs, decision and action compromise performance even in the presence of well-maintained, accurate UCC representations the research will be complemented by the converging means of characterizing performance discussed in the previous paragraph. Given this *representational* basis for capturing performance a key focus of the researcher will have to be on capturing the explicit and implicit representations used by the UCC and its individual players using converging data sources.

Data Collection and Analysis: Protocol's Development to Support Capturing the Crisis Environment

The focus in this section will be on developing questionnaires and being prepared to observe and capture data in terms of the crisis environment specified in the DC5 framework. The script itself can be reviewed by both researcher and evaluators to gain a characterization of crisis intensity as proscribed by the framework. Player interviews after the fact can be used to triangulate such interpretations. Once [CE] is captured using the framework it can be used to interpret performance characterizations in terms of distributed cognition system fitness.

Data Collection and Analysis: Protocol's Development to Ensure Distributed Cognition Fitness Assessment Does Not Lead to Measurement Influence

The key to meeting this objective, primarily one of data collection as opposed to data analysis, is for the researcher to follow practical guidelines

based on the vast experience of other researchers in the development of questionnaires to ensure that measurement is as precise and accurate as possible. A review of such methods is undertaken in Appendix III where the questionnaires themselves are presented.

Summary

The purpose of this chapter was to develop a research design that will attempt to validate the proposed DC5 framework, specifically addressing focused objective 4 developed in Chapter I. To this end, a description of data sources was provided. They were subsequently integrated with specific case study design strategies developed to enhance research rigor and soundness. The net result was the development and presentation of a research design protocol detailing the guidance for developing and deploying design instruments that will be used to capture, consolidate, and analyze case data. The instruments themselves that flow from this research design and the resulting protocol are provided in Appendix III. A final note on data collection is in order. The case database will be maintained by the researcher on CD-ROM and, in the case of field notes, in a filing system.

CHAPTER V

ANALYSIS

Purpose and Organization of Chapter

The purpose of this chapter is to 1) present the data gained from the cases, and 2) to present a discussion of the data that leads to the validation or modification of the proposed DC5 framework. As discussed in Chapter IV, the research approach involved 1) a case study involving an Air Force unit conducting two successive operational readiness exercises in preparation for a final formal operational readiness inspection, for a total of three case data collection iterations, and 2) a second case involving an Air Force unit participating in a single operational readiness inspection. Each case and iteration presented the opportunity to validate or refine the DC5 framework in terms of its usefulness for understanding the distributed cognition phenomena occurring in the unit's control center. Furthermore, the time between the successive operational readiness exercises in the first case presented the opportunity to further test the framework's usefulness as a basis for intervention by developing an exercise script designed to train control center systems and personnel to improve the center's performance.

Figures 4.1 and 4.2 from the last chapter summarize the research design. The organization of this chapter will be 1) a brief overview of the case data from the first operational readiness exercise involving the first case, 2) a summary of findings based on this data, 3) the subsequent refinement of the DC5 framework,

4) development of the intervening script for the second operational readiness inspection, 5) a brief overview of the case data from the second operational readiness exercise, 6) a summary of findings from this second exercise, 7) the subsequent refinement of the DC5 framework, 8) a brief overview of the case data from the operational readiness inspection for the second case, 9) the subsequent step of refining the DC5 framework, 10) a brief overview of the case data from the final operational readiness inspection for the first case, and 11) the subsequent and final iterative refinement of the DC5 framework. The second case is inserted between the second and third iterations of the first case in the discussion here because that is the position longitudinally in time in which the case occurred. The detailed results of the data collection instruments from the case iterations upon which the overview summaries presented in this chapter are based can be found in the case database.

In the brief overviews of case data for each Operational Readiness Exercise or Inspection suggested above, only the key raw findings from the data collection instruments relating to distributed cognition will be discussed. Many raw findings will have little to do with distributed cognition; for example, data from evaluators, participants, and other sources may converge showing that the unit being inspected has significant problems across personnel, even control center personnel, with safe handling and care of weapons. Such a finding has little to do with distributed cognition and will not be presented here. Alternatively, other findings will be initially listed and detailed in their raw form in these overviews because they represent emergent manifestations of underlying issues relating to

distributed cognition. Explanation of why such raw findings relate to distributed cognition will be provided in the subsequent sections as their impact on the DC5 framework is presented.

In addition to the narrative discussion that follows, after the review of each Operational Readiness Exercise or Operational Readiness Inspection, the iterative refinement of the DC5 framework will be captured by 1) rewriting Table 3.1, Crisis Environment Effects on DC5 Subsystem Performance and 2) redrawing Figure 3.4, DC5 Theoretical Framework. The former captures the specific impacts of the crisis environment on distributed cognition phenomena while the latter captures the interrelationships and definitions key to the framework's development.

Finally, as the case data is analyzed and used to validate each individual cell within the progressively refined tables that follow, the researcher will provide a qualitative assessment regarding the degree to which the data converges with the proposed theory. The intent is to distinguish, only at the ordinal level, the degree of such convergence within the case database; it became apparent as analysis began, that in some instances such convergence was of a much greater degree than in others in which it was indeed still present, and in others still where little or no convergence was noted. This assessment will be based on the 1) degree to which the data converges itself; that is a variety of data sources concur that a finding is accurate and 2) the degree to which that finding confirms the impact of the crisis environment on distributed cognition phenomena as suggested by the DC5 framework. An assessment rating of "Considerable

Convergence" will be given those cells in which 1) a large majority, that is at least 2/3rds of informants who have insight into the particular issue, agree that a particular issue was noteworthy and 2) the noted effect aligns with that predicted by the DC5 framework. An assessment rating of "Notable Convergence" will be given those cells in which 1) a simple majority, that is more than 50% of informants having insight into an issue, find it noteworthy and 2) it aligns with some of the particular effect suggested by the DC5 framework but not all of it, in other word the data suggests some but not all predicted effects as well as some non-predicted effects. If the data suggest some non-predicted effects according the fractions of observing informants suggested above the appropriate level of convergence will be noted and appropriate modification to the DC5 framework will be presented. Finally, in many instances there may be no intersection between the predicted effects and the given case scenarios; a particular crisis element may not be experienced during the evaluation or inspection. In this case the provided assessment will be "no intersection with DC5 constructs."

Overview of Data from Case 1, 1st Operational Readiness Exercise

This overview of the case data from the first operational readiness exercise (ORE) will include 1) an introduction to the specific setting in which the ORE occurred and a description of the unit participating in the ORE, 2) a listing describing the key events of the ORE as seen by the researcher and other evaluators, 3) and a summary of the raw findings obtained after an analysis performed by the researcher and other evaluators. Afterwards, in subsequent

analysis, this information will be analyzed as suggested by the research methodology and design.

The Setting of the First Case

In developing a schedule and plan of preparation for their April 2006 formal Operational Readiness Inspection to be conducted by Air Combat Command's (ACC) Inspector General (IG) team, the executive officer, who works directly for the wing commander – the head of the unit to be inspected, was referred by members of the inspector general team to the researcher. The unit was seeking 1) someone who could aid in developing and implementing ORE scripts similar to those the IG would use in the formal inspection and 2) someone who could aid specifically in improving the performance of the wing's Survival Recovery Center (SRC). The entire wing had originally been inspected in May 2005 and two specific functional component performance areas were found to be below ACC standards, one of those being the performance of the survival recovery center. As a result, the deficient areas were scheduled for the re-inspection in a limited (i.e., not the entire wing) ORI scenario by the IG in May 2006.

With regard to the deficient performance of the SRC in the original May 2005 ORI, the formal inspection report cites the following recommended areas for improvement: 1) the SRC did not have redundant procedures for sector chiefs during relocation operations causing a 1-hour and 30-minute delay in post attack reconnaissance team release, 2) Lack of status boards to track contaminated

personnel and equipment did not allow a quick reference for the Wing Operating Center commander, 3) the SRC did not have all functional squadrons represented in the SRC halting critical post-attack assessments, 4) the SRC did not utilize appropriate functions during post-attack assessment to advise the commander, 5) Sector representatives in the SRC did not retrieve and report post-attack assessments to readiness representative, 6) the SRC did not prioritize facility damage IAW Base X-Plan priority list, 7) the SRC did not track Airfield Damage Repair or status of repairs on the airfield, 8) Unexploded Ordnance (UXO) prioritizing and plotting was confusing and took too much time, holding up the mission, 9) the Base went alarm green MOPP 2 general release without UXOs identified on the base grid map, 10) the SRC plotted one UXO four times and held up recovery operations, 11) the SRC was unaware of a cleared UXO until 9 hours after clearance, and 12) the SRC relied heavily on the base attack recovery tracking system (BARTS) computer message board not utilizing functional representatives in the SRC.

It was in light of these difficulties and the desire to correct them that the wing sought help from the IG as they prepared for their May 2006 re-inspection. Thus the researcher and the wing executive officer, acting in his position as head of the wing's exercise evaluation team, met prior to the ORE in November 2005 and scripted the exercise. After some discussion, it was decided that given the extent of the deficiencies in the SRC and another completely separate, functional area with problems cited by the IG, the primary focus of the script should be first, on allowing the wing to start slowly and begin to re-learn basic task-executional-

proficiency in these areas and 2) provide enough intensity to gain a measure of where these areas stood in terms of performance that assessments and future training regimens could be established. To generalize, the operative analogous phrase used to describe this idea was *"you have to walk before you can run."*

The Key Events of the First Case: The Script as Implemented

In terms of the intensity of the script, suggestive of the pace of events and scale of events of the DC5 framework developed in Chapter III, on the first day of the exercise this amounted to 1) a false alarm of an inbound enemy missile to allow the unit to begin slowly and gain a feel for executing wartime response procedures, 2) an inbound missile attack resulting in a broad range of differing impacts across the base play area, 3) a small narrowly focused small ground based aggressor attack with minimal damage 4) a focused missile attack resulting in extensive damage to a single building/organization while the rest of the base remained unscathed, and 5) relatively limited damage from a nighttime missile attack. On the second day of the exercise the script consisted of 1) one widely impacting missile impact, 2) one focused, limited missile attack and 3) one limited small ground attack by aggressors. It should be noted that after reaching a consensus with evaluators at the end of the first day, the evaluator team chief and the researcher scaled the script back even further as another area of unit performance outside of command and control was found to be significantly deficient in terms of performance as to require near remedial training by

evaluators. Training which was determined could best be accomplished with a very light script intensity in terms of attack intensity.

<u>The Raw Results of the First Case – First ORE</u>

Drawing on the case data from the data collection instruments described in Chapter IV, specifically the interviews/discussions with players and evaluators, the final exercise report, and the researchers notes, convergence seemed to emerge around the following raw findings to be discussed in further detail below: 1) contextually, the deficient performance of a key area outside that of command and control, the focus of this research, limited to a degree the ability to stress the survival recovery center, 2) control and tracking of Post-Attack Reconnaissance (PAR) teams was weak and non-expeditious, 3) the unit's implementation of an innovative computerized message board system greatly facilitated command and control while introducing some novel challenges to control center, 4) some improvement in the use of visual aids would facilitate a quicker processing of information by control center personnel and 5) distribution of imminent attack information could be improved. Further description and elaboration on these points is provided below in raw terms as they emerge from the collection instruments. Actual refined discussion of their interpretation in terms of the proposed DC5 framework will follow in the next section. A more exhaustive review of the data collected during the case and the degree, or lack of thereof, of data convergence on particular issues is presented in summary form in Appendix V, Case 1 Data Results using the questions of the data collection instruments as a means of presenting and summarizing the results of each individual data collection effort.

As described in the discussion on the setting of the exercise, a key area of unit performance separate and outside that of the survival recovery center was found to be deficient during a formal inspection in May of 2005. As a result, when the terms of evaluation were negotiated for the re-inspection to take place in May of 2006, the vast majority of the unit's functions that were found to meet or exceed Air Force standards were eliminated from the re-inspection. Therefore contextually, the value of the exercise to training the control center, and as result to this research was somewhat limited because 1) the amount of participants, organizations, buildings, and infrastructure involved in the exercise and therefore available to be damaged stressing command and control was limited and 2) the other deficient area referred to here required enough significant attention from senior leadership and evaluators that the ability to focus on the control center was limited. This point was 1) noted by the researcher throughout preparation and execution of the exercise, 2) was specifically cited by several players in the control center as well as senior leaders during the exercise in the course of conversation and during post-exercise interviews, 3) and was noted by several evaluators during and after the exercise. Convergence on this point is clear.

Following any type of attack on an air base, including missile, bomb, or mortar impact or physical or small arms ground attack by combatants, a post-attack reconnaissance (PAR) sweep of the base land area and assets is conducted. In general, a PAR sweep involves the release of teams in sectors of the base who then sweep there area of responsibility looking for damage, casualties, accounting for personnel, unexploded ordnance and any other areas

or causes for concern. As the PAR teams complete their sweeps and up-channel the information the SRC collects and assembles the information into displays, messages, and prioritized visual aids eventually assembling a picture of the base for senior leadership to act on in terms of returning some normalcy to operations. Both the researcher based on experience and senior evaluators agreed PAR information was 1) not being collected fast enough 2) not flowing to the control center fast enough and 3) the PAR teams were not being controlled or perhaps pushed or motivated to accomplish their tasks quickly and proficiently enough. The impact of this general slowness was that unit leadership was unable to return the unit to some sense of normal operations, or launching of aircraft, in an expeditious manner. The observations of the researcher and evaluators were made both during and following the exercise. Similar convergence on the issue was noted in the discussion of control center personnel as they waited for an extended period for information to flow. Some improvement was seen over the course of the exercise but the deficiency was significant enough to see the issue repeatedly cited in the final report.

The unit had developed a computerized message board system that allowed the survival recovery center, subordinate unit control centers, and indeed anyone with limited password-controlled access to the base network the ability to monitor any information being posted throughout the unit. Such information included attack damage, threat intelligence, recovery operations, unit status, personnel accountability, and other general information wing leadership or others wished to communicate. The speed with which the information was posted and

read, in the judgment of the author, was much faster than typical verbal, phone and radio based communication and limited only by the speed and diligence by of the posters and readers. Convergence on the strength of this artifact of the unit's command and control system was of lesser degree than other key findings cited here, primarily because other evaluators lacked the command and control evaluation experience to compare it to general standards of performance of other units and their systems. To the extent evaluators other than the researcher observed the system in action they were positive. Unit leadership was both happy with the capability of the system and its performance and considered its innovation and development a point of pride. It should be noted that when the survival recovery center was formally evaluated by the ACC IG team in May 2005, some areas for improvement relating to the system were noted. Specifically cited was an over-reliance on the system to the negation of using control room personnel to distribute, interpret, and analyze information. In the researcher's opinion this observation, also noted in the November 2005 ORE, represents implementation issues associated with the system more than a lack of convergence on the attributes of the system as positively or negatively impacting performance. As more detailed discussion of the specific issues cited by the IG team lends itself to framing questions associated with the DC5 framework, it will be covered in the next section.

The control room visual aids could have been improved. Cited by both the researcher and the evaluation team chief, these included 1) adding a large base map in the survival recovery center with damage plotted by type for easy referral

by unit leadership and control center personnel would have led to quicker more accurate understanding of events and reaction times and, 2) a visual aid with an easily readable listing of damage prioritized for response should have been used. While noted primarily by the researcher in his observations, some convergence on this point in discussions with control room personnel and wing leadership existed.

Finally, executing key command and control functions in disseminating essential imminent attack and threat information needed improvement. These mistakes in the execution included general slowness or ineptness in using information distribution systems to indicate changes in threat/alarm conditions from the control center to the unit at large. Specifically, outdoor loudspeakers were slow in passing on key timely information regarding attack, frequently the speaker stumbled on her words or misspoke, and use of flags to indicate threat condition was slow and incorrectly executed. The researcher's notes, observations of other evaluators, the final exercise report, and to a lesser extent, discussion with control center and leadership personnel, all converged on the importance and accuracy of these observations.

Analysis of First Case Key Findings

The analysis of the case data from the first case will consist of three parts. As discussed in Chapter IV, the research design/analysis will follow two tracks: 1) the first being interpreting the emergent converging themes of the case data into those supporting the DC5 framework as the theory was developed in Chapter III

and those supporting modification of or incongruity with the framework. This first track analysis will then be applied by modifying the DC5 framework accordingly. 2) The second track of the research design will involve using the DC5 framework and the case data to characterize the crisis environment in order to develop a fitness assessment based on the DC5 framework. This assessment in turn will be used to develop the crisis environment for the second ORE, for the unit in question with the hope that the framework will prove its usefulness by serving as training tool for such control centers.

Before either of these discussion tracks begins some critical reflection on expectations developed regarding the research versus the reality of what was found and the resulting impact on the research is in order and follows thusly.

Researcher Expectations vs. Case Realities

The gap seen by the researcher between prior expectations for the research and the reality of the first case after reflecting upon it, focus around the impact of the limitations of the ORE setting on the ability to completely apply the developed research design for validating the DC5 framework. As discussed in the previous section, the ACC/IG team inspected the unit that was the subject of the case in May of 2005 and two key areas of performance, one being the SRC, were rated as below standard and scheduled for re-inspection in May of 2006. This re-inspection would involve only those portions of the unit that had been rated poorly and as a result a significant fraction of the unit would not be playing in the retake. This scenario, which would also be used for the OREs conducted

by the unit in preparation for the formal ORI, then necessarily impacted the ability to stress the SRC because a significant fraction of the information flow generated during the exercise would disappear or be greatly minimized by the lack of playing sub-units.

This lack of play impacted the research in three ways. 1) Because only one other significant section of the unit was playing in the ORE, the diversity of sources and disciplines generating information was limited. Specifically, this limited the ability to collect data relating 1) to the DC5 construct of coordination as a key system of the control center and 2) to the ability to create a crisis environment demanding the integration of diverse expertises in the control center. As a result, in the analysis that follows, relating to the interpretive research approach, track one, of the research design, interpretation in terms of DC5 constructs, little is postulated in this area. In addition to limiting the ability to create a crisis environment testing integration of diverse information flows, the limited size of the scenario, to a lesser extent, also limited the ability to stress the SRC with information overflow. Although the SRC was stressed and case data indicates such, this additional source of stress was not available. Finally, as a result of the scenario limitations, track 2 of the research design, developing a fitness assessment and subsequent training crisis environments, was also impacted.

Despite these limitations specifically detailed above and given that their impact upon the research is precisely cited, the case data and the research

design remains viable for interpreting, testing, and validating the remainder of the DC5 framework as well as for proving the remainder's usefulness.

Track 1: Interpretation of Case Data: Emergent Converging Themes and the DC5 Framework

The first track of the research design seeks to show the actual usefulness of the DC5 framework for interpreting the observed distributed cognition phenomena. To the extent emerging observations readily converge with suggested theory the framework has demonstrated its holistic (i.e., nomological) validity as well as its specific construct validity. To the extent emerging observations do not readily converge with the suggested theory then the framework has demonstrated the need for modification or further study. Table 5.1, mirroring Table 3.1, Crisis Environment Effects on DC5 Subsystem Performance, which described in detail the theoretical impacts of crisis conditions on distributed cognition phenomena, provides the organization for the detailed discussion which follows regarding: 1) the areas in which emergent observations from case 1 converged with suggested framework constructs and their interaction, 2) diverged from the suggested theory, 3) required modification to the suggested theory, or 3) remained ambiguous with regards to the suggested theory. Table 5.2, Case 1 Implications for DC5 Framework, based on the framework of Table 5.1 summarizes the researcher's assessment of the case data and its implications for the DC5 framework. An exhaustive discussion of how these assessments were reached for each cell in Table 5.2 is provided in Appendix VI.

Table 5.1: Crisis Environment Effects on DC5 Subsystem Performance (Reprint of Table 3.1)

	S1. Autonomous Units	S2. Coordination	S3. Control	S3*. Monitoring	S4. Intelligence	S5. Identity	Context
Real Crisis Pressure (Potential for adverse organization outcomes + inducement of stress)	- System self-doubt might increase - Sensitivities to stimulus increased -Focus changes	- Differences amplified - Acquiesce to consensus - May not seek consensus	- Pressure S1 to provide more information and S2 to process more information - Increase demands on S4 for implementable solution	- Must determine if S1's are handling pressure appropriately	- Demand more information to get representation right	- Seek more confidence in representation before selecting alternatives - Selection/ decision/action goes to the organization core so balance is less routine	- Increase focus/pressure may cause HOV to be ignored - Increase pressure on individual systems may cause loss of IS with other systems - Staff competence directly impacted - Leadership directly impacted
Complexity: Demand For High Levels Of Specialized Expertise	- Ability to correctly inquire about data increasingly challenged	- Possible increased demand between systems	- Must ascertain when S1 has become overwhelmed	- Must ascertain when S1 is no longer up to environmental demands	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- Staff competence up to the task - Leadership increasing S1 performance
Complexity: Demand for Integrated Expertise	- Ability to correctly inquire about data increasingly challenged	- Challenged with knowing who needs to be involved in processing information	- Must ensure coordination is functional	- Must ascertain if S2 is no longer capable of meeting requirements	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- HOV and IS crucial - SC and Leadership also important
Complexity-Novelty unknowability	- Ability to correctly inquire about data increasingly challenged		- Can recognize when more data collection is fruitless		- Can recognize when more data collection is fruitless	- Required to adjust decision making approach based on known lack of knowledge	
Complexity-Novelty number of entities	- Ability to track and process data challenged because of volume	- Ability to coordinate/assimilate data challenged because of volume	- Can recognize when systems becoming overwhelmed	- Must ascertain if S1's and S2 up to task/replaceable	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- Flexibility key - Redundancy may prevent processing errors
Complexity-Novelty pace of events	- Ability to receive and process data challenged	- Ability to process data challenged	- Increase demand for a timely plan of action	- Must ascertain if S1's and S2 up to task/replaceable	- Ability to interpret data increasingly challenged	- Senses need to act quickly	- Redundancy may prevent processing errors

Table 5.2: Case 1 Results: Convergence between DC5 Framework and Emergent Themes

	S1. Autonomous Units	S2. Coordination	S3. Control	S3*. Monitoring	S4. Intelligence	S5. Identity	Context
Real Crisis Pressure (Potential for adverse organization outcomes + inducement of stress)	Notable Convergence	Insufficient Data	Considerable Convergence	Notable Convergence and Modification needed	Considerable Convergence and Modification needed	Considerable Convergence	Not Validated/ Insufficient Data
Complexity: Demand For High Levels Of Specialized Expertise	Insufficient Data	Insufficient Data	Notable Convergence	Notable Convergence and Modification needed	Insufficient Data	Notable Convergence	Notable Convergence
Complexity: Demand for Integrated Expertise	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
Complexity-Novelty unknowability	Insufficient Data		Insufficient Data		Insufficient Data	Notable Convergence	
Complexity-Novelty: number of entities	Considerable Convergence	Considerable Convergence	Notable Convergence	Notable Convergence/ MODIFICATION NEEDED	Notable Convergence/ MODIFICATION NEEDED	Notable Convergence	Considerable Convergence
Complexity-Novelty pace of events	Considerable Convergence	Considerable Convergence	Considerable Convergence	Considerable Convergence/ MODIFICATION NEEDED	Considerable Convergence MODIFICATION NEEDED	- Considerable Convergence	Considerable Convergence

Track 1, Case 1: Summary of Case Data versus DC5 Framework

The key points seen arising from the first case in terms of validating the DC5 framework are 1) the limitations of the narrowness of the scenario resulted in a significant portion of the framework not being able to be validated, as detailed in the discussion and Table 5.2, positively or negatively, 2) A significant portion of the framework was indeed validated; case data and key findings were readily interpretable by DC5 constructs and relationships, again as detailed in the discussion and in Table 5.2, 3) the case readily demonstrated that as crisis conditions intensified the ability for the S3 control sub-system to perform the audit, fire, and replace functions became less realistic of an option; because of the crisis constraints, the distributed cognition system is stuck with the subsystems it enters the crisis with to great extent, and finally 4) assessing the relative importance of incoming information, distinguishing signal from noise, is a vital part of the intelligence function, S4, of distributed cognition system functions in crisis conditions.

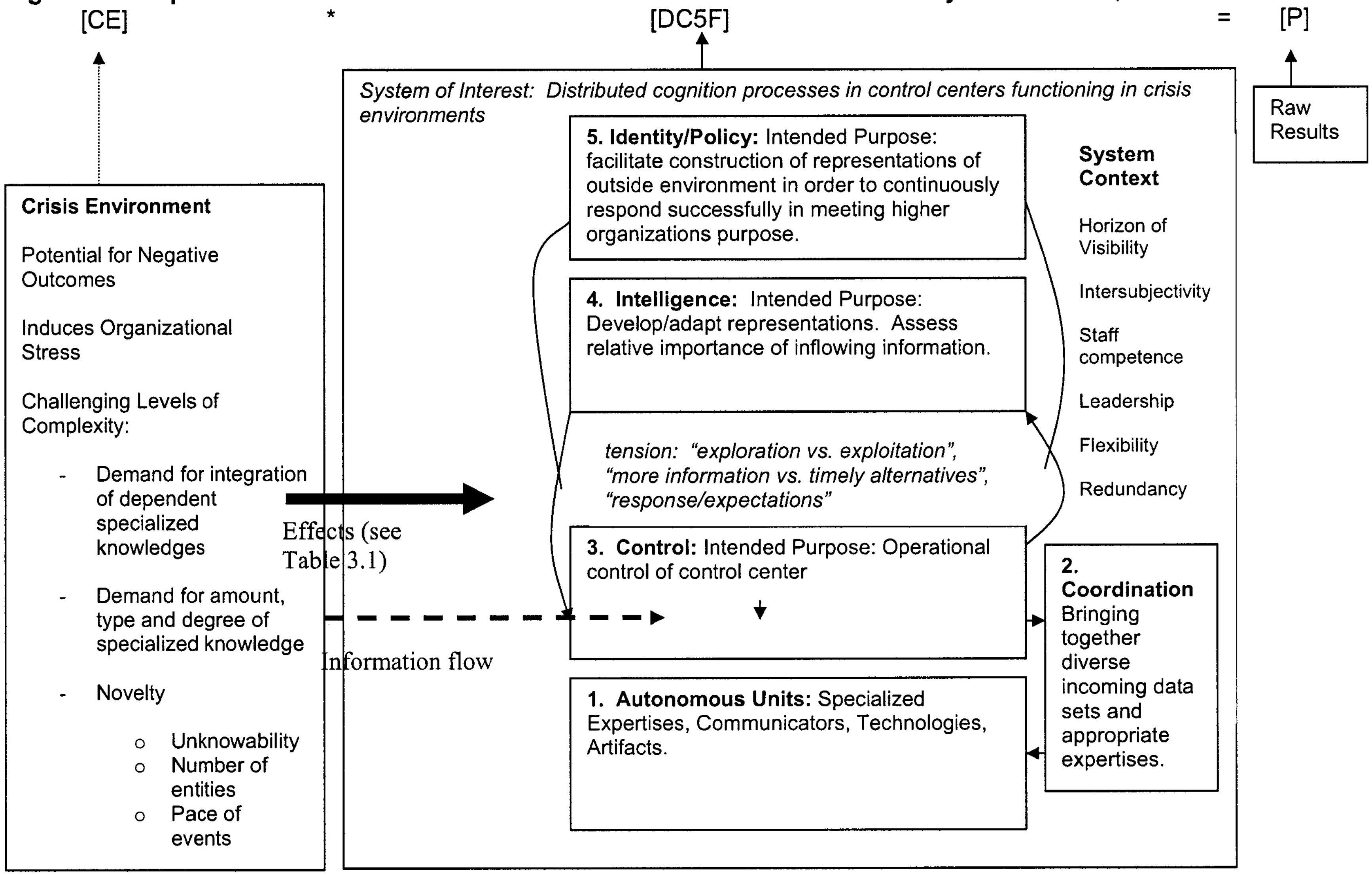
Table 5.3 captures the modifications suggested by the latter two points above as does Figure 5.4. The functions of S3* are reflected in S3 as they still represent real responsibility for S3 but as the ability to performed detailed audit like investigations become limited, the separate functional subsystem is eliminated. Additionally, the S4 system is updated emphasizing the importance of assessing the relative importance of incoming information as crisis conditions intensify.

The next step in applying the research design will be initiating track 2, attempting to use the framework to characterize crisis environment, control center fitness, performance, and develop a script accordingly for the next ORE, all in an effort to demonstrate the usefulness of the DC5 framework.

Table 5.3a: Crisis Environment Effects on DC5 Subsystem Performance - Modifications from Case 1, Track 1 - First ORE

	S1. Autonomous Units	S2. Coordination	S3. Control	S4. Intelligence	S5. Identity	Context
Real Crisis Pressure (Potential for adverse organization outcomes + inducement of stress)	- System self-doubt might increase - Sensitivities to stimulus increased - Focus changes	- Differences amplified - Acquiesce to consensus - May not seek consensus	- Pressure S1 to provide more information and S2 to process more information - Increase demands on S4 for implementable solution - Must determine if S1's are handling pressure appropriately	- Demand more information to get representation right - Heightened awareness of need to assess the relative importance of information	- Seek more confidence in representation before selecting alternatives - Selection/ decision/action goes to the organization core so balance is less routine	- Increase focus/pressure may cause HOV to be ignored - Increase pressure on individual systems may cause loss of IS with other systems - Staff competence directly impacted - Leadership directly impacted
Complexity: Demand For High Levels Of Specialized Expertise	- Ability to correctly inquire about data increasingly challenged	- Possible increased demand between systems	- Must ascertain when S1 has become overwhelmed - Must ascertain when S1 is no longer up to environmental demands	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- Staff competence up to the task - Leadership increasing S1 performance
Complexity: Demand for Integrated Expertise	- Ability to correctly Inquire about data increasingly challenged	- Challenged with knowing who Needs to be involved in processing information	- Must ensure coordination is functional -Must ascertain if S2 is no longer capable of meeting requirements	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- HOV and IS crucial - SC and Leadership also important
Complexity-Novelty unknowability	- Ability to correctly inquire about data increasingly challenged		- Can recognize when more data collection is fruitless	- Can recognize when more data collection is fruitless	- Required to adjust decision approach based on known lack of knowledge	
Complexity-Novelty number of entities	- Ability to track and process data challenged because of volume	- Ability to coordinate/assimilate data challenged because of volume	- Can recognize when systems becoming overwhelmed - Must ascertain if S1's and S2 up to task/replaceable	- Ability to interpret data increasingly challenged - Heightened awareness of need to assess relative importance of information	- Required to adjust decision making approach based on known lack of knowledge	- Flexibility key - Redundancy may prevent processing errors
Complexity-Novelty pace of events	- Ability to receive and process data challenged	- Ability to process data challenged	- Increase demand for a timely plan of action - Must ascertain if S1's and S2 up to task/replaceable	- Ability to interpret data increasingly challenged - Heightened awareness of need to assess relative importance of information	- Senses need to act quickly	- Redundancy may prevent processing errors

Figure 5.4a: Updated DC5 Theoretical Framework after Modifications from analysis of Case 1, Track 1 – First ORE



Track 2: Using the DC5 Framework for Training

Track 2 of the research design focuses on demonstrating the usefulness of the DC5 framework for developing training scripts over time for successive OREs to improve the performance of an SRC. Specifically a characterization of a scripted crisis environment, [CE], in DC5 terms can be drawn from an ORE script and compared to a characterization of the performance [P] of an SRC during that ORE and a DC5 fitness assessment [DC5F] can be generated. The DC5F in turn then can be used to develop the next script specifically targeting areas of the control center for improvement.

The analysis that follows is organized first, into characterizing the crisis environment from the script of the first ORE, second, around developing a characterization of the performance of the SRC observed in the ORE, third, around comparing these first two characterizations to develop the fitness assessment of the Case 1 SRC and lastly, into developing a script for the next ORE specifically designed to maximize the training value of the ORE to the SRC. If performance improvements are seen overtime in the unit's final ORI, then some credit could be given to the use of DC5 framework for scripting purposes.

Before accomplishing this analysis and after reflecting upon the case data from the first case, the researcher believes a few critical comments are in order. First, this approach, similarly to Track1 is impacted significantly by the limitations of the setting and second and more generally, the merits of the criticism that the approach is overly sophisticated for the problem of developing training scripts.

The narrowness of the overall ORE setting, specifically the large fraction of the unit not participating in the ORE, as previously discussed, limits the ability to develop scenarios fully testing the SRC. As such, any qualitative crisis environment [CE] characterization will be also be narrow and in turn comparison with performance [P] characterizations will lead to narrow fitness profiles [DC5F] and narrow successive ORE scripts. The two responses to such criticism are 1) that it is valid, but if such limitations are used in developing conclusions and modifications to the DC5, then the best that can be done with the given case is being done, and 2) the effort of going through the process suggested by Track 2 should develop a more sophisticated and refined understanding of distributed cognition, the DC5 framework, and its implications. Further discussion along these lines and the researcher's lessons learned regarding case selection are provided in Chapter VI.

More generally, some may argue that a degree of sophistication is being applied to a problem that doesn't merit it or require it. A good script can be developed by an experienced evaluator simply by reviewing a previous exercise report and applying that experience rather than going through such steps. The researcher wholeheartedly agrees with this statement but argues that the process being applied tacitly by such an experienced evaluator, if made more explicit, essentially becomes the process of track 2. The sophistication being applied in articulating such a process allows for a better understanding of distributed cognition phenomena by more people and thus facilitates better script writing.

Characterizing the Crisis Environment in the First Case

The crisis environment as specified in the DC5 framework is shown in Figure 5.5: Crisis Environment Specification. Qualitatively characterizing the crisis environment in the first case requires detailing the individual crisis scenarios according to the DC5 framework.

Figure 5.5: Crisis Environment Specification

Crisis Environment

Potential for Negative Outcomes/Induces Organizational Stress

Challenging Levels of Complexity:

- Demand for integration of dependent specialized knowledge
- Demand for amount, type and degree of specialized knowledge
- Novelty
    - o Unknowability
    - o Number of entities
    - o Pace of events

As described in the section on the Case 1 ORE setting the script on the first day of the exercise amounted to: 1) a false alarm of an inbound enemy

missile to allow the unit to begin slowly and gain a feel for executing wartime response procedures, 2) an inbound missile attack resulting in a broad range of differing impacts across the base play area, 3) a small narrowly focused ground based aggressor attack with minimal damage 4) a focused missile attack resulting in extensive damage to a single building/organization while the rest of the base remained unscathed, and 5) a relatively limited damage from a nighttime missile attack. On the second day of the exercise the script consisted of 1) one widely impacting missile impact, 2) one focused, limited missile attack and 3) one limited small ground attack by aggressors. As detailed in the setting description the second day's script was altered mid-course as it was decided by the evaluating team chief and a consensus of evaluators that a deficient area of unit performance outside of command and control in the SRC required urgent attention and training time. Thus only the first day's events will be characterized here.

In terms of potential for negative outcomes, the pressure was constant once an attack and recovery phase was underway. UCC personnel were aware that when an attack started, the potential for making errors that would lead the unit astray, disappoint leadership, or disappoint themselves was much more likely. As a result organizational stress was induced. In the larger in-depth and in-breadth attacks more such stress was induced due to awareness that the potential for error was higher than anticipated. Interpreting performance characterizations must be done in terms of the timing of the key events from non-

stress inducing, to some stress inducing, to significant stress inducing in the script leading to the performance observations.

As detailed in the description of the setting of the ORE in Case 1, the demand for integration of multiple disciplines and the demand for a high degree of expertise in any single discipline were limited by the lack of unit sub-organizations participating in the exercise. The SRC provided a means of processing scenarios that were rather simplistic for the control center personnel.

The complexity involved in the ORE however, was due to the pace of events involved in the exercise. The attacks in breadth proscribed by the ORE script relate well to the specification in the development of the DC5 framework of complexity due to pace of events. Essentially an attack, missile or ground threat, that struck in small measure across the play area led to a series of rapid fire phone calls being made to the SRC as organizations called in damage impacts and then called in resulting secondary events, casualties, fuel spills, etc. This in turn required the SRC to juggle the posting and understanding of more events and do it more rapidly. More stress was also generated as personnel had to focus stronger attention on assessing importance of inflowing information and notifying the wing commander accordingly.

Complexity also arose out of the scale of events involved in "in-depth" attacks. In these attacks, missile or ground, a single localized impact would be extensive, (i.e. resulting in fires, craters, casualties, unexploded ordnance, mission impacts aircraft damage, and local evacuations). As it was noted in the previous section, a key difference seen in the cognitive processing of these

events, as opposed to those more characterized as being complex as result of the pace of events, is the required amount of sorting information out from overlapping reports as opposed to merely juggling issues and responses. In evaluating the coming characterization of DC5 performance, it must be specified which type of attack, pace dependent or scale dependent, was incurred.

As described in the previous discussion, no scenarios were provided by the scripted events that represented complexity characterized by unknowability; researcher and evaluators agreed all scenarios were imminently understandable given time and reasonable study given the exercise constraints. The unit personnel themselves generated some temporary unknowability for the leadership due to the slowness of the PAR teams.

Figure 5.7, Crisis Environment Characterization for Case 1, summarizes the characterization of the crisis environment from Case 1.

Figure 5.7: Crisis Environment Characterization for Case 1

Crisis Environment

Potential for Negative Outcomes/Induces Organizational Stress: Generally, elevated stress throughout the exercise, due to stress of inspection training, previous poor results, and embarrassment that may result from errors

Challenging Levels of Complexity:

- **Demand for integration of dependent specialized knowledge:** none
- **Demand for amount, type and degree of specialized knowledge:** none to little
- **Novelty**
    - **Unknowability:** none to little
    - **Number of entities:** during in "in-depth" attacks
    - **Pace of events:** during in "in-breadth attacks"

Case 1 Performance Characterization

As it was previously discussed in the section on the raw findings of the first case, characterizations of SRC performance converge around four main points: 1) the message board system, BARTS, developed and implemented by the unit to transfer, present, and store information, proved valuable in allowing the unit to develop a timely understanding of post-attack environments while presenting interesting challenges to control center personnel, 2) control and tracking of Post-Attack Reconnaissance (PAR) teams was weak and non-expeditious and needed improvement, 3) use of visual displays in the SRC could use improvement, and 4) the expeditious and accurate distribution of imminent attack information needed improvement. Overall, evaluators, the researcher, and team members agreed the performance would have barely been satisfactory in the eyes of ACC's inspector general team.

DC5 Fitness Assessment

The objective of this portion of the research design is to understand these responses in light of the crisis environment characterization to gain an overall assessment of the UCCs DC5 fitness. As such, each of the DC5 subsystems will be discussed in terms of the four raw findings and in terms of the crisis environment characterization.

Table 5.6, S1 DC5 Fitness Assessment, illustrates the assessment of the S1 subsystems in light of the crisis environment and observed findings. Specifically, future exercises will need to create environments that force the S1's

to aid in assessing the relative importance of information and environments that stress the specific S1's that were cited for not performing proficiently.

Table 5.7, the S2 DC5 Fitness Assessment, illustrates the assessment of the S2 subsystem in light of the crisis environment and observed findings. Specifically, future exercises will need to create environments that motivate the SRC to build and maintain better displays of information facilitating coordinated understanding of and response to emerging circumstances. BARTS, in particular makes the actual act of coordinating much easier by ensuring the same post attack data is readily available to all responsible for understanding such data and acting on it.

Table 5.8, the S3 DC5 Fitness Assessment, illustrates the assessment of the S3 subsystem in light of the crisis environment and observed findings. Specifically, future exercises will need to create environments that force S3 to ensure information importance is being assessed, PAR teams are performing well, and better displays are being used.

Table 5.9, the S4 DC5 Fitness Assessment, illustrates the assessment of the S4 subsystem in light of the crisis environment and observed findings. Specifically, future exercises will need to create environments that force S4 to assess information importance, to insist on more timely response from PAR teams, and to insist on better displays.

Table 5.10, the S5 DC5 Fitness Assessment, illustrates the assessment of the S5 subsystem in light of the crisis environment and observed findings.

Specifically, future exercises will need to create environments that force S5 to continue to pressure for better proficiency from S1's.

Of interesting note, is that when a similar type of process of interpreting the raw performance findings to assess the performance of the DC5 system contextual factors in light of the particular crisis environment found in the case 1 ORE was attempted, it was quickly seen that these attributes of the DC5 system being studied were subsumed in the assessment of the other subsystems. For example, the staff competence and leadership attributes are readily seen in the assessments of the S1 and S3 systems respectively. Similarly, flexibility and redundancy are captured in the assessment of the impact of BARTS in terms of coordinating responses. The lesson learned is that the contextual elements of the DC5 framework express themselves through the operation of the systemic functions of the framework.

Table 5.6: S1 (Autonomous Units) DC5 Fitness Assessment

S1				
CRISIS ENVIRONMENT	KEY OBSERVATIONS REGARDING DISTRIBUTED COGNITION PERFORMANCE OF THE UNIT			
	Use of BARTS	Slow PAR teams	Need for Better Visual Displays	Poor Communication of Alarm Condition
General Crisis Pressure	- Alleviated pressure by reducing data processing errors - Raised pressure by presenting more information for processing	- General slowness really not attributable to crisis pressure, teams were just weak in terms of competence	- Displays help manage the assessment of relative importance of information - Without them such assessment becomes more difficult	- General ineptness may be attributable to crisis pressure, second guessing of himself/herself by siren/giant voice operator
Number of Entities	-Allowed larger number of entities to be processed	- General slowness really not attributable to attack scale, teams were just weak in terms of competence	- Better displays would have allowed for broader understanding of post-attack information	- General ineptness really not attributable to attack scale, personnel were just weak in terms of competence
Pace of Events	- Allowed processing time of information bits to be greatly reduced	- General slowness really not attributable to pace of events, teams were just weak in terms of competence	- Better displays would have allowed for better paced understanding of post-attack information	- General ineptness really not attributable to attack scale, personnel were just weak in terms of competence
S1 Assessment:	- S1's need continued training on aiding in assessing the relative importance of information - Specific S1's just need more practice at performing their basic function proficiently			

Table 5.7: S2 (Coordination) DC5 Fitness Assessment

S2				
CRISIS ENVIRONMENT	KEY OBSERVATIONS REGARDING DISTRIBUTED COGNITION PERFORMANCE OF THE UNIT			
	Use of BARTS	Slow PAR teams	Need for Better Visual Displays	Poor Communication of Alarm Condition
General Crisis Pressure	- Increased HOV due to BARTS ensures all see the same data ensuring all act with the same data in mind. Coordination much better	- No interaction with S2	- Displays help manage the assessment of relative importance of information allowing different S1's to coordinate responses	- No interaction with S2
Number of Entities	- Increased HOV allows for increased coordination in responding to larger scale attacks	- No interaction with S2	- Better displays would have allowed for broader understanding of post-attack information and better coordination of responses	- No interaction with S2
Pace of Events	- More timely HOV allows for increased coordination in responding to faster paced event streams	- No interaction with S2	- Better displays would have allowed for better paced understanding of post-attack information and more timely coordination of responses	- No interaction with S2
S2 Assessment:	-S2 was generally satisfactory throughout the exercise. Event streams demanding better displays of information may make this deficiency more noticeable			

Table 5.8: S3 (Control) DC5 Fitness Assessment

S3				
CRISIS ENVIRONMENT	KEY OBSERVATIONS REGARDING DISTRIBUTED COGNITION PERFORMANCE OF THE UNIT			
	Use of BARTS	Slow PAR teams	Need for Better Visual Displays	Poor Communication of Alarm Condition
General Crisis Pressure	- S3 must ensure that assessment of relevant importance of information is being accomplished due to larger HOV	- S3 must do better job of tracking and pressuring PAR teams to perform to address pressure for information flowing from S4	- S3 must ensure better displays are built and maintained to eliminate error and ensure proficient responses	- No interaction with S3 specifically other than more pressure to get announcements done correctly
Number of Entities	- S3 must ensure that assessment of relevant importance of information is being accomplished due to larger HOV	- No interaction with S3	- S3 must ensure better displays are built and maintained to accommodate larger information flows	- No interaction with S3 specifically other than more pressure to get announcements done correctly
Pace of Events	- S3 must ensure that assessment of relevant importance of information is being accomplished due to larger HOV	- No interaction with S3	- S3 must ensure better displays are built and maintained to accommodate larger information flows	- No interaction with S3 specifically other than more pressure to get announcements done correctly
S3 Assessment:	- Scenarios should be designed which force S3 to ensure information importance is being assessed, - PAR teams are performing well, and -Better displays are being used			

Table 5.9: S4 (Intelligence) DC5 Fitness Assessment

S4				
CRISIS ENVIRONMENT	KEY OBSERVATIONS REGARDING DISTRIBUTED COGNITION PERFORMANCE OF THE UNIT			
	Use of BARTS	Slow PAR teams	Need for Better Visual Displays	Poor Communication of Alarm Condition
General Crisis Pressure	- More pressure for intelligence to assess relevant importance of information due to larger HOV	- S4 pressures for more timely PAR information	- S4 pressures S3 for better displays	- No interaction with S4
Number of Entities	- S4 must assess relevant importance of information due to larger HOV	- No interaction with S4	- S4 for must pressure S3 for more detailed displays	- No interaction with S4
Pace of Events	- S4 must provide more timely assess relevant importance of information due to larger HOV	- S4 must pressure for more timely PAR information	- S3 must pressure for more timely displays	- No interaction with S4
S4 Assessment:	- Scenarios should be designed which force S4 assess information importance, and which force S4 to insist on more timely response from PAR teams and insist on better displays			

Table 5.10: S5 (Identity/Policy) DC5 Fitness Assessment

S5				
CRISIS ENVIRONMENT	KEY OBSERVATIONS REGARDING DISTRIBUTED COGNITION PERFORMANCE OF THE UNIT			
	Use of BARTS	Slow PAR teams	Need for Better Visual Displays	Poor Communication of Alarm Condition
General Crisis Pressure	- Greater HOV due to BARTS provides greater confidence in crucial decision making	- Balances pressure between S4 and S3 to ensure more proficient action	- Balances pressure between S4 and S3 to ensure more proficient action	- Balances pressure between S4 and S3 to ensure more proficient action
Number of Entities	- Greater HOV due to BARTS provides greater confidence in crucial decision making	- No relation between constructs	- No relation between constructs	- No relation between constructs
Pace of Events	- Greater HOV due to BARTS provides greater confidence in crucial decision making	- No relation between constructs	- No relation between constructs	- No relation between constructs
S5 Assessment:	Scenarios needed that require S5 to continue to pressure for better proficiency from S1's			

Table 5.11: System Context DC5 Fitness Assessment

System Context				
CRISIS ENVIRONMENT	KEY OBSERVATIONS REGARDING DISTRIBUTED COGNITION PERFORMANCE OF THE UNIT			
	Use of BARTS	Slow PAR teams	Need for Better Visual Displays	Poor Communication of Alarm Condition
General Crisis Pressure	Improves HOV, eliminates processing errors	Greater staff competence, intersubjectivity, and leadership needed	Greater staff competence needed	Greater staff competence needed
Number of Entities	Improves HOV, eliminates processing errors	No relation between constructs	No relation between constructs	No relation between constructs
Pace of Events	Improves HOV, eliminates processing errors	No relation between constructs	No relation between constructs	No relation between constructs
System Context:	Need Scenarios which stress expeditious use of PAR teams and better displays and facilitate more practice for alarm condition announcers			

Summary of DC5 Fitness Assessment and Criticism of DC5 Fitness Assessment Research Design Track

In summary, consolidating the work above, the DC5 fitness assessment calls for the development of a crisis environment that exerts crisis pressure, with sufficient number of entities, and pace of events, so that 1) the need for assessing the relevant importance of information is stressed to all subsystems, 2) S1's gain more practice at performing and becoming more proficient at their basic tasks and 3) other systems feel the need to pressure and help improve S1's task proficiency.

These objectives, along with those generated by other portions of the post exercise unit evaluation report outside the scope of this work, were incorporated into the script for the February '06 Operational Readiness Exercise. Specifically, 1) attacks were scripted close to scheduled aircraft launch times so that the impact of PAR team slowness in returning the unit to a general, normal operational level is clearly seen, 2) several attacks were scripted close in the schedule so that alarm condition announcers would be stressed, and 3) attacks were designed to be of larger scale or greater depth to further stress the need for quick, reliable processing of information, assessment of its relative importance, interpretation and action.

In retrospect, after working through the second track of the research design described above, the researcher notes two areas of potential criticism applicable to using the approach: 1) it can be argued, in a general sense, that the approach is simply overly sophisticated for the problem of training a control

center team, 2) the approach, in the more narrow sense of this particular case, is significantly limited by the case context.

After conducting the case study, the researcher to some degree feels the approach may be an overly sophisticated tool to use for the purposes of training Air Force control center staff's and systems. While the technique of analyzing performance in terms of crisis intensity and DC5 subsystem provides a holistic method of developing an assessment, indeed one more comprehensive and usable than current inspection criteria, the objective of precisely characterizing the crisis environment using qualitative means is difficult to reach. As a result, such imprecision, may be amplified as a DC5 fitness assessment is made and further amplified as future crisis environments are scripted to optimize their training value. It is difficult to argue that the resulting training value will be much better than the traditional approach of merely using seasoned evaluators to cite areas for improvement and to have players review their reports before the next exercise.

More narrowly, the approach is inherently limited by the restrictions of the case context. As discussed in the description of the case setting, a significant portion of the unit in the case was not participating in the exercise, thus the ability to script a variety of crisis environments and tailor them with any level of precision beyond simply attacks-in-breadth, attacks-in-depth, or high-paced-event-streams was very difficult.

In response to these valid criticisms some important points are worth noting. First, the relative newness, of this approach being applied in the general

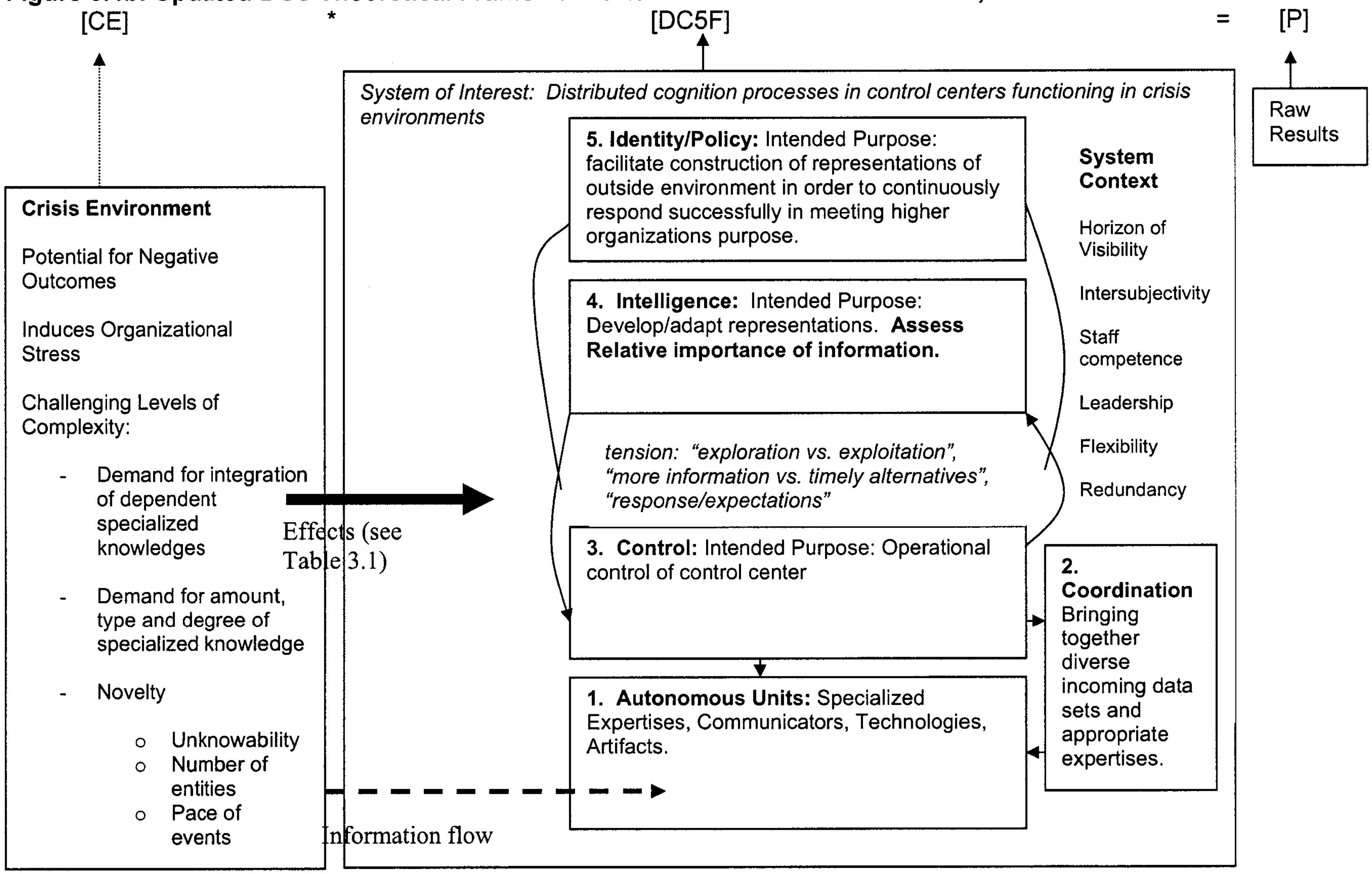
setting of developing a training system for Air Force control centers, necessarily means that first attempts will uncover difficulties not fully anticipated. Such difficulties are also lessons learned and can be used in further iterations of the research. Future work, methodologies, and designs can be deployed with these limitations in mind to better account for them. Further work can include focusing on development of a means to more precisely and rigorously characterize and specify crisis environments. Cases can be more rigorously selected and planned to ensure a broader range and more tailorable range of scenarios are achievable. Data collection instruments can then be better tailored to the specific scenario from which they wish to capture information regarding DC5 fitness.

Second, in terms of research value to understanding distributed cognition in crisis environments, the second track of the research design still retains significant value. It further highlights issues seen in track one's interpretive approach to the case. Specifically, that assessment of the relative importance of information grows in importance, first, as information technologies increase the horizon of visibility and second as crisis intensity increases in terms of complexity. The second track approach more readily focused interpreting the relative importance of the S4 functions in terms of crisis intensity and added converging weight to this research theme. This reinforcing convergence with the results of track 1 is highlighted in Table 5.3b and Figure 5.4b on the next pages.

Table 5.3b: Crisis Environment Effects on DC5 Subsystem Performance - Modifications from Case 1, Track 2 - First ORE – (Reinforcing changes from track 1 highlighted in bold)

	S1. Autonomous Units	S2. Coordination	S3. Control	S4. Intelligence	S5. Identity	Context
Real Crisis Pressure (Potential for adverse organization outcomes + inducement of stress)	- System self-doubt might increase - Sensitivities to stimulus increased - Focus changes	- Differences amplified - Acquiesce to consensus - May not seek consensus	- Pressure S1 to provide more information and S2 to process more information - Increase demands on S4 for implementable solution - Must determine if S1's are handling pressure appropriately	- Demand more information to get representation right **- Heightened awareness of need to assess the relative importance of information**	- Seek more confidence in representation before selecting alternatives - Selection/ decision/action goes to the organization core so balance is less routine	- Increase focus/pressure may cause HOV to be ignored - Increase pressure on individual systems may cause loss of IS with other systems - Staff competence directly impacted - Leadership directly impacted
Complexity: Demand For High Levels Of Specialized Expertise	- Ability to correctly inquire about data increasingly challenged	- Possible increased demand between systems	- Must ascertain when S1 has become overwhelmed - Must ascertain when S1 is no longer up to environmental demands	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- Staff competence up to the task - Leadership increasing S1 performance
Complexity: Demand for Integrated Expertise	- Ability to correctly Inquire about data increasingly challenged	- Challenged with knowing who needs to be involved in proc-essing information	- Must ensure coordination is functional -Must ascertain if S2 is no longer capable of meeting requirements	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- HOV and IS crucial - SC and Leadership also important
Complexity-Novelty unknowability	- Ability to correctly inquire about data increasingly challenged		- Can recognize when more data collection is fruitless	- Can recognize when more data collection is fruitless	- Required to adjust decision approach based on known lack of knowledge	
Complexity-Novelty number of entities	- Ability to track and process data challenged because of volume	- Ability to coordinate/assimilate data challenged because of volume	- Can recognize when systems becoming overwhelmed - Must ascertain if S1's and S2 up to task/replaceable	- Ability to interpret data increasingly challenged **- Heightened awareness of need to assess the relative importance of information**	- Required to adjust decision making approach based on known lack of knowledge	- Flexibility key - Redundancy may prevent processing errors
Complexity-Novelty pace of events	- Ability to receive and process data challenged	- Ability to process data challenged	- Increase demand for a timely plan of action - Must ascertain if S1's and S2 up to task/replaceable	- Ability to interpret data increasingly challenged **- Heightened awareness of need to assess the relative importance of information**	- Senses need to act quickly	- Redundancy may prevent processing errors

Figure 5.4b: Updated DC5 Theoretical Framework after Modifications from Case 1, Track 2 - First ORE



Overview of Data from Case 1, Operational Readiness Exercise No.2

This overview of the case data from the second operational readiness exercise (ORE) will include 1) an introduction to the specific setting in which the second ORE occurred, 2) a descriptional listing of the key events of the ORE as seen by the researcher and other evaluators, 3) and a summary of the raw evaluational findings of the researcher and other evaluators. Afterwards, in subsequent analysis, this information will be analyzed as suggested by the research methodology and design.

The Setting of the First Case—Second Operational Readiness Exercise

The second ORE observed as part of this research, involved the same subject unit from the first ORE. The general setting in terms of time of day, overall scenario, was all the same. In this iteration, before the actual exercise the researcher met with the evaluation team chief and other senior evaluators to develop a script for the ORE partially based on the analysis above. As in the previous ORE, the unit was training for upcoming ORI and hoping to improve upon the lessons learned and analysis form the first ORE. Also, as in the previous ORE, only those portions of the unit that had performed below standards in the prior year's inspection were participating, thus a major portion of the unit was not involved. Finally, as previously noted, in addition to the need to evaluate and improve the performance of the SRC, a second major area of the unit's performance outside the scope of this research was the focus of the exercise and the resulting script development.

Though the evaluation team scripted out a complete two-day exercise, the entire second day of the actual exercise was pre-empted by a severe winter blizzard. The unit commander made the decision to cancel the remainder of the exercise in the early morning a few hours before the start of the second day's events and notified the unit and evaluation team personnel by a telephone recall system. Thus the remainder of this script description and indeed the remainder of this analysis were limited to the activities of just the first day of the exercise.

There were four scripted attacks on the first day. The first, initiated right at the beginning of the exercise simulated a severe, multiple-missile impact attack with major damage to three facilities, one fire requiring complete evacuation, multiple wounded and killed casualties, and four unexploded warheads. As discussed in the previous discussion the severity of the attack was designed to generate substantial amounts of information forcing control center personnel to assess the relative importance of information, as well as stressing the basic S1 response functions of the control center.

Although the second attack was a ground-mortar attack, it was also a severe multiple-impact attack designed for the same purposes as the first attack. Four unexploded ordnance responses were required, two buildings were left in flames requiring evacuation, and three wounded casualties required response.

The third attack was a small missile attack designed primarily to test a response area outside of the scope of this research although a single unexploded warhead inhibited a key delivery route for munitions requiring the control center to develop a workaround quickly.

The final attack of the first day, and what turned out to be the entire exercise, as a result of the weather, was a ground attack involving several unexploded munitions inhibiting response and mission capability and requiring the development of alternative measures to return to mission operations. Additionally, horizon of visibility was purposefully severely restricted by jamming the radio networks of a key sub-unit organization.

The Raw Results of the First Case – Second Operational Readiness Exercise

Drawing on the case data from the data collection instruments described in Chapter IV, specifically the interviews/discussions with players and evaluators, the final exercise report, and the researcher's notes, convergence seemed to emerge around the following raw findings to be discussed in further detail below: 1) as in the first ORE contextually, the deficient performance of a key area outside that of command and control, the focus of this research, limited, to a degree, the ability to stress the survival recovery center, 2) the unit incorporated lessons learned during the first ORE, specifically, a) PAR team execution, tracking, and control was improved, b) distribution of imminent attack information was improved, and c) use of more intuitive visual aids in the SRC facilitated representation construction, and 3) the unit improved in managing the increased horizon of visibility provided by the BARTS message board system. In general, the SRC performed exceedingly well. So well, in fact, that the research value of the second ORE is called into question. Specifically, the question arises if a crisis environment was ever attained.

Detailed Analysis of First Case, Second Operational Readiness Exercise

The greatly improved performance of the control center coupled with the exercise scenario limitations, significantly constrained the ability to create and raise crisis intensity for the evaluators. This situation in turn, inherently limited the research value of the second ORE in terms of directly, iteratively, improving the DC5 framework as was done in the first ORE as part of track 1 of the research design. Similarly, track 2 was also limited some extent in terms of research value for DC5 iterative improvement. While iterative improvement at a subsystem level by either track was impacted by the results of the exercise, a generalist retrospective view yields some increased understanding of distributed cognition in the proscribed setting.

In general, during the limited duration of the exercise due to the winter storm, the unit performed well, errors were small S1-type mistakes, non-trending or noteworthy, and were quickly captured and corrected by control center personnel. In what the evaluators thought would be a very difficult time period, while the jamming of key radio networks was ongoing, the unit implemented work-around procedures proficiently and continued with very little impact to operations. In another case, designed to test control center capability to rapidly assess relative importance of information and then work together to develop a new workaround, all DC5 systems performed well. In this case, at nighttime as the beginning of the winter storm was setting-in, an impact crater in one location and unexploded ordnance in another location rendered vehicle haul routes for

both jet fuel and munitions useless. Control center personnel realized the mission impact of these occurrences while information was still flowing in from observers and quickly developed and implemented one expedient work around for immediate use while developing another more permanent response for longer-term operations.

The unit had obviously learned from the previous exercise and incorporated feedback from the evaluation team. The limits of the exercise constrained the ability of the scripters to raise crisis intensity; indeed, two senior evaluators, several SRC players, and the researcher concurred that because of the improved performance of the control center it would have been difficult to call even the most intense of the attacks a crisis. Specifically, articulating in terms of the crisis definition proposed in this work, the scenarios, though full or potentially full of negative consequences for the unit, was not complex enough to confound the improved control center systems and thus did not generate significant stress levels in those systems. As a result, the step-by-step analysis used in track 1 of the research design for the first ORE will not be duplicated in this analysis. The SRC implemented the lessons they learned in the first exercise, incorporating the feedback of evaluators to such an extent that it is difficult to say a crisis even occurred from the perspective of the control center, rendering analysis for purposes of improving the DC5 framework dubious. Implications of this fact for the research and researcher are discussed in further detail in the upcoming section on lessons learned from the second ORE.

Retrospectively, because of the limits to crisis intensity during the second ORE discussed above, it is also difficult to use track 2 of the research design to iteratively improve the DC5 framework. In the rigorous terms of the research design, the unit's performance reflected a high degree of proficiency, a crisis environment was hardly realized, and thus a DC5 fitness assessment is 1) beyond the measuring capacity of the research design approach and, 2) yields little information to iteratively improve the DC5 framework on a detailed surface level. Returning to the analogy of the sophisticated track coach and the new athlete, the situation would be reflective of one in which the coach gives the athlete a performance test to measure the athlete's fitness and the athlete finds the test so easy that nothing is gained in terms of measuring fitness. While track 2, and track 1 as discussed previously, proved unfruitful in terms of iteratively improving the DC5 framework, some more general conclusions about the distributed cognition are still realizable and some important lessons were still learned by the researcher.

General Analysis of First Case, Second Operational Readiness Exercise

Though frustrating in terms of not providing the expected improvements to the DC5 framework, reflection on the second ORE, 1) highlights a key aspect at the center of this research, the crisis environment and 2) leads the researcher to a suspicion worthy of further research relating to the interaction of information technologies, increasing horizons of visibility, inter-subjectivity, and performance.

The second ORE reinforced the notion that the DC5 framework is specific to the case of crisis environments. Without sufficient crisis intensity, the ideas postulated and framed by DC5 are not readily applicable to other situations. The constructs and interactions raised in Beer's (1984) VSM are still applicable to normal environments, but the DC5 framework depends on a crisis environment to understand and gain insight into the distributed cognition phenomena occurring in control centers as expressed in Table 3.1.

As seen in track 1 of the research design and even more readily in track 2, the DC5 fitness level of the control center is inherently tied to the ability of different scenarios to raise crisis intensity. More specifically, the DC5 fitness of a control center is a key factor in terms of 1) what constitutes sufficient complexity or how complex a problem may be and 2) how stressed a control center may get. Indeed, it could be argued that when fitness rises to certain levels in terms of the ability to deal with complexity, the potential for negative outcomes either decreases or rises to levels where it stops introducing additional stress. For the DC5 framework then it can be said that the crisis environment does not exist independently of the control center but must be expressed in terms of the fitness level of the control center. A crisis environment is one in which 1) the potential for negative outcomes is beyond that of the one in which the control center is used to regularly operating, 2) the complexity exceeds that of the one in which the control center is used to regularly operating, and 3) in turn the environment produces additional stress in the control center.

In terms of track 2, this notion of interaction between the state of fitness of the control center and what constitutes a crisis environment expresses itself in terms of measurement uncertainty. First, if the intensity in the environment is readily manageable by a fit control center then no crisis exists. Second, a given set of events may constitute different levels of crises for control centers of different fitness levels. Third, it's not possible to gain insight into the DC5 fitness of a given control center without a crisis environment of sufficient intensity for that particular control center at that time. Finally, as discussed previously in Chapter III, and demonstrated by the improvement between the first and second OREs, the act of measuring the DC5 fitness level of a control center as proscribed in this work necessarily changes, in this case for the better, the fitness level of that control center.

One additional general area noted by the researcher and other evaluators in the second ORE was the continued success of the BARTS message board system. The unit readily used the system as an effective, alternative means of communication when key radio nets were jammed during the exercise. In discussions with other evaluators about the success of BARTS, converging agreement was reached that the resulting increase of horizon of visibility provided by the system alone wasn't sufficient to explain the continued good performance of the command and control functions of the wing. The inter-subjectivity control center personnel had with outside unit personnel was key to understanding, assessing, and interpreting the large information flow facilitated by BARTS. The unit in whole, beyond the SRC, was characterized by having a

large fraction, relative to otherwise similar units, of personnel who had known and worked with each other over many years and through many exercises, enhancing the ability of control center personnel to understand nuances in communication and assess relative importance. While inter-subjectivity between control center personnel and personnel beyond the boundary of the control center is beyond the scope of this work, the researcher and other evaluators thought this attribute was of significant importance in wringing the additional benefit out of the increased horizon of visibility provided by the information technology.

Lessons Learned and Conclusion from Case Study 1—Second Operational Readiness Exercise

In conclusion, the limitations of the setting for the second ORE, specifically the lack of a scripted environment of sufficient crisis intensity and the unexpected shortening of the exercise due to inclement weather limited the value in terms of validating and modifying the DC5 framework. More generally, however, these same limitations raised awareness to the need for a key caveat to be introduced into the framework, the crisis definition proposed in Chapter II, and the specific detailing of the crisis environment in the DC5 framework. As discussed in the previous section, the crisis environment should be expressed and characterized in terms of the perceived fitness of the control center being studied. Finally, the lesson learned after the first ORE, regarding the importance of case selection to the work was once again reinforced. The limits of the case setting impacted the

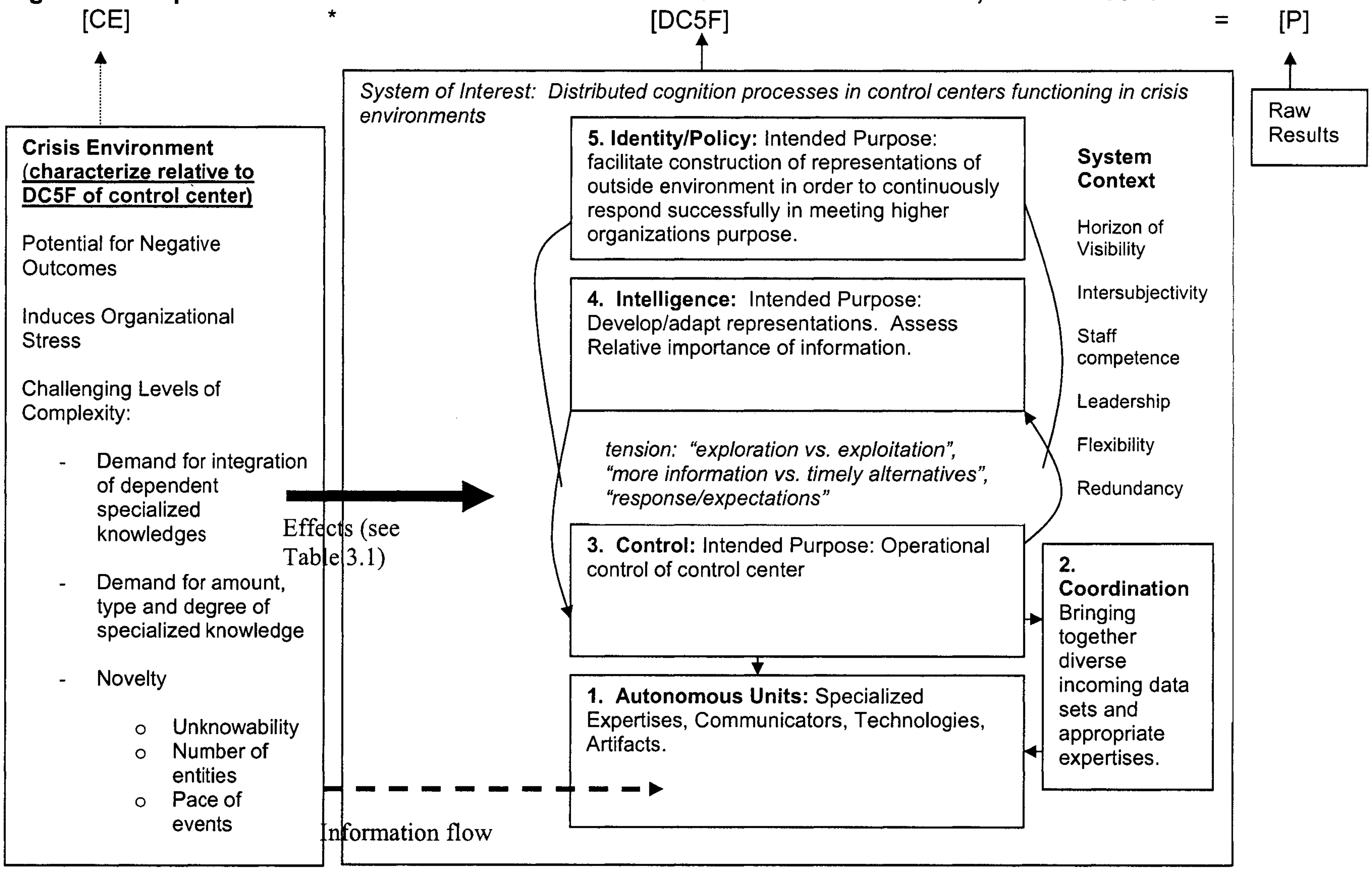
ability to stress the control center inhibiting the value of the research. Still both OREs and both research tracks applied during this case provided significant insights that led to key improvements in the DC5 framework, and turn into better understanding of distributed cognition phenomena.

Thus in summary Table 5.3c and Figure 5.4c capture the next iterative development of the framework, the qualification of what constitutes a crisis environment is relative to the distributed cognition fitness of the control center under study.

Table 5.3c: Crisis Environment Effects on DC5 Subsystem Performance - Modifications from Case 1, Track 1 - Second ORE – (Changes highlighted in bold)

	S1. Autonomous Units	S2. Coordination	S3. Control	S4. Intelligence	S5. Identity	Context
Real Crisis Pressure (Potential for adverse organization outcomes + inducement of stress) **relative to the dcog fitness level of the control center (RTDF)**	- System self-doubt might increase - Sensitivities to stimulus increased - Focus changes	- Differences amplified - Acquiesce to consensus - May not seek consensus	- Pressure S1 to provide more information and S2 to process more information - Increase demands on S4 for implementable solution - Must determine if S1's are handling pressure appropriately	- Demand more information to get representation right **- Heightened awareness of need to assess the relative importance of information (HANTARII)**	- Seek more confidence in representation before selecting alternatives - Selection/ decision/action goes to the organization core so balance is less routine	- Increase focus/pressure may cause HOV to be ignored - Increase pressure on individual systems may cause loss of IS with other systems - Staff competence directly impacted - Leadership directly impacted
Complexity: Demand For High Levels Of Specialized **(RTDF)**	- Ability to correctly inquire about data increasingly challenged	- Possible increased demand between systems	- Must ascertain when S1 has become overwhelmed - Must ascertain when S1 is no longer up to environmental demands	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- Staff competence up to the task - Leadership increasing S1 performance
Complexity: Demand for Integrated Expertise relative to the dcog fitness level of the control center	- Ability to correctly Inquire about data increasingly challenged	- Challenged with knowing who Needs to be involved in processing information	- Must ensure coordination is functional -Must ascertain if S2 is no longer capable of meeting requirements	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- HOV and IS crucial - SC and Leadership also important
Complexity-Novelty unknowability **(RTDF)**	- Ability to inquire about data increasingly challenged	[redacted]	- Can recognize when more data collection is fruitless	- Can recognize when more data collection is fruitless	- Required to adjust decision approach based on known lack of knowledge	[redacted]
Complexity-Novelty number of entities **(RTDF)**	- Ability to track and process data challenged because of volume	- Ability to coordinate/assimilate data challenged because of volume	- Can recognize when systems becoming overwhelmed - Must ascertain if S1's and S2 up to task/replaceable	- Ability to interpret data increasingly challenged **- (HANTARII)**	- Required to adjust decision making approach based on known lack of knowledge	- Flexibility key - Redundancy may prevent processing errors
Complexity-Novelty pace of events **(RTDF)**	- Ability to receive and process data challenged	- Ability to process data challenged	- Increase demand for a timely plan of action - Must ascertain if S1's and S2 up to task/replaceable	- Ability to interpret data increasingly challenged **- (HANTARII)**	- Senses need to act quickly	- Redundancy may prevent processing errors

Figure 5.4c: Updated DC5 Theoretical Framework after Modifications from Case 1, Track 1 - Second ORE -



Overview of Data from Case 2, Operational Readiness Inspection

Longitudinally, the second case study, a formal operational readiness inspection of another Air Force unit separate and different than the subject unit of the first case study, occurred before the third and last iterative portion of the first case study and will be reviewed here. The second case was limited to a track-1 approach, seeking to validate and enhance the interpretive value of the DC framework. As discussed in the research design and specified in the research protocol the same data collection instruments were used here as were used in the first case. This overview of the case data from the formal ORI will include 1) an introduction to the specific setting in which the ORI occurred and a description of the unit participating in the ORI, 2) a descriptional listing of the key events of the ORI as seen by the researcher and ACC/IG inspector, 3) and a summary of the raw inspection findings of the researcher and the inspectors. Afterwards, in subsequent analysis, this information will be analyzed as suggested by the research methodology and design.

The Setting of the Second Case

The researcher contacted members of the IG team and the unit to be inspected and requested permission to collect data as specified in the research protocol. Both organizations agreed and granted the researcher the additional access to players and inspectors as requested. As opposed to the two OREs composing the portion of the first case discussed thus far, the second case was composed of just one formal ORI being conducted by the IG team. While the first

case involved a flying wing training during OREs for an eventual ORI, the subject unit of the ORI in the second case was a heavy construction/engineering unit consisting of 400 personnel commanded by an Air Force Colonel with a complement of 10 officers participating in the inspection. The unit had prepared for the ORI by conducting two OREs itself.

The overarching scenario involved the simulated air transported deployment of the unit to a forward point of debarkation, followed by actual over-the-road convoy to an austere location, where the unit bedded itself down and established operations. The actual location could be described as field-like terrain with wooded perimeters, dirt roads, with little-to-no improvements, and clearings designated to be future expedient construction sites. No utilities of any kind were physically available; the unit had to demonstrate established levels of self-sufficiency by bringing in and constructing all of its own supporting infrastructure (i.e. the power generator, mobile communications, and field plumbing). The unit had to demonstrate the ability to internally respond to an established ground threat level thus all troops were supplied with appropriate small-arms weaponry with a small complement of heavier arms. Ground threat engagements were simulated by firing blanks and responses were evaluated by IG security forces inspectors. As the actual location was austere, facilities consisted of expedient shelters known as “TemporTents” approximately 30x20x10 ft in size. The unit provided its own organic sleeping and dining arrangements. The unit arrived with a complement of 42 vehicles, 30-day food supply, 5-day fuel supply, and 5-day water supply. Contact with theater higher

headquarters was simulated by mobile communication technologies with IG personnel.

The unit's mission during the ORI was multi-faceted: among other directives, 1) it was required to establish self-sufficient organic operations, 2) demonstrate the ability to produce its potable water from a non-potable source, 3) establish secure perimeters and defend itself against an established ground threat level, 4) protect itself during missile attacks, and 5) accomplish the design and construction of several expedient construction projects. Such projects included the repair of cratered runway, road construction, power line installation, hard wall expedient facility construction, small-bridge construction, concrete pad installation, aircraft revetment construction, and various earthwork projects. Additionally the unit was required to provide engineering designs, siting, and logistical planning for a variety of other projects including the complete beddown of an Air Force wing of 4000 personnel and 100 aircraft at a hypothetical austere bare forward base presently consisting of only an airfield and a potable source of water.

The phase II, or deployed-wartime, scripted activities of the inspection took place over 4 days. Seven hours each night were reserved as no-play time as proscribed by Air Force regulation applicable to such exercises. The focus of the research was on the unit control center (UCC) that oversaw the operations and responses of the unit. The UCC consisted of a single tent, with an alternate back-up, manned by nine personnel including the acting commander and executive officer, a log keeper and alarm announcer, a plotter for the visual aids,

the units senior non-commissioned officer, a representative of the units engineering section, a representative of its operations section, one of its logistics section, and one of its support and admin section. The layout of this UCC tent is provided in the appendices.

The Key Events of the Second Case: The Script as Implemented

The script for the first day of the inspection, actually called transition day when inspecting units of this type, involved no outside attack. The unit merely had to convoy to the austere site establish operations as described previously. Command and control was established, the UCC tent was erected, equipped, and manned but because no hostile action was simulated and therefore no crisis environment existed. Transition day was ruled out as a source for observational data by the researcher for purposes of this work.

The first actual day of hostile action play began with scripted instructions for the unit to begin design and construction of 8 projects while the scripted events included 1) a scenario involving a defector with a white flag trying to enter the units primary cantonment area, 2) a false alarm of an inbound missile, 3) a mortar attack resulting in cantonment area generator damage, 4) a non-impacting sniper attack, 5) a potentially chemically armed missile attack requiring the 30 minute wear of gas mask and chemical gear until the presence of no-chemicals was verified, 6) and a second non-impacting sniper attack.

In addition to the projects ordered the first day, 3 more construction projects were ordered on the second day. Hostile action on the second day

consisted of, 1) a mortar attack involving more generator damage, vehicle damage, and unexploded ordnance left in the cantonment area, 2) another non-impacting sniper attack, 3) a mortar attack resulting in three casualties, air conditioner loss for cold storage, a vehicle workcenter being destroyed, 4) a low intensity ground engagement resulting in the capture and detainment of an enemy prisoner of war 5) a mortar attack resulting in no damage, and 6) a chemical missile attack requiring wear of gas mask and chemical ensemble by personnel for two hours but no further damage.

The scripted events of the third day of the exercise involved a single chemical missile attack requiring wear of mask and chemical ensemble for two hours, causing two casualties, enflaming the UCC tent and requiring UCC relocation to an alternate tent, missing personnel.

Researcher's General Thoughts on the Second Case

Some general notes are worthy of discussion before proceeding with the detailed analysis that follows. First, in comparison with the script for the subject unit in the first case study, this script was much more challenging for the UCC because all reporting parties were playing in the exercise, thus stressing all S1 systems in the UCC. Second, the scenario called for wear of chemical mask and suit, which inhibits movement, breathability, communication, vision, and is generally hot and uncomfortable. Capturing the impact of this burden on UCC personnel in terms of the DC5 framework was a key to the interpretive value of the case to this research. Third, while the scenarios were more intense for the

UCC, as will be seen in the discussion of the case results, the UCC in the eyes of inspectors, the researcher, and even some players performed poorly. This weak level of performance limits the value of the case for the research; performance was poor regardless of crisis intensity so some impacts of crisis environment upon distributed cognition phenomena are difficult to interpret in terms of the DC5 framework. These will be discussed in further detail in the analysis of the case.

The Raw Results of the Second Case

Drawing on the case data from the data collection instruments described in Chapter IV, specifically the interviews/discussions with players and inspectors, the final inspection report, and the researcher's notes, convergence seemed to emerge around specific raw findings to be discussed in further detail next. Further description and elaboration on these points is provided ahead in raw terms as they emerged from the collection instruments. Actual refined discussion of their interpretation in terms of the proposed DC5 framework will follow in the next section. A more exhaustive review of the data collected during the case and the degree, or lack of thereof, of data convergence on particular issues is presented in summary form in Appendix V--Case 2 Data Results. The questions of the data collection instruments were used as a means of presenting and summarizing the results of each individual data collection effort.

The key findings upon which considerable convergence was seen between data sources, including the players themselves, the four inspectors

evaluating UCC performance, and the researcher regarding UCC performance noted during the exercise were 1) the UCC failed to engage and reallocate manpower and resources when a variety of real-world and exercise inputs brought certain projects to a halt, 2) simple procedures for backing up information in redundant locations and ensuring congruity in information sets were not implemented resulting in confusion, 3) simple procedures for accounting for personnel, vehicles, and equipment were not implemented, 4) project status boards were not used or updated in a timely fashion, 5) rigorous facility evacuation procedures were not established or followed resulting in significant information loss, 6) untimely, inaccurate, or no alarm/attack notification during every attack, and 7) poor, untimely PAR team performance.

As previously discussed, these findings represent poor performance below written standards. Indeed, the unit received a rating reflective of this fact from the IG team. Given how far behind the unit was throughout the exercise, it is difficult to draw conclusions on how a crisis environment may have impacted performance that was already sufficiently poor in situations of what were considered prior to the inspection to be of little to no crisis intensity. Still, interpreting these findings in terms of DC5 constructs and interactions as follows is to some extent beneficial for this investigation.

Additionally, attempting to interpret the impact of the wear of the chemical mask and ensemble on distributed cognition phenomena in terms of the DC5 framework also serves to enlighten the analysis and will be undertaken in the next section.

Key Findings in the Analysis of the Second Case – Operational Readiness Inspection

As in the track 1 interpretive analysis of the first case's first ORE the objective will be to interpret the emergent converging themes of the case data using the constructs and interactions specified by the DC5 framework validating the framework where possible and modifying it if necessary. As discussed in analysis of the first case, to the extent emerging observations readily converge with the suggested theory, then the framework has demonstrated its holistic validity as well as its specific construct validity. To the extent emerging observations do not readily converge with the suggested theory then the framework has demonstrated the need for modification or further study. Table 5.4, mirroring Table 3.1, Crisis Environment Effects on DC5 Subsystem Performance, which described in detail the theoretical impacts of crisis conditions on distributed cognition phenomena, provides the organization for the detailed discussion which follows regarding the areas in which emergent observations from case two converged with suggested framework constructs and their interaction, diverged from the suggested theory, or remained ambiguous with regards to the suggested theory. Again, as described in the previous section, the general overall poor performance of the UCC is an overarching theme that significantly limits the value of the data for interpreting crisis environment effects upon control center cognition. This fact is reflected in the large portion of Table 5.4 detailed as not validated by the insufficient case data. Table 5.3d and Figure 5.4d, summarize the case data and its implications for the DC5 framework. An

exhaustive analysis of the case data based on Table 5.4 on a cell-by-cell basis is provided in Appendix VII.

As mentioned in the previous section, of particular interest in this case was the wear of the chemical protective gear by participants in the unit control center; in the first case the control center was simulated-chemically-protected and thus wear of chemical defense gear was not required. Air Force personnel are familiar with the varieties of degradation in performance at a variety of tasks resulting from wear of this gear. Capturing and articulating the impact of such effects upon control center distributed cognition using DC5 constructs can also demonstrate its usefulness as working framework.

Personnel chemical gear, formally known as the Mission Operating Personal Protective (MOPP) ensemble, consists of rubber overboots, a charcoal lined over suit composed of paints and jacket, rubber gloves and glove liners, and a rubber hooded gas mask. After receiving notice of possible impending chemical attack or the possible presence of chemical agents, the user must don the mask first, ideally within eight seconds, and then the remainder of the ensemble, ideally within two minutes. The immediate personal physical effects of the suit are 1) it does not breathe, causing the user's perspiration to condense onto the skin causing discomfort, 2) it is extremely insulating causing the user to become hot and perspire even more, 3) the gas mask greatly reduces visibility, especially to the periphery, creating a sense of Closter phobia in most users anecdotally, 4) the gas mask muffles the ability to annunciate clearly as well as listen to others speaking and greatly reduces the ability to use telephone and

radio communication devices, and lastly 5) other normal bodily functions cannot be undertaken while the suit is on.

In terms of DC5 constructs, the ensemble primarily impacts distributed cognition phenomena contextually in terms of horizon of visibility and intersubjectivity. Because sounds are muffled and vision is impaired, the horizon of visibility previously available to control center personnel is greatly reduced. Personnel in Case 2 were observed becoming significantly more focused on their immediate tasks of processing information flowing into them and less able to monitor the background chatter of the room and the updating of artifacts such as status boards. Additionally, since the ensemble isolates the wearer from his or her fellow control center workers, intersubjectivity is greatly reduced; the ability to monitor personal cues that amplify communicative capability amongst participants that have grown together as a team over time is greatly reduced. As a result timeliness of responses and processing of information was delayed significantly in the control room greatly increasing the susceptibility of the control center to crises involving increasing paces of events or larger scale events. Additionally the ability to respond to scenarios requiring integrating expert knowledge bases was also reduced. Finally, in terms of primary effects the discomfort of the suit and the knowledge of its impacts on performance further stress the control center participants. Secondary interactions relating to ensemble wear seemed to impact on a contextual basis also. First, more experienced personnel, “staff competence” as captured in the DC5 framework, seemed to be impacted less by the discomfort of the suit and as is generally

thought in Air Force, and demonstrated in the case, leadership could act to mitigate some of the impact of the suit on performance and motivate personnel to press on with their duties. Wear of the ensemble represents an opportunity for further in-depth research into the impacts of changing levels of horizons of visibility and intersubjectivity directly upon distributed cognition performance potentially using a variety of methodologies, but such work is beyond the scope of this research and would require further study of cases involving such setting specifics.

Case 2: Summary of Case Data versus DC5 Framework

The key points seen arising from the second case in terms of validating the DC5 framework are 1) the limitations of the case, in terms of research value, due to the general overall poor performance of the UCC in all respects, 2) a small portion of the framework was moderately validated; case data and key findings were interpretable by DC5 constructs and relationships, again as detailed in the discussion and in Table 5.4, and 3) the case readily demonstrated the opposing response to the key conclusion generated from the second ORE in the first case. In that ORE the DC5 fitness of the SRC was of such degree to render the scripted environment a mere series of non-crisis events. In the second case, the DC5 fitness level of the UCC was so inadequate it turned any scenario involving minimal information processing into a crisis. This aspect of the case reiterated the notion that in characterizing the crisis intensity of a given set of events for a

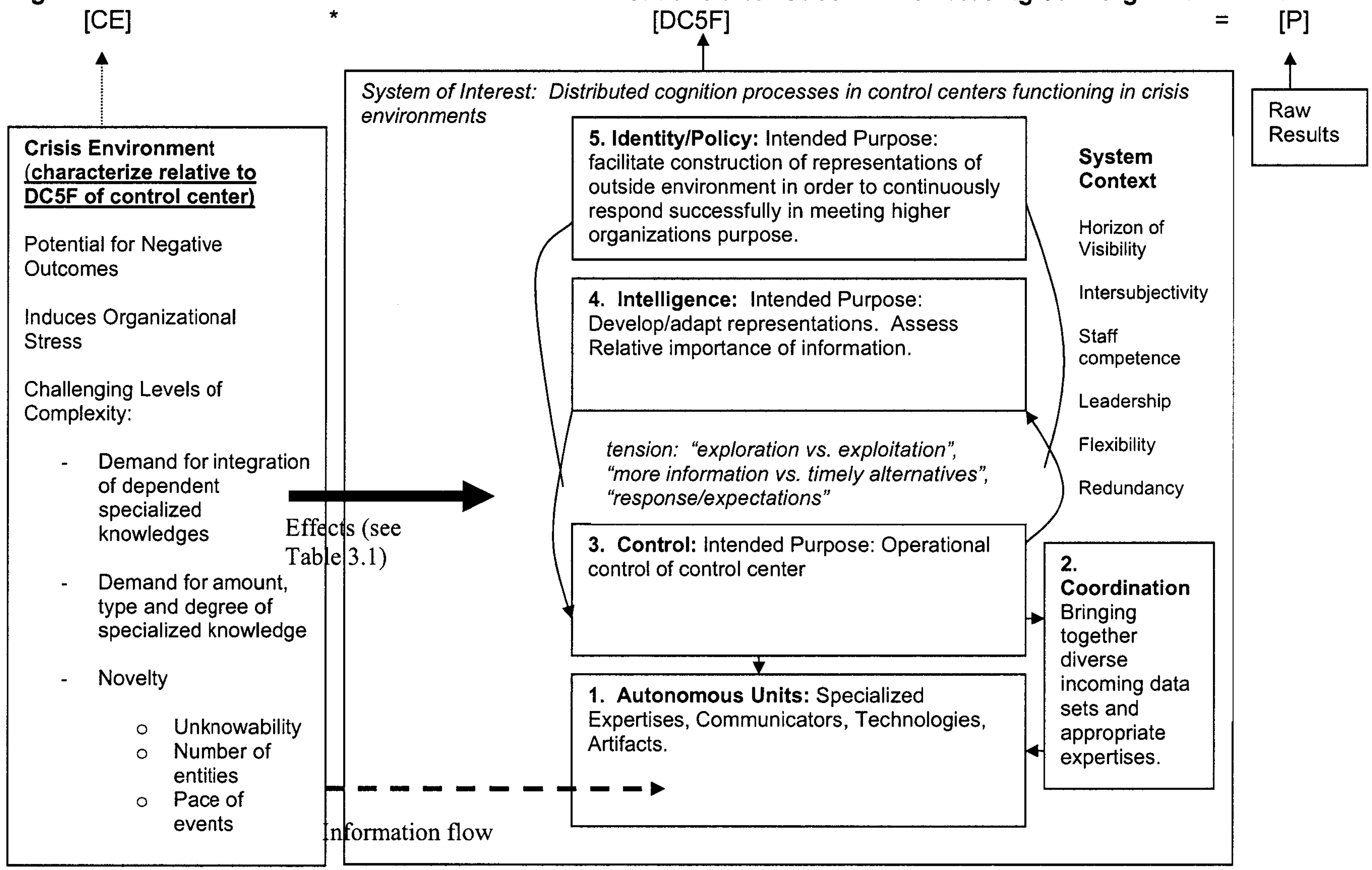
control center, one must take that the DC5 fitness level of that control center into account.

Table 5.3d captures the modifications suggested by the last two points above as does Figure 5.4d on the following pages.

Table 5.3d: Crisis Environment Effects on DC5 Subsystem Performance - After Case 2 (reinforcing convergence highlighted in bold)

	S1. Autonomous Units	S2. Coordination	S3. Control	S4. Intelligence	S5. Identity	Context
Real Crisis Pressure (Potential for adverse organization outcomes + inducement of stress) **relative to the dcog fitness level of the control center (RTDF)**	- System self-doubt might increase - Sensitivities to stimulus increased -Focus changes	- Differences amplified - Acquiesce to consensus - May not seek consensus	- Pressure S1 to provide more information and S2 to process more information - Increase demands on S4 for implementable solution - Must determine if S1's are handling pressure appropriately	- Demand more information to get representation right **- Heightened awareness of need to assess the relative importance of information (HANTARII)**	- Seek more confidence in representation before selecting alternatives - Selection/ decision/action goes to the organization core so balance is less routine	- Increase focus/pressure may cause HOV to be ignored - Increase pressure on individual systems may cause loss of IS with other systems - Staff competence directly impacted - Leadership directly impacted
Complexity: Demand For High Levels Of Specialized Expertise – **(RTDF)**	- Ability to correctly inquire about data increasingly challenged	- Possible increased demand between systems	**- Must ascertain when S1 has become overwhelmed** **- Must ascertain when S1 is no longer up to environmental demands**	- Ability to interpret data increasingly challenged	**- Required to adjust decision making approach based on known lack of knowledge**	**- Staff competence up to the task** **- Leadership increasing S1 performance**
Complexity: Demand for Integrated Expertise - **(RTDF)**	- Ability to correctly inquire about data increasingly challenged	- Challenged with knowing who needs to be involved in processing information	- Must ensure coordination is functional - Must ascertain if S2 is no longer capable of meeting requirements	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- HOV and IS crucial - SC and Leadership also important
Complexity-Novelty Unknowability - **(RTDF)**	- Ability to correctly inquire about data increasingly challenged		- Can recognize when more data collection is fruitless	- Can recognize when more data collection is fruitless	- Required to adjust decision making approach based on known lack of knowledge	
Complexity-Novelty number of entities- **(RTDF)**	**- Ability to track and process data challenged because of volume**	**- Ability to coordinate/ass-imilate data challenged because of volume**	**- Can recognize when systems becoming overwhelmed** **- Must ascertain if S1's and S2 up to task/replaceable**	**- Ability to interpret data increasingly challenged** **- (HANTARII)**	**- Required to adjust decision making approach based on known lack of knowledge**	**- Flexibility key** **- Redundancy may prevent processing errors**
Complexity-Novelty pace of events - **(RTDF)**	**- Ability to receive and process data challenged**	**- Ability to process data challenged**	**- Increase demand for a timely plan of action** **- Must ascertain if S1's and S2 up to task/replaceable**	**- Ability to interpret data increasingly challenged** **- (HANTARII)**	**- Senses need to act quickly**	**- Redundancy may prevent processing errors**

Figure 5.4d: DC5 Theoretical Framework with Modifications after Case 2 – Reinforcing convergence underlined



Overview of Data from Case 1, Final Operational Readiness Inspection

The third and final portion of the first case was the subject unit's formal ORI conducted by ACC/IG inspectors. In terms of this research the data collection effort relating to this ORI occurred longitudinally after the second case which involved one, single ORI of an Air Force heavy construction unit. This portion of the case was limited to the track 1, interpretive research design approach. The applied research of track 2 could not be undertaken because the researcher did not have input into script production for the ORI, which was closely held by the IG team and not released to the researcher until after the ORI was conducted. Additionally as no subsequent, exercise was scheduled following the ORI little use in terms of training value for subsequent scripting could be gained by undertaking the applied research approach. This overview of the case data from the formal ORI will include 1) a descriptional listing of the key events of the ORI as seen by the researcher and ACC/IG inspector, and 2) a summary of the raw inspection findings of the researcher and the inspectors. Afterwards, in subsequent analysis, this information will be analyzed as suggested by the research methodology and design.

It should be noted that a description of the setting of the ORI is not provided here as it matches that used in both previous OREs. In this case the IG team developed and implemented the script. The researcher stood out of the way in the control center for the duration of inspection and compiled observations.

The Key Events of the First Case, Final Operational Readiness Inspection: The Script as Implemented

The script called for two twelve-hour days of hostile play for purposes of the inspection. The first days activities consisted of 1) two false-alarms of inbound missiles, 2) three separate individual ground aggressor attacks, 3) a ground-based mortar attack resulting in the relocation of the unit's fuel storage control center, damage to bulk fuel storage tanks, fire in an aircraft maintenance shop, two instances of unexploded ordnance, and three casualties, 4) another ground based mortar attack resulting in damage to an aircraft maintenance control center and a communication antenna and 5) an additional ground based mortar attack coupled with three aggressors infiltrating the flightline area resulting in one instance of unexploded ordnance.

The second days scripted activities consisted of 1) the offline loss of the BARTS message board communication system for eight hours during which, 2) a missile attack occurred resulting in relocation of a maintenance operations control center due to building damage and damage to a key refueling vehicle, 3) two separate ground aggressor attacks occurred resulting in three friendly casualties, and 4) a ground based mortar attack occurred in concert with an attack by a vehicle-borne suicide bomber resulting in damage to two aircraft maintenance shop buildings and three casualties. After BARTS was restored another 5) ground based mortar attack occurred in concert with a sniper attack resulting in two casualties and two instances of unexploded ordnance and finally 6) a false alarm of a missile attack occurred.

Researcher's General Thoughts on the First Case, Final Operational Readiness Inspection

As presented in the previous discussion of the OREs associated with the first case study, the limits of the setting of the ORI inherently extend to the value of the research. Specifically, the limited amount of playing sub-units in the organization inherently limited the ability of the IG team to stress the unit as a whole and subsequently the SRC. In contrast to the motivation behind script construction for the ORE evaluators, the IG had no goal of giving the poorly performing unit subarea outside of the UCC a chance to improve. The IG merely wished to see if this separate subarea met standards. Thus, script intensity, specifically in terms of pace of events, was slightly greater for the ORI than the OREs. The researcher and evaluation team had strived to develop scenarios to both maximize training value to the unit, as well as, mimic what we thought the IG team would provide in its script. Generally, the ORE scripts and ORI scripts were close in terms of intensity though the IG tended to have a few more attacks per day of lesser intensity than those orchestrated by the evaluators during the OREs.

The Raw Results of the First Case, Final Operational Readiness Inspection

Drawing on the case data from the data collection instruments described in Chapter IV, specifically the interviews/discussions with players and evaluators, the final inspection report, and the researcher's notes, convergence seemed to emerge around specific raw findings to be discussed in further detail below.

Actual refined discussion of their interpretation in terms of the proposed DC5 framework also follows in the next section.

The key findings upon which considerable convergence was seen between data sources, including the players themselves, the two inspectors evaluating SRC performance, and the researcher regarding SRC performance noted during the exercise were 1) the generally superior performance of the SRC characterized by "smooth, accurate, and timely communications" facilitating "quick reaction" (quoted from the final inspection report) by senior leadership to a rapidly changing environment, 2) the successful implementation of BARTS into all command and control functions and its subsequent rewards, and 3) two small S1 type errors involving use of the wrong facility priority list by some SRC personnel during two attacks and lack of rigorous adherence to checklists by two SRC personnel on the first day of the inspection. The inspection was a success as far as the SRC was concerned. The inspection received a rating of Excellent by the IG. One of the SRC inspectors commented that he would have even considered awarding the rarely used Outstanding rating had the scenario not been so limited. This inspector also commented that "I've thrown everything I can at them, including taking down BARTS, and it doesn't phase them."

After the inspection, the researcher and ORE evaluators were gratified to see that their assessment following the second ORE, that the fitness of the SRC was simply beyond the ability of the environmental setting to generate a crisis, was validated by the inspection team during the ORI when it counted. As with the second ORE, it is of little use to conduct the stepwise analysis through the

DC framework because a crisis environment from the perspective of the SRC was simply not realized. The IG assessment reiterates the importance of characterizing crisis intensity in terms of DC5 fitness. What constitutes a crisis for one UCC does not necessarily constitute a crisis for another UCC.

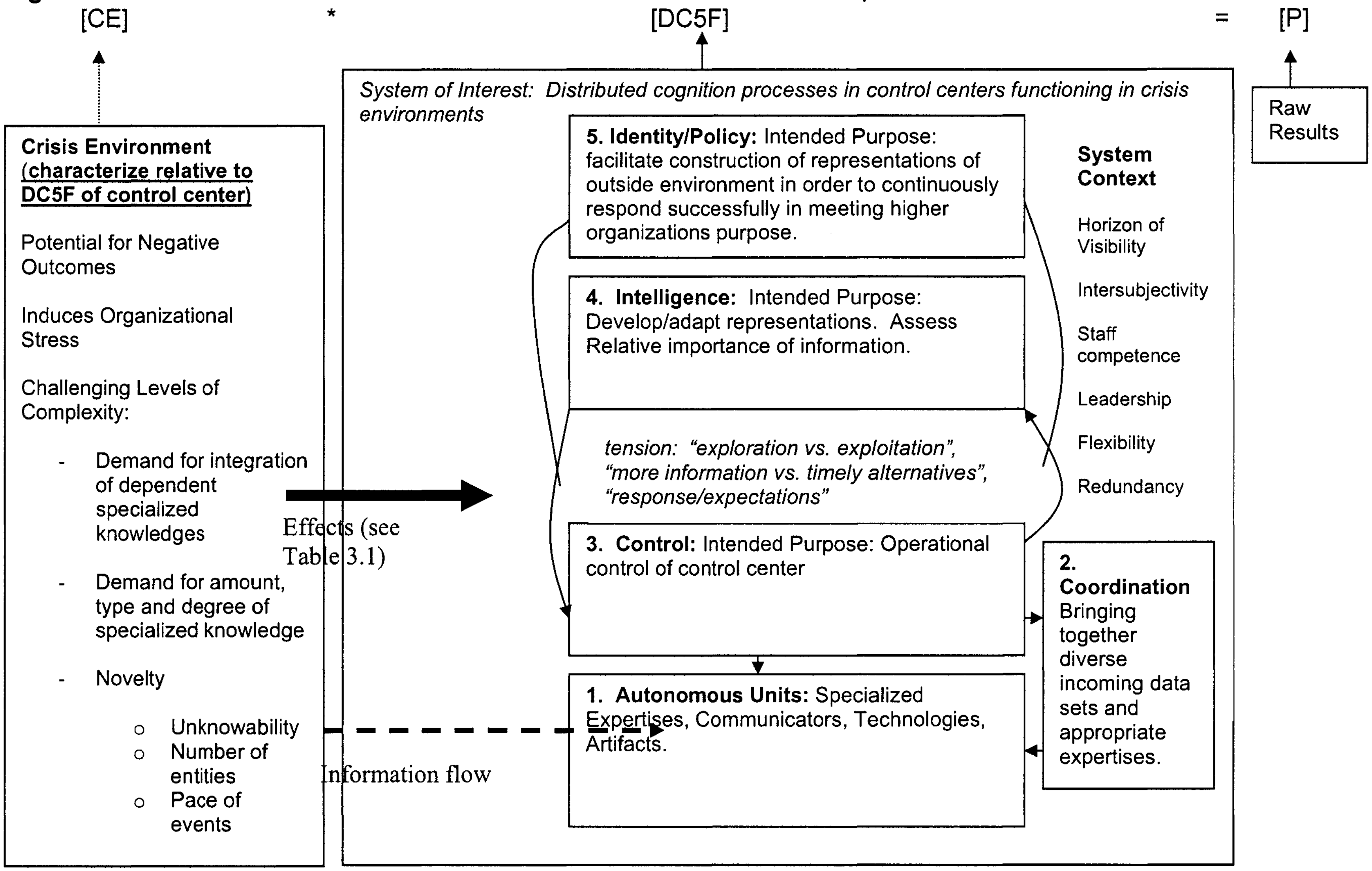
The S1 miscues noted by the IG and detailed above were corrected during the inspection after the S3 function engaged and ensured proper artifacts were used. Senior leadership also engaged and motivated SRC members to refocus for the remainder of the exercise. It is also important to note that IG inspectors captured the UCC's ability to facilitate rapid reaction following attack by senior unit leadership. This implies accurate representation construction on the part of the SRC.

Unfortunately the success of the SRC in the ORI and second ORE limits the value of the data for the research somewhat. As discussed, crisis intensities were not reached because of the proficiency of the SRC. Thus, further iterative development of the DC5 framework is not possible and it remains as captured in Table 5.3e and Figure 5.4e on the following pages.

Table 5.3e: Crisis Environment Effects on DC5 Subsystem Performance - After Case 1, ORI (reinforcing convergence highlighted in bold)

	S1. Autonomous Units	S2. Coordination	S3. Control	S4. Intelligence	S5. Identity	Context
Real Crisis Pressure (Potential for adverse organization outcomes + inducement of stress) **relative to the dcog fitness level of the control center (RTDF)**	- System self-doubt might increase - Sensitivities to stimulus increased -Focus changes	- Differences amplified - Acquiesce to consensus - May not seek consensus	- Pressure S1 to provide more information and S2 to process more information - Increase demands on S4 for implementable solution - Must determine if S1's are handling pressure appropriately	- Demand more information to get representation right - Heightened awareness of need to assess the relative importance of information (HANTARII)	- Seek more confidence in representation before selecting alternatives - Selection/ decision/action goes to the organization core so balance is less routine	- Increase focus/pressure may cause HOV to be ignored - Increase pressure on individual systems may cause loss of IS with other systems - Staff competence directly impacted - Leadership directly impacted
Complexity: Demand For High Levels Of Specialized Expertise – **(RTDF)**	- Ability to correctly inquire about data increasingly challenged	- Possible increased demand between systems	- Must ascertain when S1 has become overwhelmed - Must ascertain when S1 is no longer up to environmental demands	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- Staff competence up to the task - Leadership increasing S1 performance
Complexity: Demand for Integrated Expertise - **(RTDF)**	- Ability to correctly inquire about data increasingly challenged	- Challenged with knowing who needs to be involved in processing information	- Must ensure coordination is functional - Must ascertain if S2 is no longer capable of meeting requirements	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- HOV and IS crucial - SC and Leadership also important
Complexity-Novelty Unknowability - **(RTDF)**	- Ability to correctly inquire about data increasingly challenged		- Can recognize when more data collection is fruitless	- Can recognize when more data collection is fruitless	- Required to adjust decision making approach based on known lack of knowledge	
Complexity-Novelty number of entities- **(RTDF)**	- Ability to track and process data challenged because of volume	- Ability to coordinate/assimilate data challenged because of volume	- Can recognize when systems becoming overwhelmed - Must ascertain if S1's and S2 up to task/replaceable	- Ability to interpret data increasingly challenged - (HANTARII)	- Required to adjust decision making approach based on known lack of knowledge	- Flexibility key - Redundancy may prevent processing errors
Complexity-Novelty pace of events - **(RTDF)**	- Ability to receive and process data challenged	- Ability to process data challenged	- Increase demand for a timely plan of action - Must ascertain if S1's and S2 up to task/replaceable	- Ability to interpret data increasingly challenged - (HANTARII)	- Senses need to act quickly	- Redundancy may prevent processing errors

Figure 5.4e: DC5 Theoretical Framework with Modifications after Case 1, ORI



Summary of Framework Analysis

In summary, the track 1 interpretive analysis of the first case, first ORE validated a significant portion of the DC5 framework. It also resulted in the removal of S3* from the DC5 framework. Data showed that as crisis intensity increased, the S3 function simply did not have the time or capital to invest in detailed monitoring or auditing of S1 performance. Judgment had to be made quickly and firing and training replacements became less of a viable option. The control center was stuck with the competence of the staff with which it entered the crisis. In a minor adjustment to the framework, this ORE also highlighted the differing impacts of pace of events and scale of events. The first seemed to generally result in the control center's S4 or intelligence function struggling to put pieces together to assemble an accurate representation of the outside environment. The latter seemed to result more in the S4 function deconflicting multiple information streams regarding the same event stream. Finally, the first case highlighted the fact that as information technologies greatly increased the control centers horizon of visibility it became an increasingly important function of the S4--the intelligence function of the control center to assess the relative importance of the incoming information.

The applied research, or track 2 approach to evaluating the first case's data from the first ORE, reiterated the finding from track 1 that assessing the relative importance of information became a much greater portion of S4's systemic functions as horizon of visibility increased. Substantial improvement was seen between the first and second OREs in the first case. This assessment

of improved performance was reinforced by the data from the final ORI in this case. While it's tempting to try to point to track 2 as having some responsibility for this improvement, this point cannot be sustained. The impact of track 2 would not have been seen until the ORI, as it was first really applied in scripting the second ORE. The SRC learned and improved as a result of the script of the first ORE. To the extent that planning track 2 and applying the constructs and ideas of the DC5 framework played a role in the scripting of this first exercise, then some credit may be taken. It should be noted, however, that 1) the mere practice value for personnel in the first ORE, 2) the use of the highly enabling BARTS message board system, 3) unit leadership, and 4) SRC personnel competence could also explain the increase in performance.

The first case's second ORE proved of little value to iterative internal framework validation and adjustment because the UCC's performance was so brilliant. It did however, highlight the importance of expressing crisis intensity in terms of the DC5 fitness level of the control center under study. The importance of this relative interaction between fitness and crisis definition was highlighted by the opposite extreme in the second case when the most basic of control center information processing proved to be a crisis for that particular control center.

The second case did serve to further validate a portion of the DC5 framework as basic information processing requirements rose to crisis levels for the subject UCC and some convergence with the framework was noted in terms of the interaction between pace and scale of events and DC5 subsystem impacts.

Finally, the final ORI in the first case again reinforced the notion of the relationship between DC5 fitness of a particular control center and characterization of crisis intensity. As in the second ORE however, the superior fitness of the SRC exceeded the ability of the environment to be viewed as a crisis. Table 5.3e and Figure 5.4e represent the final iteration of the DC5 framework for purposes of this research.

The researcher has other significant conclusions, criticisms, reflections, and lessons learned to discuss, specifically with regard to case selection and the limits of research into distributed cognition but these will appear in Chapter VI, along with discussions about the impact and potential benefits of the research and potential for future research.

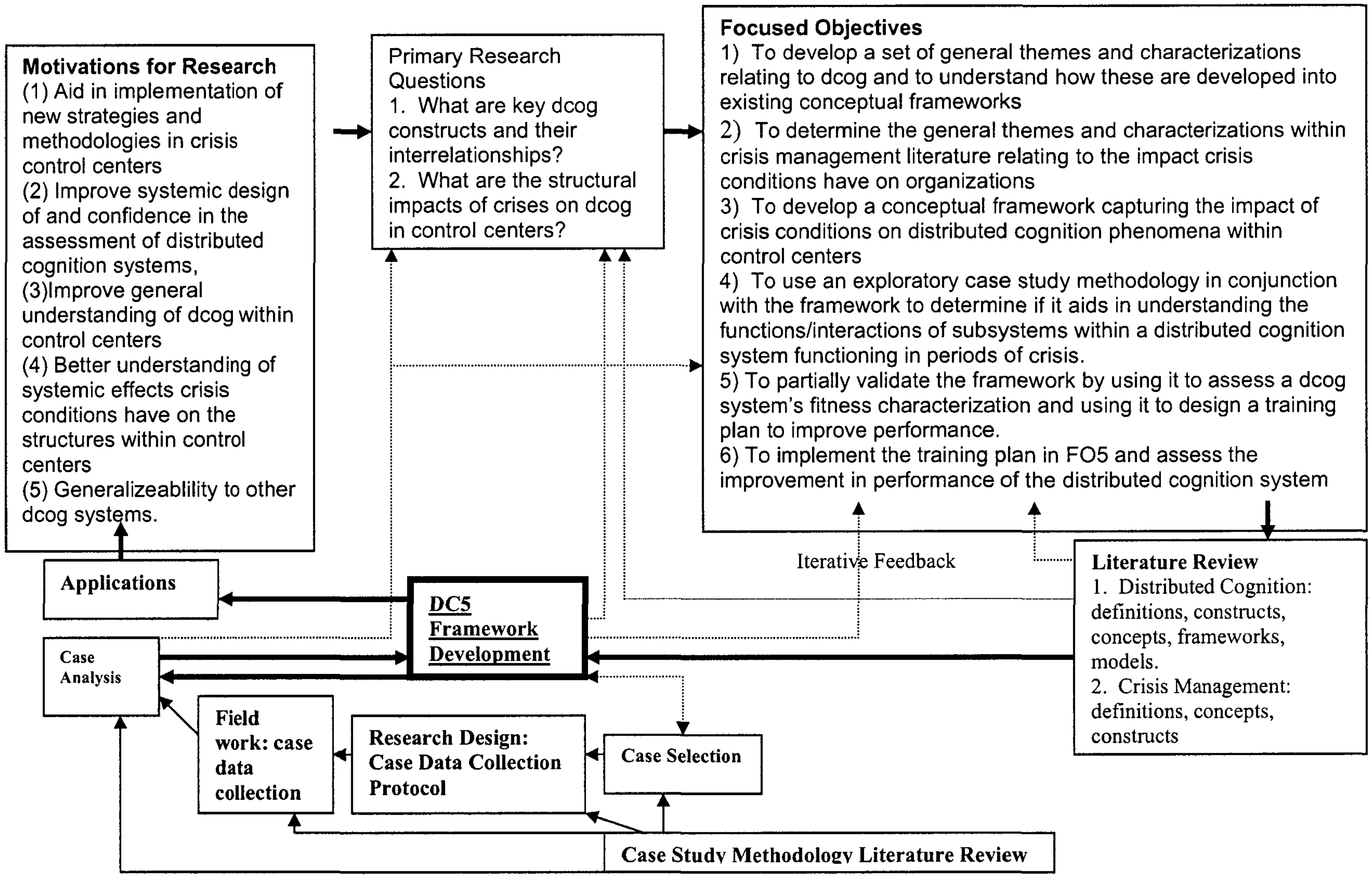
CHAPTER VI

CONCLUSION

Organization of Conclusion

This final chapter of the dissertation will be organized around the primary research question, motivations, and focused objectives presented in Chapter I. Figure 6.1, Research Approach Overview is a reprint of Figure 1.3 and will serve to guide the majority of this final discussion, specifically the degree to which the work addressed the primary research questions and the resulting focused objectives as well as the early motivations for the research. Additionally, the researcher will also summarize his reflections, criticisms, and lessons learned following the research effort and will follow up by discussing subject matter relating to the research that may serve as a fruitful area of future research inquiry. Lastly, one final summary of the key conclusions resulting from the research will be provided as well as the researcher's assessment of the research's key contribution to the body of knowledge relating to the subject matter.

Figure 6.1: Research Approach Overview



Addressing the Primary Research Questions and Focused Objectives of the Research

The first primary research question sought to determine the key constructs and interrelationships one must understand to build a coherent, holistic understanding of distributed cognition phenomena. Chapter II, a) reviewed several existing frameworks (see Figure 2.3) in the literature identifying the key functions of organizational learning phenomena seen by other authors and b) attempted to distill out the common themes of focus from the literature (Figure 2.2). In so doing the focused objectives detailed in Chapter I were met: 1) an understanding of the general themes and constructs relating to distributed cognition in the existing literature was reached as was an understanding of how these issues had been conceptually framed by other authors, 2) the general themes and constructs of what constitutes crisis environments were distilled out of existing literature, and 3) these were integrated to produce the DC5 structure.

Chapter III sought to provide this structure by capturing these constructs and their interrelationships and by grouping them and then adapting them to Beer's (1979, 1984) viable system model. Once the first primary research question was answered, the next primary research question's motivation was to see if this emergent structure of constructs, themes, and interrelationships served to provide additional knowledge.

The structure provided by Beer's VSM was sought by the researcher because it was difficult to articulate the impact of a growing crisis environment on distributed cognition phenomena. For example, how would a sudden increase in

the pace of events outside a control center impact its ability to construct an understanding of that outside environment? Such issues were the focus of the second primary research question: developing a systemic understanding of the impact of crisis conditions on distributed cognition systems. Chapter III speculated on what such affects may be by developing and articulating the initial DC5 framework (Figure 3.4 and Table 3.1) and Chapter V provided validation or modification to a substantial part of the framework resulting in the final framework at the time of research completion (Table 5.3e and Figure 5.4e). While the selected cases did little to validate a key portion of the framework (i.e. the nature of a crisis environment's demands for the application and integration of specialized expertise sets on distributed cognition in control centers) other major portions of the framework were validated or improved, substantially answering the second primary research questions. The interpretive, exploratory research approaches, track 1, to the cases demonstrated the value of the framework as a basis for understanding distributed cognition phenomena. The applied research approach, track 2, similarly proved valuable by enhancing the understanding of the phenomena and setting, indeed validating the need to modify the framework by identifying the importance of assessing the relative significance of information by the intelligence functions of a distributed cognition system as horizon of visibility grows. Due, however, to the unanticipated improvement in the first case in performance in the SRC between the first and second OREs it is difficult to gauge the validating impact of this research design approach on the final performance during the ORI and therefore on the framework. Further discussion

of this shortfall can be found in the upcoming section on the researcher's reflections and criticisms. In general though, the primary research questions and resulting focused objectives of the research introduced in Chapter I were addressed.

The Potential Benefits of the Research

Chapter I introduced 5 potential benefits, PB1 – PB5 in Table 1.1, of the research. PB3 and PB4 were clearly met through the conduct of the research. The research did indeed provide for a better understanding of distributed cognition phenomena in the systems within control centers (PB3). The research provided a better understanding of the systemic effects of crisis conditions on control center distributed cognition (PB4). The remaining benefits identified in Chapter I require further explanation.

One of the anticipated benefits of the research (PB1) was that it would provide a basis for better development of implementation strategies for adapting new methodologies and technologies to support control centers. While the researcher believes that full scale development and deployment of such methodologies and technologies are good examples of future areas of research inquiry based on this work, the track 2 research method is a key example of this benefit.

Typically, training for an ORI involves an Air Force unit internally running three to four successive OREs in preparation for the final test. Usually these OREs are planned and evaluated by senior, experienced personnel within the

unit who do not play in the ORE. The planning of these OREs, specifically the scripting of events, is usually done with the unit's key functions, such as operating and maintaining aircraft, securing base perimeters, maintaining base infrastructure, and other such functions in mind. In turn these events cascade up and serve as the events that will generate information for the control center to process. This bottoms-up approach to exercise scripting does not allow for control centers to necessarily be hit with scenarios ideal to enhancing heir effectiveness.

The applied research portion of this work, track 2, as developed in Chapter IV is an example of an implementation strategy based on the DC5 framework. By using an early ORE to assess the existing fitness level of a control center in a detailed, systemic manner based on the DC5 framework, an ORE evaluation team can prepare a script specifically designed to train that particular control center. Such focused design should prove more useful than the more traditional method of repeating the same script over and over again with minor changes to maintain surprise. The fact that it is difficult to gauge the impact of this approach in the given case in which it was used is discussed in a later section as is the prospect for using this approach in future research.

The paragraphs above identified potential benefits in using the DC5 framework in planning exercises, but it can also be of benefit in assessing (PB2) the performance of control centers after such exercises. Specifically, using the framework, as a basis for such assessment can yield much more useful information than typical criteria. Typically, following an exercise, evaluators will

use existing established Air Force criteria to evaluate a UCCs performance (see Appendix 1). As evaluation reports are read and reviewed by players they merely see their emergent errors identified, for example: "weak use of checklists and visual aids," and the players in turn focus on more rigorously using checklists and visual aids in the next ORE. The track 2 approach, alternatively, allows a reader to review an assessment in light of the specific environment that created it and understand its impact on the UCCs mission of constructing and acting upon representations. Again, using this approach to evaluating performance needs to be further tested and could be the subject matter of future research.

The last potential benefit identified in Chapter I, is the notion that the increased understanding provided by this research relating to distributed cognition and crisis environments may find application outside the setting of Air Force control centers. As was detailed extensively in Chapter III's discussion of qualitative case study research methodologies, the generalizability outside the studied sample that is typically gained from strictly quantitative approaches is not realizable. As Yin (1984) concludes however, case study data is generalizable to theory. Chapters I and II identified many settings outside of those at the focus of this work in which distributed cognition takes place: academic spheres, political spheres, and organizational settings to name a few. These settings also occasionally experience crisis environments in which learning must take place in stressful periods. It is hoped that the increased understanding provided by this work of crisis environment impacts on such learning and information processing can provoke similar areas of interests and increase focus upon such phenomena.

Further limits to such transferability are reflective of the limits of the selected cases with respect to validating the DC5 framework as shall be discussed in the next section.

Limitations

In retrospect, in viewing this work as a whole, four major limiting issues are worthy of reflection. 1) The subject matter of the work was necessarily broad impacting the results and the extent of its contribution to the body of knowledge; 2) while intuitively obvious, it should be said that the cases selected for study necessarily limit the impact of the research; 3) as discussed in Chapter III, the case study approach used here as means of validating the DC5 framework inherently limits the validity of the research and 4) lastly, some argue that the work represents application of a level of sophistication beyond that of the problem it seeks to address. This section addresses these limiting factors and potential criticisms.

The subject matter of this research, specifically framing distributed cognition in crisis environments, was relatively broad in scope and coping with this breadth was a key challenge to the research. Attempting to develop an entire new framework meant not only the study and mastery of existing frameworks relating to distributed cognition but the study and development of systemic methods to be used in providing such a framework. Additionally, the focus of the research lies at the intersection of two separate focus areas of research, distributed cognition and crisis management, requiring the extensive

literature review to support the framework's development. Finally, a rigorous review of case study methods, also added to the work required to support the research.

The resulting DC5 framework was necessarily broad in the set of circumstances covered, as demonstrated by the extent of detail in Table 5.13 and in the exhaustive cell-by-cell analysis discussions relating to this Table in Chapter V. One may argue that such breadth yields little in the way of deep insight and as will be addressed in the next few paragraphs makes validation difficult to achieve in a holistic sense. Such criticism is valid but one must also ask if such research should in turn be avoided altogether because of the issue of breadth. The researcher found it difficult to apply the varieties of settings within a crisis environment to the existing frameworks and understand their impact explicitly on distributed cognition phenomena. Thus, necessarily in order to proceed, a new structured perspective had to be developed and fielded. It is hoped that future research can and will succeed in validating and sharpening the framework and improve its usefulness and thereby the depth of the validity of the work. Because little other work could be found addressing the research focus area, a large initial increment of research had to be attempted before further refinement could take place.

The primary weakness of the research in the researcher's opinion is the limited validation of the DC5 framework, specifically the lack of validation of the DC5 framework in the areas of understanding the impact of a crisis environments demands for specialized and integrated expertise on distributed cognition

phenomena. The research necessarily required a rigorously observable crisis environment. The researcher saw the analogy between crisis environments and lightning strikes as expressed in a popular movie: “the problem is you never know when and where lightning is going to strike.” Similarly, the strength of the case category, Air Force OREs and ORIs, from a research perspective was that the researcher would have access to a controlled, scripted, manipulatable, observable crisis environment with performance being graded by experienced personnel using established criteria. Such rigor was exceedingly rare in the cases or stories frequently reviewed in the literature.

The limits of such cases, however necessarily limit the validating capability they can provide to the framework being tested. In the case of the AF OREs and ORIs, the researcher realized upon observing the first ORE in the first case that they only require a surface level of learning or information processing. The deeper or double loop learning referred to by Argyris and Schon (1978, 1996) just wasn’t called for in such settings; indeed all the different types of scenarios involved in the exercise and inspection scripts are scenarios that are often discussed and even separately trained for repeatedly in Air Force settings. While such settings require the application of specialized expertise and require integrated, interdisciplinary responses from Air Force personnel, little on the spot, in-crisis deeper learning is called for that causes subjects to reevaluate or abandon basic underlying assumptions and foundations. Thus, a large portion of the framework, specifically those rows of Table 5.13 relating to specialized and

integrated expertise remains un-validated. Further discussion in this respect will follow in the next section on future research focus areas.

The cases studied necessarily limited the impact of the research also in the way the control centers performed relative to their environment. The DC5 framework necessarily defines itself as one in which a crisis is taking place. Implicit in this definition is the assumption that it will be applied to a control center functioning in such an environment. Upon reflection, this represents a narrow envelope where the framework is applicable, that is when the proposed distributed cognition fitness level of control center is just being exceeded by the environment in which it is functioning. In iterations where the control center's proficiency is far beyond that of the environment, little validating effect can be found. Similarly, in cases where the environment swamps what little proficiency the control center does have only moderate validating value can be found. The researcher speculates that even had he been aware of this issue of fitness-environment relevance to the degree these cases raised such awareness beforehand, it would have been difficult to predict the suitability of the cases to validating the framework. This suggests that it would have been difficult to predict the fitness-environment relevance until after each control center had been seen in action. Future work in this area may have to factor eliminating such cases into the completion timelines for such research as well as the likelihood of finding cases that fit the envelope for study.

Thirdly, as discussed in Chapter III, case study research necessarily limits the validity of the work. The five steps cited in the literature in Chapter III to

address construct validity or the problem of researcher objectivity were, to review, 1) thoroughly detailing the background, demographic and experiential, of the researcher so that the audience can assess his potential biases as well as familiarity with case issues, 2) thoroughly detailing the means by which access to case data sources was gained, again for the purpose of allowing reviewers to assess potential biases 3) triangulating data and conclusions by seeking confirmation from multiple sources of evidence within the case, 4) establishing a chain of evidence that a reviewer can follow to determine what support a given finding had, and 5) having the actual informants review the descriptions and conclusions of the researcher. Such steps were taken in this research. Similarly, 3 prescribed steps from the case study methodology literature review were taken to address internal validity or the problem of researcher interaction, those being 1) identifying recurring patterns within cases to trace causality, 2) using other experts and informants to build explanations for observations, and 3) identifying, detailing, and addressing rival explanations for observations. External validity is the notion within quantitative research methods that the research is significant because it is generalizable to a broad set of contexts outside that of the existing study. As previously discussed, towards this criticism, case studies do not have a valid answer. The researcher acknowledges that sampling logic is outside of the grasp of the work given the contextual depth and small number of cases. Rather it has been proposed that case study findings can be generalized to existing theory (Yin 2003; Eisenhardt, 1989). Adding the separate study of case two and the second track methodology for case 1 adds weight to the theoretical

propositions of the DC5 framework (Yin, 2003). The findings of the case study should be transferable to other similar contexts but the work is inherently limited only to the context of Air Force Control Centers and not generalizeable to other settings. Pressing this notion even further, the generalizability of the research is also limited by the artificialities of associated with exercises and inspections relative to real-world Air Force crisis events. As documented in the case description, operational readiness exercises and inspections are high-stress events but casualties, material damage, and mission impacts are simulated and at the end of a participant's shift they return to their own homes or hotel rooms. Such limitations are just that, limitations, the cases still represent quite an opportunity for research not crisis environments as long as the limitations are captured contextually.

Finally, reliability refers to the notion within traditional quantitative research that experiments may be followed and repeated and results should be reproducible. Again because of the dependence of case studies on contextual depth they're inherently limited in their ability to be reproduced in other settings. This too is acknowledged by the case study researcher who offers in return the ability to audit his results by developing and using a rigorous case protocol and maintaining a case database, as was done in this work so that other researchers can agree that had they done the research the same findings would have been reached (Yin, 2003; Eisenhardt, 1989).

Finally, some may argue that a degree of sophistication is being applied to a problem that doesn't merit it or require it. A good script can be developed by

an experienced evaluator simply by reviewing a previous exercise report and applying that experience rather than going through the process of rigorously and explicitly understanding distributed cognition and applying it as in track 2 of the research design, to training a control center to become more proficient. The researcher wholeheartedly agrees that such experienced and talented professionals exist that can provide such levels of expertise for training control centers but argues that the process being applied tacitly by such and experienced evaluator if made more explicit essentially becomes the process of Track 2. The sophistication being applied in articulating such a process allows for a better understanding of distributed cognition phenomena by more people and thus facilitates better script writing, better performance, and better assessments of performance.

Recommendations for Further Research

As suggested in the previous section the focus of this research was necessarily broad because little could be found in the literature regarding the interrelationship between distributed cognition phenomena and crisis environments. It is hoped that the framework proposed here and validated to some extent san serve as basis for outlining and mapping this focus area for further research. The breadth of the DC5 framework leaves lots of room for further validation, modification, or rejection of individual propositions of the framework or categorical reframing of the subject matter itself. The researcher sees four major areas of focus that might be immediately used in the next

iteration of academic inquiry into the subject matter: 1) Portions of the DC5 framework can be isolated for further more extensive study and in-depth validation and study; 2) cases can be more rigorously selected for study to avoid some of the limitations in this work or accepted for study for just the portion of the framework to which they have validating, modifying, rejecting, or impacting content; 3) the applied research design of track 2 can be refined and applied over several iterations to see if it indeed has validity as a training paradigm, and 4) perhaps other settings in which distributed cognition occurs in crisis situations can use the holistic, systemic approach used here to gain understanding of the subject matter.

Future work could avoid the challenges of this work associated with the breadth of establishing a new framework by focusing on specific portions of the framework itself. Specifically, research into control centers implementing new technologies like BARTS, might yield insights analogous to those seen here where increased horizon of visibility increases demands on intelligence forming systems. The impacts of sudden changes in horizons of visibility on various performance measures may prove interesting. Measurements of intersubjectivity may be applicable to performance metrics. Finally, the general approach tried here of broad validation could be repeated to add weight to the theory.

As case characteristics were identified as a key limiting factor on the research, it is recommended that future research that may use the DC5 framework, seek 1) to immediately rule out cases where the fitness-environment relevance is not suited to the framework's envelope and avoid spending precious

research capital in such areas, 2) accept cases for their strengths as its difficult to predict the individual attributes of a control center and validate the portions of the framework they apply to, and 3) try if possible to seek out cases with attributes that may validate un-validated portions of the framework or add weight where its necessary.

Of particular interest to the researcher is utilizing applied research along the lines of the track 2 training methodology proposed here to refine the framework. The researcher supposes that if access can be gained to an Air Force unit in the initial stages of training for an ORI before any exercises have been conducted then more rigorous, thorough, and complete application of the methodology can be attempted. Environment characterization, fitness characterization, and performance characterization can be refined into a sophisticated training paradigm that can be validated or can gain weight if it leads to improvements in performance.

Finally, as the work was ongoing the researcher began to view many of the ongoing stories in the news and in his area of academic interest through the prism of the research. Distributed cognition takes place throughout our world, in markets, in politics, in diplomatic and military affairs, in history, and in science. Occasionally, it takes place in crisis environments. Sporadically, the deeper learning of Argyris and Schon (1978, 1006) only takes place in crisis environments. A key weakness of the cases used in this research is that they didn't present the opportunity for such learning to take place. While the difficulties associated with knowing when a crisis may happen and capturing data

in a rigorous manner will have to be overcome or addressed in studying such matters the variety of contexts for gaining insight into how distributed cognition can be improved in such circumstances is engaging.

Summary and Final Overview of Conclusions and Contribution the Body of Knowledge

This work sought to develop an understanding of the impact of crisis conditions on distributed cognition phenomena. To this end an extensive review of both key focus areas of subject matter, crisis management and distributed cognition, was undertaken. The key themes and constructs of both fields were condensed into characterizing elements and sub-functions. The researcher concluded that existing frameworks describing organizational learning and distributed cognition proved unfruitful for articulating the impact of crisis conditions on distributed cognition phenomena. To address this challenge the researcher applied Beer's Viable System Model to create a systemic, holistic, structured framework out of the constructs and interrelationships of distributed cognition research which could in turn be used to understand the impacts of a variety of crisis conditions upon distributed cognition phenomena. This effort produced the DC5 framework at the center of this work.

Two research methodologies were then proposed to attempt to validate the framework. The first, an interpretive approach, involved using the framework as a means of understanding case study observations. The second, an applied research approach, involved using the framework as a means of assessing the

distributed cognition fitness level of a control center and designing training environments to maximize their performance enhancing value. Two case studies, one involving three units of analysis and the other just a single unit of analysis, were undertaken to apply these methodologies. The case studies provided initial validation for a substantial portion of the DC5 framework. Repeat case studies in future research can add further validating weight to the framework and could potentially address those areas of the DC5 framework unaddressed by the selected cases in this work.

The primary benefits of this research to the body of knowledge fall into three main categories, that is, its contributions in terms of 1) synthesizing existing literature, 2) theory, 3) methodology, and 4) in practice. First, in terms of the literature, this work reviewed the existing constructs and frameworks as well as general themes from two usually separate, non-intersecting areas of study, distributed cognition and crisis management. It then further studied these literature sets through the lens of systems analysis developing a structured review of the literature and citing a gap existing in the literature. Second, this work goes beyond existing theory by, 1) developing a systemic structured framing of distributed cognition phenomena not found in the existing literature, 2) using existing literary constructs to develop a theoretical means of characterizing a crisis environment, and 3) integrating these two innovations into a single overarching new framework capturing the systemic impacts of a crisis environment upon distributed cognition phenomena. Third, the use of the framework as a means of relating raw control center performance assessments

to characterizations of control center fitness and crisis environments represents an innovative approach the methodologically applying the developed theoretical framework. Fourth, the application in the first case, involving this methodology of interpreting performance in terms of crisis environment and distributed cognition fitness levels, to develop first and assessment and second an intervention, in the form of a script, represents an innovation in terms of applied practice. These four innovations represent the sum of the contribution of this work to the body of knowledge and lay a broad, promising foundation for future more focused, in depth research which can further, more rigorously 1) validate and refine the DC5 framework and 2) comprehend the phenomena at the center of the work.

In terms of guidance for practitioners, specifically Air Force personnel involved in manning, training, and evaluating unit control centers, track two of the research design represents a practical means of employing the theory developed here. The assessment approach involved in this work provides more depth than existing methods and lays the basis for more rigorous development of training plans and script development. The key lessons for practitioners from this work are 1) that crises come in different varieties which can be characterized by the DC5 framework, 2) the cognition that occurs in control centers should be viewed as a system of interacting constructs, 3) environmental impacts to the control center affect its cognitive abilities systemically and the DC5 framework provides a means for anticipating, understanding, and planning for these impacts, 4) control center performance should be interpreted in light of this systemic view

and 5) assessment and training regimens should be deployed with such a framework in mind.

In terms of future research more specifically, this work provides a structured framework for understanding the impacts of a crisis environment on distributed cognition phenomena in the setting of control centers, the framework could serve as a basis for developing strategies for integrating new technologies or methodologies into control center operations. The framework can also serve as a basis for developing new means of assessing control center performance improving the precision and usability of such assessments of control center performance. Finally and hopefully, though limited in its own inherent generalizability, this work can spur thought and future work and research into both similar settings and different settings in which distributed cognition takes place under the stress of crisis conditions.

Lastly, in terms of contributions to the field of Engineering Management, 1) the work represents an innovative application of Systems Engineering concepts to a problem for which the researcher could not find a previous application. 2) The subject matter involves the management of complex, technical infrastructure and highly skilled engineers and technologists, under relatively unstudied circumstances. 3) Finally, the work synthesizes and combines themes, crisis stress and organizational learning, from the field of organizational behavior, a key area of study within Engineering Management research. For Engineering Managers the work represents an advancement of the field.

APPENDIX I

SAMPLE OF EXISTING UCC INSPECTION CRITERIA

FROM AIR COMBAT COMMAND INSTRUCTION 90-201, ADDENDUM F

The following is the section of criteria used by the Air Force's Air Combat Command Inspection Team to evaluate and grade the Unit Control Center of a squadron (in this case a RED HORSE, or heavy construction squadron of 400 personnel) during an Operational Readiness Inspection. One goal of this work was to develop criteria based on an underlying, validated framework that would provide for a more robust, comprehensive assessment of unit control center performance during Operational Readiness Inspections:

5.2. Subarea--Command and Control. Unit command and control will be evaluated to determine if appropriate actions were taken by command and leadership to sustain, defend, survive, and recover.

5.2.1. Rated Items--Command and Control. The following items will determine the overall rating for Command and Control:

5.2.1.1. Plans and Procedures.

5.2.1.2. Local Alarm System.

5.2.1.3. Execution.

5.2.2. Subarea Rating--Command and Control:

5.2.2.1. OUTSTANDING. Plans and Procedures and Execution OUTSTANDING with Local Alarm System at least EXCELLENT.

5.2.2.2. EXCELLENT. Plans and Procedures and Execution at least EXCELLENT with Local Alarm System at least SATISFACTORY.

5.2.2.3. SATISFACTORY. Plans and Procedures and Execution at least SATISFACTORY with Local Alarm System at least MARGINAL.

5.2.2.4. MARGINAL. Plans and Procedures and Execution at least MARGINAL.

5.2.2.5. UNSATISFACTORY. Does not meet other criteria.

5.2.3. Item--Plans and Procedures. Evaluate integration, coordination, and effectiveness of pre-, trans-, and post-attack measures and adequacy of command and control systems. Evaluate the availability of charts, maps, checklists, directives, information boards and reference documents necessary to execute war, contingency response plans and unit emergency action taskings. Evaluate unit's ability to activate an alternate command center to ensure mission continuation in the event of an evacuation/relocation.

5.2.4. Item--Local Alarm System. Evaluated for redundancy, appropriateness, and effectiveness during conventional and Nuclear, Biological and Chemical (NBC) attack situations. Units must utilize the alarm signals specified by the host theater. Units must be capable of implementing timely alarm notifications through more than one medium.

5.2.5. Item--Execution. Ability to collect, display, report, and disseminate attack data through clear lines of authority, rapid communication of data, unity of command, and liaison with appropriate support agencies will be evaluated. Additionally, the ability to track and manage non-attack data and information and properly manage resources and priorities to accomplish taskings will be evaluated. Prioritization of mission tasking to ensure the highest priority tasking is met before lower priority tasking.

APPENDIX II

GLOSSARY OF TERMS, ABBREVIATIONS, AND ACRONYMS

Crisis Control Center: an organization's centralized establishment for facilitating distributed cognition in the event the organization encounters a crisis environment (p.81)

CE: abbreviation used in this work for crisis environment.

Crisis Environment: crisis environments are those with potential for significantly more negative organizational outcomes and of a significantly greater level of complexity than organizations are usually prepared for and in turn cause significant internal organizational stress

Dcog: abbreviation used in this work for distributed cognition

Distributed Cognition: the ongoing accumulation, distribution, and synthesis of knowledge across time, amongst personnel and systems, and at all levels within a bounded organization, which leads to the development, adjustment, and sometimes tearing down of shared mental representations of the outside world within which the organization is trying to pursue its goals (p. 11, 33)

Distributed Cognition System: a system designed or used by organizations for the intended purpose of facilitating distributed cognition as described above. (p. 33).

Distributed Cognition System Fitness: a qualitative characterization of the fitness of a given distributed cognition system based on the DC5 framework. (p.130)

DC5: Abbreviation for the Distributed Cognition in Control Centers in Crisis Conditions Framework developed in this research

DC5F: Abbreviation for DC5 Fitness

Organizational Cognition: a term used somewhat interchangeably throughout the literature having the same general meaning as distributed cognition although perhaps more focused around the occurrence of the phenomena in the context of organizations as opposed to groups in general (p. 33).

UCC: Abbreviation for an Air Force Unit Control Center

Unit Control Center: An Air Force specific term for crisis control centers for various echelons within a typical wing organization functioning in wartime environments or simulated wartime environments for exercise or inspection purposes (p. 82)

APPENDIX III

CASE PROTOCOL AND DATA COLLECTION INSTRUMENTS

Case Protocol Organization

This protocol is presented in outline form. Its purpose is to serve as a potentially auditable resource explaining how research data, analysis, and results were developed. As such each protocol element is presented along with development and discussion, or reference to where that development may be found discussion may be found elsewhere in this text. The elements composing this protocol are: 1) the overall research design, 2) case requirements, suitability, and selection, 3) available case data sources, 4) case access and rules of engagement

Case Protocol

I. Overall Research Design

a) Discussion and Development: See Chapter IV, Figures 4.1 and 4.2

II. Case Requirements, Suitability, and Selection

a) Discussion and Development: See Chapter IV

b) Correspondence with ACC/IG and Inspected Unit: See Appendix IV

III. Available Case Data Sources

a) Discussion and Development: See Chapter IV, Figure 4.3

IV. Case Study Design Tactics

a) Discussion and Development: See Chapter IV, Table 4.1

V. Case Access and Rules of Engagement

a) Discussion and Development: See Chapter IV

b) Supporting Correspondence: See Appendix IV

c) Researcher Rules of Engagement: See Appendix IV, Table 4.1

VI. Research Challenges for Data Collection Instruments

a) Discussion and Development: See Chapter IV, Table 4.2

b) Data Collection Instruments: See later in this Appendix (III), Tables A3.1 thru A3.6.

VII. Procedures for Analysis

a) Discussion and Development by element: See Chapter IV

b) Data Analysis Summaries: To be accomplished on an iterative basis in prospective Chapter V, Case Analysis

VIII. Supporting Documentation

a) Researcher's Resume: See Appendix IV

b) Researcher's Background Narrative: See Appendix IV

c) Samples of supporting correspondence: See Appendix IV

d) Researcher subject verification and validation of data collection instruments, analysis, and conclusions: To be included in Chapter IV.

VIII. Case Database

a) Discussion and Development: See Chapter IV

b) All data sourcing correspondence, data itself collected from the instruments, supporting documentation, and data summaries to be

maintained on CD-ROM by researcher and, in the case of field notes, maintained in a filing system.

Data Collection Instruments

The data collection instruments that follow are derived from the protocol guidance developed in Chapter IV, expressed in Table 4.2. The constructs of the DC5 framework guide the breakdown of questions and observation guidance while the research challenges captured in Table 4.2 are detailed according to the intersecting cell labels provided there. As the protocol suggests the data collection instruments are geared to seek both convergence and triangulation as well as rival explanation and divergence, thus many of the questions that follow are repetitive seeking to focus responses from the interviewee to confirm or reject various DC5 framework constructs.

The data gained from these six instruments along with the other materials detailed in the protocol, researcher background, access correspondence, rules of engagement regarding researcher/unit/evaluator interaction, and interviewee follow-up correspondence, will comprise the case database. For each of the three exercises and one inspection which are being observed, the researcher expects 6 to 10 UCC participant pre- and post-exercise questionnaire responses, two to four, one set of researcher observations, and one evaluation report for review. This database may be made available by contacting the researcher.

Table A3.1: Pre-Exercise Questionnaire for UCC Participants

#	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	General discussion in their terms	A1, A3	What are your expectations of the upcoming exercise? What is your position in the organization? How do think you'll do? In what areas do you think the UCC will excel in, do poorly in?
2	Potential for negative outcomes	A1, A3	How do you feel about the fact that you are being evaluated? For having things go badly in the exercise?
4	Induces Organizational Stress	A1, A3	What are you expecting in terms of stress in the exercise?
5	Demand for Specialized Expertise	A1, A3	What do you think of your expertise/qualifications to respond to scenarios?
6	Demand for Integration of Expertise	A1, A3	What do you think of the UCC's expertise/qualifications to respond to scenarios?
8	Novelty: Number of Entities/Pace of Events	A1, A3	Do you feel you'll be able to handle the amount of information required and processed during the exercise?
10	Context: HOV	A1, A3	Any thoughts on layout/general functioning of UCC? Are you able to monitor information outside just the portion you are focused upon?
11	Context: IS	A1, A3	How well do you know your fellow UCC personnel, their jobs. How long have you worked together in a UCC?
12	Context: Leadership and Staff Competence	A1, A3	Any observations relating to the apparent observed Leadership and Staff Competence?
14	System 1	A1, A3	Can you describe the jobs of the various people in the UCC? The purpose of the systems/artifacts?
15	System 2	A1, A3	How well do you think the UCC team will interact and coordinate their action?
17	System 3	A1, A3	What did you think of the general operational control of the UCC? Are personnel and systems being provided with tools to accomplish their function? How is performance being routinely monitored and feedback being provided?
18	Demographics	NA	Age, rank, gender, race, time in service, time in career field, experience in UCCs

Table A3.2: Post-Exercise Questionnaire for UCC Participants

#	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	General discussion in their terms	D1, D2, D3, D4, D5	How did you think the UCC performed? Rating. Relative to others you've seen. Scenario specific? How would explain the performance successes/lapses/failures?
2	Representations	D1, D2, D3, D4, D5	Can you identify times during the exercise when working representations departed significantly from the real world? If so why do you think they occurred?
3	Potential for negative outcomes	D1, D2, D3, D4, D5	Did you perceive knowledge on the potential for negative outcomes, grade-related and scenario related, impacting performance of the UCC? Specifically, where?
4	Induces Organizational Stress	D1, D2, D3, D4, D5	Where/how did you detect signs of stress impacting you, other, personnel and systems in the UCC? Scenario Specific.
5	Demand for Specialized Expertise	D1, D2, D3, D4, D5	Did you feel any lack of performance/errors were due to the CE's demands for more specialized expertise than existed in the UCC? Scenario specific.
6	Demand for Integration of Expertise	D1, D2, D3, D4, D5	Did you feel any lack of performance/errors were due to the CE's demands for more integrated expertise than existed in the UCC? Scenario specific.
7	Novelty: Unknowability	D1, D2, D3, D4, D5	Did you feel any lack of performance/errors were due to the fact that CE was simply unknowable? Scenario specific.
8	Novelty: Number of Entities	D1, D2, D3, D4, D5	Did you feel any lack of performance/errors were due to the number of entities having to be processed by the UCC? Scenario specific.
9	Novelty: Pace of Events	D1, D2, D3, D4, D5	Did you feel any lack of performance/errors were due to the pace of events having to be processed by the UCC? Scenario specific.
10	Context: HOV	D1, D2, D3, D4, D5	Did you think layout/general functioning of UCC impacted operations? If so, how?
11	Context: IS	D1, D2, D3, D4, D5	What did you think about team member interactions? What motivated them? How did they affect performance
12	System 1	D1, D2, D3, D4, D5	What did you think of the personnel functions? And system functions within the UCC? How did they relate to performance?
13	System 2	D1, D2, D3, D4, D5	Any thoughts on the coordination of actions amongst UCC elements?
14	System 3	D1, D2, D3, D4, D5	What did you think of the general operational control of the UCC? Are personnel and systems being provided with tools to accomplish their function? How is performance being routinely monitored and feedback being provided?
15	System 3	D1, D2, D3, D4, D5	Did you observe any tension relating to the need for more information versus the need for implementable action? Scenario specific.
16	System 5	D1, D2, D3, D4, D5	Any thoughts on issues/challenges that went to the core of the organization, senior leadership, basic policies governing conduct, actions, and work, addressing any tension existing between UCC elements?
17	Researcher Interaction	D6	What effect, if any, did you think the presence of the researcher had on the actions of the UCC?
18	Demographic Information	NA	Age, rank, gender, race, time in service, time evaluating, experience in UCCs

Table A3.3: Post-Exercise Questionnaire for UCC Evaluators

#	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	General discussion in their terms	E1, E2, E3, E4, E5	How did you think the UCC performed? Rating. Relative to others you've seen. Scenario specific? How would explain the performance successes/lapses/failures?
2	Representations	E1, E2, E3, E4, E5	Can you identify times during the exercise when working representations departed significantly from the real world? If so why do you think they occurred?
3	Potential for negative outcomes	E1, E2, E3, E4, E5	Did you perceive the knowledge on the potential for negative outcomes, grade-related and scenario related, impacting performance of the UCC? Specifically, where?
4	Induces Organ-ization Stress	E1, E2, E3, E4, E5	Where/how did you detect signs of stress impacting personnel and systems in the UCC? Scenario Specific.
5	Demand for Specialized Expertise	E1, E2, E3, E4, E5	Did you feel any lack of performance/errors were due to the CE's demands for more specialized expertise than existed in the UCC? Scenario specific.
6	Demand for Integration of Expertise	E1, E2, E3, E4, E5	Did you feel any lack of performance/errors were due to the CE's demands for more integrated expertise than existed in the UCC? Scenario specific.
7	Novelty: Unknowability	E1, E2, E3, E4, E5	Did you feel any lack of performance/errors were due to the fact that CE was simply unknowable? Scenario specific.
8	Novelty: Number of Entities	E1, E2, E3, E4, E5	Did you feel any lack of performance/errors were due to the number of entities having to be processed by the UCC? Scenario specific.
9	Novelty: Pace of Events	E1, E2, E3, E4, E5	Did you feel any lack of performance/errors were due to the pace of events having to be processed by the UCC? Scenario specific.
10	Context: HOV	E1, E2, E3, E4, E5	Did you think layout/general functioning of UCC impacted operations? If so, how?
11	Context: IS	E1, E2, E3, E4, E5	What did you think about team member interactions? What motivated them? How did they affect performance
12	Context: Leadership and Staff Competence	E1, E2, E3, E4, E5	Any observations relating to the apparent observed Leadership and Staff Competence?
13	Context: Flexibility	E1, E2, E3, E4, E5	Any description of UCC actions demonstrating flexibility or lack thereof?
14	System 1	E1, E2, E3, E4, E5	What did you think of the personnel functions? And system functions within the UCC? How did they relate to performance?
15	System 2	E1, E2, E3, E4, E5	Any thoughts on the coordination of actions amongst UCC elements?
17	System 3	E1, E2, E3, E4, E5	What did you think of the general operational control of the UCC? Are personnel and systems being provided with tools to accomplish their function? How is performance being routinely monitored and feedback provided?
18	System 3	E1, E2, E3, E4, E5	Did you observe any tension relating to the need for more information versus the need for implementable action? Scenario specific.
19	System 4	E1, E2, E3, E4, E5	NA – covered by question 2
20	System 5	E1, E2, E3, E4, E5	Any thoughts on issues/challenges that went to the core of the organization, senior leadership, basic policies governing conduct, actions, and work, addressing any tension existing between UCC elements?
21	Researcher Interaction	E6	What effect, if any, did you think the presence of the researcher had on the actions of the UCC?
22	Evaluator Demographic Information	NA	Age, rank, gender, race, time in service, time evaluating, experience in UCCs

Exercise Script and Exercise Script Review

The purpose of the script review is to evaluate the scenarios in terms of the DC5 framework. As the script represents the environment in which the UCC will be functioning, the CE attributes detailed in the DC5 framework should be applied to the scripted scenarios in order to develop a descriptive characterization in such terms for each scenario. This will facilitate further discussion post-exercise to describing the impacts of the crisis environment on the distributed cognition phenomena occurring in the control center. Additionally, part of the descriptive characterization of each scenario will include a concise statement describing the state of the outside environment. This will serve the purpose of guiding the research observations as the control center builds and maintains its representation of that environment. Two data documents will be supplied to the case database for each exercise from this data source, the script itself and the descriptive characterization.

The specific questions, flowing from the CE portion of the DC5 framework, guiding the researcher in capturing the descriptive characterization of the outside environment are:

Table A3.4: Exercise Script and Exercise Script Review

#	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	Potential for negative outcomes	B1, B2, B3, B5	Outside of the exercise environment itself, are there specific elements of the scenario that have the potential for outcomes potentially more negative than usual for the UCC or for the Wing organization?
2	Induces Organizational Stress	B1, B2, B3, B5	Are there attributes from the scenario that would be expected induce stress into the UCC?
3	Demand for Specialized Expertise	B1, B2, B3, B5	To what degree does the scenario require a specialized expert understanding to develop a suitable response?
4	Demand for Integration of Expertise	B1, B2, B3, B5	To what degree does the scenario require a specialized expert understanding to develop a suitable response?
5	Novelty: Unknowability	B1, B2, B3, B5	Does the scenario present an unknowable challenge to the UCC? Describe.
6	Novelty: Number of Entities	B1, B2, B3, B5	Does the scenario present a challenge to the UCC in terms of the number entities that must be understood in order to develop and maintain representations?
7	Novelty: Pace of Events	B1, B2, B3, B5	Does the scenario present a challenge to the UCC in terms of the pace of events that must be processed in order to develop and maintain representations?
8	Representation	B1, B2, B3, B5	Provide description (representation) of the specified environment the scenario entails to compare with observations made during the exercise.
9	DC5F impact	B1, B2, B3, B5	Detail, by Systems 1 through 5, which portions of the DC5F may be expected to be impacted by the scenario

Table A3.5: Researcher Observation Guidance

The purpose of this table is to give the researcher guidance on what to look for in terms of validating DC5 as he takes notes. There may be key observations outside of those anticipated here, however.

#	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	Context: HOV	C1, C2, C3, C4, C5, C6	Provide description of UCC layout and systems interaction within that layout
2	Context: IS	C1, C2, C3, C4, C5	Monitor and provide description of how IS or lack thereof impacts P
3	Context: Leadership and Staff Competence	C1, C2, C3, C4, C5	Describe observations relating to the apparent observed Leadership and Staff Competence.
4	Context: Flexibility	C1, C2, C3, C4, C5	Provide description of UCC actions demonstrating flexibility or lack thereof
5	System 1	C1	Capture and describe the various personnel functions and system artifacts being used to process information flowing through the UCC.
6	System 1	C1, C2, C3, C4, C5	Describe the actions/performance at System 1 level
7	System 2	C1, C2, C3, C4, C5	Capture and describe any actions relating to the coordination of actions amongst UCC elements. What precipitated the coordination? Its follow-through? Its end?
8	System 3	C1, C2, C3, C4, C5	Capture any actions relating to the ongoing control of the UCC. Are personnel and systems being provided with tools to accomplish their function? How is performance being routinely monitored and feedback being provided?
9	System 3	C1, C2, C3, C4, C5	Capture the interaction and any tension between this function and S4 relating to the need for more information versus the need for implementable action
10	System 4	C1, C2, C3, C4, C5	Detail the ongoing processing of representations as they are discussed, displayed, and eventually acted on.
11	System 5	C1, C2, C3, C4, C5	Detail interactions in the UCC that approach or address the identity of the organization. When does senior leadership become involved? What basic policies exist governing conduct, actions, and work? If a tension exists between S4 and S3, how is addressed?
12	Rival Explanations	C1, C2, C3, C4, C5	In capturing events as they unfold do other unifying constructs present themselves?
13	Researcher Interaction	C6	Capture and describe any actual or perceived interactions or issues relating to the researcher's presence
14	CE	C1, C2, C3, C4, C5	In addition to and in conjunction with the scenario characterization of the CE, capture information as it actually flows in and impacts systems.
15	Representations	C1, C2, C3, C4, C5	Capture representations as they are processed, discussed, displayed, and acted upon. Compare and

			contrast with actual state of the environment from script. The difference here represents P.

Table A3.6: Exercise Evaluation Report Guidance

For purposes of this report the goal of reviewing the formal exercise reports is to capture any official judgments and supporting interpretations relating to UCC performance. As such, basically this guidance involves seeking to apply the DC5 framework to the report to see if convergence exists or if perhaps rival explanations exist.

#	DC5 Construct Focus	Table 4.2 Cell References	Question
1	Context: HOV	F1, F2, F3, F4, F5	Does the report discuss this issue/construct?
2	Context: IS	F1, F2, F3, F4, F5	Does the report discuss this issue/construct?
3	Context: Leadership and Staff Competence	F1, F2, F3, F4, F5	Does the report discuss this issue/construct?
4	Context: Flexibility	F1, F2, F3, F4, F5	Does the report discuss this issue/construct?
5	System 1	F1, F2, F3, F4, F5	Does the report discuss this issue/construct?
6	System 2	F1, F2, F3, F4, F5	Does the report discuss this issue/construct?
7	System 3	F1, F2, F3, F4, F5	Does the report discuss this issue/construct?
8	System 3	F1, F2, F3, F4, F5	Does the report discuss this issue/construct?
9	System 4	F1, F2, F3, F4, F5	Does the report discuss this issue/construct?
10	System 5	F1, F2, F3, F4, F5	Does the report discuss this issue/construct?
11	Rival Explanations	F1, F2, F3, F4, F5	Does the report discuss this issue/construct?
12	Representations	F1, F2, F3, F4, F5	Does the report discuss this issue/construct?

APPENDIX IV

SUPPORTING DOCUMENTATION

This appendix provides some of the supporting documentation discussed in the text. Specifically the following documentation is provided: 1) the researcher's resume is provided as a means of disclosing his personal background, 2) also provided as a means of disclosing the researcher's background is a brief narrative containing the researcher's demographics as well as his experience relating specifically to the institutional processes used as a data source in the research, (3) samples of the correspondence between the researcher and the Air Combat Command Inspection Team, as well as, the wings to be inspected, involved in securing access, to the case data resources, 4) the proposed rules of engagement (RoE) governing conduct of the research and interaction with the ACC/IG and inspected wing organizations and 5) samples of correspondence with informants indicating their review of the researchers notes and conclusions.

Researcher Resume

CHRISTOPHER J. WEST

MAJ, USAF | **Military Resume**

AFIT/CIS | **SSN: 243-35-4795**

253 Mill Point Drive
Hampton, VA 23669
(757) 329-9044
email: chrisjwest@yahoo.com

DOR: 20Aug 2002
Clearance: Secret
Age: 36
Marital Status: Single

SERVICE HISTORY

Doctoral Student in Engineering Management and Systems Engineering, Old Dominion University, Norfolk, VA, sponsored by Air Force Institute of Technology Faculty Pipeline Program: Aug 02 – Present.

Civil Engineer Inspector; Headquarters Air Combat Command Inspector General Squadron, Langley AFB, VA: Jan 00 – Aug 02.

Inspects ACC Civil Engineer and RED HORSE squadrons during Operational Readiness Inspections, Unit Compliance Inspections, and Nuclear Surety Inspections documenting performance for ACC/CE staff, providing command-wide crosstell on program implementation, and educating personnel on wartime and peacetime procedures and methods. Additionally, ensures security of Nuclear Weapons through inspection of facilities and other supporting systems. Acted as effective CE Inspection Section Chief supervising 10 inspectors during 6-month position vacancy.

Readiness Flight Commander; 347 Civil Engineer Squadron, Moody AFB, GA; Oct 98 – Jan 00.

Managed 36 Civil Engineer, Support Group, and Wing Operational Response Plans and managed chemical warfare defense training for 4000 base personnel in a composite wing of A-10's, F-16's, HC-130's, and HH-60's. Directed the Prime Base Engineer Emergency Force posturing and training, air base operability, and disaster response programs. Supervises 8 personnel. Moved to this position in preparation for the first wing ORI at Moody in nine years. Implemented Wing CC's idea of integrating AEF concept into Phase II Exercises. 347 CES received a grade of "Excellent". Cited by ACC/IG as a Wing Superior Performer for developing bare base beddown plan in response to IG input in addition to serving as Survival Recovery Center Commander.

Deployed Maintenance Engineering Flight Commander, 363 Expeditionary Civil Engineer Squadron, Prince Sultan Air Base, Kingdom of Saudi Arabia; Jun 99 – Oct 99.

Managed 4-person work order planning shop, 3-person service contract quality assurance evaluator shop, and 23-person service contractor force protection escort shop. Directed the planning of $125,000 in CE in-house accomplished work orders at Prince Sultan Air Base. Developed and implemented 15 new base service contracts worth annual value of over $4 million including potable water supply, sewage removal, refuse removal, grounds maintenance, alarms and suppression, etc).

Environmental Flight Commander; 347 Civil Engineer Squadron, Moody AFB, GA; Jan 97 – Oct 98.

Led 13 personnel in overall management of wing environmental programs valued at over $10.5M including the largest base Installation Restoration Program, $9.3M, and Pollution Prevention Program, $186K, in Air Combat Command. Negotiated with regulators on policies, permits, and procedures. Ensured Environmental Impact Analysis Process was completed on all major base actions including two separate base mission changes and beddown of new rescue mission. Partnered with federal, state, local, and civic organizations to establish the Grand Bay/Banks Lake Council Ecosystem Management Cooperative and the Georgia/DoD Pollution Prevention Partnership, the second of its kind in the US. Managed the base Environmental Compliance Assessment Management Program (ECAMP) including development of corrective action plans for follow up with MAJCOM and base agencies. Facilitated all aspects of the wing Environmental Protection Committee.

Graduate Student, Engineering and Environmental Management; Air Force Institute of Technology; Wright-Patterson AFB, OH; Apr 95 – Jan 97

Project Engineer; 554 RED HORSE Squadron, Osan AB, Republic of Korea; Apr 94 – Apr 95

Responsible for construction project design development and review, development of accurate bills of material, coordination of pre-construction meetings with applicable agencies, creation of construction schedules and served as on-site commander at all deployed locations. Chief RED HORSE Engineer on contingency projects totaling $1.5M in one year including $160K dining hall renovation, $280K Army storage facility, and $110K aircraft parking ramp. On short notice designed then deployed as leader of 25-man crew to accomplish 4 projects worth $392,000 at remote Korean air base in response to rising threat conditions on the peninsula.

Maintenance Engineer; 27 Civil Engineer Squadron, Cannon AFB, NM; Nov 92 – Apr 94

Responsible for developing and managing long term infrastructure maintenance programs for the CE Operations Flight relating to the base electrical distribution system, natural gas distribution system, facility generators, roads and airfield, water distribution system, and sanitary and storm sewer systems. Managed $1.5M Natural Gas account ensuring Cannon purchased the cheapest gas available at spot market prices saving the base over $200K in costs.

Project Engineer; 27 Civil Engineer Squadron, Cannon AFB, NM; Feb 92 – Nov 92

Designed, advised, and provided contractor oversight on base electrical projects including $1M installation of new base communication system and $60K facility power system renovation.

EDUCATION

PME:	Squadron Officers School, Resident Air University
Civilian:	Master of Science in Engineering and Environmental Management, Air Force Institute of Technology, 1996
	Bachelor of Science in Electrical Engineering, Auburn University, 1991

AWARDS AND DECORATIONS

2000 – ACC/IG Company Grade Officer of the Year
1999 - 363rd Wing Company Grade Officer of the Month
1999 - 347th Wing Operational Readiness Inspection Superior Performer
1998 - 347th Support Group Company Grade Officer of the Year
1998 - 347th Wing Company Grade Officer of the Quarter
1997 – 347th Civil Engineer Officer of the Quarter

1996 - George K. Dimitroff Award for Best AFIT Master's Thesis Supporting Air Force Civil Engineering
Meritorious Service Medal
Air Force Commendation Medal (3 OLC)
National Defense Service Medal

PROFESSIONAL AFFILIATIONS

Institute of Electrical and Electronics Engineers
American Society of Engineering Managers
Society of American Military Engineers
Auburn University Electrical Engineer Alumni Association

Researcher Background Narrative

The researcher is a 36 yr old, white male, born in Charlotte, North Carolina and raised both in North Carolina and Alabama. He is single and has not married. He presently lives in Hampton, Virginia. As described in the preceding resume he is an US Air Force Officer with the rank of Major, with 14 yrs of experience on active duty in the Air Force's Civil Engineering career field.

The researcher's experiential relationship to the subject matter of this research, specifically unit control centers functioning in crisis condition, stems from two main sources. First, throughout his career, with the exception of his education assignments, he has been assigned to Air Force bases that regularly train for their wartime mission and operational readiness inspections by conducting operational readiness exercises. Generally, these exercises occurred on a quarterly basis, although two sets of four exercises each, were done on a monthly basis in preparation for operational readiness inspections, both of which the researcher participated in as a player. In these exercises and inspections, the researcher served as: an assistant engineering officer in an engineering control center, the officer in charge of an engineering control center, an engineering representative in a base's overall control center, and as officer in charge of the base's control center. The researcher estimates that he must have participated in at least 15 operational readiness exercises as a player. He participated in two operational readiness inspections as a player.

During his assignment on Air Combat Command's Inspector General team, the researcher served as both an assistant, as well as, lead engineering

officer responsible for planning inspections, developing and implementing scripts, and evaluating unit performance. During these inspections the researcher was specifically responsible for evaluating the performance, based on published Air Force regulation, policy, and doctrine of a variety of different types of unit control centers. The researcher served as an inspector on 15 of these inspections.

Case Access Correspondence

This first set of email threads represents follow-ups to telephone conversations with personnel representing a wing preparing for an operational readiness inspection by conducting three operational readiness exercises. For reasons discussed in the proposed rules of engagement for the research, which follows later in this section, names and unit specific information has been deleted or in some cases replaced by explanatory titles which have been underlined in the text.

Date: Wed, 9 Nov 2005 11:28:39 -0800 (PST)
From: "Christopher West" <chrisjwest@yahoo.com> View Contact Details Add Mobile Alert
Subject: Re: ORE preparation
To: ________________
CC:

Maj ________________________

Just got off the phone with Lt Col ____________,he agreed that a drive up Monday and return after the ORE (I believe the 19th) is doable. Could you please send fund cite to cover gas and motel or billeting. I've done the drive to several times and takes me around 5 hrs. If the wing thinks it better for me to fly and rent a car I can do that too no problem. Will forward the fund cite

to my supporting office at AFIT (Wright Patt) for orders and keep you in the loop and make sure you get hard copies of orders when I arrive. Pls don't hesitate to write or call if you have any questions.

-chris
wrote:

> Hi Chris,
>
> It's getting close to the ORE. We need get together to discuss scenarios.
> Can you call me this afternoon? I'll be back in the office after 1400.
> Work is. Or you can call my cell after 1200 at
>
> -------------------------
> Sent from my BlackBerry Wireless Handheld

CHRISTOPHER J. WEST, Maj, USAF
AFIT/CI PhD Student
chrisjwest@yahoo.com
757 329-9044

From: **Inspected Wing Commanding Officer**
To: "'chrisjwest@yahoo.com'" <chrisjwest@yahoo.com>
CC: Other Inspected Wing Leadership Personnel
Subject: FW ORI - Warlord
Date: Thu, 6 Oct 2005 16:07:13 -0400

Thanks again Chris...It'll be great having you onboard to help guide us through the inspection. The EET Team **Chief Lead Inspected Wing Officer**. His phone number is ________or _______. He is putting together the EET members and developing a tailored scenario to meet

our unique ORI focus - Maintenance Centric, Conventional Only War. I am including a few attachments (maps, briefing slides, minutes, ORI Report, etc.) to get you somewhat indoctrinated into what we have already done to prepare for this re-inspection. Please feel free to call me at any time if you have any question. Again, thanks for volunteering to help support our efforts.

Signed by Inspected Wing Commanding Officer

Date: Wed, 19 Oct 2005 09:01:13 -0700 (PDT)
From: "Christopher West" <chrisjwest@yahoo.com> View Contact Details Add Mobile Alert
Subject:
To:

Looking forward to it too, sir. My info's below. I have to finish up some work for my dissertation committee today and tomorrow morning but I'll talk to my IG contacts and then put some together some details explaining what I'm working on. As I said, I can keep the research's footprint very small relative to your ORE's. Basically it involves designing/scripting scenarios designed to maximize improvement/training value in UCC's and UCC's - which should fall in line with your wing's purposes of bringing me on board for script help and warlord duties.

As discussed, 1st week in November works great for me to get up there an meet with you guys in person if necessary. Working via email also works great for me too.

-chris

Inspected Wing Exercise Officer wrote:

> Hi Chris,
>
> Looking forward to working with you on the OREs and ORI. Per our conversation this morning, here's my info:
>
> **Contact Info for Inspected Wing Exercise Officer follows**

The following email threads are samples of the correspondence with Air Combat Command Inspector General personnel involved in gaining access to the case data. As discussed in Chapter IV, the researcher agreed to serve as an inspector on an ORI to meet an IG manpower shortage requirement in exchange to access to case data later. The ORI in which the researcher served as an augmenting inspector was not used for data collection for purposes of this research however the experience was used by the researcher to plan for the research design involved in this work. For confidentiality purposes, names and personal information have been masked and replaced with position titles. Such alterations of the email text are underlined here.

Subject: Package for IG Access
Date: Thu, 30 Jun 2005 08:41:20 -0400
From: **ACC/IG Engineering Inspector Officer**
To: "Christopher West" <chrisjwest@yahoo.com>

Chris,

I talked to one of the two Support Branch Chiefs. He says to put a package together addressing the key areas: what you are doing, how you will collect data, what you will do with the data, level of access required, trips you are interested, your status on those trips (i.e. permissive tdy or TDY from AFIT), disclosure info, and anything else you think an 0-6 needs to know to grant you access. I would also recommend a bio mentioning that you are a former IG member. The suggested items are suggested, I am sure you have protocols that state how to approach research subjects/gain access to data.

Address package to, **the Inspection Squadron Commander.**

E-mail is ok. Send E-mail to me, which I will send to **IG Branch Chief**. His masters was AFIT/CI and he will put a blurb on how important it is to have an AF related topic and access to data. He will then forward up.

IG Branch Chief, wasn't sure how well it would be received higher up. A lot depends on initial presentation and he thinks concerns will be what data is collected, how data is used, who needs to agree, etc. His other concern is that attending 110 FW may be a stretch; depending on how well it is received.

My suggestions about how to approach the leadership are just my suggestions. If your training and experience says otherwise, I am not offended. Let me know how I can help.

Signed ACC IG Engineering Inspector

From: Christopher West [mailto:chrisjwest@yahoo.com]
Sent: Thursday, June 30, 2005 7:56 AM
To: ACC IG Engineering Inspector
Subject: RE: Fomer IG Officer augmentee services in exchange for SRC/DCC Phase II performance data for research

ACC IG Engineering Inspector,

Got your message - will work up a staff package explaining/asking permission with attachments, talking paper etc. Proposal I'm working on for my prof is taking longer than expected but should have staff package ready later this quarter.

-chris

Subject: RE: Fomer IG Officer augmentee services in exchange for SRC/DCC Phase II performance data for research
Date: Fri, 24 Jun 2005 01:16:28 -0400
From: ACC IG Engineering Inspector Officer
To: "Christopher West" <chrisjwest@yahoo.com>

Chris,

Good to talk to you today. First I will discuss **upcoming unit to be inspected** then your research.

upcoming unit to be inspected – 8-18 Aug 05

I am looking for a warlord and greatly appreciate you volunteering. **ACC/IG Branch Chief Officer**, the former CE section chief, left last week. His replacement, **ACC/IG Branch Chief Officer**, does not arrive until the week before the ORI and we are not sure if he will be attending. The Deputy IG, (his undergrad was CE), will be the team chief. For core CE IG officers, there is myself and a new **ACC/IG Engineering Inspector**. He will have inspected only two NSIs and two ORIs when we get to **upcoming unit to be inspected**. He is too green to be warlord. I could be RH warlord, but since I will be lead CE, or number 2 but 1st IG trip for **ACC/IG Branch Chief Officer**, I would rather be out and about. I have a couple of RH experienced officers as auggies, but I do not want an auggie to be warlord because they do not have the full IG background. You will be perfect. You have been warlord on RH before, know IG, etc. We will have to bring you up to speed on some changes over the last couple of years, but it should be a smooth transition. **ACC/IG Engineering Inspector**. suggested your name a couple of days ago and when I told him you said yes, he gave a big thumbs up. Again thanks. Of course this trip will be paid for by IG.

Research Trips

I do not have a big need for officer auggies in the next couple of months, but can always use experienced help. I would be willing to take you as an auggie, with IG funding, as long as your primary focus was being an inspector. I also would have no problem with you being with the team during inspections and having full IG access to planning sessions, IG meetings, IG discussions, etc. in support of you research. In the latter case, you would not have to focus on being an inspector and would be free to focus on what you need to. I say I have no problem, but, of course, I would have to run it up the chain. Funding on the other hand may be issue. Money is tight for the rest of the fiscal year. ACC has cut 40% of its flying hours from 1 Jun to 1 Oct and a

Guard ORI scheduled for Aug has been moved to the new FY. I will inquire about you coming along for research at IG expense, but I can not make any promises.

I will be back in town next week and I will discuss more. Your research sounds exciting and you have my support. Attached is the Form 117 required for auggies and our current inspection schedule. The inspection scheduled is official for the rest of this calendar year. 2006 is not official yet, is not visible outside the IG (most units know dates or at least window), and is subject to change, especially the latter half of the year.

<<Form 117 - Maj West.doc>>

<<Current Inspections 2.mht>>

Your name is very familiar, but also not sure why. I know we have not been stationed together, but may have crossed paths somewhere. Below is where I have been....

Thanks,

Signed **ACC/IG Engineering Inspector**.

From: Christopher West [mailto:chrisjwest@yahoo.com]
Sent: Thursday, June 23, 2005 3:17 PM
To: **ACC/IG Engineering Inspector**.
Subject: Fomer IG Officer augmentee services in exchange for SRC/DCC Phase II performance data for research

Your name is ringing the CE officer bells in my head but I'm not sure we've met. My name is Chris West - I was your CE predecessor one or two iterations ago (2000-2002) on the IG team - you may have seen my name floating around some of the old paperwork there in the Harbor Center.

I went from the IG team to working on a PhD for AFIT at Old Dominion University. My research is focused on how control centers perform in crisis environments. I can provide much more specific/excruciating detail to you or whomever else may need it at a later time but basically UCC's and or DCC's in Phase II's represent potential data sources for my work.

To get to the point, I would like to offer my services as an augmentee inspector (when I was on the team we we're always looking for suitable officers - knowledge of CE criteria, IG methods/policies/procedures, etc. - it was a challenge) in exchange for the opportunity to "observe" (at this point I'm still defining/negotiating what that means with my research committee - ranging from copious note-taking and interviewing/surveying players to possibly transcribing video taped sessions) a few (3 to 5) UCC's or DCC's in action in Phase II's. Attending these events as a Wing hosted "observer" is another potential route for me take but I think I'd prefer to do it under IG auspices (and potentially travel funding) if possible - in order to be exposed to inspector discussions (another data source) of performance as ratings are determined. Willing to offer my augmentation services on any inspections you may need - even outside potential resea! rch cases and am willing to travel as soon as you may need.

Again, this is a preliminary float of the basic idea to see if you or the team might potentially be interested - I can provide much more information on the research, the approach/acceptability to getting/using data, discuss possible funding issues/options, augmentation requirements etc. I talked to your office today on the phone and I understand you're on the road. If you would like to discuss via phone please send a commercial number and a convenient time to call (I recall those hours we used to work on the road) or I can wait to your back in Hampton Roads to discuss.

-Maj Chris West

Rules of Engagement for Researcher interaction with Inspected Wing, and Inspector General Team

These rules of engagement serve to delineate what can be expected of the researcher 1) as he collects data while the inspected wing prepares for an operational readiness inspection by conducting three internal operational readiness exercises and 2) as he collects data during the actual research inspection. The researcher realizes his objective of collecting sound research data to support his work must be subordinate to the institutional needs of the Air Force, specifically the objective of the inspected wing to perform as well as possible in the upcoming ORI and the objective of the ACC/IG team to properly assess the performance of the inspected wing. These objectives of proper assessment, strong wing performance, and the collection of sound research data govern these rules of engagement. All three entities agree that the focus of the research is in the Air Force interest and can be accommodated if the rules are followed.

The researcher has identified six sources from which to collect data during each of three internal wing operational readiness exercises and one formal operational readiness inspection. These data sources in conjunction with the objectives described above form the foundation of the rules of engagement which follow.

Inspected Wing Operational Readiness Inspections

Data Source – Pre-Exercise Interviews:

1) Inspected wing will allow researcher access to UCC players. Interviews will be no longer than 30 minutes in length and will be based on questionnaires submitted by researcher to unit for approval.

2) Interview notes and summaries will be submitted to players for review and comment

Table A4.1: Researcher-Inspected Wing-IG Rules of Engagement

		Objectives		
ORE/ORI	**Data Sources and other issues**	**ACC/IG: Proper Assessment of Unit Performance**	**Inspected Wing: Maximize Performance During ORI**	**Researcher: Data Collection and Research Soundness**
Internal Wing Operational Readiness Exercises	General	ACC/IG has no interaction with inspected wing other than to agree to general ground rules/planning items relating to the inspection. ACC/IG and the researcher will have no interaction relating to unit training and performance.	Unit coordinates with IG to ensure basic inspection planning items are agreed upon so that OREs will mirror ORIs. Inspected wing seeks to maximize ORI performance by soliciting researcher advice, review, and recommendations based on his research constructs. Inspected unit will have access to all data collection notes/summaries and the right to remove portions as necessary to retain confidentiality for institutional purposes. Inspected unit will have access to all research analysis and conclusions and any comments will be incorporated in the case database.	Researcher has no interaction with IG regarding unit training and performance during OREs. Researcher seeks to gain data from data sources discussed below as well as work with wing to devise ORE scripts suited to train/improve UCC performance based on research constructs. Researcher will remove all references in edditted collect case data to the specific unit, as well as, to specific personnel to retain confidentiality for Air Force purposes and anonymity for research soundness
Internal Wing Operational Readiness Exercises	Pre-ORE Player Interviews	ACC/IG will have no interaction at this level.	Unit will make players available for interviews	Researcher will submit interview questions to unit

		Objectives		
ORE/ORI	**Data Sources and other issues**	**ACC/IG: Proper Assessment of Unit Performance**	**Inspected Wing: Maximize Performance During ORI**	**Researcher: Data Collection and Research Soundness**
			based on questionnaires.	leadership for review and conduct interviews as discussed in data collection instrument guidelines. Researcher will submit interview summaries to players for review and comment following interview. Comments will be incorporated in case database.
Internal Wing Operational Readiness Exercises	Internal Wing Exercise Scripts	ACC/IG will have no interaction at this level.	Researcher will work with unit to develop initial ORE script based on experience with what constitutes good scenarios. Researcher and Unit will work together to develop subsequent ORE scripts based on research framework constructs – seeking to improve performance.	Researcher will work with unit to develop initial ORE script based on experience with what constitutes good scenarios. Researcher and Unit will work together to develop subsequent ORE scripts based on research framework constructs – seeking to improve performance. Researcher may keep scripts for documentation and analysis purposes.
Internal Wing Operational Readiness Exercises	Researcher Notes	ACC/IG will have no interaction at this level.	Researcher shall have access to UCC during OREs.	Researcher will remove all reference to specific personnel/organizations

		Objectives		
ORE/ORI	**Data Sources and other issues**	**ACC/IG: Proper Assessment of Unit Performance**	**Inspected Wing: Maximize Performance During ORI**	**Researcher: Data Collection and Research Soundness**
			Unit will have opportunity to review notes and summaries and comment accordingly. Comments will be incorporated in the case database.	from notes for confidentiality/anonymity purposes.
Internal Wing Operational Readiness Inspections	Post-ORE Player Interviews	ACC/IG will have no interaction at this level.	Unit will make players available for interviews based on questionnaires.	Researcher will submit interview questions to unit leadership for review and conduct interviews as discussed in data collection instrument guidelines. Researcher will submit interview summaries to players for review and comment following interview. Comments will be incorporated in case database.
Internal Wing Operational Readiness Exercises	Post-ORE Evaluator Interviews	ACC/IG will have no interaction at this level.	Unit will make evaluators available for interviews based on questionnaires.	Researcher will submit interview questions to unit leadership for review and conduct interviews as discussed in data collection instrument guidelines Researcher will submit interview summaries to evaluators for review and

		Objectives		
ORE/ORI	**Data Sources and other issues**	**ACC/IG: Proper Assessment of Unit Performance**	**Inspected Wing: Maximize Performance During ORI**	**Researcher: Data Collection and Research Soundness**
				comment following interview. Comments will be incorporated in case database.
Internal Wing Operational Readiness Exercises	Post ORE Evaluation Report	ACC/IG will have no interaction at this level.	Unit will provide report to researcher.	Researcher will incorporate report into database.
Formal Wing Operational Readiness Inspection	General	Researcher shall be able to observe inspector discussion during and following inspection. Researcher will keep all comments regarding performance and inspection to himself until report is written to support unbiased inspection. Researcher shall not interact with inspected unit other than to observe performance and will not interfere with inspection in anyway. IG will have access to all data collection notes/summaries and the right to remove portions as necessary to retain confidentiality for institutional purposes.	Inspected unit will have access to all data collection notes/summaries and the right to remove portions as necessary to retain confidentiality for institutional purposes. Inspected unit will have access to all research analysis and conclusions and any comments will be incorporated in the case database.	Researcher has no interaction with IG regarding unit performance during ORI prior to report writing completion other than to observe discussion Researcher will remove all references in editted collect case data to the specific unit, as well as, to specific personnel to retain confidentiality for Air Force purposes and anonymity for research soundness

		Objectives		
ORE/ORI	**Data Sources and other issues**	**ACC/IG: Proper Assessment of Unit Performance**	**Inspected Wing: Maximize Performance During ORI**	**Researcher: Data Collection and Research Soundness**
		IG will have access to all research analysis and conclusions and any comments will be incorporated in the case database.		
Formal Wing Operational Readiness Inspection	Pre-ORI Player Interviews	ACC/IG will have no interaction at this level.	Unit will make players available for interviews based on questionnaires.	Researcher will submit interview questions to unit leadership for review and conduct interviews as discussed in data collection instrument guidelines. Researcher will submit interview summaries to players for review and comment following interview. Comments will be incorporated in case database.
Formal Wing Operational Readiness Inspection	ORI Exercise Script	Researcher shall not have access to script until after ORI has ended. IG shall provide copy of script to researcher for research analysis purposes following ORI.	Unit has no interaction at this level.	Researcher may keep scripts for documentation and analysis purposes.
Formal Wing Operational Readiness Inspection	Researcher Notes	Researcher shall confine himself to no interaction with inspected unit other	Researcher shall have access to UCC during ORI.	Researcher will remove all reference to specific personnel/organizations

		Objectives		
ORE/ORI	**Data Sources and other issues**	**ACC/IG: Proper Assessment of Unit Performance**	**Inspected Wing: Maximize Performance During ORI**	**Researcher: Data Collection and Research Soundness**
		than to take notes. IG shall have access to all researcher notes and review/comment accordingly. Comments will be incorporated in case database.	Unit will have opportunity to review notes and summaries and comment accordingly after ORI has ended. Comments will be incorporated in the case database.	from notes for confidentiality/anonymity purposes.
Formal Wing Operational Readiness Inspection	Post-ORI Player Interviews	ACC/IG will have no interaction at this level.	Unit will make players available for interviews based on questionnaires.	Researcher will submit interview questions to unit leadership for review and conduct interviews as discussed in data collection instrument guidelines. Researcher will submit interview summaries to players for review and comment following interview. Comments will be incorporated in case database.
Formal Wing Operational Readiness Inspection	Post-ORI Inspector Interviews	Inspectors involved in evaluating UCC will be available for interview according to questionnaire.	Unit has no interaction at this level.	Researcher will submit interview questions to IG leadership for review and conduct interviews as discussed in data collection instrument guidelines Researcher will submit interview summaries to

		Objectives		
ORE/ORI	**Data Sources and other issues**	**ACC/IG: Proper Assessment of Unit Performance**	**Inspected Wing: Maximize Performance During ORI**	**Researcher: Data Collection and Research Soundness**
				inspector for review and comment following interview. Comments will be incorporated in case database.
Formal Wing Operational Readiness Inspection	ORI Report	ACC/IG will make report available to researcher following completion.	Unit has no interaction at this level.	Researcher will incorporate report into database.

Samples of Correspondence relating to Informant Reviews of Field Notes from Interviews

Below are two samples of email correspondence with informants regarding their review of the author's notes relating to the data collection interviews. Additionally, the first sample highlights previous telephone discussion of the researcher's conclusions following the first case-first ORE as well as formally solidifying the rest of the research plan as it related to the unit's subsequent OREs and ORI; the plan had not been formally reviewed/accepted by unit leadership at that point; verbal approval had been given at lower levels of leadership prior to the first ORE.

From: <Officer from Case 1 First ORE> View Contact Details Add Mobile Alert

To: "'Christopher West'" <chrisjwest@yahoo.com>
Subject: RE: Nov ORE – Informant Review
Date: Fri, 17 Nov 2005 06:45:41 -0500

Hi Chris,

(Please call me ________)

My apologies if you've been trying to call my cell phone. Comm gave me a "new and improved" phone. Enough said there. I have not been able to check voicemail for about a week.

1. I agree with your notes on the interview. Your comments <for inclusion on the unit's internal ORE report> are great. I will send you a copy of the ORE Report. There is a problem locating the Fuels information. It is not where it is supposed to be and both of our fuels inspectors (from Maryland) are TDY.
2. List is being finalized for <another unit officer> to take to the IG

3. As I mentioned at our last discussion at the base – most definitely! Yes, please start scripting. I have already invited the same inspectors back for Feb. I will need to have one two of the maintenance EET personnel come in ahead of time to give scripting for the maintenance arena since neither you or I have that strength and we will need to stress them with more complex maintenance issues (load config changes, simulated problems, etc.)

P.S. Comm just called and said that my cell phone should be working so I guess I'm "back on the air"

If I don't get a chance to talk to you before hand, I hope you and your family will have a great holiday weekend!

<sig block>

From: Christopher West [mailto:chrisjwest@yahoo.com]
Sent: Thursday, November 16, 2005 1:42 PM
To: <Officer from Case 1 First ORE>
Subject: Nov ORE – Informant Review

Sir,

Tried to call a couple times and I assume you're pretty busy. Was trying to follow up and touch base before Thanksgiving -

1) Hope you found my notes on the Nov. exercise/interview satisfactory. If you do, could you please send an email indicating such as we discussed for filing in my database. I would also like to get a copy of your final ORE report if possible for my research purposes. I will delete all names/unit references for purposes of the research records - we can discuss further if you like.

2) Was wondering if you (or others) had contacted the IG on the issues we discussed requiring further clarification (i.e.: flightline aggressor artificiality, offline tasking of the SRC)

3) I would like to return for further help if possible in your subsequent exercises (and for more data collection for my purposes), any possible other ORI specific training the wing may be doing, and for the ORI. I will use my notes, the Nov script, and your report to start working on script planning for the next ORE if you like.

Please let me know if you might need further info.

Thx,

Chris
CHRISTOPHER J. WEST, Maj, USAF
AFIT/CI PhD Student
chrisjwest@yahoo.com

From: "<Engineering Officer from Case 2> View Contact Details Add Mobile Alert

To: "'Christopher West'" <chrisjwest@yahoo.com>

Subject: RE: Need Review Acknowledgment for ORI notes

Date: Mon, 13 Mar 2006 08:23:49 -0600

Chris,

I have read Major's West's notes re: our discussions during the ORI and they're accurate.

How's that?

You're on the list. Stay out of the bars and finish your dissertation :)

<sig block>

From: Christopher West [mailto:chrisjwest@yahoo.com]
Sent: Friday, March 10, 2006 2:53 PM
To: "<Engineering Officer from Case 2>
Subject: ORI observer request

Hi ____,

Good talking to you this afternoon. Hope you've had a chance to review my notes from the ORI interviews. As we talked about-for my research files, can you please reply with an acknowledgment that they are inline with what we discussed?

-chris

CHRISTOPHER J. WEST, Maj, USAF
AFIT/CI PhD Student
chrisjwest@yahoo.com

APPENDIX V

RAW DATA COLLECTION SUMMARY

The purpose of this section is to summarize the data in the case database by case. The tool used to present this summary is the data collection instrument tables presented Appendix III. The tables here represent the researcher's summary by instrument type of the individual data collection instruments themselves. Where considerable convergence was seen that it's verbally indicated. On questions where less of a degree of convergence or no convergence is seen that is also verbally indicated. In some cases individual questions associated with the data collection instruments proved unfruitful in gaining data as open interviews were conducted and that is also indicated. As noted in the text, the second ORE in the first case resulted in limited data collection due to partial cancellation of the exercise due to inclement weather and more importantly due to the limited crisis environment relative to the fitness increases gained by the unit; since that data is more generally discussed in the text it is not included here. The tables and figures are labeled according to the case they were associated with, i.e. the second numerical digit in the table or figure represents the case number observed.

Case 1- 1st ORE Raw Data Summary

Table A5.1.1.1: Data Summary for Pre-Exercise Questionnaire for UCC Participants

#	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	General discussion in their terms	A1, A3	8 personnel interviewed. Most expected to do better in terms of performance than they had in the May '05 ORI. Most thought the IG inspectors were somewhat biased against their reliance on the new electronic BARTS system for message posting exercise information. A smaller minority (two or three) weren't sure how they would perform in the ORE
2	Potential for negative outcomes	A1, A3	Most expressed the desire to not have their performance rated substandard again. All expressed their knowledge of unit leaderships desire to see performance improve.
4	Induces Organizational Stress	A1, A3	All expressed a desire to have the exercises and ORI over with.
5	Demand for Specialized Expertise	A1, A3	All thought they were experts in their respective career field. A minority expressed reservations about applying their expertise in a control room setting.
6	Demand for Integration of Expertise	A1, A3	Most thought the group could work well together to apply their disciplines. A minority were unsure because of the May '05 inspection.
8	Novelty: Number of Entities/Pace of Events	A1, A3	Most were unsure how they would perform. One thought it would be too hard.
10	Context: HOV	A1, A3	All liked BARTS. Two thought layout was good. Majority had not considered layout.
11	Context: IS	A1, A3	All new each other for more than a year. Most had prior experience working together in the SRC. Three had not worked in an SRC before the Nov ORE
12	Context: Leadership and Staff Competence	A1, A3	None expressed reservations about leadership. All felt competent with other personnel.
14	System 1	A1, A3	All could describe purpose of SRC displays, BARTS, and jobs of other personnel.
15	System 2	A1, A3	All thought coordination would go well.
17	System 3	A1, A3	All thought they would function well, and would be ably led.
18	Demographics	NA	All were Caucasian. 3 were female. 2 in 30's. 4 in 40's. 2 in 50's. 5 enlisted: E5+. 3 Officer: O-4, O-5, O-6.

Table A5.1.1.2: Post-Exercise Questionnaire for UCC Participants

#	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	General discussion in their terms	D1, D2, D3, D4, D5	4 thought poorly. 3 thought satisfactory. 1 thought well.
2	Representations	D1, D2, D3, D4, D5	None thought representations departed greatly from real world in terms of accuracy. All thought time to gaining accuracy could be improved.
3	Potential for negative outcomes	D1, D2, D3, D4, D5	All acknowledged pressure to perform with each attack, especially initial attacks of the exercise. All said this pressure lightened as the exercise continued – they got used to executing during attacks. Three said prior mistakes/slowness led to increased pressure to perform.
4	Induces Organizational Stress	D1, D2, D3, D4, D5	Most said they felt stress after errors/slowness in PAR sweeps were reported by them to senior leadership, and keeping up with incoming data. Two felt little stress other than that of being in an exercise.
5	Demand for Specialized Expertise	D1, D2, D3, D4, D5	No concerns we're voiced in this area.
6	Demand for Integration of Expertise	D1, D2, D3, D4, D5	No concerns we're voiced in this area.
7	Novelty: Unknowability	D1, D2, D3, D4, D5	No concerns we're voiced in this area.
8	Novelty: Number of Entities	D1, D2, D3, D4, D5	Most reported the breadth of the second attack was daunting.
9	Novelty: Pace of Events	D1, D2, D3, D4, D5	Most reported significant stress in managing the pace of events associated with the MOC relocation exercise.
10	Context: HOV	D1, D2, D3, D4, D5	All felt BARTS helped tremendously and facilitated the quick distribution of information across career fields.
11	Context: IS	D1, D2, D3, D4, D5	All said nature of attack required interaction i.e.: aggressors required security response and maintenance response
12	System 1	D1, D2, D3, D4, D5	Giant Voice and Flag indications were slow and errant. All reported stress as a result of such errors and impact
13	System 2	D1, D2, D3, D4, D5	Inconclusive responses
14	System 3	D1, D2, D3, D4, D5	Most thought SRC director did a good job of directing efforts. Some thought tendency to become over focused was present.
15	System 3	D1, D2, D3, D4, D5	All noted leadership's dissatisfaction with slowness of PAR information and the need to go to general release.
16	System 5	D1, D2, D3, D4, D5	All noted the stress all felt as a result of the previous inspection report
17	Researcher Interaction	D6	No participants expressed concerns in this area
18	Demographic Information	NA	See previous questionnaire

Table A5.1.1.3: Post-Exercise Questionnaire for UCC Evaluators

#	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	General discussion in their terms	E1, E2, E3, E4, E5	The researcher and the eval team chief were the only eval team members evaluating the SRC thus the comments below are those of the Team Chief
2	Representations	E1, E2, E3, E4, E5	Recurringly, only due to slowness in PAR team communication. In a couple case due to locating errors associated with UXOs
3	Potential for negative outcomes	E1, E2, E3, E4, E5	Perceived stress associated with negative May 05 inspection report. Also with slowness of general release do to PAR team slowness
4	Induces Organizational Stress	E1, E2, E3, E4, E5	See above.
5	Demand for Specialized Expertise	E1, E2, E3, E4, E5	None perceived.
6	Demand for Integration of Expertise	E1, E2, E3, E4, E5	None perceived.
7	Novelty: Unknowability	E1, E2, E3, E4, E5	Non-perceived.
8	Novelty: Number of Entities	E1, E2, E3, E4, E5	Extensive MOC attack/relocation made keeping up with information difficult and stressful.
9	Novelty: Pace of Events	E1, E2, E3, E4, E5	Extensive MOC attack/relocation made keeping up with information difficult and stressful.
10	Context: HOV	E1, E2, E3, E4, E5	Felt BARTS helped facilitated the quick distribution of information across career fields but agreed with IG assessment that it limits chatter in the SRC.
11	Context: IS	E1, E2, E3, E4, E5	Did not think exercise was intense enough to make the effects of good IS visible in performance
12	Context: Leadership and Staff Competence	E1, E2, E3, E4, E5	No information volunteered.
13	Context: Flexibility	E1, E2, E3, E4, E5	Not really.
14	System 1	E1, E2, E3, E4, E5	Repeated concerns with Giant Voice and PAR teams seen elsewhere
15	System 2	E1, E2, E3, E4, E5	Not Really.
17	System 3	E1, E2, E3, E4, E5	Tendency to get over focused on problems beneath their level of management
18	System 3	E1, E2, E3, E4, E5	Repeated concerns with PAR teams seen elsewhere
19	System 4	E1, E2, E3, E4, E5	NA – covered by question 2
20	System 5	E1, E2, E3, E4, E5	Cited general stress associated with previous inspection failure.
21	Researcher Interaction	E6	None.
22	Evaluator Demographic Information	NA	Team Chief is white male, 40 yr old, O-5.

Table A5.1.1.4: Exercise Script and Exercise Script Review

#	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	Potential for negative outcomes	B1, B2, B3, B5	First attack was designed to have breadth second to have depth, designed to stress both unit and control center.
2	Induces Organizational Stress	B1, B2, B3, B5	Same as above.
3	Demand for Specialized Expertise	B1, B2, B3, B5	Not really in terms of command and control.
4	Demand for Integration of Expertise	B1, B2, B3, B5	Not so much expertise as information.
5	Novelty: Unknowability	B1, B2, B3, B5	Not really.
6	Novelty: Number of Entities	B1, B2, B3, B5	MOC relocation attack represents an attempt to challenge the processing limits of the SRC.
7	Novelty: Pace of Events	B1, B2, B3, B5	Breadth attack represents an attempt to challenge the processing limits of the SRC.
8	Representation	B1, B2, B3, B5	See script in case database
9	DC5F impact	B1, B2, B3, B5	See discussion Ch. 5

Table A5.1.1.5: Researcher Observation Guidance

F	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	Context: HOV	C1, C2, C3, C4, C5, C6	The SRC sat in front of and below a screened off battlestaff room for senior leadership. Four displays were projected onto screens readable by 8 SRC staff as well as battlestaff. The staff consisted of a director, a logkeeper/BARTS updater, an engineering representative, a medical representative, a security forces representative, a communications representative, a maintenance representative, a logistics representative, and a senior enlisted chief. Personnel were seated at a long wraparound desk with laptops, phones, and radio communications. Displays included priority lists of facilities, actions, reconnaissance sweeps, and BARTS information (see Figure A5.1, layout).
2	Context: IS	C1, C2, C3, C4, C5	IS was good because all players knew each other as local ANG members but negative in that only 4 had worked together in the May '05 ORI. In the researcher's opinion script did not stress SRC personnel enough to note the impact of good or poor IS.
3	Context: Leadership and Staff Competence	C1, C2, C3, C4, C5	Workers (S1) were competent in job knowledge. Somewhat week in interaction due to lack of SRC work together. Criticism: SRC leadership and multiple workers tended to become over focused on solving singular, relatively minor issues in comparison, to the exclusion of other issues.
4	Context: Flexibility	C1, C2, C3, C4, C5	Not much in this area to observe although SRC responded very well to loss of BARTS operation.
5	System 1	C1	See SRC layout description above and discussion of BARTS in Chapter V.
6	System 1	C1, C2, C3, C4, C5	See SRC layout description above and discussion of BARTS in Chapter V. One criticism is performance of tracking PAR teams and communicating alarm signals discussed in ch. 5. Accountability checks should have been more regular.
7	System 2	C1, C2, C3, C4, C5	Coordination greatly facilitated by BARTS, almost becoming mindless.
8	System 3	C1, C2, C3, C4, C5	Not much of observational note other than the need to apply more pressure for completion of PAR sweeps.
9	System 3	C1, C2, C3, C4, C5	See discussion of slow PAR sweeps in Ch. 5
10	System 4	C1, C2, C3, C4, C5	SRC for the most part accurately captured and displayed the varieties of attack damage, impact, prioritization. Script did not significantly test the mental construction of representations as most were straightforward. A map display would have helped processing of incoming data, and action development in response.
11	System 5	C1, C2, C3, C4, C5	Senior leadership's significant interaction with SRC during the ORE was to insist upon quicker PAR sweeps.
12	Rival Explanations	C1, C2, C3, C4, C5	Easiness of script did not lead to observations in this area.
13	Researcher Interaction	C6	None observed.
14	CE	C1, C2, C3, C4, C5	See discussion in Ch. 5
15	Representations	C1, C2, C3, C4, C5	See discussion in Ch. 5

Figure A5.1: UCC Layout

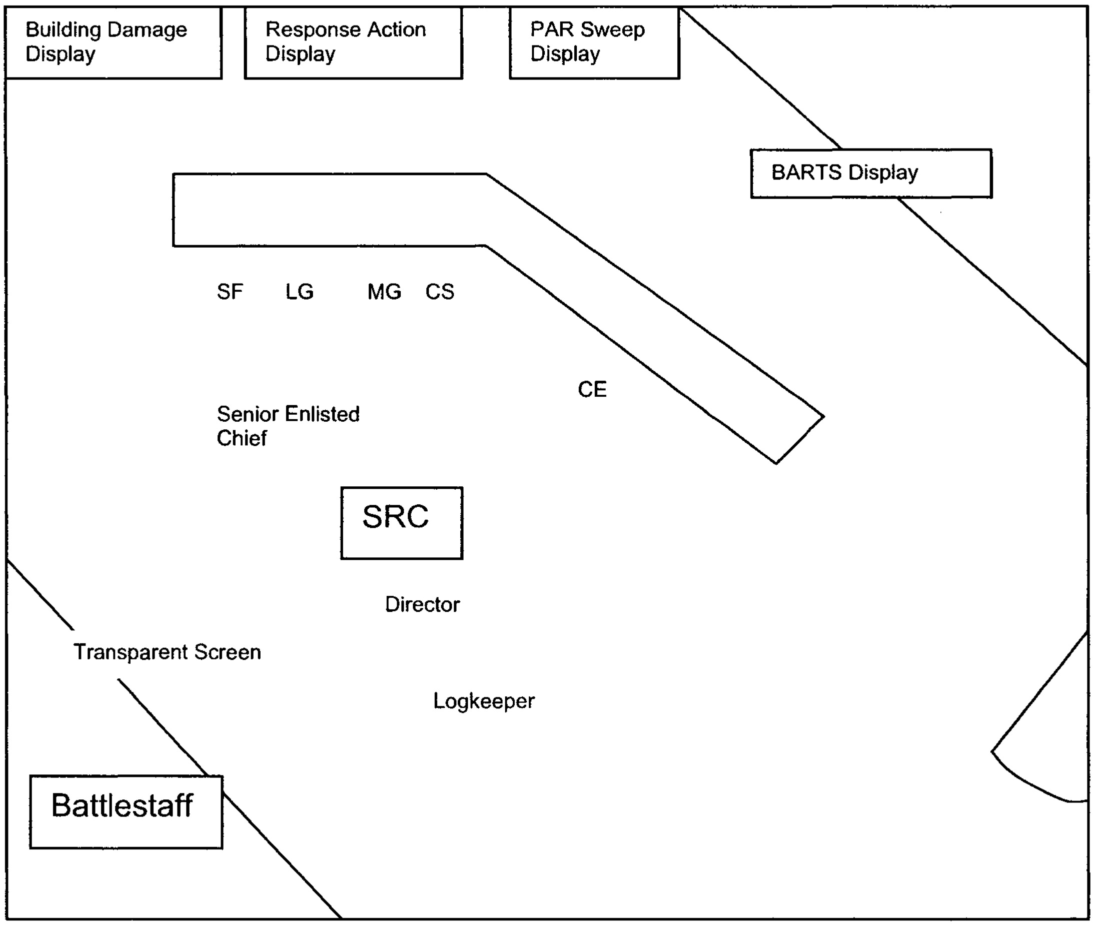


Table A5.1.1.6: Exercise Evaluation Report Guidance

#	DC5 Construct Focus	Table 4.2 Cell References	Question
1	Context: HOV	F1, F2, F3, F4, F5	Yes in terms of BARTS. Provides wider view of actions relatively quickly and retains messages improving HOV. But tends to decrease chatter allowing for simultaneous monitoring of issues.
2	Context: IS	F1, F2, F3, F4, F5	NO
3	Context: Leadership and Staff Competence	F1, F2, F3, F4, F5	NO
4	Context: Flexibility	F1, F2, F3, F4, F5	Positively in terms of BARTS system loss response.
5	System 1	F1, F2, F3, F4, F5	Negatively in terms of PAR sweeps, and Giant Voice communication
6	System 2	F1, F2, F3, F4, F5	NO
7	System 3	F1, F2, F3, F4, F5	Negatively in terms of PAR sweep team motivation.
8	System 3	F1, F2, F3, F4, F5	Negatively in terms of PAR sweep team motivation
9	System 4	F1, F2, F3, F4, F5	Negatively in terms of PAR sweep team motivation
10	System 5	F1, F2, F3, F4, F5	No
11	Rival Explanations	F1, F2, F3, F4, F5	No
12	Representations	F1, F2, F3, F4, F5	Negatively in terms of PAR sweep team motivation

Case 2 - ORI Raw Data Summary

Table A5.2.1: Data Summary for Pre-Exercise Questionnaire for UCC Participants

#	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	General discussion in their terms	A1, A3	9 personnel interviewed. Most expected to perform satisfactory
2	Potential for negative outcomes	A1, A3	Most expressed the desire to do well. Most expressed their knowledge of unit leaderships desire do well.
4	Induces Organizational Stress	A1, A3	All expressed a desire to have the ORI over with.
5	Demand for Specialized Expertise	A1, A3	All thought they were experts in their respective career field.
6	Demand for Integration of Expertise	A1, A3	All thought the group could integrate their expertises.
8	Novelty: Number of Entities/Pace of Events	A1, A3	Most thought they would handle the intensity well. Two expressed reservations about not having enough practice.
10	Context: HOV	A1, A3	Most thought the layout was good.
11	Context: IS	A1, A3	All new each other for more than a year. Most had only worked together in the SRC in one exercise before the ORI.
12	Context: Leadership and Staff Competence	A1, A3	None expressed reservations about leadership. Most felt competent with other personnel. Three thought more practice OREs would have been better
14	System 1	A1, A3	Most could generally describe purpose of SRC displays, and jobs of other personnel although articulation of basic procedures diverged significantly as more details were discussed
15	System 2	A1, A3	Most thought coordination would go well. Three thought it would be a challenge.
17	Systems 3, 4, 5	A1, A3	All thought they would function well, and would be ably led.
18	Demographics	NA	Eight were Caucasian. One was African-American. 3 were female. 4 in 30's. 3 in 40's. 2 in 50's. 6 enlisted: 1 SNCO, 3 NCO, 2 Airman. 2 Officer: O-4, O-6.

Table A5.2.2: Post-Exercise Questionnaire for UCC Participants

#	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	General discussion in their terms	D1, D2, D3, D4, D5	All thought poorly.
2	Representations	D1, D2, D3, D4, D5	All thought timeliness of information flow impacted UCC direction of response actions.
3	Potential for negative outcomes	D1, D2, D3, D4, D5	All acknowledged pressure to perform with each attack, Most said that IG feedback (negative) increased pressure to perform.
4	Induces Organizational Stress	D1, D2, D3, D4, D5	Most acknowledged increased stress as a result of negative IG feedback.
5	Demand for Specialized Expertise	D1, D2, D3, D4, D5	Most thought the UCC team had the required expertise but lacked he practice of working with each other. Two were unsure.
6	Demand for Integration of Expertise	*D1, D2, D3, D4, D5*	Most thought the UCC team had the required expertise but lacked he practice of working with each other. Two were unsure.
7	Novelty: Unknowability	D1, D2, D3, D4, D5	No concerns we're voiced in this area.
8	Novelty: Number of Entities	D1, D2, D3, D4, D5	Most thought the attacks involved lots of damage.
9	Novelty: Pace of Events	D1, D2, D3, D4, D5	All reported significant stress in managing the pace of events throughout the exercise.
10	Context: HOV	D1, D2, D3, D4, D5	All felt MOPP gear inhibited their ability to monitor information flows outside their own,.
11	Context: IS	D1, D2, D3, D4, D5	Some said MOPP gear caused them to focus more on themselves and less on others.
12	System 1	D1, D2, D3, D4, D5	Flag indications were slow and errant. Status Board updates and accountability checks were untimely. Checklist use was minimal. Errors were openly acknowledged by most.
13	System 2	D1, D2, D3, D4, D5	All thought more practice was required to sharpen coordination skills.
14	System 3	D1, D2, D3, D4, D5	Inconclusive comments. No convergence of opinion.
15	System 3	D1, D2, D3, D4, D5	Inconclusive comments. No convergence of opinion.
16	System 5	D1, D2, D3, D4, D5	Inconclusive comments. No convergence of opinion.
17	Researcher Interaction	D6	No participants expressed concerns in this area
18	Demographic Information	NA	See previous table.

Table A5.2.3: Post-Exercise Questionnaire for UCC Inspectors

#	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	General discussion in their terms	E1, E2, E3, E4, E5	Inspectors agreed unanimously that all aspects of performance were poor.
2	Representations	E1, E2, E3, E4, E5	Untimely across the board leading to numerous errors.
3	Potential for negative outcomes	E1, E2, E3, E4, E5	Perceived stress associated negative feedback but also thought lack of action/improvement indicated lack of stress.
4	Induces Organizational Stress	E1, E2, E3, E4, E5	Perceived stress associated negative feedback but also thought lack of action/improvement indicated lack of stress.
5	Demand for Specialized Expertise	E1, E2, E3, E4, E5	Inspectors agreed inspection script did not call for any group or single expertise not readily available to UCC personnel.
6	Demand for Integration of Expertise	E1, E2, E3, E4, E5	Inspectors agreed inspection script did not call for any group or single expertise not readily available to UCC personnel.
7	Novelty: Unknowability	E1, E2, E3, E4, E5	Inspectors agreed all scenarios were easily discernable.
8	Novelty: Number of Entities	E1, E2, E3, E4, E5	All Inspectors thought attacks were light in terms of depth of impact to operations.
9	Novelty: Pace of Events	E1, E2, E3, E4, E5	Inspectors agreed the pace of events was demanding and constant except for the last day.
10	Context: HOV	E1, E2, E3, E4, E5	At researcher's prompting, inspectors agreed HOV was impacted by wear of chemical gear but thought performance was already low enough to be able to really comment on extent of impact.
11	Context: IS	E1, E2, E3, E4, E5	At researcher's prompting, inspectors agreed HOV was impacted by wear of chemical gear but thought performance was already low enough to be able to really comment on extent of impact.
12	Context: Leadership and Staff Competence	E1, E2, E3, E4, E5	Inspectors chose not to comment directly but thought more practice would have helped the unit
13	Context: Flexibility	E1, E2, E3, E4, E5	No convergence in this area.
14	System 1	E1, E2, E3, E4, E5	Flag indications were slow and errant. Status Board updates and accountability checks were untimely. Checklist use was minimal. No information backup procedures were used. Relocation procedures were not written down/were informal at best.
15	System 2	E1, E2, E3, E4, E5	Coordination was weak.
17	System 3	E1, E2, E3, E4, E5	Performance deficiencies were not cited or looked to for improvement.
19	System 4	E1, E2, E3, E4, E5	Severely limited representation construction due to untimely across the board processing of information leading to numerous errors.
20	System 5	E1, E2, E3, E4, E5	Inspectors chose not to comment in this area.

21	Researcher Interaction	E6	None.
22	Evaluator Demographic Information	NA	All inspectors were white male officers, 2-40 yr old O-5s, 1-30yr old O-4, 1 30yr old O-3..

Table A5.2.4: Exercise Script and Exercise Script Review

#	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	Potential for negative outcomes	B1, B2, B3, B5	Generally in terms of inspection report impact. Attacks involved casualties and severe mission impact in terms of completing construction requirements.
2	Induces Organizational Stress	B1, B2, B3, B5	Pressure as described above.
3	Demand for Specialized Expertise	B1, B2, B3, B5	Not really required in terms of UCC personnel
4	Demand for Integration of Expertise	B1, B2, B3, B5	Not so much specialization/expertise as information processing/specialization
5	Novelty: Unknowability	B1, B2, B3, B5	Not required.
6	Novelty: Number of Entities	B1, B2, B3, B5	Attacks were really not large in scale or deep in mission impact.
7	Novelty: Pace of Events	B1, B2, B3, B5	Event pace was challenging and constant except for last day.
8	Representation	B1, B2, B3, B5	See script in case database
9	DC5F impact	B1, B2, B3, B5	See discussion Ch. 5

Table A5.2.5: Researcher Observation Guidance

#	DC5 Construct/Issue Focus	Table 4.2 Cell References	Question
1	Context: HOV	C1, C2, C3, C4, C5, C6	The UCC consisted of a Temper Tent housing nine people and communication equipment. Four displays were projected onto screens readable by the staff. The staff consisted of the commander and executive officer, a logkeeper, a communications specialist, a plotter, a SrNCO, an engineering representative, a logistics representative, and an engineering representative. Personnel were seated at a long desks with laptops, field phones, and radio communications. Displays included priority lists of facilities and generators, project status, post attack actions, and accountability information (see Figure A5.2, layout).
2	Context: IS	C1, C2, C3, C4, C5	IS was good because all players knew each other as local ANG members but negative in that they had practiced together only once.
3	Context: Leadership and Staff Competence	C1, C2, C3, C4, C5	Workers (S1) were competent in job knowledge. Week in interaction due to lack of practice. Poor performance was not singled out and fixed.
4	Context: Flexibility	C1, C2, C3, C4, C5	No observations other than to wonder if better procedures and implementation would have facilitated better attack responses.
5	System 1	C1	See SRC layout description above.
6	System 1	C1, C2, C3, C4, C5	See SRC layout description above. Accountability checks, status updates, alarm notification, basic procedures should have been more timely.
7	System 2	C1, C2, C3, C4, C5	Coordination week and untimely and accomplished only in reaction to events going wrong. Coordination severely inhibited by wear of chemical gear.
8	System 3	C1, C2, C3, C4, C5	Poor performance was not singled out for action, correction, or improvement.
10	System 4	C1, C2, C3, C4, C5	Lack of timely processing of information severely inhibited command and control of unit
11	System 5	C1, C2, C3, C4, C5	Senior leadership and unit were unsure of themselves and lacked confidence in the ORI setting – most likely do to lack of practice.
12	Rival Explanations	C1, C2, C3, C4, C5	General agreement amongst data sources that performance was poor.
13	Researcher Interaction	C6	None observed.
14	CE	C1, C2, C3, C4, C5	See discussion in Ch. 5
15	Representations	C1, C2, C3, C4, C5	See discussion in Ch. 5

Figure A5.2: UCC Layout

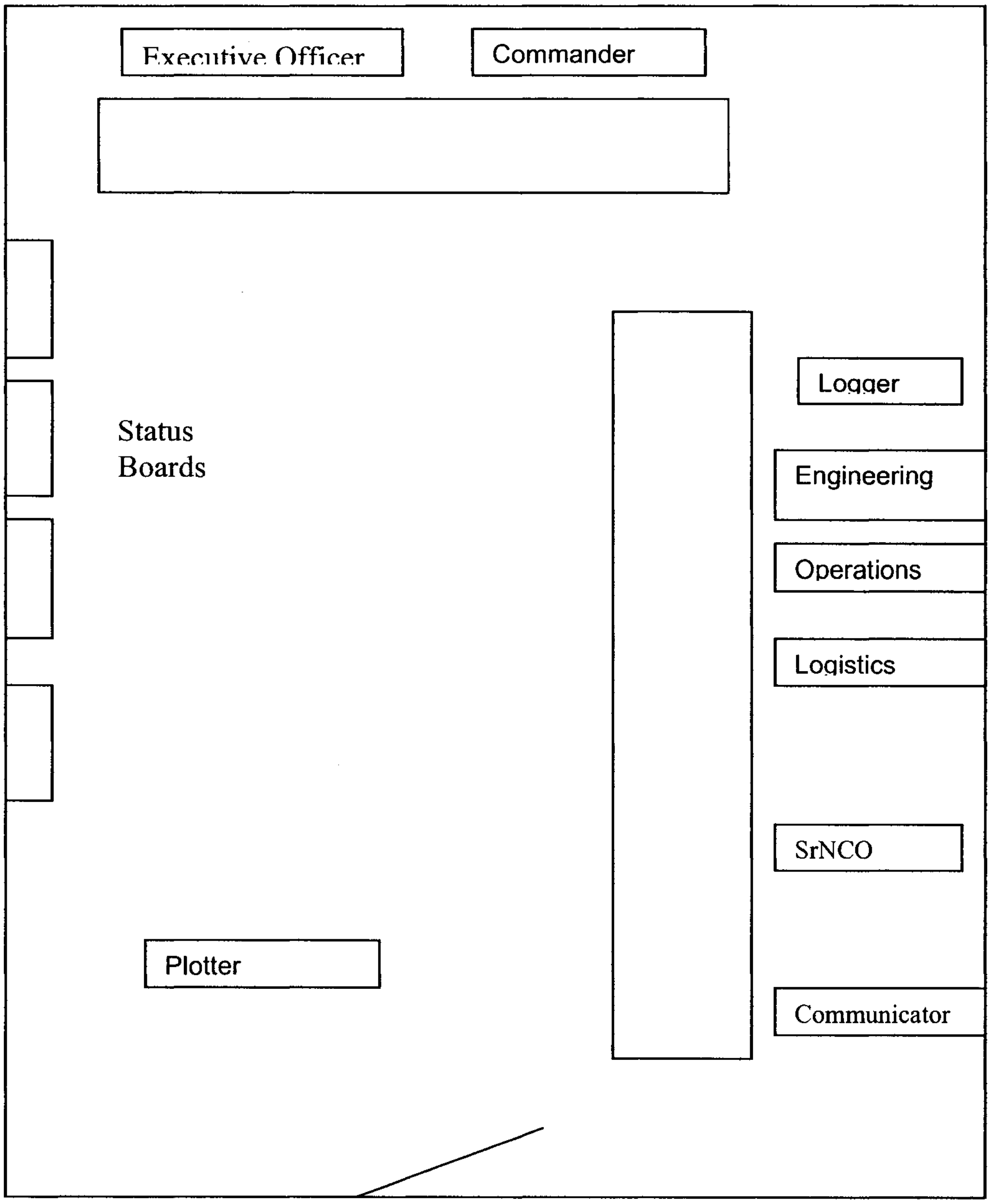


Table A5.2.6: Inspection Report Guidance

#	DC5 Construct Focus	Table 4.2 Cell References	Question
1	Context: HOV	F1, F2, F3, F4, F5	NO
2	Context: IS	F1, F2, F3, F4, F5	NO
3	Context: Leadership and Staff Competence	F1, F2, F3, F4, F5	NO
4	Context: Flexibility	F1, F2, F3, F4, F5	Yes, in terms of lack of rigorous procedures for information back up and relocation inhibiting attack response
5	System 1	F1, F2, F3, F4, F5	Negatively in terms of PAR sweep management, Alarm Communication, Lack of established procedures and checklists, non-use or untimely use of status boards.
6	System 2	F1, F2, F3, F4, F5	NO
7	System 3	F1, F2, F3, F4, F5	Yes in terms of untimely response/reallocation of resources to mission impacting conditions
8	System 3	F1, F2, F3, F4, F5	No
9	System 4	F1, F2, F3, F4, F5	Yes in terms of untimely response/reallocation of resources to mission impacting conditions. Yes in terms of untimely updating of status boards
10	System 5	F1, F2, F3, F4, F5	No
11	Rival Explanations	F1, F2, F3, F4, F5	No
12	Representations	F1, F2, F3, F4, F5	Yes in terms of untimely updating of status boards

APPENDIX VI

DETAILED ANALYSIS OF CASE DATA FOR CASE 1, FIRST OPERATIONAL READINESS EXERCISE

The first track of the research design seeks to show the actual usefulness of the DC5 framework for interpreting the observed distributed cognition phenomena. To the extent emerging observations readily converge with suggested theory the framework has demonstrated its holistic (i.e., nomological) validity as well as its specific construct validity. To the extent emerging observations do not readily converge with the suggested theory then the framework has demonstrated the need for modification or further study. Table A6.1, mirroring Table 3.1, Crisis Environment Effects on DC5 Subsystem Performance, which described in detail the theoretical impacts of crisis conditions on distributed cognition phenomena, provides the organization for the detailed discussion which follows regarding: 1) the areas in which emergent observations from case 1 converged with suggested framework constructs and their interaction, 2) diverged from the suggested theory, 3) required modification to the suggested theory, or 3) remained ambiguous with regards to the suggested theory. Table A6.2, Convergence between DC5 Framework and Emergent Themes, based on the framework of Table A6.1 summarizes the researcher's assessment of the case data and its implications for the DC5 framework. An exhaustive discussion of how these assessments were reached follows.

Table A6.1: Crisis Environment Effects on DC5 Subsystem Performance (Reprint of Table 3.1)

	S1. Autonomous Units	S2. Coordination	S3. Control	S3*. Monitoring	S4. Intelligence	S5. Identity	Context
Real Crisis Pressure (Potential for adverse organization outcomes + inducement of stress)	- System self-doubt might increase - Sensitivities to stimulus increased -Focus changes	- Differences amplified - Acquiesce to consensus - May not seek consensus	- Pressure S1 to provide more information and S2 to process more information - Increase demands on S4 for implementable solution	- Must determine if S1's are handling pressure appropriately	- Demand more information to get representation right	- Seek more confidence in representation before selecting alternatives - Selection/decision/ action goes to the organization core so balance is less routine	- Increase focus/pressure may cause HOV to be ignored - Increase pressure on individual systems may cause loss of IS with other systems - Staff competence directly impacted - Leadership directly impacted
Complexity: Demand For High Levels Of Specialized Expertise	- Ability to correctly inquire about data increasingly challenged	- Possible increased demand between systems	- Must ascertain when S1 has become overwhelmed	- Must ascertain when S1 is no longer up to environmental demands	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- Staff competence up to the task - Leadership increasing S1 performance
Complexity: Demand for Integrated Expertise	- Ability to correctly inquire about data increasingly challenged	- Challenged with knowing who needs to be involved in processing information	- Must ensure coordination is functional	- Must ascertain if S2 is no longer capable of meeting requirements	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- HOV and IS crucial - SC and Leadership also important
Complexity-Novelty unknowability	- Ability to correctly inquire about data increasingly challenged		- Can recognize when more data collection is fruitless		- Can recognize when more data collection is fruitless	- Required to adjust decision making approach based on known lack of knowledge	
Complexity-Novelty number of entities	- Ability to track and process data challenged because of volume	- Ability to coordinate/assimilate data challenged because of volume	- Can recognize when systems becoming overwhelmed	- Must ascertain if S1's and S2 up to task/replaceable	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- Flexibility key - Redundancy may prevent processing errors
Complexity-Novelty pace of events	- Ability to receive and process data challenged	- Ability to process data challenged	- Increase demand for a timely plan of action	- Must ascertain if S1's and S2 up to task/replaceable	- Ability to interpret data increasingly challenged	- Senses need to act quickly	- Redundancy may prevent processing errors

Table A6.2: Case 1 Results: Convergence between DC5 Framework and Emergent Themes

	S1. Autonomous Units	S2. Coordination	S3. Control	S3*. Monitoring	S4. Intelligence	S5. Identity	Context
Real Crisis Pressure (Potential for adverse organization outcomes + inducement of stress)	Notable Convergence	Insufficient Data	Considerable Convergence	Notable Convergence and Modification needed	Considerable Convergence and Modification needed	Considerable Convergence	Not Validated/ Insufficient Data
Complexity: Demand For High Levels Of Specialized Expertise	Insufficient Data	Insufficient Data	Notable Convergence	Notable Convergence and Modification needed	Insufficient Data	Notable Convergence	Notable Convergence
Complexity: Demand for Integrated Expertise	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
Complexity-Novelty unknowability	Insufficient Data		Insufficient Data		Insufficient Data	Notable Convergence	
Complexity-Novelty: number of entities	Considerable Convergence	Considerable Convergence	Notable Convergence	Notable Convergence/ MODIFICATION NEEDED	Notable Convergence/ MODIFICATION NEEDED	Notable Convergence	Considerable Convergence
Complexity-Novelty pace of events	Considerable Convergence	Considerable Convergence	Considerable Convergence	Considerable Convergence/ MODIFICATION NEEDED	Considerable Convergence MODIFICATION NEEDED	- Considerable Convergence	Considerable Convergence

The first row in Table 5.1 attempts to capture the general impact of crisis conditions on a control center's distributed cognition. The first cell in this row suggests that the general pressure of a crisis may lead to basic mistakes by autonomous units as they question themselves more intently as they perform in a crisis, become more sensitive to outside stimulus, and focus on items relating primarily to the needs of the crisis. Case observations relating to S1 systems included the errors and slowness made by the alarm condition change notification systems and the slowness of the PAR teams. The former seemed fairly constant throughout the exercise and seemed to be the inadvertent mistakes of a single set of individuals, these seemed to occur both during periods of increased stress and periods of less stress. With regards to the latter, as the unit leadership, through the SRC director, and the S1 representatives in the SRC made clear its desire to speed up PAR team response and information, the response indeed got better. Multiple case sources agreed that this pressure resulted in better more focused performance and information. Thus, Case 1 supports the notion suggested by the DC5 framework of crisis impacting S1 focus and sensitivity to stimulus but provides little insight into its impact on second-guessing oneself. The lack of extreme stressful environment resulting from the limited ORE scenario provides little insight into a suggested fall off in performance in terms of focus and sensitivity following an initial increase as suggested by the framework. Notable convergence with the framework was noted in this area.

The second cell in the first row of Table 5.1 suggests that crisis pressure impacts the ability of control center personnel and systems to coordinate the construction of representations and responses. As cited in the description of the ORE setting, the narrowness of the particular scenario in the case due to lack of participation by many sub-units limited the ability to generate scenarios requiring coordinated response and therefore interpretation in this portion of the framework. Thus, it is concluded that this portion is "not validated."

The third cell of the first row of Table 5.1 captures the framework's notion that crisis pressure impacts the S3 function of a control center by increasing the demands on the S1 systems to generate accurate, quick information and to quickly generate solutions. This reaction was readily seen in the case 1 data. Slow PAR team sweeps were responded to with demands and prompting for increasing speed. Similarly, communication errors in relaying alarm changes to the unit populace were met with demands to "get it right next time." S3 serves as a conduit for transferring the pressure of the crisis impacting the organization as a whole or in framework terms, its identity (S5), to the S1 control systems. Considerable convergence between case data and framework postulates was seen in this area.

The fourth cell of Table 5.1 captures the audit function of the control function within a control center. While formalization on the level of an actual operational audit as Beer suggests with his VSM did not take place, there simply isn't the time in a crisis for that degree of attention, much greater attention was paid to poorly performing S1 systems, the PAR teams and alarm notification

systems. Notable convergence between case data and framework constructs in this area was noted. As suggested, the case data did illustrate the impossibility of audit level interaction during crisis conditions suggesting a need to modify the framework.

The fifth cell of the first row Table 5.3 suggests that crisis pressure will result in the demand for more timely and more accurate information. This construct is the raw expressed response of the intelligence function of a control center to crisis pressure. Considerable convergence was noted in this area.

The sixth cell of the first row of Table 5.3, suggests that the crisis pressure will directly impact the very identity of the control center in terms of balancing the need for intelligence and the need for response. This was readily seen in the case data as the unit leadership began to demand faster PAR team sweeps so that the unit could return to normal flying operations, that is, the mission or identity of the unit. Considerable convergence was noted in this area.

The last cell suggests the impact of crisis pressure on the contextual elements of a control center. The narrowness of the ORE scenario again impacted the ability to observe this construct; intersubjectivity breakdowns amongst control center personnel, and increasing incompetence were not observed. These relationships could not be validated using the case data.

The first and second cell of the second row of Table 5.3 suggests the notion that an increasingly complex scenario may impact the ability of S1 systems to function as the demand for a single specialized expertise increases and that those demands may impact the ability to coordinate actions.

Unfortunately again, the narrow setting in Case 1 did not provide scenarios in which such situations existed.

The third cell of the second row of Table 5.3 suggests the notion that the demands for specialized expertise resulting from an increasingly complex scenario may require the control function of the control center to determine when such expertise has been exceeded and act accordingly. Though, as stated above, scenarios did not exist in this ORE where “expertises” were exceeded, the initial dullness of the PAR teams was noted by the control function and steps were taken to improve their performance. Mild convergence was noted in this area. Again, as stated above and referencing the fourth cell of the second row of Table 5.3, a formal audit of individual PAR teams was impossible given the crisis constraints thus while some investigation was done by the S3 function, the case highlights that as crisis conditions intensify the S3*, audit function, must begin to evaporate and S3 must internalize this effort into more simplistic controls.

The sixth cell of the second row of Table 5.3 suggests that the crisis’s demands, in terms of specialized expertise to deal with the crisis’s complexity, pressure organizational leadership to make decisions based on less data than usual. While the scenarios in the case did not necessarily create situations in which demands for different specialized expertise were exceeded, they were challenged and PAR teams did not perform initially as they should have. In turn leadership felt the driving need to go to general release and begin flying again without having sweeps complete. Notable convergence between case data and framework postulate was noted here.

Similarly, as referenced in the last cell of the second row of Table 5.3, in terms of system context, staff competence (again the PAR teams) was stressed by the scenario and leadership responded accordingly. Notable convergence was noted here.

With regard to the third row of Table 5.3, as discussed in the section on the ORE setting, the limited scenario did not generate crisis situations in which the demand for integration of disciplines was necessary therefore it was not possible to validate this portion of the framework.

In terms of the fourth row of Table 5.3, in the researcher's judgment and that of other evaluators as well as the reflections of the participants afterwards, no scenarios were really presented to the SRC that would have represented crises because they were composed of simply unknowable events. All scripted scenarios were imminently knowable given the time and expertise involved. Thus most of the postulates relating to unknowability cannot be validated positively or negatively by the case data. The exception being that when viewed in isolation the leadership of the unit was confronted with decision making while not knowing the full extent of the facts that should have been provided by the less than expeditious PAR teams and felt the pressure to act anyway (i.e., release personnel back to normal operations). Thus some notable convergence with the framework was noted here.

The first cell of the fifth row of Table 5.3 captures the framework's notion that the volume of information flow from a large number of entities may challenge a control center's ability to process the large amount information. The

two "in- depth attacks" on a single facility described in the setting represent such a scenario. Stress was noted as the amount of discussion in the SRC increased immediately following the attacks and S1 units became hyper-focused on solving individual problems rather than assembling a base-wide picture; that is while each S1 unit may have been aware of the particular circumstances they were focused on at the time, they were not actively working together demonstrating cognition. Simply put, the amount of information generated by the scenario impacted the functional representatives in the SRC and their ability to perform. Considerable convergence was noted here.

In the second cell of the fifth row of Table 5.3, the notion that coordination is impacted by the scale of events is postulated. While the narrowness of the scenario limited the requirement for coordination, the scale of the attack resulted in multiple sources calling in the same damage to the SRC, creating the need for the SRC S1 and S4 systems to determine if reports overlapped in constructing representations of the outside environments. This is important in that the researcher suspected some convergence between the constructs of pace of events and scale of events, but this overlapping phenomena distinguishes the two constructs. Considerable convergence between framework and data was noted in this area.

The third cell of the fifth row of Table 5.3, captures the notion that the number of entities involved in a crisis will challenge a distributed cognition system's S3 function's to ensure that S1 functions are not being overwhelmed. While scenarios were limited by the setting of the ORE, the in-depth attacks did

result in significant overlapping information flow and the case data reflects heightened awareness of the this fact as expressed by the SRC director and noted by the researcher. Notable convergence is noted in this area.

The fourth cell of the fifth row of Table 5.3, captures the notion that the control function of a distributed cognition system must occasionally audit S1 systems in hopes of determining if they are up to the job at hand. What is again illustrated by the case data, is that in crisis there becomes less time as the crisis progresses to perform such auditing functions as well the ability to retrain, further train, or replace. While this pressure to perform auditing type action was is present in the control centers, and thus the notable convergence noted, elimination of the audit function becomes increasingly mandated.

The fifth cell of the fifth row of Table 5.3 suggests that the increasing number of entities that must be sorted through as a crisis intensifies, impacts the ability of a control center to make sense of them. As described previously the heightened sense of awareness noted immediately following the in-depth attacks is reflective of this pressure felt by control center personnel as they sorted out what happened, although the actual representation of what happened was developed pretty easily. Notable convergence between case data and the framework was noted here.

The sixth cell of the fifth row of Table 5.3 references the suggested impact of large-scale events upon the identity of the organization. Again, heightened awareness and increased stress levels were noted throughout the SRC and

expressed by SRC leadership during the in depth attacks, so some convergence between framework and data is noted here.

The final cell of the fifth row of Table 5.3 captures the notion that redundancy of systems and visualization tools provide flexibility by making tracking of data easier and more reliable thereby increasing the useable horizon of visibility. It is in this area that the unit in the case demonstrated its strong point with the use of the Base Recovery After Attack System (BARTS) message posting network in the SRC and throughout the wing. BARTS put at the fingertips of every SRC person a reliable, recorded posting of raw data as it flowed and was refined and validated; turning it into usable information and knowledge quickly. Questions posed by S4 and S2 in deconflicting rival explanations of events were more readily researchable due to these systems. Also demonstrating the importance of these constructs within the framework but in an opposing fashion was the simple lack of a base map plotting damage and issues as they raw data flowed in. Such a tool would also help in processing the volume of data flowing from the in-depth attack. Considerable convergence between framework and data was noted here.

In the final row of Table 5.1 the notion that sub-systems in the control center may not be able to keep up with the rapid pace at which events are occurring is captured. The in-breadth attacks described in the setting discussion previously, resulted in rapid-fire updates being provided to the SRC. While the SRC performed admirably in these cases, the breadth of information that had to be "pieced-together", rather than "sorted-out" after the in-depth attacks, resulted

in heightened awareness across all subsystems. Repeating what's been described previously, individual representatives felt the urgency to collect and verify information quickly before next set of data flowed in; what little coordination had to be accomplished was done quickly; pressure flowed from S5 and S4 through S3 to motivate PAR teams to move faster, and finally, the positive impact of BARTS and negative impact of not having mappable displays available were noted. All construct interactions between system and crisis environment postulated by the framework considerably converged with case data.

Not specifically postulated by the framework but requiring some grounding in theoretical interpretation still, is the weakness noted by the IG in the May 2005 ORI and also noted by the researcher in the unit's use of the BARTS system, which is that it eliminated or reduced conversation in the SRC highlighting important information requiring response and thus slowing response and a sense of urgency by the SRC. Some discussion in terms of DC5 constructs presents the need to sharpen the construct of Intelligence or S4. BARTS provided such complete, easily accessible, readable, recordable, and redundant information processing that it significantly widened the horizon of visibility and facilitated S1 actions to the point that human operators tended to sit back and let the system deliver information out to the unit itself. As much of the information contained in this widened horizon of visibility required simple actions that sub-units outside the SRC could take care of themselves, no action was required by the SRC and it could be easily lulled into a sense of ease. These simple, less important matters amount to noise. Still at some point, significant information will flow through

BARTS as a crisis intensifies (i.e. more signal than noise). This function of distinguishing between signal to noise becomes of heightened importance as more noise is introduced through growing information horizons and is a key function of the intelligence, S4, subsystem not previously articulated to such extent in developing the DC5 framework. Thus, in addition to constructing representations a key portion of the S4 intelligence subsystem is distinguishing between signal and noise or assessing the relative importance of incoming information. To the extent the unit in the case was being lulled into a sense of complacency by the ease with which BARTS processed the lesser important items, then the S4 function was performing poorly. The case data suggests adding to the S4 function in the DC5 framework the importance of assessing the relative importance of information.

APPENDIX VII

DETAILED ANALYSIS OF CASE DATA FOR CASE 2

As in the track 1 interpretive analysis of the first case's first ORE the objective will be to interpret the emergent converging themes of the case data using the constructs and interactions specified by the DC5 framework validating the framework where possible and modifying it if necessary. As discussed in analysis of the first case, to the extent emerging observations readily converge with the suggested theory, then the framework has demonstrated its holistic validity as well as its specific construct validity. To the extent emerging observations do not readily converge with the suggested theory then the framework has demonstrated the need for modification or further study. Table A7.1, mirroring Table 5.3c, Crisis Environment Effects on DC5 Subsystem Performance - Modifications from Case 1, Track 1 - Second ORE, which captured in detail the impacts of crisis conditions on distributed cognition phenomena according to the latest iteration of the DC5 framework , provides the organization for the detailed discussion which follows regarding the areas in which emergent observations from case two converged with suggested framework constructs and their interaction, diverged from the suggested theory, or remained ambiguous with regards to the suggested theory. Again, as described in the previous section, the general overall poor performance of the UCC is an overarching theme that significantly limits the value of the data for interpreting crisis environment effects upon control center cognition. This fact is

reflected in the large portion of Table A7.2 detailed as not validated by the insufficient case data. Table A7.2 summarizes the case data and its implications for the DC5 framework.

Table A7.1: Crisis Environment Effects on DC5 Subsystem Performance - Modifications from Case 1, Track 1 - Second ORE – (Changes highlighted in bold)

	S1. Autonomous Units	S2. Coordination	S3. Control	S4. Intelligence	S5. Identity	Context
Real Crisis Pressure (Potential for adverse organization outcomes + inducement of stress) **relative to the dcog fitness level of the control center (RTDF)**	- System self-doubt might increase - Sensitivities to stimulus increased - Focus changes	- Differences amplified - Acquiesce to consensus - May not seek consensus	- Pressure S1 to provide more information and S2 to process more information - Increase demands on S4 for implementable solution - Must determine if S1's are handling pressure appropriately	- Demand more information to get representation right - **Heightened awareness of need to assess the relative importance of information (HANTARII)**	- Seek more confidence in representation before selecting alternatives - Selection/decision/ action goes to the organization core so balance is less routine	- Increase focus/pressure may cause HOV to be ignored - Increase pressure on individual systems may cause loss of IS with other systems - Staff competence directly impacted - Leadership directly impacted
Complexity: Demand For High Levels Of Specialized Expertise **(RTDF)**	- Ability to correctly inquire about data increasingly challenged	- Possible increased demand between systems	- Must ascertain when S1 has become overwhelmed - Must ascertain when S1 is no longer up to environmental demands	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- Staff competence up to the task - Leadership increasing S1 performance
Complexity: Demand for Integrated Expertise **(RTDF)**	- Ability to correctly Inquire about data increasingly challenged	- Challenged with knowing who Needs to be involved in processing information	- Must ensure coordination is functional -Must ascertain if S2 is no longer capable of meeting requirements	- Ability to interpret data increasingly challenged	- Required to adjust decision making approach based on known lack of knowledge	- HOV and IS crucial - SC and Leadership also important
Complexity-Novelty unknowability **(RTDF)**	- Ability to correctly inquire about data increasingly challenged		- Can recognize when more data collection is fruitless	- Can recognize when more data collection is fruitless	- Required to adjust decision making approach based on known lack of knowledge	
Complexity-Novelty number of entities **(RTDF)**	- Ability to track and process data challenged because of volume	- Ability to coordinate/assimilate data challenged because of volume	- Can recognize when systems becoming overwhelmed - Must ascertain if S1's and S2 up to task/replaceable	- Ability to interpret data increasingly challenged **- (HANTARII)**	- Required to adjust decision making approach based on known lack of knowledge	- Flexibility key - Redundancy may prevent processing errors
Complexity-Novelty pace of events **(RTDF)**	- Ability to receive and process data challenged	- Ability to process data challenged	- Increase demand for a timely plan of action - Must ascertain if S1's and S2 up to task/replaceable	- Ability to interpret data increasingly challenged **- (HANTARII)**	- Senses need to act quickly	- Redundancy may prevent processing errors

Table A7.2: Case 2 Results: Convergence between DC5 Framework and Emergent Themes

	S1. Autonomous Units	S2. Coordination	S3. Control	S4. Intelligence	S5. Identity	Context
Real Crisis Pressure (Potential for adverse organization outcomes + inducement of stress)	Not Validated/ Insufficient Data	Not Validated /Insufficient Data	Not Validated/ Insufficient Data	Not Validated/ Insufficient Data	Not Validated/ Insufficient Data	Not Validated/ Insufficient Data
Complexity: Demand For High Levels Of Specialized Expertise	Insufficient Data	Insufficient Data	Notable Convergence	Insufficient Data	Notable Convergence	Notable Convergence
Complexity: Demand for Integrated Expertise	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
Complexity- Novelty unknowability	Insufficient Data		Insufficient Data	Insufficient Data	Insufficient Data	
Complexity- Novelty: number of entities	Notable Convergence	Notable Convergence	Notable Convergence	Notable Convergence	Notable Convergence	Notable Convergence
Complexity- Novelty pace of events	Notable Convergence	Notable Convergence	Notable Convergence	Notable Convergence	Notable Convergence	Notable Convergence

The first row in Table 5.4 attempts to capture the general impact of crisis conditions on a control center's distributed cognition. The first cell in this row suggests that the general pressure of a crisis may lead to basic mistakes by autonomous units as they question themselves more intently as they perform in a crisis, become more sensitive to outside stimulus, and focus on items relating primarily to the needs of the crisis. Case 2 observations relating to S1 systems included the untimely processing of project progress information, attack damage information, untimely or inaccurate communication of attack and alarm notification made by the alarm condition change notification systems, and poor, untimely performance by PAR teams. The occurrences of these errors were frequent and constant regardless of scenario intensity levels. To reiterate the description provided in the previous section, basic competence was lacking in the UCC. It is thus difficult to tie a change in S1 performance to changes in the potential for negative outcomes. Similarly, it is difficult to tie changes in S1 performance to stress levels and complexity changes. Thus, no convergence with the DC5 framework was seen in the first cell of the first three rows of Table 5.4.

Similarly, coordination was seen as inadequate by both the researcher and the inspectors throughout the exercise and reflected thusly in the final report. Alarm changes impacting geographically separated construction sites were not communicated and their impacts on mission accomplishment not accounted for or anticipated. What coordination did exist was reactionary in both the researcher's view and the inspectors view. Again though, because the general

competence of the UCC team was so lacking in this area, it is difficult to attribute the coordination impacts to crisis intensity. Thus the second cell of the first three rows of table 5.4 also lacks sufficient data for validation.

As documented in the observer notes and in the inspector interviews little was specifically done in response to the slowness of the S1 systems or lack of coordination or even in response to inspector-provided feedback during the inspection. The control function was lacking. Similarly, the intelligence function within the UCC failed to understand the impact of high winds shutting down one project and in turn failed to reallocate resources to more readily constructible projects, effectively leaving a crew of a dozen people sitting around for two hours. Again, it is not possible to ascertain if this was a result of crisis pressure or just lack of UCC competence in general. This lack of competence became the identity of the command and control function of the unit. Finally, in terms of context, the inspection was characterized by a simple lack of competence on the part of the UCC team. It is difficult to attribute the lack of staff competence to crisis pressure though. Thus the remaining cells of the first row of Table 5.4 are all labeled as having not been validated by the second case.

The first and second cell of the second row of Table 5.3 suggests the notion that an increasingly complex scenario may impact the ability of S1 systems to function as the demand for a single specialized expertise increases and that those demands may impact the ability to coordinate actions. As noted by both the researcher and the inspectors, the scripted scenarios did not require high degrees of expertise, whether they are individually specialized or broadly

integrated and interdisciplinary. Mere processing of information and using local expertise to facilitate expedient interpretation was all that was required. Thus neither of these cells for the second or third rows of Table 5.4 can be considered validated by the second case's data set.

As described in the setting, the UCC team did not succeed in following up on the identification of error or slowness with specific action. The control function was not to be found. Similarly, in terms of the intelligence function, scripted scenarios did not require extensive integration of knowledge bases or further development of specific specialized knowledge bases. Lastly, the identity and the context of the UCC remained unchanged despite scenario demands for expertise. No convergence with the DC5 framework was seen in these areas. The third, fourth, and fifth cells in the second and third rows of Table 5.4 thus remain not validated.

In terms of the fourth row of Table 5.4, in the researcher's judgment and that of the inspectors, as well as, the reflections of the participants afterwards, no scenarios were really presented to the SRC that would have represented crises because they were composed of simply unknowable events. All scripted scenarios were imminently knowable given the time and expertise involved. Thus, most of the postulates relating to unknowability cannot be validated positively or negatively by the case data. Consequently, again no convergence with the framework was noted here.

The first cell of the fifth and sixth rows of Table 5.4 captures the framework's notion that the volume of information flow from a large number of

entities or quickly moving pace of events may challenge a control centers ability to process the large amount information. While, in the researcher's judgment and that of the inspectors, the scripted attacks were hardly of sufficient scale in terms of mission impact to stress more usual UCC teams, this UCC team seemed overwhelmed by basic information processing. Both the researcher and the inspectors agreed that pace of events was intense during the first two days of the exercise and this could easily have explained some lack of performance from S1s, but it difficult given the low overall competence of the UCC to distinguish between these to aspects of complexity. To borrow from track 2 in the first case study, it could be argued that the level of DC5 fitness was so low that even small-scale impacts constituted a crisis environment to this particular UCC. Simply put, the amount of information generated by any scenario impacted the functional representatives, the S1's, in the UCC and their ability to perform. Notable convergence was noted here.

In the second cell of the fifth and sixth row of Table 5.4, the notion that coordination is impacted by the scale of events is postulated. While little coordination existed in the UCC until events were growing out of control it could be said that the amount of information required to be processed exceeded the basic competence levels of the UCC to coordinate response leading to the errors captured by the raw findings. Notable convergence between framework and data was noted in this area.

The third cell of the fifth row of Table 5.4, captures the notion that the number of entities involved in a crisis will challenge a distributed cognition

system's S3 function's to ensure that S1 functions are not being overwhelmed. Similar to discussion in the previous paragraphs, as little information flows, as was required by the scripted scenarios, it exceeded the competence of the S1 functions and, as described previously, little specific action was taken to improve performance. Perhaps this is because the control function was overwhelmed by the information flow as it was. Notable convergence is noted in this area.

The fifth cell of the fifth and sixth rows of Table 5.4 suggests that the increasing volume of information flow that must be sorted through as a crisis intensifies impacts the ability of a control center to make sense of them. As described previously, little was done by the UCC to anticipate the mission impact of attacks and adjust accordingly; perhaps because the information flows as they were exceeded the S4 function's ability to assimilate the information. Notable convergence between case data and the framework was noted here.

The sixth cell of the fifth and sixth rows of Table 5.4 references the suggested impact of such large-scale events upon the identity of the organization. Again general incompetence became the identity of this UCC. The very basic function of processing small information flows as a UCC constituted a crisis environment. Notable convergence with the DC5 framework was noted here.

The final cell of the fifth and sixth rows of Table 5.4 captures the notion that redundancy of systems and visualization tools provide flexibility by making tracking of data easier and more reliable thereby increasing the useable horizon of visibility. The unit again failed in this basic area by simply not establishing or

following rigorous procedure. Thus key information was lost or forgotten and decisions that could have enhanced overall unit performance were simply not made. Again, any processing of information for this UCC constituted a crisis. Notable convergence was noted here.

The researcher additionally is drawn to assessing the impact of wearing chemical mask and ensemble on DC5 fitness. Not a part of the scenarios of case 1, use of the ensemble in this case motivated the need to articulate its impact in terms of DC5 constructs. As previously described, the ensemble and mask are severely hot and uncomfortable and inhibit hearing and vision. All data sources converged on the notion that it inhibited the UCC's ability to process information. It could be said that the mask and ensemble suddenly reduces the horizon of visibility for all UCC personnel as they have difficulty managing basic breathing and job functions and cannot readily see or hear the flow of information through the SRC. Secondarily, inter-subjectivity is reduced amongst UCC players as they become distracted by their own discomfort. This directly impacts the ability to receive information, coordinate understanding, build representations, and construct response. Wear of the mask and gear effectively reduces the competence of all personnel to some degree. Such reduction can be offset by rigorous adherence to established procedure and training in the gear to minimize its affect. Additionally, as the researcher and inspectors attest, leadership in the form of motivation and demonstration of personal disregard for the discomfort of the gear can also offset the impacts on performance. Unfortunately, the general level of poor performance by the UCC made it

impossible to characterize further degradation of performance and validate the suppositions; just detailed in terms of the DC5 constructs in Table 5.4.

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