Complex Systems Design Across Cultures

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Abstract

A lack of information exists in the field of complex system design with respect to the inherent assumptions that people in different cultural contexts make about the systems and subsystems they are designing and about the processes and methodologies they use to design and interact with other systems and subsystems designers. Without knowing the assumptions others make, it is possible that complex systems will fail due to a simple oversight. For instance, the Mars Climate Orbiter was lost due to a miscommunication between NASA JPL and Lockheed Martin over units used to compute thruster force [1].

This paper provides an overview of complex systems design. An overview of current quantifiable cultural research, focusing on ongoing work in the field of business is provided. Focus is paid to existing literature covering complex systems design across cultures. Potential avenues to formalize a process to reveal cultural blind spots and assumptions are discussed. This area of research is largely unexplored and holds promise to improve the reliability of complex systems design.

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Chapter 1

Introduction

While the 18th and 19th centuries were the period of the industrial revolution, the 21st century, as McFarland states, is becoming known as "the century of the 'global world'" [2]. Part of the push toward globalization has been the rise of multi-cultural design teams. The world of complex system engineering is no stranger to multi-cultural teams crossing many cultural divides. Many industries and organizations employ engineering teams that span the globe both culturally and physically.

To date, little research has been conducted to formally determine and quantify the risks that multi-cultural design teams pose to complex system designs. Anecdotal accounts of complex systems design failures due to multi-cultural teams are provided in Section 1.1 of this chapter. This document provides an overview of complex systems engineering. Topics such as the definition of complex systems design, examples of complex systems designs, methods of facilitating complex system designs, and teamwork in the complex systems engineering environment are presented. Past and current cultural research is examined, paying special attention to the definition of culture and measuring culture quantitatively. The intersection of culture and complex systems design is analyzed and suggestions for further research are presented. The document concludes with a future research program outline.

1.1 Anecdotal Accounts of Complex Systems Design Failures

Few examples are provided in literature of complex systems failures due to cultural problems. Nasa provides one of the few good examples in literature. The Mars Climate Orbiter

was lost due to a miscommunication between NASA JPL and Lockheed Martin over units used to compute thruster force [1]. Beyond that, few examples are provided in the literature. Several anecdotes have been collected by the author of this paper and are included below. They are very generalized and do not include detail due to confidentiality issues.

1.1.1 Software Development Woes

A friend of the author has worked for the last several years for a software startup company in Silicon Valley. During his tenure, the company has had experiences working with software developers in India. The software developers in India were tasked with developing a section of the back-end code. The end result was, due to cultural miscommunication and other issues, the Indian development team was let go and many months worth of their coding was thrown away.

1.1.2 Oil Industry Safety

An acquaintance of the author worked for many years in an Arab country for a major oil company. During his tenure, he time and again ran into serious problems while operating the complex systems of the oil drilling and refining equipment. These problems were created due to cultural clashes between the culture of the host country and the culture of the oil company's home country. Several times, the entire installation was nearly lost due to these problems.

1.1.3 Hi-Tech Conflict

Another acquaintance of the author worked at a company that made testing devices for semiconductor components. He worked for a time on a joint development project between the company, based in America, and a company based in Japan. The project was highly complex. After more than a year of work with the Japanese company, frustrations were mounting on both sides of the relationship. In the end, the partnership was dissolved, and most of what the Japanese company had developed was scrapped and redesigned.

Chapter 2

Complex Systems Design

This chapter provides an overview of complex systems engineering. Topics such as the definition of complex systems design, examples of complex systems designs, methods of facilitating complex system designs, and teamwork in the complex systems engineering environment are presented. Several examples of failed complex systems design projects are presented including the costs of their failures.

2.1 Defining Complex System Design

A standardized definition of Complex Systems Design is hard to come by in the literature. The concept of complex systems encompasses a wide range of disciplines and methodologies. It is instructive to examine the words that comprise the term Complex Systems Design.

"Complex" can be defined as something that is "composed of interconnected and interacting parts, components, elements, or subsystems" [3]. A useful definition of "System" is "a set of different elements connected or related so that they perform a unique function not performable by the elements alone" [3]. For the purposes of this paper, "Design" refers to the intentional process of creating and developing a plan for a component, structure, product, or system [4].

Together, these definitions paint a picture of Complex Systems Design[1] as an intentional process of creating a set of interconnected and interacting elements that, when combined together, perform a unique function that the constituent parts could not perform on their

[1] In this paper, Complex Systems Design encompasses engineered systems and neglects naturally occurring systems.

own. Further, from observing Complex Systems literature, systems that are found worth of the "Complex" marquee usually are composed of many separate subsystems[2] that consist of many hundreds of parts or elements. The interaction of these elements often results in emergent behavior of the system that was not originally intended, designed, or desired.

There are many other hallmarks of complex systems. For instance, a single optimum design point rarely exists [5, 3]. This is generally as a result of a proliferation of design variables, and stakeholders; and the conflicting viewpoints and interests of the stakeholders, and designers. Other traits include scheduling delays and cost overruns due to designs that become increasingly complex, frequent failures due to unanticipated emergent system behavior, and multiple disciplines are involved in the design and construction of the complex system.

2.2 Examples of Complex System Design: Successes and Failures

Examples of complex systems include nuclear power plants, automobiles, spacecraft, aircraft, computer systems, dams, and stock exchanges. Table 2.1 provides an overview of specific examples within each of these types of complex systems. All contain the hallmarks of complex systems and are considered by their designers to be complex systems.

Table 2.1: Examples of Complex Systems

Category	Specific Example
Nuclear Power Plants	Trojan Nuclear Power Plant on the Columbia River (now decommissioned)[6]
	Three-Mile Island Nuclear Generating Station in Pennsylvania (reactor 1 operational, reactor 2 decommissioned after accident)[7]
	Diablo Canyon Power Plant in California (both reactors operational)[8]
Automobiles	Toyota Prius [9]
	MRAP combat vehicle [10]
Spacecraft	American Space Shuttle [11]
	Continued...

[2]Often, subsystems themselves are complex systems that also require at least a subset of the tools available to Complex Systems Designers

Table 2.1: (continued)

Category	Specific Example
	Mars Phoenix Lander [12]
	Odyssey and Spirit twin Mars Rovers [13]
	The Apollo Program [14]
	Space-X Falcon I Rocket [15]
Aircraft	Boeing 787 Dreamliner [16]
	B-2 Stealth Bomber [17]
	MiG-35 Russian Export Figher Jet [18]
	Bombardier Global Express [19]
Computer Systems	IBM Deep Blue [20]
	IBM Roadrunner (the world's fastest super computer as of November, 2008) [21]
	Googleplex and its Server Farms [22]
	Berkeley Open Infrastructure for Network Computing (BOINC) [23]
Dams	Bonneville Power Administration Columbia River Projects [24]
	Three Gorges Dam [25]
	Aswan High Dam [26]
Stock Exchanges	New York Stock Exchange (NYSE) [27, 28]
	Deutscher Aktien IndeX (DAX) [27, 28]
	London Stock Exchange (LSE) [27, 28]

Many complex systems projects fail for a variety of reasons. These include poor planning during design and development, attempting to partition a complex system into too small and simple of units without considering the interactions between these systems[3], a specific methodology is not followed, customer requirements radically change without enough time to react[29], poor communication between the subsystems engineers, and poor understanding of the true customer requirements and expectations. There are myriad of examples of multi-million dollar failed projects in the literature and around the world. Table 2.2 outlines a number of failed projects and the cost in dollars – and in one case lives – for a number of complex systems.

Table 2.2: Large Engineering Project Failures. (Adapted from [30]).

System Function - Responsible Organization	Years of Work	Approximate Cost
Vehicle Registrations, Drivers Licenses - California DMV [31, 32, 33, 34, 35, 36]	1987-1994	$44M
Automated reservations, ticketing, flight scheduling, fuel delivery, kitchens and general administration - United Airlines [37]	Late 1960's-Early 1970's	$50M
State-wide Automated Child Support System (SACCS) - California [38, 39]	1997-1997	$110M
Hotel reservations and flights - Hilton, Marriott, Budget, American Airlines [40]	1988-1992	$125M
Advanced Logistics System - Air Force [41]	1968-1975	$250M
Taurus Share trading system - British Stock Exchange [42]	1990-1993	$100-600M
IRS Tax Systems Modernization projects [43]	1989-1997	$4B
FAA Advanced Automation System [44]	1982-1994	$3-6B
London Ambulance Service Computer Aided Dispatch System [45]	1991-1992	$2.5M & 20 lives

2.3 Methods of Facilitating Complex System Design

There are many approaches to facilitating complex system design. Before the advent of software programs, armies of paper-pushers were employed to juggle paperwork between subsystems designers, system-level architects, and management. As designs were finalized, number-crunching teams would rush in to try to zero in on satisfactory design solutions. A large, complex system would typically take many years to complete. This was especially true in the design of ocean going vessels.

Today, software has largely replaced the office clerks and mathematicians. Sophisticated analytic packages allow distributed design to be conducted at paces never before achieved.

Like Computer Aided Drafting revolutionized the speed and accuracy of part design, so too have new software solutions revolutionized the ability for engineers to meet the challenges of complex system design. What once was a multi-year process now can be completed in a number of weeks.

2.3.1 Ship Design Example

Until recently, ship design was a linear process. The Evans-Buxton-Andrews Spiral approach was most widely used in industrialized nations during the first half of the 21st Century. The Spiral approach got its start in 1959 when Evans [46] created a design visualization tool known as the "general design diagram" which is reproduced in Figure 2.1. The design process is laid out in a sequential and iterative framework. Using this design methodology is an expensive and time-consuming process [47].

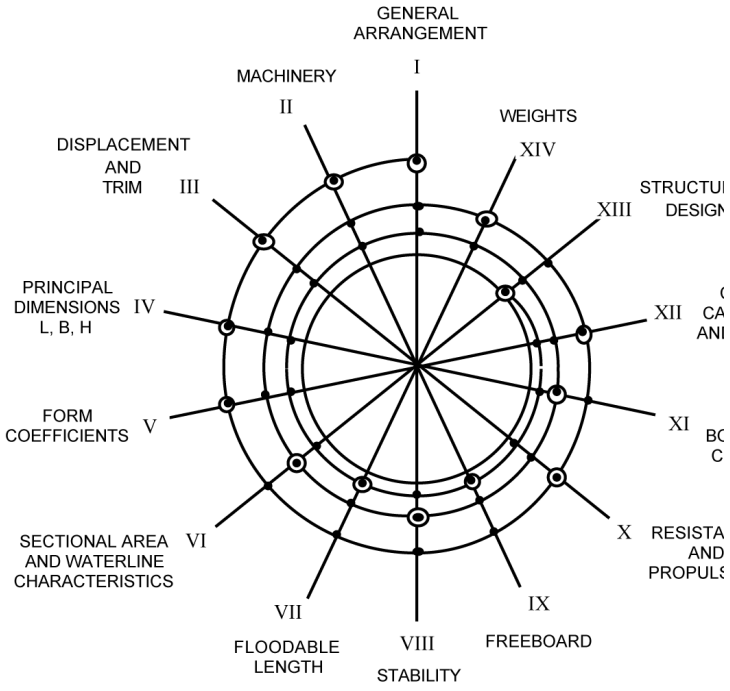

Figure 2.1: Evan's General Design Diagram [46]. (Adapted from [47].)

Later, Buxton included economic considerations in the spiral [48]. In the early 80's, Andrews added a time dimension to the process [49]. The then-state-of-the-art design process known as the Evans-Buxton-Andrews spiral was thus complete. A graphical representation of the process is depicted in Figure 2.2.

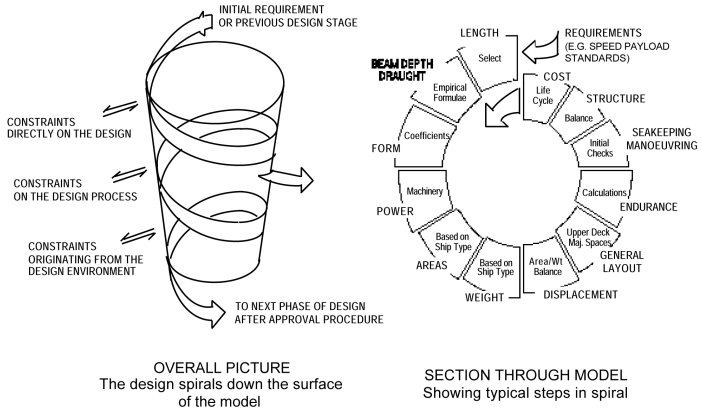

Figure 2.2: Andrews' Overall Ship Design Process Model [49]. (Adapted from [47].)

The Evans-Buxton-Andrews Spiral model was used largely without modification up into the 1990's. The approach certainly does create satisfactory designs but is not particularly efficient in doing so and does not find superior solutions. During periods of intense ship building when the industry as a whole is doing well, little notice is paid the large overhead cost of this design method. This is generally as a result of almost all designs being built thus validating the effort put into the design; small, incremental improvements are included in series of ships and between old and new classes of ships; and large amounts of data are available on similar types of ships [50].

During economic downturns, and for highly specialized, one-off ship construction, the Evans-Buxton-Andrews Spiral approach doesn't work. The process is too costly and time-consuming to be cost-effective for the aforementioned situations. In the past, a small contingent of other methods were tried to address this issue for economic downturns and specialized ships as well as general ship construction but none caught on [51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 50].

Ship design has more recently moved toward Decision-Based Design[3] and Systems Design approaches. The methods proposed and developed by Mistree [47] and others [64] have slowly changed the ship industry from the slow dinosaur that it was to something more agile that is quicker to respond to customer demands, more innovative with its designs, and more economic with its practices.

[3]Decision-Based Design is a method of design where the principal role of a designer is to make decisions. See [47, 62, 63] for further discussion.

2.3.2 NASA'S Team-X

The trends in ship design have been seen across other industries as well. For instance, at National Aeronautics and Space Administration (NASA), a group called Team-X has generated over 1000 spacecraft conceptual designs to date at its facility within the Jet Propulsion Laboratory [65]. Prior to 1996 when Team-X was formed, a typical conceptual design would take in excess of 25 weeks to complete and cost $250,000. Only one or two new missions would be considered per year. In 1996, the number of new missions considered jumped to 45, concept design time was reduced to 2 weeks, and cost was reduced to roughly $75,000. In 2002, 80 missions were conceptualized, average cost was $50,000, and average time to complete a conceptual design was 4 weeks [66].

Many companies have attempted to copy the stunning success of Team-X. These include teaching facilities at the California Institute of Technology, the Boeing Satellite Systems Concurrent Integrated Engineering Lab, United Technologies Integrated Total Aircraft Power Systems Program, and many others [66]. The idea has also spread within NASA to other laboratories and programs including at the Glenn facility and others. The benefits of the Team-X process to large-scale complex system designs have been obvious to industry for some time.

At its core, Team-X is a collaborative design environment that brings together all major players into one room that is designed to facilitate face-to-face and virtual interaction. Software and hardware systems are deployed in the collaborative design room that enable more effective and efficient collaboration. Software packages such as Advanced Trade Space Visualization (ATSV) and ModelCenter, discussed in Subsection 2.3.3, allow data and subsystems models from each subsystems engineer to be pulled together into one central model. The software further facilitates visualization and exploration of the trade space created by the model. Hardware interfaces such as headphones and microphones styled after those found in small aircraft allow virtual small breakout meetings to occur within the larger context of the Team-X environment.

In this way, Team-X takes what once was a disjointed process that took several days to a week per iteration to a streamlined collaborative parallel process where each iteration can be performed in a matter of minutes or hours. Virtually all important information and personnel are pulled out of their filing cabinets and offices, and brought into one room. Meaningful real-time access to people and data, and the ability to purposefully construct and analyze a model based upon the knowledge contained therein is the true secret behind Team-X's success [67].

2.3.3 Cutting-Edge Software that Makes Complex Systems Engineering Easier

Several software packages developed over the last decade have transformed the way complex systems design teams operate. In the days before cheap desktop computing power was available, optimization and trade space exploration algorithms either had to be calculated by hand or coded into mainframes. Each was a time-intensive and expensive process highly prone to error. Software packages in use today such as ATSV and ModelCenter, among others, greatly improve the speed, efficiency, accuracy, and quantity of iterations of optimization and trade space exploration algorithms.

ATSV is a software tool that facilitates the integration of multiple data sources into a powerful trade space and optimization package. The software also contains an impressive data visualization suite that allows quick, intuitive comprehension and exploration of the trade space. The program also allows for a systems engineer to follow a Design by Shopping[4] approach [70].

Phoenix Integreation's ModelCenter integrates many of the functions of ATSV into a robust package that employs the concept of wrappers[5] to the complex systems design process. The wrappers can be linked together so that variables from one design tool can be interfaced with variables produced by another tool. The design tools can be controlled from multiple computers across a network allowing large-scale collaboration on the order of a Team-X-style environment.

ModelCenter automates the process of running trade space exploration and design optimization algorithms through the interconnected wrappers. The actual computations can be run either on a local machine or a remote cluster of servers using a server program included with the software. Very large data sets can be created quite quickly in this manner. Many visualization techniques and trade study[6] tools are included in the ModelCenter software. These tools allow a design team to quickly find weaknesses in a design, find optimal solution sets using multi-variable and multi-weight trade studies, and in general aid the design process [73].

Many other software packages exist to facilitate collaborative design. For instance, Accord

[4]Design by Shopping was proposed by Balling [68] who defined it as a paradigm where a decision-maker explores a design space prior to choosing an optimal solution from a set of possible design solutions. This allows the decision-maker to have more control over the process as compared to traditional design optimization techniques. Rather than being an *a priori* approach, Design by Shopping is an *a posteriori* approach [69].

[5]Wrappers are used to interface design tools such as Mircosoft Excel, EES, and CATIA with an optimization and/or trade space exploration program [71].

[6]A trade study is performed by a multidisciplinary team, often formed of subsystems engineers, with the goal of identifying a set of balanced technical solutions from a larger set of potential solutions [72].

can be used to augment decision support systems based on Bayesian Team Support methods [74]. Software that is useful to complex systems design generally either aids analysis, decision making, or both. The goal of all software packages used by complex systems designers is to increase the quality of the design while decreasing the development time and cost. The above mentioned software packages all do just that.

2.4 Teamwork in Complex Systems Engineering

At the core, complex systems engineering is a conversation between people. A team of subsystems engineers labors together to create a final design. The give and take between subsystems engineers, and the direction provided by the systems-level engineers shape the direction of the design and the final outcome. Personalities can become major factors in the outcome of a design.

The typical design team has many different types of personality traits and group behaviors within its membership. Some behaviors and traits are assets while others can be detrimental to the project. Traits such as always saying "yes," and group behaviors such as Groupthink can be detrimental to the outcome of a project. On the other hand, there are several methods to create high-performing teams that produce good results.

2.4.1 Yes Men and Groupthink

It is very easy for people to become "Yes Men." Several reasons are generally identified for creating a conformist culture. Incentive packages sometimes direct employees, whether intentionally or otherwise, toward conforming with the opinions of their supervisors. Often this is the case in firms that use subjective performance evaluation techniques inappropriately [75, 76]. People from some cultures, notably Japan and China [77, 78], will say "yes" even when they mean "no" as a way of saving face.

The phenomena of "Groupthink" has been investigated since the mid 1950's. While early research was not conclusive with regards to the negative outcomes of Groupthink [79], more recently, academics and industry have accepted Groupthink as something to be avoided [80]. Groupthink can be defined as a type of thought and behavior exhibited by team members who attempt to minimize conflict and friction within a group. They try to reach a consensus without critically evaluating, testing, or analyzing the ideas being proposed. Teams operating under the guise of Groupthink lose individual creativity, independent thinking, and uniqueness of thought in order to achieve group cohesion [81].

There are many causes for Groupthink. Janis found that structural faults in an organization such as lack of impartial leadership and an over-homogenized team, and provocative situational contexts such as high-stress external threats and moral dilemmas often lead to Groupthink [82]. McCauley determined that Groupthink occurs when there is directive leadership, a homogeneous team, and the group is isolated from outside sources of information and analysis [83]. For instance, in one study it was found that within the NASA Team-X environment, managerial styles between morning and afternoon facilitators differed significantly and affected the outcome of the Team-X session results [84].

At least eight negative outcomes of Groupthink have been identified in the literature. Table 2.3 lists these negative outcomes.

Table 2.3: Groupthink Outcomes. (Adapted from [85]).

Illusions of invulnerability creating excessive optimism and encouraging risk taking.
Rationalising warnings that might challenge the group's assumptions.
Unquestioned belief in the morality of the group, causing members to ignore the consequences of their actions.
Stereotyping those who are opposed to the group as weak, evil, disfigured, impotent, or stupid.
Direct pressure to conform placed on any member who questions the group, couched in terms of "disloyalty."
Self censorship of ideas that deviate from the apparent group consensus.
Illusions of unanimity among group members, silence is viewed as agreement.
Self-appointed members of the team who act as "Mindguards," shielding the team from dissenting information.

Janis proposed seven methods to prevent teams from falling into the Groupthink trap. They are listed in Table 2.4.

Table 2.4: Avoiding Groupthink. (Adapted from [85]).

Leaders should assign each member the role of "critical evaluator." This allows each member to freely air objections and doubts.
Higher-ups should not express an opinion when assigning a task to a group.

Continued...

Table 2.4: (Continued)

The organization should set up several independent groups, working on the same problem.
All effective alternatives should be examined.
Each member should discuss the group's ideas with trusted people outside of the group.
The group should invite outside experts into meetings. Group members should be allowed to discuss with and question the outside experts.
At least one group member should be assigned the role of Devil's advocate. This should be a different person for each meeting.

It is generally agreed that if these guidelines are followed, Groupthink is much less likely to occur. For instance, after the abortive Bay of Pigs invasion, John F. Kennedy actively attempted to avoid Groupthink throughout the Cuban Missile Crisis. Many argue that if the White House had continued operating as it did during the Bay of Pigs, the world would have experienced global nuclear warfare [86]. Similarly, the NASA Space Shuttle Columbia's tragic demise was a result of Groupthink within NASA [87].

2.4.2 Getting from Dysfunction to High-Performance

In the business realm there are a whole host of techniques and tools that managers use to produce high-performance highly effective teams. Not all tools are suited for all environments nor are all equally effective. However, all do have the ability to improve the performance of a team. Some, such as the Nominal Group Technique and the Delphi Method are used to make decisions and predict likely outcomes of events. Others, such as the 360 Degree Review Feedback Process are designed to provide avenues of personal and team improvement. Many other methods exist beyond those presented here. The below is only a small subset of the full suite of techniques and tools available to create a well-functioning complex systems design team.

The Nominal Group Technique

The Nominal Group Technique, originally formalized by Delbecq and VandeVen [88, 89] , is a decision-making method that is used in groups of all sizes. It is ideally suited for teams that want to make decisions quickly and in the same style as voting but that want

all opinions taken into account rather than just the majority opinion [90]. The difference between standard voting and the Nominal Group Technique is in the tallying of the votes.

The group starts by having every member present their solution. Each member then rank orders the solutions. The scores each solution receives are then tallied. The solution with the lowest total ranking is found and used as the final solution. Variations on this technique are found in industry. This method can be modified to identify strengths and weaknesses in a design and can also be used to subjectively evaluate solutions.

The Delphi Method

The Delphi Method is a method that uses an independent panel of experts to systematically and interactively forecast outcomes of questions or problems. Generally, several iterations of the process are completed. After each iteration, a facilitator produces an anonymous summary of the experts' forecasts and the reasoning behind them. During the next round, the experts are encouraged to revise their previous answers. Through several rounds, the range of answers slowly decreases and the group converges toward a single answer or set of answers. At a pre-determined criterion, such as number of iterations, stability of answers, or attainment of consensus, the process is stopped and the mean and/or median scores of the final round of answers determine the results produced by the group [91].

Delphi has been adapted for use in face-to-face meetings where it is often referred to as mini-Delphi or Estimate-Talk-Estimate (ETE) [92]. Due to its flexibility and the results produced, the Delphi Method has found wide adoption business forecasting [93]. ETE often finds use in engineering settings in industry as well.

The 360 Degree Review Feedback Process

The 360 Degree Review Feedback Process is used to elicit feedback to judge an employee's performance and produce feedback for continued employee improvement. The process generates feedback from a representative subsection of the people an employee comes in contact with on a regular basis. The representative sample generally includes peers, subordinates, managers, customer, suppliers, vendors, and other stakeholders. Self-assessment is also part of the process. The results of the process are normally used to plan continued professional development and training of the employee being reviewed. Often, the results are also used as the basis of pay decisions and promotions as well as layoffs [94].

Chapter 3

Cultural Research

This chapter presents a review of the many definitions of culture. It looks at systems currently available to analyze culture on a quantitative level. Information on examining the culture of a person's mind through psychological personality testing tools is also presented.

3.1 Defining Culture

Invoking the word *culture* brings up a myriad of potential meanings and images. The English word finds its roots in the Latin word *cultura* that stems from *colere*, meaning "to cultivate" [95]. Cells and tissues are cultured in biology. Whole organs can be grown to replace ones that are old, damaged, and defective [96]. Plants can be cultivated. None of the previously biologic systems are of interest to the purposes of this thesis. There is one more thing that can be cultured: the mind.

Looking inside the mind, what increases the amount of culture present? How does one enter cultural programming into the brain? The phenomenon of "mental programming" is mentioned in the work of Ibn Khaldun where he states: "Indeed, the mind in its original state is ready to absorb any influence, good or bad. As Mohammed has said: 'Every child is born in a natural state. It is his parents who make him into [a specific culture]'" [97].

Is it even possible to have more or less culture between different minds? Questions of the level of culture present between different groups of Humans have been posed for many hundreds of years with sometimes disastrous results. Modern theories show that one culture being different from another is not grounds to call one primitive and the other civilized. Instead, cultural complexity and diversity is found spread throughout all of the known

cultures of the world [98].

Television shows, sporting events, political rallies, and pop music concerts all are cultural events [99]. High-brow symphony performances and art gallery showings can be considered cultured [100]. Museums and aquariums are cultural institutions. Bridges and monuments, too can be part of the cultural landscape. Social codes and norms such as the way people dress, the language they speak, the religion they practice, the rituals they follow, and the manners they practice are all considered part of culture [101].

Is culture, therefore, part of society? Are they the same things? Kashima, from a Cross-Cultural Psychologist's perspective states:

> First, culture should be conceptually distinguished from society, by which I mean a human grouping of some size and structure. A grouping could vary in size from a relatively small tribe, to a nation-state, to humanity as a whole. A culture may be shared (to some extent) in a society, but culture and society refer to analytically separable, theoretical entities[102].

Thus, as Kashima states, there are many different levels of culture. One culture can be contained partially or entirely within another.

Culture exists not only in the Human world but also in the animal kingdom [103]. Primatologists view culture as something that exists within all primates, not just Homo sapiens [104]. Other fields similarly argue that culture exists in elephants, dolphins, and many other animals [105].

With so many different facets and aspects to the word *culture*, how can an all-encompassing definition be made? The oft-overlooked secret is that there are many different definitions of *culture* that apply either very narrowly, as in the case of cultivating cells, or very broadly, as is the case in many of the definitions discussed in Section 3.2.

3.2 The Many Definitions of Culture

Culture has been defined, parsed, and redefined thousands of times across an untold number of fields. Many of these definitions do not prove particularly instructive to the main purpose of this text and are thus not discussed here. Even with throwing out definitions of culture often used by art critics, pop music icons, and micro biologists, hundreds of definitions remain. The mainstream definitions used in several fields including anthropology, business, psychology, and related areas are detailed in the subsequent subsections.

3.2.1 Definitions in Anthropology

Many people first encounter a formal definition of culture when studying anthropology. Anthropology, after all, is the root of the bulk of modern studies of culture. If any field were expected to have standardized on a definition, it is anthropology that has had the longest time to create a definition. It can be argued that the the most scholarly discourse of any field has also occurred in Anthropology. Instead of concentrating on a single, refined definition of culture, hundreds of definitions have been created with more being spawned every day.

For instance, in 1953, Kroeber and Kluckhohn inventoried 164 different definitions of culture in the anthropological literature of the day [106]. These definitions not only approach culture with varying degrees of focus, but they also approach it either from an emic or etic perspective [1]. While Kroeber and Kluckhohn did not explicitly call for a single definition to be settled upon, two decades later Keesing called upon the anthropological community to try to settle upon one narrow definition of culture [108]. Keesing's plea fell upon largely deaf ears. The number of definitions within anthropology continues to multiply with every passing year.

To add to the large body of definitons, both Kroeber and Kluckhohn defined their own meanings of culture at various points in their careers. Kluckhohn's definition reads, "Culture consists in pattered ways of thinking, feeling and reacting, acquired and transmitted mainly by symbols, constituting the distinctive achievements of human groups, including their embodiments in artifacts; the essential core of culture consists of traditional (ie: historically derived and selected) ideas and especially their attached values" [109]. Kroeber defines culture as "transmitted and created content and patterns of values, ideas and other symbolic-meaningful systems as factors in the shaping of human behavior and the artifacts produced through behavior" [110].

Similarly, Hall, another prolific anthropological writer, defined culture based upon pattersn of context, time, information flow, and space [111, 112, 113]. De Mooij found that his concept of context as related to culture is very useful for understanding consumer behavior and advertising in different cultures [99].

The original anthropological definition comes from Tylor who in 1874 defined culture thusly:

[1] In terms of research, including research on culture, research conducted from an emic approach aims to understand a topic from the inside. Research using an etic approach tries to understand a subject using universal categories [107]. In the case of culture, this would put descriptive anthropologists who describe a culture from first-hand accounts and field research in the emic camp. People who construct cultural dimensions to explain culture would be found with the etics.

> Culture or civilization, taken in its wide ethnographic sense, is that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society [114].

3.2.2 Definitions in Psychology

Psychology is rich with definitions of culture and the ensuing scholarly arguments back and forth between researchers. Psychology has a legacy of being intertwined with culture. At one point in time, psychology and culture used to be closely connected. Culture was an integral part of psychology, but then it was decoupled and ignored. In the last few decades, culture in psychology has made a comeback [102].

Nisbett describes four basic assumptions that have been made in psychology regarding human cognition and culture. They are listed in Table 3.1

Table 3.1: Nisbett's Four Basic Assumptions of Cognition and Culture in Psychology (Adapted from [115, 116])

Universality: Basic cognitive processes such as sensation, perception, attention and memory are found throughout humanity and do not vary between cultures.
Content Independence: Basic cognitive processes do not vary between different content nor do they vary across different content and different cultures.
Environmental Sufficiency: General learning and inference cognitive processes equip children based on environmental circumstances. Environmental differences explain cognitive differences rather than cultural differences.
Infinite Cultural Variance: Cognition does not place constraints on the design space of cultures.

In general, psychologists study culture as the study of peoples, not people [117]. This is partially as a result of the bridge between culture and anthropology in the form of cultural psychologists. Shweder states the main goal of cultural psychologists is "not to draw up lists of common denominators. It is to understand a particular way of life, from a psychological point of view" [118].

Kashima distinguishes culture by way of breaking it apart from society. He thus defines

culture by what it is not. "[A society is a] human grouping of some size and structure. A grouping could vary in size from a relatively small tribe, to a nation-state, to humanity as a whole. A culture may be shared (to some extent) in a society, but culture and society refer to analytically separable, theoretical entities" [102]. Shweder extends to define culture as the "local or community-specific ideas about what is true, good, beautiful, and efficient" [118]. Culture is thus somewhat muddled in psychology, much like it is in anthropology.

3.2.3 United Nations Defintion of Culture

The United Nations Education, Scientific, and Cultural Organization (UNESCO) recently stated that "culture should be regarded as the set of distinctive spiritual, material, intellectual and emotional features of society or a social group, and that it encompasses, in addition to art and literature, lifestyles, ways of living together, value systems, traditions and beliefs" [119]. The definition comes from a United Nations (UN) declaration on the 2002 International Mother Language Day. The decree further goes on to outline what UNESCO does to promote and retain cultural and linguistic diversity. The UN definition encompasses a large portion of what prior definitions try to convey while also clearly bounding what is considered culture.

3.2.4 Definitions in Business

A couple of methods of defining and using culture have been settled upon in the academic business community. For instance, de Mooij found that it was more useful to use culture in advertising than try to define it. On the other hand, Hofstede succinctly defined culture and has made a career of quantifying the cultures of the world.

de Mooij's Use of Culture

De Mooij states that, in the English language, culture is a very complicated word. She notes that culture is used to describe high art such as classical music, painting, sculpture, and the theater. It is used to describe popular art like Madonna or the Beetles. Biologists produce cultures of bacteria, and agriculture and horticulture are both incorporate the word into their respective fields. She finds that it is not as useful in business to define culture as it is to use it to find differences in the expressions of culture for marketing and advertising purposes [99].

Hofstede's Culture Definition

Hofstede has become known as one of the leading scholars of culture among the business academic community. Starting in the 1960's during his stint at International Business Machines Corporation (IBM), Hofstede developed his first models of culture. Coming from a mechanical engineering background, he attempted to quantify culture, discussed in Section 3.4. Hofstede's definition of culture is very instructive for the rest of this text.

Hofstede defines culture simply as "the collective programming of the mind that distinguishes the members of one group or category of people from another" [120]. He reaches this definition from looking at several scholars in other disciplines including Kluckhohn [109, 121, 106], Kroeber and Parsons [110], and Triandis [122], and fusing this information with his own long experience. Hofstede goes on to expand on his definition of culture to include an "onion diagram" visualization, as seen in Figure3.1 that places values at the center, rituals the next level out, heroes one level further out, and symbols as the outer-most layer. Practices is shown to penetrate from the surface through to the core-values.

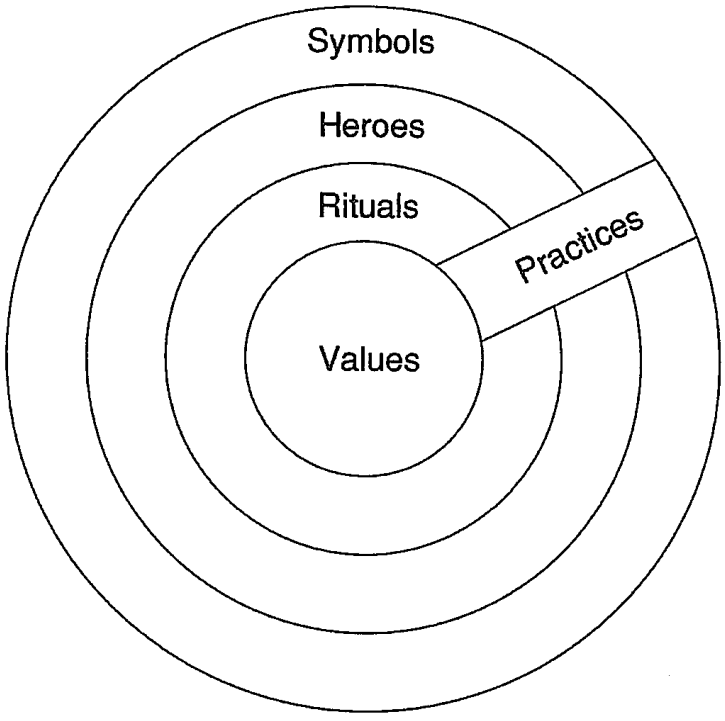

Figure 3.1: Hofstede's Onion Model of Culture: Cultural Values are located at the core and are surrounded by Rituals, Heros, and Symbols with Practices drilling down from the outside to the Values center. Reproduced from [120].

GLOBEs Culture Definition

The Global Leadership and Organizational Behavior Effectiveness Research Program (GLOBE) Study, a massive study that recently created a new scheme of cultural dimensions, discussed in depth in Subsection 3.4.3. GLOBE is meant primarily as a tool for business researchers. The GLOBE definition of culture is "shared motives, values, beliefs, identities, and interpretations or meanings of significant events that result from common experiences of members of collectives that are transmitted across generations" [123].

3.3 Culture: A Phenomena at What Level?

Among the many definitions of culture there also exists many levels of culture. For instance, there are specific cultures within a home, in a neighborhood, at an elementary school, in a town, in a state, in a region, and in a country. Often, neighborhoods, towns, and even countries share many of the same cultural traits. Sometimes households can have radically different cultures within yet still be neighbors. It is therefore difficult to pick at exactly what level of culture is appropriate to conduct analysis.

Looking at within-nation-level cultural variations, Schwartz found that in 183 of 187 instances, the cultural differences between nations were greater than the differences within nations [124]. However, Marcus found that even within a nation that might be viewed as largely homogeneous, cultural variations occur. He found that people in southern regions of China prefer bright colors while people in the north of China prefer more subdued palates[125].

Hoeken et. al. studied Western European markets to determine if they are truly segmented between nations for advertising campaigns. They tested two hypotheses listed in Table 3.2. The authors determined that Western European audiences can in fact receive the same value appeals with the same results [126].

Table 3.2: Hypotheses of Advertising in Western Europe.
(Adapted from [126])

Hypothesis 1: Appealing to a high uncertainty avoidance value yields a more persuasive advertisement in Belgium and Spain whereas appealing to a low uncertainty avoidance value yields a more persuasive advertisement in the Netherlands.

Continued...

Table 3.2: (Continued)

Hypothesis 2: Appealing to a masculine value yields a more persuasive advertisement in Germany and the UK whereas appealing to a feminine value yields a more persuasive advertisement in the Netherlands.

It is thus very difficult for a researcher to determine at what level to examine culture. Determining this level has to be done on a project-by-project basis. As will be detailed in Section 3.4, most existing accepted data reside at the nation-level view of culture. Because of this, much of the quantitative research performed using quantitative cultural data is performed at the national level.

3.4 Measuring Culture Quantitatively

The concept of measuring culture in quantifiable terms first started showing up in the literature in the 1960's. Hall published a series of anecdotes in the Harvard Business Review that were intended to get American businesspeople thinking about how cultures in different countries would affect their work overseas [113]. As part of the article, Hall broke cultural differences into different categories that he called "languages." These "languages" are listed in Table 3.3.

Table 3.3: Hall's Cultural Languages Categories. (Adapted from [113])

Time
Space
Material Possession
Friendship Patterns
Agreements

In the following decades, several scholars began to further refine the idea of quantifying culture. Hofstede was the first to publish a significant study defining (originally) four cultural dimensions [127]. Others followed suit including Schwartz [128, 129, 130, 124] and the GLOBE Study [123, 131]. The work of Schwartz has been largely ignored and dismissed by the bulk of the cultural dimensions community, and the GLOBE Study is still too new

and too large for many researchers to use. Hofstede's original four cultural dimensions have been expanded first to five [120] and quite recently to six [132] The GLOBE Study, however, will most likely one day supplant Hofstede's research as hundreds of academics have pinned their collective carriers on the successful outcome of the

3.4.1 Schwartz's Cultural Dimensions

Schwartz and Bilsky found seven different measures of culture. However unlike Hofstede's dimensions, the Schwartz's measures are not independent of one another and thus are not dimensions. The seven measures are listed in Table 3.4.

Table 3.4: Schwartz's Cultural Measures

Conservatism
Intellectual Autonomy
Affective Autonomy
Hierarchy
Mastery
Egalitarian Commitment
Harmony

Some of Schwartz and Bilsky's measures do correlate with Hofstede's dimensions and many of them correlate with gross national per capita income but because of the dipolar structure of Schwartz and Bilsky's measures, their method becomes overly complicated for other researchers to effectively use. In the end, Schwartz's measures boil down to one dimension which can be summed up as a passive versus active attitude toward life. Additionally, limited data are available for countries as compared to Hofstede and GLOBE [128, 129, 130].

3.4.2 Hofstede's Cultural Dimensions

Hofstede's Cultural Dimensions first started to take shape in the late 1960's and early 1970's during his employment at IBM. He and his colleagues conducted two rounds of surveys across the company's many worldwide offices. In total, more than 116,000 responses from 72 countries in 20 languages were generated. Hofstede's initial analysis was limited to 40 countries who had 50 or more respondants to the survey. Later Hofstede was able to add three multi-country regions and ten additional individual nations to the dataset [120].

The analysis Hofstede conducted on the massive dataset focused on the differences between countries in answers to questions about employee values. He validated the data taken from the employees at IBM by comparing it to data collected at the former International Management Development Institute in Lausanne, Switzerland. Statistical analysis across individuals was conducted. Variance analysis was also performed on the data set by using country, occupation, gender, and age as criteria. It was found that the most crucial were correlation and factor analyses that were based on matched employee samples across countries [127].

Through the lengthy analysis process, Hofstede found four cultural dimensions. They are Power Distance, Uncertainty Avoidance, Individualism versus Collectivism, and Masculinity versus Femininity [127]. The Power Distance and Uncertainty Avoidance dimensions were found through what Hofstede terms an "eclectic" analysis of the data based on correlation analysis and theoretical reasoning. Individualism and Masculinity were derived from country-level factor analysis of scores on work goal importance, standardized for eliminating acquiescence [120]. Upon later reflection and research, Hofstede found that Inkeles and Levinson predicted the Hofstede's four cultural dimensions in a review article published in 1969 [120, 133].

Hofstede conducted a country-level factor analysis of the dataset to create an integrated picture of the four dimensions. He conducted a comparison between the two survey rounds and found that there were only minor country-level value shifts over the six years between the surveys. He verified the statistical independence of the four dimensions. The four dimensions were validated against Rokeach's Values Survey [134]. The results compared favorably [107]. Hofstede's four dimensions allowed him to form cultural clusters of nations throughout the world where the cultural dimensions are largely the same [120].

Several years after Hofstede released his seminal work, Bond and Hofstede collaborated on a survey known as the Chinese Values Survey [135]. From that survey, Hofstede found a fifth dimension that would remain his final cultural dimension until 2008. It is Long-term versus Short-term Orientation. The five cultural dimensions and Hofstede's descriptions of them are presented in Table 3.5.

Table 3.5: Hoftede's Five Cultural Dimensions. (Quoted and adapted from [120])

Cultural Dimension	Description Additional Information
Power Distance Index	The extent to which the less powerful members of organizations and institutions accept and expect that power is distributed unequally. The basic problem involved is the degree of human inequality that underlies the functioning of each particular society. Hofstede borrowed the term Power Distance from the Dutch social psychologist Mulder who conducted experiments in the 1960's investigating interpersonal power dynamics [136, 137, 138].
Uncertainty Avoidance Index	The extent to which a culture programs its members to feel either uncomfortable or comfortable in unstructured situations. Unstructured situations are novel, unknown, surprising, and different from usual. The basic problem involved is the degree to which a society tries to control the uncontrollable. The term Uncertainty Avoidance is borrowed from Cyret and March [139].
Individualism versus Collectivism Index	The degree to which individuals are supposed to look after themselves or remain integrated into groups, usually around the family. Positioning itself between these poles is a very basic problem all societies face. Sociology provides a variety of distinctions associated with the individualism dimension. Tönnie's distinction between gemeinchaft (low individualism) and gesellschaft (high individualism) is especially instructive [140].
Masculinity versus Femininity	The distribution of emotional roles between the genders, which is another fundamental problem for any society to which a range of solutions are found; it opposes "tough" masculine to "tender" feminine societies.

Continued...

Table 3.5: (Continued)

Cultural Dimension	Description Additional Information
	Surveys on the importance of work goals conducted at IBM and other companies showed that women almost universally attach more importance to social goals such as relationships, helping others, and the physical environment. Men attach more importance to ego goals such as careers and money. Additionally, the IBM database revealed that the importance respondents attached to "feminine" and "masculine" work goals varies across countries and occupations [120].
Long-term versus Short-term Orientation	The extent to which a culture programs its members to accept delayed gratification of their material, social, and emotional needs. This dimension was not originally found in Hofstede's IBM surveys. This is most likely because the original surveys were written and exclusively by Westerner researchers including Dutch, British, French, Norwegians, and Americans who had their own cultural biases. From Bond's later work in China, this dimension emerged [135].

In Hofstede's 2001 book, he noted that additional dimensions must be both conceptually and statistically independent from the five dimensions that he had previously established. Further, he stated that they must be validated by significant correlations with external measures. He did not rule out more dimensions but he did challenge the community by stating "candidates are welcome to apply" [120].

In early 2008, Hofstede and his colleagues released a new cultural dimension. Hofstede's new cultural dimension is Indulgence versus Restraint [132]. This new dimension comes from research conducted by Minkov who used the World Values Survey databank [141] to find several potential new dimensions. Hofstede currently only includes Indulgence versus Restraint in his cultural dimensions. The other dimensions that Minkov proposed are Exclusionism versus Universalism and Monumentalism versus Flexiumility. Table 3.6 provides more information on these new dimensions.

Table 3.6: Minkov's Proposed Additions to Hofstede's Cultural Dimensions. (Quoted and adapted from [142, 143, 132])

Cultural Dimension	Description
Exclusionism versus Universalism	This dimension is statistically very similar to Hofstede's Individualism versus Collectivism dimension.
Indulgence versus Restraint	This dimension measures a person's happiness, sense of freedom, and leisure. It is similar to the Tightness versus Looseness dimension that Gelfand [144, 145] recently proposed [143].
Monumentalism versus Flexiumilility	The positive pole in this dimension is defined by national pride, the desire to make parents proud, and viewing religion as important. The negative pole contains the concepts of humility, and not believing one has a stable and invariant self. Minkov believes there are some correlations between this dimension and Hofstede's masculinity - femininity dimension [143, 142].

3.4.3 The GLOBE Study

The GLOBE Study, started in the early 1990's, took more than a decade to start to reach fruition. Part of the reason for the long duration between inception and results is the size and complexity of the study. In total, 170 investigators participated in 62 different cultures. Data was pulled from more than 17300 managers in 951 organizations to test 27 hypotheses [123, 131]. The study was massive in scope and participation. Many hundreds of professors and their grad students have attached themselves to the study, and have a vested interest in its success.

GLOBE attempts to answer five specific questions, listed in Table 3.7. The researchers believe that GLOBE has answered the questions. Others, such as Hofstede, have their doubts [146].

Table 3.7: GLOBEs Specific Questions. (Quoted from [123])

1. Are there leader behaviors, attributes, and organizational practices that are universally accepted and effective across cultures?
2. Are there leader behaviors, attributes, and organizational practices that are accepted and effective in only some cultures?
3. How do attributes of societal and organizational cultures influence whether specific leader behaviors will be accepted and effective?
4. How do attributes of societal and organizational cultures affect selected organizational practices?
5. What is the relationship between societal cultural variables and international competitiveness of the societies studied?

Through statistical analysis, GLOBE found nine cultural dimensions. Some, however, claim that in fact GLOBE has 18 dimensions [146]. This is as a result of two measures of each dimension being present. One measure ranks a an individual's perception of him or herself while the other measure ranks an individual's perception of other people within his or her own culture. Table 3.8 lists the dimensions and their GLOBE descriptions.

Table 3.8: GLOBE Cultural Dimensions (Quoted and adapted from [123])

Cultural Dimension	Description
Uncertainty Avoidance	The extent to which members of an organization or society strive to avoid uncertainty by relying on established social norms, rituals, and bureaucratic practices. People in high uncertainty avoidance cultures actively seek to decrease the probability of unpredictable future events that could adversely affect the operation of an organization or society and remedy the success of such adverse effects.
Power Distance	The degree to which members of an organization or society expect and agree that power should be stratified and concentrated at higher levels of an organization or government.

Continued...

Table 3.8: (Continued)

Cultural Dimension	Description
Institutional Collectivism (Collectivism I)	The degree to which organizational and societal institutional practices encourage and reward collective distribution of resources and collective action.
In-Group Collectivism (Collectivism II)	The degree to which individuals express pride, loyalty, and cohesiveness in their organizations or families.
Gender Egalitarianism	The degree to which an organization or a society minimizes gender role differences while promoting gender equality.
Assertiveness	The degree to which individuals in organizations or societies are assertive, confrontational, and aggressive in social relationships.
Future Orientation	The degree to which individuals in organizations or societies engage in future-oriented behaviors such as planning, investing in the future, and delaying individual or collective gratification.
Performance Orientation	The degree to which an organization or society encourages and rewards group members for performance improvement and excellence.
Humane Orientation	The degree to which individuals in organizations or societies encourage and reward individuals for being fair, altruistic, friendly, generous, caring, and kind to others.

GLOBE counters the claims of Hofstede and others [146] by stating

> On an individual level of analysis (the level that GLOBE measures tap to make inferences about societal and organizational culture) the disparity between perceptions of practices and value judgments can be interpreted as deprivation. That is, when respondents perceive practices as less or more dominant in their society or organization than they think they should be, or perceive them as inappropriate, there will be a disparity between their reports of practices and values. On a society or organizational level of analysis, their common perceptions of a disparity between practices and values imply the people's sympathy with respectively higher or lower levels of cultural values than practices [131].

Another phase of the GLOBE Study was recently released that attempts to combine both culture-specific and culture-general [2] approaches. A total of 25 individual country chapters are presented both at a culture-general level and a culture-specific level. The questions raised by Triandis and others [149] about sufficient sample size in the GLOBE Study are answered in [131] through follow-up work to confirm hypotheses that was conducted in India and the United States of America.

It should be noted that only leadership in organizations was studied by GLOBE. The sample populations only consisted of middle managers who were selected from two to three identical industries found in all countries included in the survey. Anyone can tell that this does not provide a representative sample of an entire country. It does, however, provide a very representative sample of the group surveyed [123, 131].

3.4.4 Tools to Measure the Individual

While it is useful to measure and understand culture at a national level, it is also important to determine qualities of an individual. Many companies in industry use tests such as the Big Five Personality Traits Test (Big Five), the Myers-Briggs Type Indicator Test (MBTI), and many other proprietary personality trait tests. These results are often used to help teams understand one another, form new project teams, and are instructive for the people taking the tests. At least part of the cultural construct of a person is generated at the individual level. Personality tests are one way of trying to ascertain an individual's internal cultural dimensions.

The Big Five Personality Traits Test

The Big Five Test, also known as the Five Factor Model, is considered to be the most comprehensive and empirical test of personality currently in wide use. The first reference to the Big Five came from an address given by Thurstone to the American Psychological Association in 1933 [150]. Since then, the Big Five has been used broadly in psychology and in industry.

The five factors in the Big Five are listed in Table 3.9 and include the traits that these factors measure.

[2]The standard criticism of the culture-general approach – neglecting the nuances and subtleties of a culture due to high levels of abstraction [147] – is addressed in [131] by augmenting constructs of the culture-general approach with culturally contingent findings and concepts [148].

Table 3.9: The Big Five Factors and Traits [151, 152]

Factor	Traits
Openness / Intellect	Appreciation for art, emotion, adventure, unusual ideas, imagination, curiosity, and variety of experience.
Conscientiousness	A tendency to show self-discipline, act dutifully, and aim for achievement; planned rather than spontaneous behavior.
Extroversion	Energy, positive emotions, and the tendency to seek stimulation and the company of others.
Agreeableness	A tendency to be compassionate and cooperative rather than suspicious and antagonistic towards others.
Neuroticism / Emotional Instability	A tendency to experience unpleasant emotions easily, such as anger, anxiety, depression, or vulnerability.

Research shows that Big Five test scores remain stable over time [153]. In general, levels of Conscientiousness and Agreeableness increase gradually increase while Neuroticism and Openness tend to decrease with time which points toward an effect due to people maturing [154]. Other studies have found that individual people change based on life-altering events and other variables that are unique to specific individuals [155].

The Myers-Briggs Type Indicator Test

The MBTI is a questionnaire-based test that measures psychological preferences in perception and decision-making abilities of individuals [156]. The MBTI originated in the work of Jung in 1921 [157] and was developed further through Briggs and Myers during World War II. Unlike some other personality trait tests that were originally developed to diagnose psychological disorders, the MBTI was developed for psychologically normal participants [158].

Many researchers have criticized MBTI over the years for lacking a valid dataset [159, 160, 161]. However, companies who specialize in administering the test for profit cite anecdotal information of successful behavioral predictions [162]. Some studies have found evidence of internal consistency, construct validity, and test-retest reliability but there was still variation observed [163, 164].

The MBTI uses four bipolar word pairs to create 16 possible combinations of personality types. The four word pairs are presented in Table 3.10. The 16 possible combinations, denoted by the first letter of each word pair choice, are listed in Table 3.11 with their descriptors.

Table 3.10: The MBTI Bipolar Word Pairs [165]

Extroversion	Introversion
Sensing	iNtuition
Thinking	Feeling
Judging	Perceiving

Table 3.11: The 16 MBTI Personality Types. (Quoted from [166])

Personality Type	Description
ISTJ	Quiet, serious, earn success by thoroughness and dependability. Practical, matter-of-fact, realistic, and responsible. Decide logically what should be done and work toward it steadily, regardless of distractions. Take pleasure in making everything orderly and organized – their work, their home, their life. Value traditions and loyalty.
ISFJ	Quiet, friendly, responsible, and conscientious. Committed and steady in meeting their obligations. Thorough, painstaking, and accurate. Loyal, considerate, notice and remember specifics about people who are important to them, concerned with how others feel. Strive to create an orderly and harmonious environment at work and at home.
INFJ	Seek meaning and connection in ideas, relationships, and material possessions. Want to understand what motivates people and are insightful about others. Conscientious and committed to their firm values. Develop a clear vision about how best to serve the common good. Organized and decisive in implementing their vision.

Continued...

Table 3.11: (Continued)

Personality Type	Description
INTJ	Have original minds and great drive for implementing their ideas and achieving their goals. Quickly see patterns in external events and develop long-range explanatory perspectives. When committed, organize a job and carry it through. Skeptical and independent, have high standards of competence and performance – for themselves and others.
ISTP	Tolerant and flexible, quiet observers until a problem appears, then act quickly to find workable solutions. Analyze what makes things work and readily get through large amounts of data to isolate the core of practical problems. Interested in cause and effect, organize facts using logical principles, value efficiency.
ISFP	Quiet, friendly, sensitive, and kind. Enjoy the present moment, what's going on around them. Like to have their own space and to work within their own time frame. Loyal and committed to their values and to people who are important to them. Dislike disagreements and conflicts, do not force their opinions or values on others.
INFP	Idealistic, loyal to their values and to people who are important to them. Want an external life that is congruent with their values. Curious, quick to see possibilities, can be catalysts for implementing ideas. Seek to understand people and to help them fulfill their potential. Adaptable, flexible, and accepting unless a value is threatened.
INTP	Seek to develop logical explanations for everything that interests them. Theoretical and abstract, interested more in ideas than in social interaction. Quiet, contained, flexible, and adaptable. Have unusual ability to focus in depth to solve problems in their area of interest. Skeptical, sometimes critical, always analytical.
ESTP	Flexible and tolerant, they take a pragmatic approach focused immediate results. Theories and conceptual explanations bore them – they want to act energetically to solve the problem. Focus on the here-and-now, spontaneous, enjoy each moment that they can be active with others. Enjoy material comforts and style. Learn best through doing.

Continued...

Table 3.11: (Continued)

Personality Type	Description
ESFP	Outgoing, friendly, and accepting. Exuberant lovers of life, people, and material comforts. Enjoy working with others to make things happen. Bring common sense and a realistic approach to their work, and make work fun. Flexible and spontaneous, adapt readily to new people and environments. Learn best by trying a new skill with other people.
ENFP	Warmly enthusiastic and imaginative. See life as full of possibilities. Make connections between events and information very quickly, and confidently proceed based on the patterns they see. Want a lot of affirmation from others, and readily give appreciation and support. Spontaneous and flexible, often rely on their ability to improvise and their verbal fluency.
ENTP	Quick, ingenious, stimulating, alert, and outspoken. Resourceful in solving new and challenging problems. Adept at generating conceptual possibilities and then analyzing them strategically. Good at reading other people. Bored by routine, will seldom do the same thing the same way, apt to turn to one new interest after another.
ESTJ	Practical, realistic, matter-of-fact. Decisive, quickly move to implement decisions. Organize projects and people to get things done, focus on getting results in the most efficient way possible. Take care of routine details. Have a clear set of logical standards, systematically follow them and want others to also. Forceful in implementing their plans.
ESFJ	Warmhearted, conscientious, and cooperative. Want harmony in their environment, work with determination to establish it. Like to work with others to complete tasks accurately and on time. Loyal, follow through even in small matters. Notice what others need in their day-by-day lives and try to provide it. Want to be appreciated for who they are and for what they contribute.
ENFJ	Warm, empathetic, responsive, and responsible. Highly attuned to the emotions, needs, and motivations of others. Find potential in everyone, want to help others fulfill their potential. May act as catalysts for individual and group growth. Loyal, responsive to praise and criticism. Sociable, facilitate others in a group, and provide inspiring leadership.

Continued. . .

Table 3.11: (Continued)

Personality Type	Description
ENTJ	Frank, decisive, assume leadership readily. Quickly see illogical and inefficient procedures and policies, develop and implement comprehensive systems to solve organizational problems. Enjoy long-term planning and goal setting. Usually well informed, well read, enjoy expanding their knowledge and passing it on to others. Forceful in presenting their ideas.

The Problem of National Cultures and Personality Tests

The vast majority of personality tests currently in use are western-centric. They have been developed by western researchers and are calibrated to western samples. There is some evidence that a few of the tests, such as the Big Five, correlate with Hofstede's dimensions, but no test currently works seamlessly across all cultures.

The Big Five has been correlated with Hofstede's original four cultural dimensions [167]. The fifth dimension does not correlate with the Big Five after the other four dimensions are controlled for. No information is currently available on Hofstede's new sixth dimension. Hofstede and McCrae were able to correlate the four dimensions from data that is available across 33 countries [168]. Due to its popularity, the Big Five has been replicated in many different language and cultural contexts.

In spite of the correlation with Hofstede's Cultural Dimensions, Hofstede cautions that the Big Five does not paint a complete picture of the Asian mind [120, 167]. Instead, Hofstede suggests a sixth factor for the Big Five that he titles "Dependence on Others" [167]. Many studies exist and many researchers have discussed the reasons for cognitive differences between Asian cultures and the West [169, 170, 171, 172, 173, 174, 175, 121, 99, 118]. Differences are found even among Americans, Candadians, and Turks [176]. Until the Big Five and other tests account for this properly, they cannot be viewed as universal personality tests. Perhaps in the future with more research and larger datasets, definitive conclusions will be able to be drawn on the applicability of the Big Five and other psychological personality tests to different cultures.

Chapter 4

Culture and Complex Systems Design

In the past, it was entirely possible that a complex system such as a steam engine or a woolen mill could be designed, built, and operated without a whole host of cultures touching the design in some way. In modern times, it is practically impossible to find a complex system that has not been designed at least in part by a multi-cultural team. Examples in industry (see Chapter 1) abound of multi-national partnerships, global design teams, and highly multi-cultural workplaces.

While much research has been conducted to mitigate risk in complex system design, little has been done to attempt to quantify the risk associated with cross-cultural complex systems design team. Many potential risks exist in a multi-cultural design team. For instance, implicit assumptions and codes of conduct in certain cultures may not be at all apparent in other cultures, subtle meanings and cultural cues can be misinterpreted when translated across cultures and languages, and engineering practice and methodologies vary between cultural regions.

Several potential avenues appear to be worth exploring to attempt to quantify and mitigate the risk associated with cross-cultural complex systems design teams. Nation-level cultural dimensions such as those presented by Hofstede [120], GLOBE [123], and others provide a broad cultural overview and a means for comparison between disparate cultures. Follow-on GLOBE publications [131, 177] provide in-depth cultural analysis and observations along with historical perspective. Psychological personality assessment tools such as Big Five and MBTI provide a useful snapshot of individuals and their though processes. However, problems exist with meaningfully translating these tests across cultures.

The following sections discuss the risks involved with multi-cultural design teams, potential

avenues for addressing these risks, and notes holes in the current research. Chapter 5 discusses potential future research directions and further details.

4.1 Risks in a Multi-Cultural Design Team

Many risks exist for multi-cultural design teams. They include implicit assumptions and codes of contduct that vary between cultures in not always obvious ways, subtle meanings and cultural cues, and variation in engineering methods and styles across cultures. While implicit assumptions and codes of conduct, and subtle meanings and cultural cues are addressed in many different media, these items are not addressed in an engineering context. Likewise, engineering methods and styles across cultures appear to only receive cursory treatment in the literature yet are apparent in many designs around the world.

4.1.1 Implicit Assumptions and Codes of Conduct in Cultures

Every culture has certain implicit assumptions and codes of conduct. These implicit assumptions can become risks to a complex systems design project when team members from different cultures do not realize or understand the assumptions that their teammates hold. For instance, as was discussed in Chapter 2 Section 2.4.2.4.1, many Asian cultures will say "Yes" when they mean "No" for a variety of reasons. In many Arab cultures, it is considered a grave offense to talk openly about domestic politics [178]. Many other examples of cultural codes of conduct and implicit cultural assumptions exist and can be observed on the nightly news about wars in far-off places and in the immigrant neighborhoods of the larger cities of the world.

Implicit assumptions and cultural codes of conduct are already being used in the software world. Agent-based systems are using online community cultural norms to predict where users will navigate. Implicit assumptions within these communities are also being used to direct development of the platforms [179, 180, 181, 182, 183, 184].

4.1.2 Subtle Meanings and Cultural Cues

Subtle meanings and cultural cues have long given advertisers and businesspeople troubles [99]. The differences in the way one culture interprets an advertisement as compared to another culture creates problems when trying to produce universal advertisements [185,

186, 187, 188, 189, 190, 191, 192, 193, 194]. This problem carries over into engineering [195, 196].

4.1.3 Engineering Methods and Styles Across Cultures

Engineering methods and styles do not always transport across cultures. For instance, many Russian and Chinese designs look very foreign to American engineers. Some French designs carry more subtle differences from their American counterparts. Many cultural areas of the world do not have a competent technical workforce and must import foreign engineers or do without [178, 196]. Examples of interesting Chinese and French engineering are shown in Figures 4.1 and 4.2.

Figure 4.1: French Wool Processing Machinery in a Tunisian Factory

Figure 4.2: Chinese Powerline in Albania

4.2 Potential Avenues for Risk Mitigation in Multi-Cultural Design Teams

Several potential avenues exist to mitigate the risk of multi-cultural complex system design environments. Nation-level cultural dimensions, such as those proposed by Hofstede and GLOBE, cultural profiles produced by GLOBE follow-on studies and others, and individual personality tests all hold promise. None is currently a stand-alone silver bullet to diagnose and find risks within multi-cultural teams, however.

4.2.1 Nation-level Cultural Dimensions

As was discussed in Chapter 3 Section 3.4, there are several systems to measure culture quantitatively. All of the systems presented are designed to be nation-level representations of culture. The two most prominent systems, Hofstede's Cultural Dimensions [120] and GLOBEs Cultural Dimensions both have been and are continuing to be used widely in research. Hofstede's scheme, having been around much longer, has a much larger pool of research to confirm its validity while GLOBE is still in the early stages of being adopted.

Comparing the different cultures of the members of a multi-cultural complex systems design team can be very instructive. This will allow an astute team to discover that a member from Germany has a different Power Distance relationship as compared to a member from Japan, for instance. By looking at tables present in Hofstede's book [120], descriptors of what a high or a low Power Distance Index culture works. Figure 4.3 gives an example of what one of these tables contains. Each Hofstede dimension has multiple corresponding dimensions. Likewise, each GLOBE dimension has similar tables.

Low PDI	High PDI
All should be interdependent.	A few should be independent; most should be dependent.
Inequality in society should be minimized.	There should be an order of inequality in this world in which everyone has his/her rightful place; high and low are protected by this order.
Hierarchy means an inequality of roles, established for convenience.	Hierarchy means existential inequality.
Subordinates are people like me.	Superiors consider subordinates as being of a different kind.
Superiors are people like me.	Subordinates consider superiors as being of a different kind.
The use of power should be legitimate and is subject to the judgment between good and evil.	Power is a basic fact of society that antedates good or evil; its legitimacy is irrelevant.
All should have equal rights.	Power holders are entitled to privileges.
Powerful people should try to look less powerful than they are.	Powerful people should try to look as powerful as possible.
Stress on reward, legitimate and expert power.	Stress on coercive and referent power.
The system is to blame.	The underdog is to blame.
The way to change a social system is by redistributing power.	The way to change a social system is by dethroning those in power.
Latent harmony between the powerful and the powerless.	Latent conflict between the powerful and the powerless.
Older people neither respected nor feared.	Older people respected and feared.

Figure 4.3: An example of Hofstede's Power Distance Index. (Copied from [120]

It appears that the quantification of different cultures' positions on the cultural dimensions axes relative to one another provide an opportunity for relative risk information to be gleaned. Perhaps these numbers can be correlated to the risk of a complex systems design project failing or producing a result that is likely to fail in unanticipated ways. If that can be done, cultural dimensions, with appropriate conversion, could be factored into risk and reliability formulations.

4.2.2 Cultural Profiles

Cultural profiles, such as those presented in [131, 177] and elsewhere, can be very useful for complex systems design team mates to get a better grasp on the cultural background and some of the idiosyncrasies of a particular culture. So far, 25 countries have received in-depth treatment from GLOBE and another 15 have received some degree of review. The GLOBE Survey plans to eventually review each country that they have surveyed.

The Finland chapter of [131] provides a good example of what is found in most country chapters. A background is given to the development of Finnish history and culture. The education system and religion are examined. The state of the Finnish industrial sector is reviewed. A detailed analysis of the results obtained from the GLOBE survey is performed. Results are discussed about the societal culture of Finland with respect to the nine GLOBE cultural dimensions. A discussion of Finish leadership is presented with attention paid to outstanding leaders in Finland's past. Qualitative and quantitative results about Finish leadership are discussed. Implications for cross-cultural research and practice on the topic of effective Finnish leadership are presented. This same pattern repeats across all country chapters produced by GLOBE.

Further research is currently being conducted in this arena by GLOBE and others, and is expected to yield similar results for all cultures analyzed. While GLOBEs work certainly is beneficial, it is not complete in an engineering sense. Work needs to be done to systematically catalog the differences in analytic and design styles between cultures. Attention also needs to be paid to assumptions that are implicitly held by members of various cultures. Without these areas being addressed, cultural profiles will remain only a partial solution to a part of the larger issue at hand.

4.2.3 Personality Tests

While cultural dimensions do provide nation-level information and cultural profiles provide a deeper understanding of a particular national culture, a culture, like a team, is still composed of individuals. Personality tests such as Big Five and MBTI can provide insight into western minds but research [167] indicates that they do not work across dissimilar cultures. Without further research in this area, these tests will be largely meaningless to multi-cultural teams and in fact might produce bad results that will disrupt work more than if the tests had not been administered to begin with.

Chapter 5

Conclusion

The proceeding chapters reviewed multi-cultural complex systems engineering failures, complex system engineering and its many tools and applications, cultural and psychological research, and the intersection of complex system design and cultural and psychological research. The fields of cultural research and complex systems engineering are maturing. Likewise, the field of psychological personality testing has matured for western minds. However, cross-cultural psychological testing is still being developed and very few examples exist in literature of failed complex systems designs due to cross-cultural problems in spite of strong anecdotal evidence of its existence in industry.

5.0.4 Four Year Research Plan

Table 5.1: Research Plan Timeline

Timeframe	Task Description
0 to 6 months	Conduct a more in-depth literature search for examples of complex system failure do to multi-cultural engineering problems, cross-cultural psychological personality testing, and other related items.
2 to 4 months	Review risk and reliability literature (such as [197] to find how the risks and reliabilities of complex systems design teams are accounted for in complex systems engineering.

Continued...

Table 5.1: (Continued)

Timeframe	Task Description
6 to 12 months	Develop article(s) detailing engineering examples of complex systems design failures due to cross-cultural problems on development teams.
12 to 18 months	Select several focus cultures for the creation of detailed engineering cultural profiles. Find collaborators within those cultures.
18 to 30 months	Work with collaborators to develop engineering cultural country profiles. Publish the resulting profiles.
12 to 36 months	Determine methods for computing risk due to culture in complex systems design teams.
36 to 48 months	Publish articles on all topics. Unify topics into several articles culminating in PhD Dissertation.

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NASA National Aeronautics and Space Administration

JPL Jet Propulsion Laboratory

MRAP Mine Resistant Ambush Protected Combat Vehicle

BOINC Berkeley Open Infrastructure for Network Computing

MiG Mikoyan-i-Gurevich Design Bureau

NYSE New York Stock Exchange

DAX Deutscher Aktien IndeX

LSE London Stock Exchange

DMV Department of Motor Vehicles

SACCS State-wide Automated Child Support System

IBM International Business Machines Corporation

FAA Federal Aviation Administration

IRS Internal Revenue Service

ATSV Advanced Trade Space Visualization

EES Engineering Equation Solver

CATIA Computer Aided Three Dimensional Interactive Application

ETE Estimate-Talk-Estimate

UNESCO United Nations Education, Scientific, and Cultural Organization

UN United Nations

GLOBE Global Leadership and Organizational Behavior Effectiveness Research Program

Big Five Big Five Personality Traits Test

MBTI Myers-Briggs Type Indicator Test

WWII World War II