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UNDERSTANDING THE DEVELOPMENT OF GEOGRAPHIC INFORMATION SYSTEMS (GIS) AS A PROFESSIONAL FIELD

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BY

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Abstract

This dissertation is based on an exploratory study of GIS as it has evolved as a professional field. This study is relevant because it provides a fundamentally different approach to study professionals within a particular sector where technology has significantly influenced not only processes, but the individuals comprising the professional field. The study aimed to describe and expose thoughts and perspectives directly from GIS professionals from different sectors, but predominantly the government sector. This research took a critical look at the crucial milestones in the development of GIS as a professional field, the primary actors and organizations involved, and the barriers GIS has overcome in its evolution. This research observed GIS as a professional field in a temporal context and identified milestones, key actors, collaboration factors, perceived barriers and thoughts on "informational power" involved in the evolution. A survey was developed from exploratory interviews and administered to a broader context of GIS users to tie the actual timeline and introduce the context of the professionals' perceptions within the GIS field. The approach was mixed methods with initially an exploratory design including process tracing for the historical context, both exploratory and confirmatory semi-structured interviews, and an online survey.

Since GIS naturally spans boundaries within organizations, the research also considered the best organizational structure for fostering the GIS function, and whether the typical bureaucratic government structure has inhibited leveraging GIS effectively. Factors contributing to collaboration, both internally and externally, like geospatial data standards, enhanced network communication systems, and online communication were

also explored. GIS's impact on "informational power" and Emerson's General Dependency Postulate (1962) were also discovered. This research intended to discover whether there are specific qualities in a GIS professional that distinguish them from other professional association aligned experts or whether group behaviors, like Gouldner's (1957) locals and cosmopolitans or social identity theory (Tajfel & Turner, 1979), could be applied and help categorize GIS professionals internally. With the movement to Web GIS, the role of technology on GIS evolution with communication networks, innovation theory, and change management were also investigated. The ultimate goal of this study was to provide recommendations on how to promote the technology of GIS as the environment evolves and moves forward.

There is something unique about the individuals and their love for this profession that make them a little different, and this study describes those differences and how they contribute to the growth and development of GIS as a professional field. Jack Dangermond, Esri's founder, is undoubtedly recognized by most GIS professionals as the single most significant individual contributor to the field, and though much of the development of the information systems that GIS resides on was conducted by the U.S. Government, most of the applications have been enhanced by the private sector. These technological enhancements are now an expectation and are somewhat taken for granted. The world is getting smaller with technology, and GIS demonstrates just how small it really is.

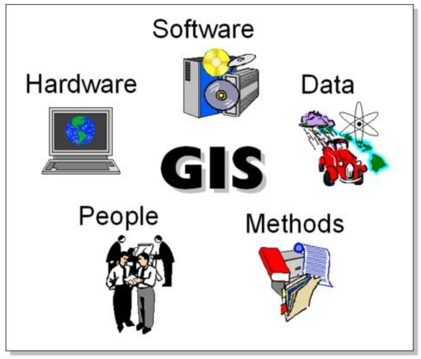
CHAPTER ONE: INTRODUCTION

Background and Definition of Geographic Information Systems (GIS)

Roger Tomlinson asserted GIS is the common ground between information processing and the disciplines utilizing spatial analysis techniques (Tomlinson, 1972). GIS has also been defined as "a system of hardware, software, and procedures that capture, store, edit, manipulate, manage, analyze, share, and display georeferenced data" (Fu & Sun, 2011, p. 4). Traditionally, geospatial data was stored, manipulated, and displayed using a paper map, which displayed preselected information about the landscape (e.g., rivers, contours) and human activity (e.g., roads, railways, towns) and was used by a wide range of individuals and organizations doing some type of land use planning. The problem with a singular map was it was limited in its flexibility to display different information for particular uses. The development of computer mapping, GPS, and powerful personal computers and smartphones has led to a myriad of specialized services like Google Maps, Google Earth, and MapQuest that make the digital map information available tailored to specific users. These are examples of GIS, which are now a critical part of every individual's life.

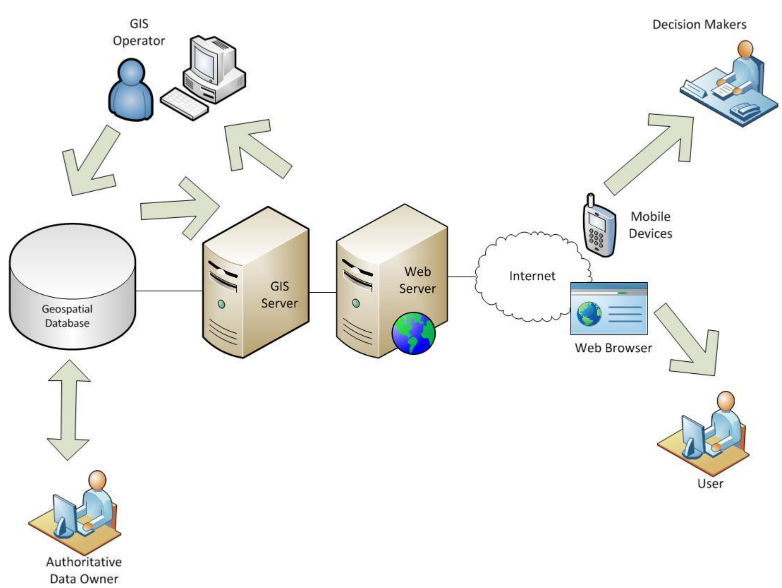
There are five key inputs that are typically very critical to the "systems" in GIS. Most definitions of GIS include the following five components: (1) hardware, (2) software, (3) data, (4) methods or procedures, and (5) people, as shown in Figure 1 below.

Figure 1: Components of a GIS (Hawaii's State Department of Health, 2012)



A GIS, or information systems for geographic information, can vary in complexity from a simple application with a user calculating driving directions with Google Maps or MapQuest web services to a very complex enterprise GIS. An example of an enterprise GIS would be software and hardware systems consisting of a geospatial database, client software, web applications, and operators of all the systems for supporting a logistics or transport organization. An example of an enterprise GIS system is shown below in Figure 2.

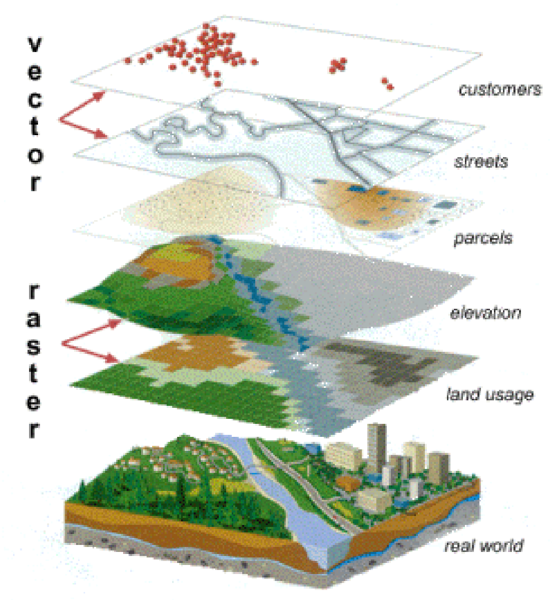
Figure 2: Enterprise GIS Diagram (Mott, 2012)



An enterprise GIS typically is comprised of a relational geospatial database, a GIS server to allow for editing/publishing of map products built and maintained by a GIS operator, and a web server to push map services to the Internet (Esri, 2012). The map products and services can then be displayed or consumed by mobile devices or web browsers for use by decision makers.

Georeferenced data in the GIS typically consists of both vector and raster data. Raster data consists of tiled datasets like digital aerial imagery, scanned maps or any other continuous datasets where coverage exists over the entire area (Esri, 2012), usually used for background maps. Vector data in a GIS represents the earth's features with points, lines, or polygons (Esri, 2012). Figure 3 displays an example of vector and raster layers within a GIS, depicting geospatial information for the real world.

Figure 3: Vector and Raster Layers for the Real World (HC-GTF, 2012)



GIS, as a computer-based system, has been utilized since at least the 1960's (Coppock & Rhind, 1991), and GIS as a professional field has been around since before then. In the time since its inception, the field of GIS has overcome many obstacles, such as lack of geospatial data standards associated with using interchangeable proprietary software applications, and has evolved through many process and technological changes, like the adoption of server-based technology to provide maps to a wider audience, to become the refined profession it is today.

GIS has evolved and plays a part in many people's everyday lives without them even realizing it. GIS operators have evolved from scientists to the average user of the Internet; however, most average users of web-based GIS wouldn't know what GIS stands for. They do not have an understanding of the underlying system enabling the geospatial analysis they are leveraging. The purpose of this study is to provide a detailed background and perceptions from experts involved in the field looking at GIS in an organizational framework to understand how GIS has evolved into what it is today and what it will evolve into in the future.

Contribution of the Study

GIS has made a fundamental impact in our society and has changed the way most organizations do business, irrespective of whether they are in the private, public, or non-governmental sectors. Given GIS has become an integral part of contemporary society, it is important to understand how it evolved to give insight into what challenges it may face in the future. This research observed GIS as a professional field in a temporal context and identified milestones, key actors, collaboration factors, perceived barriers and thoughts on "informational power" involved in the evolution.

GIS professionals from different sectors and experience levels were interviewed to explore how they view their role and their perception of milestones, key actors, factors contributing to collaboration, barriers affecting the progression of the field, and benefits and risks of the availability of GIS as the field has evolved. A survey was developed from exploratory interviews and administered to a broader context of GIS users to tie the actual timeline and introduce the context of the professionals' perceptions within the GIS field. The approach was mixed methods with initially an exploratory design including process tracing for the historical context, both exploratory and confirmatory semi-structured interviews, and an online survey.

The Department of Defense (DoD) has been and continues to be a leader in research and development (R&D) for a multitude of the technologies developed for GIS and played a major role in its evolution; however, many of the ways to utilize the technology have been advanced by the private sector and the trend is currently towards open (non-proprietary) systems. The research analyzed any differences between individuals in diverse roles, with various amounts of experience, and from different sectors, with a specific focus on those coming from the DoD. Another goal of the study was to evaluate whether the movement towards open systems, deviating away from the DoD, will be a constraint to future GIS growth.

Organizationally, this dissertation is arranged to include initially a brief background of the study, the research questions to be investigated, and the relevant associated literature. The research design and methodology is then described in detail, along with definitions of the variables researched. The researcher also included a chapter on the history of GIS, as identified through process tracing, along with some of the preliminary results from data collection. From the data collection and analysis, first the major milestones were recognized and categorized, along with some of the perceptions from the respondents on milestones that have helped define GIS. Secondly, the researcher identified leading actors and organizations and determined whether the nature of relationships and collaboration partners in GIS has changed over time. Thirdly, barriers inhibiting the progression of GIS were identified and explored in a temporal context.

The research then shifted from traceable milestones, actors, and barriers to perceptions of the field, as recognized by the participants. Relevant literature for the study included observing informational power in the GIS context, along with fit in organizational structure and group behaviors. The study also explored the role of technology in the evolution of GIS as a professional field. The researcher wanted to discover how informational power was perceived by GIS professionals and the possibilities and potential risks associated with it. Organizational structures were explored for perceived “best fit” for organizations conducting and utilizing GIS and the most effective methods to collaborate both internally and externally. This research also sought to identify whether there exists a sectoral separation of GIS professionals and whether roles could be empirically categorized and analyzed. The research viewed the impact of technology in innovation in GIS, communication networks, and change management and whether GIS is uniquely different than other information technologies (IT), and the roles of individuals involved in GIS. The dissertation closes with an analysis of the variables explored and the resulting conclusions from both the qualitative and quantitative research methods employed.

Statement of the Problem and Overarching Research Questions

Advanced technologies like GIS may not fit well into a rigid, hierarchical structure such as that traditionally favored by the DoD, as geospatial information travels across boundaries disregarding legitimate chains of command. The DoD is not alone in using this type of organizational structure; many large organizations with hierarchical organizational structures may have similar challenges now due to the nature of having more information easily accessible. Data and information providers must transform due to the expectations from end users, whose demands have changed over time. Some organizations are structured differently and may have an easier time with the rapid and often turbulent pace of change in GIS technology and software utilization.

The research investigated how GIS, which is so applicable and relevant to essentially every industry and sector, fits within the DoD and the larger context of GIS as a professional field. GIS increases informational power by allowing for access to data and information, which would otherwise be difficult to discover. This study explored how changes in informational power and in power dynamics may affect organization operations since users have more sources to the same geospatial data to make decisions, which would make them less reliant on more traditional methods. The research also explored the presence of group behavior patterns identified by Alvin Gouldner (1957) as cosmopolitans and locals as they individually and distinctly relate to GIS professionals in all sectors. This study also determined opportunities and risks in exploiting and consuming free commercially available services. It also addressed the challenges to successfully implementing Web GIS for the DoD, e.g., secure networks, service interdependencies, and lack of commitment to provide services without commercial incentives. The ultimate goal of this study was to provide recommendations on how to promote the technology of GIS as the environment evolves and moves forward.

Research Question 1: What are the perceived significant milestones in GIS development?

There are obvious and undisputable milestones identified in the progression of GIS as a professional field. The relationship between actual milestones and perceived milestones from GIS participants will be explored. The research explored whether years of experience, sector, or role correlated with specific milestones identified.

Research Question 2: Who have been the leading actors in GIS development?

There are the easily recognized organizational and individual leaders who have contributed greatly to the professional field. This study looked at whether there are perceived differences in leaders in evolution recognized by different sector, experience level or expertise from GIS professionals who participated in the study.

Research Question 3: Have the nature of relationships and collaboration between many of the primary actors changed over time?

This question aimed to understand the perception of participants on how collaboration between primary actors, both public and private, has evolved over time. This study also looked at which are the strongest factors that have contributed to collaboration in the field over time.

Research Question 4: What are the opportunities/benefits and risks/challenges in exploiting and consuming free commercially available services?

Opportunities and benefits seem to be fairly obvious in consuming free, commercially available services, as the user is able to obtain “free” services, which they don’t have to pay for and may not have otherwise had access to. Conversely, some of the risks or challenges could be either the reliability or the accuracy of the online GIS services presented. It was interesting to observe how sector, role, and years of experience play into the perceptions of opportunities and benefits, and conversely, risks and challenges.

Research Question 5: What have been the barriers or sources of resistance over time in GIS development and evolution?

Barriers or sources of resistance have been identified to be people not wanting to change and evolve, to money, computer power, and lack of data. Which sources of resistance appear to be the most important in slowing down the progression of GIS as a professional field in a temporal perspective?

Research Question 6: What are the issues the DoD may be required to overcome to capitalize on the freely available online GIS services, which is the direction in which the field is trending?

The DoD has secure networks for protecting information. Do these security measures prevent the U.S. Federal Government from taking advantage of what could be achieved with the availability of the online GIS services that are currently available?

Research Question 7: Does an advanced technology like GIS fit into a bureaucratic, hierarchical organizational structure like the DoD?

GIS inherently stretches across boundaries within organizational structures. A significant amount of early research in GIS development was conducted by the U.S.

Government and DoD, which are very hierarchical organizations. Is GIS truly a fit within this type of organization or can it easily fit into any organization? Or would it just flourish less in a bureaucratic organization?

Research Question 8: How does "informational power," which is enhanced by GIS, affect decision making in DoD organizations?

GIS is information, which in essence enhances "informational power." However, making it available to individuals throughout the organization would decrease the relative power any one individual would have with respect to informational power. It provides the user with power through geospatial awareness, but if everyone has the information, it doesn't really provide a competitive edge. It is only a hindrance if the user doesn't have it. Having more and better information should fundamentally allow the organization to make better decisions, but are there any negative side-effects that correspond with informational power?

Research Question 9: Are there fundamental significant differences between GIS professionals in the private sector versus the DoD?

This was a thematic question for the entire study, as it became clear in the initial exploratory interviews that distinctly different situations and issues were of value in their perceptions. Does the sector make a difference, and could the GIS professionals within these sectors be categorized?

CHAPTER TWO: LITERATURE REVIEW

Introduction of Theoretical Framework

The literature explored for this dissertation includes organizational structures, both internal (intra-organizational) and collaborative (inter-organizational). This chapter includes descriptions of intra-organizational structures as could be applied to an organization managing or utilizing a GIS, along with inter-organizational structures for GIS including Renis Likert's (1967) "linking pin" model. GIS as it relates to power, and more succinctly, "informational power," is described. A review of group behaviors, including Alvin Gouldner's (1957) "cosmopolitans and locals" and Tajfel and Turner's (1979) social identity theory as applied to groups of GIS professionals is given. The role of technology and how it has impacted communication networks, innovation theory, including Rogers' (1962) "diffusion of innovations," and technology as it pertains to change management is also investigated.

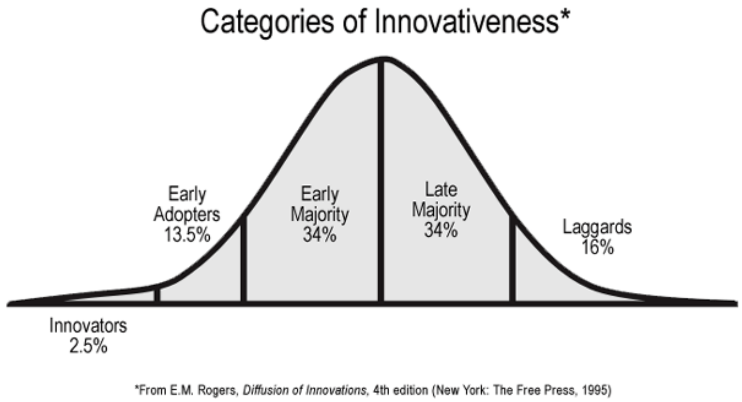
Role of Technology

Innovation Theory

Innovation is defined as any change in service that produces something new to an industry or organization (Rusaw, 2001). Bingham (1976) defined innovation as the first use of an idea by a group whose members have similar goals. Rogers (1962) asserted that innovation results from the diffusion of new ideas to organizations that adapt them to their needs. Rogers' (1962) diffusion of innovations described how an innovative idea is disseminated through the organization or through a communication network. There is some degree of uncertainty and risk associated with most innovation that occurs within an organization. Complexity is the perceived level of difficulty associated with an innovation in how relatively difficult it is to understand and to use. If there is a greater complexity associated with an innovation, there is a lower level of adoption by individuals within the organization. Moore (1993) agreed that “diffusion of innovations occurs through the collective, yet individually based decisions of individual level adopters (p. 80).” Though the organization is by itself a unit, it is still composed of individuals with their personal perceptions and the ability to make their own individual decisions. Organizational adoption is the use of the technology for performing organizational tasks – essentially the internalization into organizational processes and functions. This involves acquiring new knowledge by decentralizing power and responsibilities, an approach that is known as organizational learning (Argyris & Schön, 1978).

Rogers (1962) presented adopter distributions in Figure 4 showing “Categories of Innovativeness.” The continuum of innovativeness can be partitioned into five adopter categories (innovators, early adopters, early majority, late majority, and laggards). Early adopters tend to have more years of formal education and training and are generally from a higher socioeconomic status than are later adopters (Rogers, 1962). Earlier adopters also have a greater ability to work with abstract concepts, a more positive attitude toward change, and a greater ability to deal with uncertainty and risk (ibid.).

Figure 4: Roger's Categories of Innovativeness.



Although GIS, like other IT, has been around for a number of years, the technology continues to evolve. GIS has moved from Mylar overlays to static company-owned databases into a service-oriented architecture (SOA). Companies produce the layers in which they are the authoritative data owners and consume or leverage services provided by other organizations or agencies that maintain more robust datasets for other purposes. The SOA paradigm introduces a number of managerial decisions, ranging from strategic decisions to invest in the technology, to tactical decisions concerning buy versus build, to operational issues addressing selection, integration, and implementation of services—all of which represent productive areas for research (Choi, Nazareth, & Jain, 2010).

GIS positions itself as an innovative technology; however, due to the real world applications already implemented, consumers already see the value when implementing for their own purpose, e.g., sales, logistics and distribution, and emergency response. There are too many real world problems solved by GIS every day, so in a temporal context, the laggards are essentially the only ones newly adopting GIS into their business processes currently.

There have been a series of innovative milestones which have helped build and allow GIS to evolve. Typically the innovators are still making the milestones occur with help from the early adopters who have implemented the innovative ideas. The leading and most prevalent actors have been involved in implementing most of these major milestones in GIS.

Research Question 1: What are the perceived significant milestones in GIS development?

There have been a series of innovative ideas and concepts introduced in GIS from the advent of digitization of satellite imagery, to databases to server side technology. The researcher intended to identify and categorize critical milestones associated with the innovation of the technology in GIS. The researcher was also interested as to whether the perceptions of significant milestones were dependent on the GIS context as to which industry or sector the participant comes from.

Research Question 2: Who have been the leading actors in GIS development?

The researcher wanted to ascertain the predominant innovators and associated early adopters involved with the diffusion of innovations in GIS. The researcher believed that both academia and the DoD are part of the innovators category; however, the early adopters tend to come from the private sector – as it seems the private sector has influenced more advancements in utilizing the technology.

Communication Networks

Communication networks are the patterns of contact between the sender and the receiver when exchanging messages through time and space (Monge & Contractor, 2001). This dissertation discusses enhanced network communication systems in a majority of the sense through the Internet; however, the fundamental premise of communication networks, or the necessity of them, is of utmost importance in this research. A communication network, in the more traditional sense, consists of the degree in which individuals are linked together (or interconnectedness) through both formal and informal channels (Rogers & Kincaid, 1981). Communication networks should also be considered in discoursing on both intra- and inter-organizational collaboration.

Renis Likert's (1961) linking pin model essentially states that linking pins are individuals representing or having membership in overlapping work units. These individuals typically lead one group and also participate on a higher level team comprised of individuals representing other functions. Linking pins connect various parts or aspects of the organization and provide permanence and stability.

Though linking pins are typically referred to as an individual, the very fabric of GIS as the system it is, establishes a geospatial infrastructure. It creates a network linkage between organizational units with the geographical reference as the common denominator. Geospatial information crosses organizational boundaries and fulfills the concept of providing the geospatial reference to data being utilized at all levels within and between organizations. GIS professionals typically have dual group membership in both GIS and the discipline utilizing the GIS (e.g., logistics, planning, operations). They tend to take on the role of a bridge from a social network perspective (Brass, 1995). GIS also lends itself to lateral communication, which can save time, facilitate coordination, and help expedite accurate and efficient transfer of information or data.

Communication networks, from a temporal perspective, have created more interconnectedness, which should allow for increased collaboration.

Research Question 3: Have the nature of relationships and collaboration between many of the primary actors changed over time?

The researcher discovered which factors participants believed contributed to collaboration between organizations and individuals in the past and presently. The researcher wanted to discover which developments have advanced relationships and the role of technology in the ability to collaborate.

Communication networks – the Internet – have also allowed for a new generation of Web GIS services. Communication networks are linking consumers and providers of GIS more efficiently. There are a plethora of geospatial services out there that have yet to be exploited.

Research Question 4: What are the opportunities/benefits and risks/challenges in exploiting and consuming free commercially available services?

Advancements in IT and the Internet have made for an advanced communication network to allow for the transfer of information. The researcher sought to discover how individuals and organizations plan to capitalize on GIS services on the Internet and determine the primary benefits and opportunities, and conversely the risks and challenges that would be presented with the improved communication network system.

Change Management

Change management is essentially a structured and controlled approach to planning for and implementing a change within an organization. GIS technology, like other IT systems, relies primarily on the individual adopter to incorporate the use of the technology in the organization. Extensive literature acknowledges “computer systems problems are traceable primarily to human factors” and that “information systems failures are rarely merely of a technical nature” (Garson, 1993, p. 515). To incorporate a technological change, like introducing GIS, there are two basic approaches: (1) devise new tools to support bureaucracy’s usual activities, or (2) change the organization to use technology to full advantage, supporting processes rather than structure. The second approach is often referred to as “re-engineering” (Hammer & Champy, 1993) and may be much more difficult to implement because it features a critical rethinking of the entire production change rather than modest improvements to existing processes and systems. The second approach has influenced many organizations; however, it may be a slow road to get there as it is still evolving.

Undergoing a major organizational change typically is one of the most difficult processes an organization must endure, as it is innate in most people to continue to do what they’ve always done. In Nedovic-Budic and Godschalk’s (1996) study of the human factors involved in adopting a GIS, the top three factors to successful implementation were: (1) perceived relative advantage, (2) previous computer experience, and (3) exposure to the technology, when determining peoples’ willingness to change and adopt the new technology. GIS professionals may have the spatial insight to better see the relative advantage of making changes, and the nature of the professional field requires use of a computer. GIS professionals may also be better prepared overall to handle or manage change due to their specialized expertise, which facilitates showing visually why decisions are better.

Research Question 5: What have been the barriers or sources of resistance over time in GIS development and evolution?

This study examined which sources of resistance have inhibited the change management process for GIS to progress and evolve within individual organizations and the professional field as a whole. The combination of new technologies and the human element were both observed. GIS professionals may be intrinsically better managers of change within organizations, as the underlying technology of GIS has been evolving and changing ever since its inception. GIS, like every technology, requires change and there will always be some people who resist it. Some people or missions will still want a paper map product in lieu of a map service.

The DoD may appear to manage change differently than the private sector. Most entities affiliated with the U.S. Government have specific policies and regulations for doing business – especially when it comes to communication networks. Many GIS services are freely accessible and available, but there still may be concerns with the DoD utilizing them.

Research Question 6: What are the issues the DoD may be required to overcome to capitalize on the freely available online GIS services, which is the direction in which the field is trending?

The research studied independently the current barriers inhibiting the DoD from successfully capitalizing on GIS services on the Internet. The DoD has distinctive issues prohibiting them from capitalizing on technological innovation within their systems.

Organizational Structures

The structure of an organization, or organizational structure, refers to the composition and order of the units that comprise the organization. Some of the key factors of an organizational structure are chain of command, span of control, centralization, and formalization (Daft, 2004). The structural concept of chain of command is less relevant in modern times due, in large part, to advances in information technology (IT), as GIS like other IT platforms empowers employees to work with less direct supervision, and it unleashes their creativity. GIS also impacts span of control, as it is a technology that positions itself "differently" in most organizational structures since geospatial data crosses intra- and inter-organizational boundaries. With advances in IT, employees at all levels can access data instantaneously that was only available to upper tiers of management years ago, which affects centralization. Individuals can also communicate with anyone in the organization through informal channels like email that, prior to advancements in IT, would have been deemed impossible. This research sought to identify and relate how GIS influences organizational structures, both internally (intra-organizational) and collaboratively (inter-organizational).

Internal Structures (Intra-organizational)

One of the primary analytical considerations of organizational structure is the pattern or "shape" of the organization (McPhee & Poole, 2001) with respect to individuals within it and how they interact. The organizational pattern consists of size, horizontal differentiation, and vertical hierarchy (McPhee & Poole, 2001). With respect to size, typically larger organizations experience more challenges facilitating information exchange with more prevalent channels.

Organizational structures can be analyzed in terms of the degree to which a vertical or horizontal hierarchy exists. For instance, vertical hierarchy refers primarily to the number of levels within the organization. Horizontal differentiation is primarily concerned with "division of labor" (ibid.), as to how the various processes are distributed or separated among the individuals or sections within the organization. Horizontal differentiation also helps distinguish organizations that may have more of a functional or matrix framework combining vertical and horizontal structures. A functional framework involves specific and similar types of tasks or functions within the organization managed distinctly, while a matrix framework consists of similar functions that may be integrated into smaller sections of leadership with other, different types of responsibilities.

Formalization is also another central concept of an organizational structure. A bureaucratic organization fundamentally would consist of a high degree of formalization (ibid.). The bureaucratic design which most government organizations have employed may not be the best, or optimal, internal structure for managing a GIS. The strength of the bureaucratic design was in the ability to perform standardized activities in a highly efficient manner (Weber, 1946).

GIS does not conform to any type of real standardized activity, as it typically spans across many functions and levels within the organization. The structural principle of degree of centralization can be analytically useful since it implies where decisions can be made, as the highest degree of a centralized organization would consist of the leader at the top of the organization being responsible for making *all* decisions for the organization (McPhee & Poole, 2001). Mintzberg (1979) discusses different ways organizations lend themselves to decentralization: horizontally or vertically (where formal power is dispersed among and up and down the chain of authority) and geographically, where units are spread across the state, country, or world. GIS allows for decentralization within organizations, as it supports providing the information or relevant data at multiple levels and across networks. Overly rigid hierarchical structures have a tendency to compartmentalize critical information, including geospatial data, which nullifies what GIS attempts to facilitate.

Collaborative Structures (Inter-organizational)

For the purposes of this study, collaborative structures are described as methods or techniques an organization employs in order to collaborate between organizations or inter-organizationally. Inter-organizational knowledge sharing is a major resource of professional and organizational innovation (Powell, Koput, and Smith-Doerr, 1996). Typically, the more extensive and varied the organizational networks are, the greater depth and breadth of knowledge to share. However, the greater number and variety of stakeholders and contexts present more risks, costs, and barriers to overcome (Dawes, Creswell, & Pardo, 2009). Effective data sharing and integration across boundaries often requires cross-boundary examination and understanding of diverse business processes and practices (ibid.).

Embracing geospatial data standards and developing and sharing accurate metadata are a couple of the techniques to collaborate better between GIS organizations. Metadata refers to the logic of data structures, definitions, collection methods, processes, and interpretive schemes, and accompanies the georeferenced data (Esri, 2002). It may be poorly documented and distributed in ways that make it difficult to aggregate and share. Without sharing this knowledge, the transfer of data across organizations is unlikely to produce meaningful results (Dawes, Creswell, & Pardo, 2009). Advances in IT, like GIS, have greatly enhanced the ability to integrate explicit knowledge by making it easily assimilated, stored, discovered, and retrieved (Anand, Manz, & Glick, 1998; Rockart & Short, 1989). Besides incorporating enhancements in IT, GIS consortia have worked hard to assimilate data sharing standards to encourage inter-organizational collaboration. Standards help communicate GIS across boundaries and between departments. Bureaucratic, hierarchical organizational structures typically lend themselves to compartmentalizing.

Research Question 7: Does an advanced technology like GIS fit into a bureaucratic, hierarchical organizational structure like the DoD?

This study sought to understand the application and fit of GIS to a bureaucratic, hierarchical organizational structure, which the DoD typifies. The research also explored recommendations and perceptions by GIS professionals who participated in the study to understand differing perspectives from inside various organizational structures. The research examined the role of IT in communications and its respective influence on organizations utilizing GIS for daily operations.

Power

Emerson's General Dependency Postulate

The General Dependency Postulate in the most basic form states, "The greater B's dependency on A, the greater power A has over B (Emerson, 1962, n.p.)." The postulate is greatly influenced by the fundamental economics of supply and demand. If A is the only one who has "X," and B needs "X" to do "Y," then B is very dependent on

A; A would have more power over B. Conversely if "X" is readily available from other sources besides A, then B is less dependent on A; A has less power over B. People, who have data or knowledge others need, make others dependent on them – thus invoking the postulate and achieving more power.

Essentially Emerson's (1962) General Dependency Postulate could indicate that if everyone has the information or GIS data available, accessing the data or possession would not increase someone's power. As GIS progresses and advances, it will become more and more accessible, thus unable to provide any individual or organization a relative advantage. Essentially as GIS becomes more and more main stream, it won't provide a relative advantage for any user, but it will become an expectation and a requirement for being competitive. The power associated with GIS would not be in having access to GIS; the power would come from how it was used.

"Informational Power" Defined

Power, which typically is based on authority, is the ability to require or to get followers to act to achieve a goal or purpose (Rusaw, 2001). This definition primarily refers to formal power, which is based on individual's position within an organization. Power can come from ability to coerce or reward, from formal authority, or from "control of information (Keohane & Nye, 1998)." Informational power, or influence, as denoted by Raven (2008) can be gained from having access or control over information. In the original French and Raven (1959) literature, only five power bases are documented: legitimate power, referent power, expert power, coercive power, and reward power; informational power is omitted. Raven (2008) stated that French felt very strongly the term "power" seemed to have the overtone of getting the person to do what he or she did not want to do, and the term power was not appropriate for information-based change (ibid.). French insisted it be referred to as informational influence in lieu of power; however, Raven saw the utility and relevance of defining the influence as power.

GIS by definition is a computer system allowing for geographic understanding and analysis to be incorporated into the decision making process. GIS provides geospatial information that *could* be translated into informational power if utilized effectively in the decision making process. Many organizations believe informational power is their competitive advantage, and the *lack* of informational power could be detrimental to their success. GIS allows for transparency and disallows one organization to have the edge since the information is typically accessible. However, not all organizations employ GIS in their strategic decisions. Frequently, whether a particular organization reveals the data or not, geospatial data representing that organization will be made available. This encourages organizations to share their *own* authoritative data; otherwise they risk inaccurate data representation. These organizations may be reluctant to reveal any knowledge assets that may reduce or threaten their discretion and autonomy (Rourke, 1978) or their ability to compete for power and influence (Provan & Sebastian, 1996). Revealing information to outsiders also may pose a threat of embarrassment or sanction, or invite scrutiny (Dawes, 1995). Valuable organizational or personal assets may constitute the information or knowledge which could be revealed, and the loss of exclusive control of that knowledge could inhibit open dialogue and collaboration.

Research Question 8: How does "informational power," which is enhanced by GIS, affect decision making in DoD organizations?

The researcher wanted to confirm the perception and understanding of GIS as informational power. The proliferation of Web GIS will also impact the relative power of GIS to both individuals and organizations, as Emerson's General Dependency Postulate (1962) will be invoked, and the access to a plethora of GIS services will in effect decrease the relative power of GIS. The DoD has been known to restrict access to data or compartmentalize it. How will respondents from within the DoD perceive informational power realized from GIS?

Group Behaviors

Cosmopolitans and Locals

Alvin Gouldner's (1957) theoretical concepts of "cosmopolitans and locals" could be applied to the specialized career field of GIS professionals. Gouldner (1957) defines cosmopolitans as individuals with less loyalty to the respective employing organization, but states that they possess high commitment to specialized role skills. Cosmopolitans are also likely to use an outer reference group orientation. Locals are more loyal to their organizations and less committed to the specialized role skills, and more likely to use an inner reference group orientation. A cosmopolitan is more indicative of a true professional. Professionals have "occupations with special power and prestige (Larson, 1978, n.p.)." Cosmopolitans or professionals have also been explained as "workers whose qualities of detachment, autonomy, and group allegiance are more extensive than those found among other groups (Brown, 1992, p. 19)."

Locals are seen more as "company men" who would forego continued development in their specialized skill or trade in order to be promoted through the ranks within an organization, while a cosmopolitan remains committed to being an expert in a specific field and does not want to make themselves irrelevant in the field by, in essence, wasting the specialized, formal training they have received. Cosmopolitans are less likely to *command* any organization, and if they are in leadership roles, they tend to *sell* their beliefs to other management staff in lieu of directing action (Gouldner, 1957). Locals, unlike cosmopolitans, demonstrate loyalty to the company or organization's bottom line, rather than to a specific discipline or division within the organization.

GIS professionals are more likely to fit the cosmopolitan framework, as they must have a high degree of commitment to their specialized skill set to get and stay proficient, especially since the technology is constantly changing and advancing. The outer reference circle they "belong" to could be one of the many GIS working groups and opportunities to participate at conferences, e.g., Esri user conference (UC), which typically has approximately 15,000 GIS professionals worldwide in attendance. Locals would more likely associate with other IT professionals, who are not specific to the GIS profession, or DoD GIS professionals who got wrapped up in a GIS role, as the government organizations transformed from a mapping (or cartography) agency into a GIS agency.

For the purposes of this research, locals would be expected to be a respondent within the government sector in a managerial role, who believed automation to be one of the most critical milestones in the evolution of GIS. They would also believe that geospatial data standards contributed the most to collaboration, and that they are also the biggest barrier to progression as well. They are more likely to see the negatives as information overload or abuse and lack of privacy. The cosmopolitan would be more likely to come from the private sector in an analytical or technical role and believe the Internet is the most significant milestone. The cosmopolitan would also view online communication and conferences or workgroups as contributing most to collaboration. They also see lack of understanding by leadership and customers as the biggest barrier to progression. Inaccurate results and misinterpretation would be the single most paramount negative side effect of informational power; essentially power in the hands of someone who doesn't understand what they are working with, or the limitations of the data, is a substantial risk.

Social Identity Theory

The social identity approach is largely engrained in European social psychological literature in intergroup relations (Abrams et al., 2005). It has the underlying premise that the group is in the individual in lieu of the individual in the group (ibid.). This approach considers why the issues that are important to the group become so important to the individual. The minimal group research conducted by Tajfel (1970) was sufficient to show merely assigning a label or category to an individual adequately generated favoritism and intergroup discrimination. Most individuals would sacrifice their own self-interests for the overall benefit of the group.

Social identity theory (Tajfel & Turner, 1979) requires several conditions to be met in order for ingroup bias to occur: (1) the individual must be subjectively identified by their ingroup, (2) the attribute involved in intergroup comparison must be salient, (3) there must be some comparability between the ingroup and outgroup, and (4) the actual ranking or positions of the ingroup and outgroup must have some ambiguity in comparison. The ambiguity of comparison for the fourth condition indicating that one group is not clearly better than the other. One of the other key aspects was also that some permeability is required in the boundaries between the groups for this ingroup bias to occur, as different behaviors may transpire if the distinguishing factor was something that the individual was unable to change (e.g., gender, race, ethnicity).

This theory may be very relevant to how GIS professionals identify with their respective ingroup, and potentially how collectively they feel when comparing themselves to other professional association aligned experts (or outgroup). GIS professionals, especially in academia, but even still now with the GIS consortiums, appear to have the greater goal of GIS for everyone and interoperable systems and data as a primary goal in lieu of their own self-interests, which is evident with the movement towards open (free) systems and software utilizing non-proprietary data types and non-proprietary software. Private companies may have an ulterior motive, but many still promote GIS as a whole and how it works together rather than their own specific product or service.

Research Question 9: Are there fundamental significant differences between GIS professionals in the private sector versus the DoD?

This research addressed whether the social identity or cosmopolitans and local theoretical constructs were present within or between groups of GIS professionals or other professional association aligned experts. Group behaviors, especially considering cosmopolitans and locals, were an important theme for the entire study. The researcher hoped to demonstrate that group behaviors could be empirically tested and analyzed.

CHAPTER THREE: RESEARCH DESIGN/METHODOLOGY

Mixed Methods: Exploratory Sequential Design

Computer-based GIS as a professional field has been evolving since its inception back in the 1960's. Though there have been many studies that have addressed the relevance and possibilities of GIS, few have addressed the evolution and major players in the professional field of GIS. There was an "I-19 Social History of GIS" project compiled by Eugene McCann in 1996, but it seemed to vanish shortly afterwards and appeared to be more an attempt at compiling an annotated bibliography than actually conducting research looking at the evolving nature of the technology and applying lessons learned to the future and advancement of the field.

GIS impacts day to day operations in people's lives and activities. The purpose of this research was to look at GIS technology in a temporal context and through process tracing, identify key actors and decisions involved in the evolution of the professional field of GIS. The major milestones that have helped define GIS in the public and private sector were recognized and categorized. GIS experts from government and industry were interviewed to explore how they view their role in the development of GIS as a field over time. In this research design, it was expected that the field of GIS is somewhat unique with its reliance and involvement with both the private and government (public) sector. The most appropriate and effective organizational structures for the development of the GIS technology were explored. The research also addressed challenges and risks and, conversely, opportunities and benefits of capitalizing on GIS development – especially GIS services available on the Internet. GIS has made a fundamental impact in our society and has changed the way most organizations do business. The ultimate goal of this research was to provide recommendations on how to promote the technology of GIS within the environment in which it evolves and moves forward, and to recognize whether there exists a rationale for sectoral structuring or categorization of GIS professionals.

This research design consisted of an inductive research component where participants' observations were descriptive of situations in which they occur. This research design also utilized a mixed methodological approach with an exploratory, sequential design (Creswell & Clark, 2010). The study consisted initially of a review of archival records from the main professional association as well as an extended literature review on the history of GIS. Then interview data was collected and analyzed. These results formed the basis for a larger survey to provide comparison data. Analysis of the mixed data offered the ability to describe the GIS context as it has changed over time and to interpret the lived environment of the GIS professional. In contrast to an explanatory, sequential design, this design puts a greater emphasis and importance on the native, or lived, perspective of the GIS professionals and how they perceive the role of GIS and technology in their workplaces. Combined with the archival data and extant literature, in this study, there was potential for descriptive inferences to be made to set the stage for future empirical research.

Upon receiving Institutional Review Board (IRB) approval, the following stages were undertaken:

- Stage 1: Process tracing on accessible information related to evolution of GIS as a professional field

- Stage 2: Contacting selected individuals for the interviews with recruitment script, obtaining consent, and conducting interviews
- Stage 3: Developing survey questionnaire for Qualtrics.com and sending recruitment script via email to a broader set of participants; conducting survey
- Stage 4: Triangulation of data collected from different data collection methods

First Stage: Process Tracing

The researcher began the first stage with process tracing, wherein the researcher considered the historical context of GIS to develop a timeline of the evolution of the field and to identify key actors. The primary data for this technique was historical records available on the Internet, as they were related to GIS. In addition, evidence for process tracing was provided via interviews with experts and GIS scholars, attendance at seminars addressing the history of GIS at the Esri UC, and studying books and journals related to history of GIS, e.g., Foresman's (1998) *The history of geographic information systems: Perspectives from the pioneers*. The process tracing was performed primarily on events and significant milestones that occurred in the evolution of GIS. Additionally the key actors and organizations were identified and characterized to illustrate and observe influences in the evolution of GIS.

Qualitative research methods like process tracing allowed the investigator to gain more depth and breadth into the topic that would not necessarily be obvious to the researcher who only considered numerical values (whether measured or manipulated). Qualitative research methods can be very helpful in gaining a deeper understanding of the subjects being investigated (Lofland, Snow, Anderson, & Lofland, 2006); although conducting these methods absolutely requires more framing up front as in developing expectations and writing interview questions. It additionally requires more thoughtful time after data collection to analyze the results appropriately.

Dabbs (1982, p. 32) stated, “Qualitative and quantitative are not distinct.” There are some members of the research community that may devalue qualitative methods, as they are not scientific enough (Berg, 2007). Dabbs (1982) pointed out the intuitive differences in that qualitative refers to the *quality* of data while quantitative methods look at the *quantity* (or amount) of elemental data. Neither qualitative nor quantitative methods should be used in isolation, as they complement one other. Qualitative methods can reveal variables that the researcher may not have initially considered, whilst quantitative methods provide a framework within to compare these variables and test their significance (ibid.).

Textual analysis methods (O’Hair & Kreps, 1990), where the researcher conducts content analysis, conversation analysis, or analyzes data through unobtrusive measures (i.e., collecting and analyzing historical records) or process tracing, may also provide substance. The qualitative methods that were undertaken by the researcher in this study were process tracing and both exploratory and confirmatory interviews. Textual responses to the survey additionally provided more qualitative data which was considered by the researcher.

Descriptive inference is more than just compiling the historical facts, which is by itself, description, but also includes the inference which is essentially discovering knowledge to generalize the facts (King, Keohane, & Verba, 1994). During the initial collection of data in process tracing, the researcher may ultimately be interested in questions that had not occurred to them previously (ibid.). The history of GIS including milestones in R&D were identified and documented. Process tracing allowed the researcher to acquire more observable implications of a theory to help overcome small-*n* research issues and provided a means to look closely at "decision process by which various initial conditions are translated into outcomes (George and McKeown, 1985, p. 35)." New dependent variables were constructed by each decision in a sequence in process tracing as each decision was made (King, Keohane, & Verba, 1994). The goal in process training is to make descriptive inferences about "history as it really was" (ibid.) without getting lost in a sea of irrelevant detail. Another goal of process tracing is simplification, which should be part of every scholar's contribution to knowledge, as it is making sense out of complexity (ibid.). Process tracing is a systematic approach to making sense out of abstract facts in a random order. This systematic approach to simplification also allowed the researcher to develop some generalizations from articles researched in GIS journals, timelines on GIS-related websites for government agencies and private companies, and textbooks for GIS.

Second Stage: Interviews

The second stage consisted of recruiting GIS professionals as participants for the exploratory interviews and then conducting the face-to-face or phone interviews with semi-structured questions as to how they view their role and the progression of the field. This exploratory phase provided insight and guidance in the development of questions for the third stage. After the exploratory interviews were conducted, the researcher integrated a "confirmatory" portion, where she re-interviewed a percentage of the participants along with a new sample to see whether a majority of the participants agreed with or confirmed the themes identified by the researcher.

The researcher was approved to conduct up to 50 interviews of GIS professionals over a period of four months at mutually convenient public locations – frequently at GIS conferences that the researcher attended. However, after conducting close to 30 exploratory interviews, common themes began to emerge; henceforth, the researcher began conducting confirmatory interviews of seven of the same interviewees along with four additional participants for a total of 32 separate GIS professionals being interviewed. The GIS professionals selected to participate were predominantly from the researcher's professional network from a variety of organizations. The researcher additionally used a snowball sampling technique asking each participant for referrals for other GIS professionals to solicit for the study.

The researcher either emailed the recruitment script prior to convening for the interview or presented the verbal recruitment script immediately before conducting the interview. If the participant chose to proceed, he or she was provided the "Informed Consent to Participate in a Research Study" form and elected the appropriate options for "Waivers of Elements of Confidentiality" in order to choose their preferred level of anonymity prior to commencing with the interview. These options included consenting to being quoted directly, having their name utilized in the report, and to audio recording. Participants were allowed time to ask questions before data collection began. There was no compensation or inducements in this study.

The researcher began each interview by asking background questions of the participant, including their respective years of experience, predominant employment sector, and areas of expertise within the GIS field. This helped provide context for sector/role and amount of experience categorization of the interviewee. This also helped the subject feel comfortable with the idea they were an expert and that they had something important to say. Participants were then asked several exploratory, semi-structured interview questions according to the interview protocol (Appendix 1). The nature of the questions was more open-ended to allow for expanse and interesting thoughts from each participant.

The signed informed consent documents were kept secure at the researcher's home. An electronic file, assigning sequential research numbers to each of the participants, was maintained by the researcher on a secure, password-protected computer, and in accordance with American Psychological Association (APA) standards, the file will be kept for three years after publication – then deleted/destroyed. Within this electronic file, there were notations of which participants were willing to be quoted with and without name attribution based on the preferences checked in the signed consent document. Any audio files recorded were maintained on the secure, password-protected computer of the researcher. No audio files were released to anyone outside of the researcher and faculty sponsor and no transcripts were created of the files to assure that the data was kept secure and not accidentally released. For all the participants who consented to citation and/or attribution, the researcher sent a copy of the draft document to ensure the participants quoted were given the opportunity to review their comments in-text to assure accuracy and validity of the interpretation of their remarks.

Third Stage: Survey

The third stage consisted of distributing a survey to a sample population of GIS professionals to capture their understanding of GIS evolution as a professional field.

The purpose of the survey was to increase the size of the sample as a percentage of the whole population with the intent to triangulate information gathered from process tracing and the exploratory, semi-structured interviews (Creswell & Clark, 2010). The questions were designed based on responses from the exploratory and confirmatory interviews, to help confirm the thoughts or beliefs of the interview participants. The researcher summarized responses from the interviews for each question, input these responses into a spreadsheet, and calculated the top responses to include in the survey response sets. For those questions that did not have a high degree of convergence, the researcher either provided more response choices or allowed for textual responses.

An Internet-based survey was the preferred type of data collection technique for this research project because it was economical and allowed for fast turnaround in the overall data collection process. Another advantage of the Internet-based survey was that it offered the opportunity for questions with long or complex response categories, allowed for anonymity, and provided the ability to present questions requiring visual aids (Fowler, 2002). Despite all these advantages, the author was aware of the criticality to develop the survey carefully and of the challenge to enlist cooperation (ibid.).

The survey (Appendix 2) was administered through Qualtics.com, an Internet-based survey form for which the University of Oklahoma has a subscription. This allowed the researcher to gather data from individuals all over the world. The population being studied was essentially all GIS professionals with an emphasis on those related to the DoD. Qualtrics allowed for easy, convenient data collection and real-time accessibility. The sample for the data collection conducted through the survey was composed of GIS professionals affiliated with the DoD and other GIS professionals from the researcher's professional network and was stratified to reflect representative portions from different sectors and years of experience.

The target was at least 100 completed surveys; however, three months after the survey was released, only 82 surveys were begun with 58 completed. With a total sample size approaching the desired 100 participants from the survey and the interviews, a decision was made to discontinue data collection and begin the analysis. Due to this limited sample size, the empirical results from the survey are construed as exploratory research findings rather than deductive conclusions about the population of GIS professionals.

Fourth Stage: Triangulation

The utilization of multiple lines of sight is called triangulation (Berg, 2007). Triangulation provides convergent validation to data, methods, theories, and investigators (Campbell, 1956; Campbell & Fiske, 1959) to enhance the strength and generalization of the research. There are essentially four approaches to triangulation in research. Data triangulation allows the researcher to collect data over longitudinal or temporal studies, spatially from different geographic areas, or through interactive compositions of subjects (O'Hair & Kreps, 1990). Investigator triangulation refers to a secondary researcher conducting the same study literally, using different techniques, as in operational replication, using a different research instrument, or utilizing an entirely different process (ibid.). The researcher could also triangulate with a different theoretical background (theory triangulation) or use more than one method (methodological triangulation). In this research design, a methodological triangulation was employed.

Process tracing, the interviews, and the survey allowed for both qualitative and quantitative methods to be engaged in collecting data and analyzing results. The responses to the semi-structured interview questions helped form the basis of questions for the survey portion of the study. Both the interview and survey responses were coded to be utilized for statistical analysis and compared to records found in process tracing. Using the three different data collection processes allowed the researcher to triangulate the results methodologically and make generalizations about evidence to apply to a broader context.

Building Grounded Theory

Building grounded theory is an entirely inductive process, as the theory evolves and "builds" as the study progresses. Abrahamson (1983, p. 286) noted the inductive approach to content analysis allowed the researcher to immerse herself in documents, collect interviews and survey results to detect patterns and relationships, and develop themes from the data – by order of data reduction. The development of inductive categories allowed the researcher to ground the categories to the data from which they derived (Berg, 2007).

Essentially, the researcher suspected that GIS professionals may have unique qualities and that, as a group, they are not similar to every other technology professional, and they are in some important ways quite *different*. This exploratory research design focused on allowing participants to invite the researcher in many directions as the researcher focused in on the earlier identified topics of interest. Both the survey and interviewees' qualitative responses were coded and categorized to allow for quantitative analysis of the data collected. Quantitative data analysis allowed the researcher to apply statistical techniques to help interpret observations that are in a numerical format. Quantitative methods actually helped to reduce the data available, as both descriptive and inferential statistics helped make the data "useable." Descriptive statistics assisted the investigator in essentially organizing or tabulating the data through data reduction (O'Hair & Kreps, 1990). For the purposes of this study, descriptive and bivariate statistics were calculated. Inferential statistics used to generalize a sample to a population (ibid.) were not reported since the respondents were identified as part of convenience and snowball sample rather than a representative sample.

Understanding the Variables

Milestones

The first round of data came from process tracing through historical records regarding when and which technical developments helped the field of GIS evolve. Then, during the exploratory interviews, the respondents were asked to come up with the most significant milestones, reported in the analysis as the variable milestones [**MileSt**], without any real prompting, in terms of what they believed has shaped the field of GIS the most or significant changes over time. Almost half of the interviewees in the initial round of interviewing indicated that both the Internet and the movement from manual to electronic cartography (automation) were primary milestones. During the confirmatory interviews, the researcher asked the participants about their level of agreement with the initial responses. They also were asked why they believed both were almost equally considered major and significant milestones. Most interviewees believed it had something to do with the age of the participant or when they entered the field. Within the survey the respondents were asked to select only one significant milestone with three choices: (1) manual to electronic cartography (automation), (2) availability of the Internet to expose GIS, and (3) other, in which respondent was requested to type in a textual response.

Actors

During the exploratory interviews, the respondents were asked, without a temporal perspective or connotation, who have been the leading actors (individuals and/or organizations) in GIS development. During the latter confirmatory interviews, the researcher asked the participants whether they agreed with the initial responses of a lower percentage related to a historical actor, which was similar to a very new entrant in the field, and whether they believed the comparison to be fair. Within the survey the temporal perspective was addressed, respondents were asked to textually respond to who they believed were the most significant actors in the field of GIS when they entered the field [**ActTh**]. However, when asked about whom the leading actors were currently [**ActNow**], they were asked to rank four provided responses (Jack Dangermond, Roger Tomlinson, Google, and the U.S. Government) and an "other" response, where they were allowed to textually respond and rank. In the Qualtrics survey flow, the researcher arranged for randomization, so the responses were continually listed in differing orders to help with methodological bias.

Collaboration Factors

During the exploratory interview process, there were two questions that addressed collaboration. Initially participants were asked how they believed the nature of relationships and collaboration between actors has changed over time. They were then asked what would be the best inter-organizational structure for collaborating between organizations as the field evolves. The first question queried how they perceived the collaboration to be (good = 1 or not good = 2) [**ColGood**], and the second question was intended to address which factors contribute to collaboration between organizations [**Inter**].

The second question was also intended to explore which particular factors, whether it is about the composition of the organization or the manner in which they collaborate, contributed most to collaboration between external organizations. However, the second question appeared to be troublesome for many of the interviewees to answer, as they were unsure of what the researcher was asking. During the confirmatory interview phase, the researcher asked the interviewees whether they agreed with a majority of the respondents on the perspective of collaboration and followed up with asking them whether they agreed with the top three responses received from the exploratory phase.

In order to capture the collaboration factors in a more effective manner, the survey initially asked the respondents whether they believe collaboration to be better currently than in the past with a true/false choice, which was similar to the question asked during the interview phase. The temporal perspective was also addressed in the survey by allowing the respondents to textually respond to which factors they see as contributing most to increased collaboration between organizations/individuals in the field when the respondent first entered the field [**ColFacTh**]. They were then asked to rank order the greatest factors contributing to collaboration currently [**ColFacN**] with the choices as: (1) data standards, (2) blogs/online communication, (3) user conferences and workgroups, (4) enhanced network communication systems, and (5) other, where the respondent was able to enter a textual response.

Online Risks

During the exploratory interviews, interviewees were asked about the opportunities and benefits, and conversely, the risks and challenges for organizations exploiting and consuming free commercially available services [**OLRisk**]. In the confirmatory phase, the interviewees were asked whether they agreed with the primary responses identified during the exploratory phase. The researcher decided to break the question into two for the survey, and opportunities and benefits were addressed more as a benefit to informational power [**InfoPB**] in the survey. The responses for opportunities and benefits asked during the interviews were also coded as [**InfoPB**] for statistical analysis. In the survey, respondents were asked to select from the following list the greatest detriments to using freely available online GIS services: (1) data integrity, (2) reliability of service, (3) loss of control/privacy, or (4) other (textual response). The order of the responses was randomized and the respondent was allowed to check all that apply, therefore there were frequently multiple responses.

Barriers

During the exploratory interviews, the respondents were asked what they believe have been the barriers or sources of resistance that have inhibited the development of GIS over time. There were four primary barriers identified through the exploratory phase: (1) lack of understanding/people issues, (2) technology, (3) lack of geospatial data standards, and (4) data availability. Some respondents also indicated costs as being prohibitive to entry as well. The respondents were then asked if they agreed with the primary barriers recognized during the confirmatory interview phase.

Although not addressed during the interviews, the temporal component was incorporated into the survey, and the respondents were asked to indicate which they believed to be the most significant barrier of the four barriers previously identified both currently [**BarrNow**] and when they entered the field [**BarrThen**]. There was also an "other" choice, which allowed the respondent to textually enter a response.

DoD Issues

Data collection for this variable during both the exploratory and confirmatory interviews was purposefully limited, as the researcher expected the interviewees affiliated with the DoD to voice these types of concerns during the questions about risks and challenges of utilizing commercially available online services. Possibly the participants from the DoD did not believe there was significant benefit from using the online GIS services. Since few of the interviewees indicated any issues related to the DoD, the researcher directly focused on this variable during the survey portion. The researcher asked the respondents specifically what were the main issues [**DoDIssue**] for closed (internal or classified) DoD networks for capitalizing on Web (cloud) GIS or mobile GIS. The choices provided were: (1) inability to access data from a closed system, (2) lack of interoperability between systems (no DoD wide solution), (3) reliability of GIS online services within DoD (no commercial incentive to continuously provide services), and (4) other, where the respondent was allowed to type in a textual response. The respondents were requested to check all that apply. The respondents were then asked a follow up question on how the respondent would suggest the DoD overcome these issues to benefit from the direction GIS is evolving towards [**DoDSol**], where the user was asked to input a textual response.

Informational Power

During the exploratory interviews, the interviewees were asked whether informational power, defined as power that comes from access and control over information, which is enhanced by GIS, affects decision making in organizations. Due to the unusual responses during the exploratory phase, the researcher segmented the question into three sections to better observe the interviewees' perception of the term. During the confirmatory phase, the interviewees were asked to characterize informational power to be positive or negative [**InfoPower**]. The researcher then told the interviewee about the positive and negative perceptions and reasoning obtained during the exploratory phase and inquired why they believed the initial interviewees responded in that manner.

They were then asked what the primary benefits of informational power were [**InfoPB**] and were allowed to check all that apply from a randomized list consisting of: (1) increased transparency, (2) ability to make better decisions, (3) access to information not previously available, (4) improved situational awareness, and (5) other, where the user could type in a textual response. The respondents were then asked to textually respond as to what they would consider to be the primary disadvantages of informational power [**InfoPN**].

Qualitative Data Coding

One of the key elements in qualitative data analysis is the systematic coding of text (Strauss & Corbin 1990, p. 57; Miles & Huberman 1994, p. 56). Coding was performed on the transcribed or noted interviews the researcher conducted. Coding allows for a combination of both quantitative and qualitative analysis. The two approaches are not mutually exclusive, and Smith (1975, p. 218) notes “qualitative analysis deals with the forms and antecedent-consequent patterns of form, while quantitative analysis deals with duration and frequency of form.”

Questions from both the exploratory and confirmatory interviews were coded along with the responses from the survey to allow for methodological triangulation with both qualitative and quantitative data. A combined codebook was developed to categorize and numerically code the responses from the survey and interviews into more tangible and categorical responses.

Historical Characteristics of the GIS Context

The temporal component to significant actors and barriers inhibiting GIS development over time were only introduced during the survey, while there were several questions on fit [**Fit**], promoting GIS within their organization [**PromoGIS**] and intra-organizational [**Intra**] structures that were only asked during the interviews, as it was clear in the myriad of responses that the respondents were unclear of the researcher’s intent in asking the question. The inter-organizational [**Inter**] question from the interviews somewhat morphed into three separate questions on the survey, regarding characterization of collaboration environment [**ColGood**] and what factors contributed to collaboration early on [**ColFacTh**] and what factors contribute to collaboration currently [**ColFacN**].

The DoD issues and online risks were lines of inquiry not addressed directly during the exploratory interviews, but they were included in the survey. The researcher suspected that online risks, along with DoD issues, would be addressed when discussing risks and challenges for capitalizing on Web GIS in the exploratory interviews. However, there were few responses related to DoD issues during the exploratory interviews, so a direct question was asked during the confirmatory portion and the survey. There was a slight overlap in the two questions asked during the survey related to online risks [**OLRisk**] and negative effects of informational power [**InfoPN**], as it related to freely available online GIS services, but the researcher did want to maintain distinct questions during the survey, as one related to theory of informational power and the other was associated with the dependence and reliance on using free GIS services.

It should also be noted that due to the technique in which the questions regarding DoD issues and benefits of informational power were surveyed, the responses were dichotomous, as it was "check all that apply" – so the values would either be zero or one, depending on whether it was checked. When and if there were multiple responses for questions on the survey, including textual responses, multiple variables for each primary variable were also coded along with a total for the categorical variable.

Variables Describing the GIS Context

The following were the variables explored to document the GIS context and how it has changed over time and the future trajectory of the field and the GIS:

- Milestones [**MileSt**] – Milestones perceived as important and significant in the progression of GIS as a professional field; coded as 1 = automation/electronic cartography, 2 = Internet, and 3 = software.
- Actors then [**ActTh**] – Actors (individuals, organizations, companies) perceived as important or making significant contributions to the field when the participant

entered the field; coded as 1 = Esri/Jack Dangermond, 2 = Roger Tomlinson, 3 = other software companies, 4 = academia, 5 = utilities, oil/gas, 6 = U.S. Government, 7 = satellite imagery, 8 = Google/Keyhole, and 9 = other.

- Actors now [**ActNow**] – Actors (individuals, organizations, companies) perceived as important or making significant contributions to the field currently; coded as 1 = Esri/Jack Dangermond, 2 = Google, 3 = other software companies, 4 = academia, 5 = utilities, oil/gas, 6 = U.S. government, 7 = satellite imagery, 8 = open source/crowd-sourcing, and 9 = other.
- Collaboration good [**ColGood**] – Whether or not the participant believed there to be good collaboration between GIS professionals and organizations currently; coded as 1 = collaboration good, or 2 = collaboration not good.
- Collaboration factors then [**ColFacTh**] – Factors contributing to collaboration when the participant entered the field; coded as 1 = geospatial data standards, 2 = blogs/online communication, 3 = user conferences/workgroups, 4 = enhanced network communication systems, 5 = academics, 6 = costs, 7 = Esri tools, and 9 = other.
- Collaboration factors now [**ColFacN**] – Factors contributing to collaboration currently; coded in the same way as the previous variable, as 1 = geospatial data standards, 2 = blogs/online communication, 3 = user conferences/workgroups, 4 = enhanced network communication systems, 5 = academics, 6 = costs, 7 = Esri tools, and 9 = other.
- Barriers then [**BarrThen**] – Barriers preventing GIS from evolving when the participant entered the field; coded as1 = lack of understanding or people issues,

2 = technology, 3 = lack of standards, 4 = data availability, 5 = costs, and 9 = other.

- Barriers now [**BarrNow**] – Barriers preventing or inhibiting GIS from evolving currently; coded the same as [**BarrThen**] as1 = lack of understanding or people issues, 2 = technology, 3 = lack of standards, 4 = data availability, 5 = costs, and 9 = other.
- Online risks [**OLRisk**] – Risks of using online GIS services; coded as 1 = data integrity, 2 = service reliability, 3 = loss of control or privacy, and 9 = other.
- Informational power [**InfoPower**] –Variable as to how the participant characterized the phrase; coded as 1 = positive or 2 = negative.
- Informational power benefits [**InfoPB**] – Perceived benefits of informational power; coded as 1 = increased transparency, 2 = ability to make better decisions, 3 = access to information not previously available, and 4 = improved situational awareness.
- Informational power negative effects [**InfoPN**] – Negative or detrimental effects of informational power; coded as 1 = information overload, 2 = data quality, 3 = abuse/privacy, 4 = inaccurate results/misinterpretation, and 9 = other.
- DoD issues [**DoDIssue**] – Issues with DoD capitalizing on online GIS web services; coded as 1 = inability to access from closed networks, 2 = lack of interoperability between systems/no DoD-wide solution, 3 = reliability of services within the DoD, and 4 = other issues like security.

- DoD solutions [**DoDSol**] – Solutions to help DoD overcome issues related to capitalizing on Web GIS; coded as 1 = encryption/security, 2 = connect or communicate with the outside, and 9 = other.
- Ways to promote GIS [**PromoGIS**] – Suggestions for promoting GIS within respondent's organization; coded as 1 = show real world examples, 2 = education, 3 = integrate with IT, and 9 = other.
- Fit [**Fit**] – How well GIS fits into bureaucratic organization; coded as 1 = it fits, 2 = provides value for decision making, 3 = it does not fit, 4 = lack of leadership understanding, and 9 = other.
- Inter-organizational structures for collaboration [**Inter**] – Best ways to collaborate between organizations; coded as 1 = geospatial data standards, 2 = online communication/blogs, 3 = conferences/working groups, 4 = enhanced network communication systems, 5 = academics, 6 = costs, and 7 = Esri tools.
- Intra-organizational structure [**Intra**] – Best organizational structures within GIS organization; coded as 1 = skilled/smart people, 2 = integrate with IT department, 3 = flat (few levels of leadership), 4 = small, 5 = focused (GIS-specific), and 6 = embeds in other organizations.

Characteristics and Experiences of the Individual

The following variables were used to explore the role that different characteristics and experiences of the GIS professional may play in the relationships observed for the main variables of interest:

- Sector [**Sector**] – Industry sector variable, as in public or Federal Government, state or local government, or private sector, e.g., software companies, consultants or contracting companies; coded as 1 = private/commercial sector, 2 = state/local government, and 3 = U.S. Federal Government or DoD.

- Role [**Role**] – This variable took into account the current role the individual plays within the GIS field; coded as 1= manager, 2= analyst, and 3 = other.
- Years of experience [**YrExp**] – This variable looked at experience within the GIS field either as a manager or an analyst. This ordinal variable allowed for capture of age and time frame from which the participant entered the field. The categories the participants could select from were coded as 1 = less than ten years, 2 = ten to 15 years, 3 = 15 to 20 years, 4 = 20 to 25 years, and 5 = greater than 25 years.
- Year respondent entered field [**YrEnter**] – Interval variable took into account time frame for respondents who may not have spent entire career in GIS field. Variable was not coded, as responses were already numerical. Variable was seldom used in statistical analysis; it was used more for simple comparisons.
- Years as manager (recoded) [**RYrMgr**] – Recoded variable from years as manager [**YrMgr**], as this encapsulated the data into three different categories; coded as 1 = no managerial experience, 2 = less than ten years, and 3 = more than ten years, for simplification.
- Favorite role [**FavRole**] – Variable indicated whether individual preferred a manager or technical type of position which allowed for capturing of personal preference in lieu of solely occupational title; coded as 1 = manager, 2 = analyst/technical role, and 3 = other.

- Reason for favorite role [**WhyFav**] – This variable allowed the observance of personal preferences of participant, as to whether they enjoyed; coded as 1 = problem-solving, 2 = process improvement, and 3 = interaction with customers or team members.

Index Variables: Local and Cosmopolitan

The researcher also created two index variables to address Gouldner's (1959) "cosmopolitans and locals." Essentially, the variable for locals [**Local**] was set up using the following expected characteristics of the respondent: government sector, management type employee who believes automation is one of the most critical milestones and that geospatial data standards contributed the most to collaboration, but that standards are also the biggest barrier to progression as well. The local was more likely to see the negatives of informational power as information overload or abuse/lack of privacy. Someone who fit all these characteristics would have a perfect index score of 6.00. The cosmopolitan type of employee [**Cosmo**] is private sector, analyst type who believes the Internet was more of a critical milestone and that online communication and conferences/workgroups contributed most to collaboration. The biggest barrier to the [**Cosmo**] is lack of understanding by leadership and customers. Inaccurate results and misinterpretation would be the single most paramount negative side effect of informational power; essentially power in the hands of someone who doesn't understand what they are working with or the limitations of the data is atrocious. Someone who fit all these characteristics would have a perfect index score of 7.00.

Survey Data Analysis

Frequency distributions were needed to address some of the research questions of the study. The researcher initially analyzed the frequency distributions for all variables collected. The variables were analyzed for mean, median, mode, skewness, kurtosis, and outliers (Hays, 1994, p. 165). Initially univariate frequency distributions and histograms were run for every variable to determine if recoding would be necessary based on the magnitude and dispersion of the data. In the examination of the univariate distributions of the variables, the normal distribution assumption was predominantly violated, so nonparametric statistics seemed to be the best course of analysis for the analysis that was to follow.

Table 1 shows descriptive statistics for all dependent variables analyzed in this study.

Table 1: Descriptive Statistics for Dependent Variables

Var label	Var Type	N	Mean	Median	Mode	Std. Dev	Skewness	Kurtosis
MileSt	Categ	97	2.24	2	1	2.05	2.60	6.26
MileSt1	Categ	39	3.90	2	2	3.09	1.04	-0.80
ActTh1	Categ	89	2.67	1	1	2.49	1.36	0.63
ActTh2	Categ	59	4.12	3	3	2.49	0.44	-1.05
ActNow1	Categ	54	3.56	4	4	1.21	-0.80	-0.22
ActNow2	Categ	54	1.70	1	1	0.96	1.69	3.26
ActNow3	Categ	54	2.67	3	3	1.18	0.19	-0.67
ActNow4	Categ	54	2.85	3	4	1.17	-0.07	-1.02
ActNow5	Categ	54	4.22	5	5	1.16	1.21	0.11
ColGood	Dichot	96	1.36					
ColFacTh1	Categ	65	4.06	3	1	3.12	0.60	-1.22
ColFacTh2	Categ	22	4.64	4	4	2.84	0.48	-0.93
ColFacN1	Categ	55	2.67	3	4	1.29	0.06	-1.32
ColFacN2	Categ	55	3.15	3	4	1.41	-0.23	-1.32
ColFacN3	Categ	55	2.69	3	3	1.17	0.06	-0.84
BarrTh	Categ	91	2.92	2	1	2.22	1.47	1.84
BarrTh1	Categ	19	3.47	3	1	2.55	0.96	0.36
BarrNow	Categ	53	2.28	1	1	1.56	0.67	-1.15
OLRisk	Categ	91	2.57	2	1	2.37	1.92	2.78
OLRisk1	Categ	19	5.00	3	9	3.56	0.25	-2.02
InfoPower	Categ	91	2.47	1	1	3.04	1.71	0.97
InfoPB1	Dichot	97	0.30					
InfoPB2	Dichot	97	0.53					
InfoPB3	Dichot	97	0.42					
InfoPB4	Dichot	97	0.48					
InfoPN1	Categ	53	3.79	3	4	2.73	1.11	-0.06
InfoPN2	Categ	10	2.90	3	2	0.88	0.22	-1.73
InfoPN3	Categ	92	2.37	1	0	2.95	1.25	0.66
DoDIssue1	Dichot	69	0.58					
DoDIssue2	Dichot	69	0.55					
DoDIssue3	Dichot	69	0.39					
DoDIssue4	Dichot	69	0.12					
DoDSol	Categ	38	4.42	1	1	3.56	0.54	-1.76
YearsExp	Ordinal	92	2.78	3	2	1.31	0.38	-0.88
Sector	Categ	92	2.23	3	3	1.40	2.34	10.09
Role	Categ	92	2.34	2	2	2.11	2.74	6.22
RYrMgr	Ordinal	92	1.66	2	1	0.71	0.60	-0.78

The researcher further went on to analyze bivariate cross-tab calculations and correlations to respond to specific research questions addressed in the study. Although cross-correlations were performed with the dependent variables, there were not any statistically significant relationships to report. Many of the variables were categorical or ordinal. For this reason, the analysis was limited to the identification of statistically significant bivariate correlation coefficients for lambdas (λ), Spearman's rho (r_s), and Pearson's r depending on the combination of independent and dependent variables. Primarily Spearman's rho correlation coefficient, denoted as r_s, was used due to the non-normal distributions predominantly obtained from the data collected. For data that was normally distributed, the researcher denoted these correlations with Pearson's correlation coefficient (r). A relaxed statistical significance threshold value of 0.10, in lieu of 0.05, was used due to the study's exploratory nature.

Sample Descriptive Statistics and Participant Demographics

There were 97 total participants in the sample, with 39 interviews conducted and 58 surveys completed with at least one or more response to questions beyond the initial consent form. The Qualtrics online survey had 82 participants begin; however, only 58 participants completed the survey. Though 58 participants answered a majority of the survey questions, only 54 respondents provided responses to the demographics questions at the end of the survey. Table 2 displays the distribution of the participants by sector, role, and years of experience with number of respondents in the first column and percentage of total in the second column.

Table 2: Sample Participants' Sector [**Sector**], Role [**Role**], and Years of Experience [**YrExp**]

	Interview		Survey	
# of Participants	39	40%	58	60%
Sector				
Private/Commercial	26	28%	17	18%
Local/State Government	0	0%	5	5%
DoD/Federal Government	13	14%	29	31%
Other	0	0%	3	3%
Role				
Analyst	25	27%	22	24%
Manager	12	13%	15	16%
Other	2	2%	17	18%
Years of Experience				
Less than 10	5	5%	12	13%
Between 10 and 15	12	13%	14	15%
Between 15 and 20	9	10%	17	18%
Between 20 and 25	4	4%	5	5%
Greater than 25	9	10%	6	6%

Included in the count of 39 interviews are seven re-interviews that were conducted to confirm the researcher's initial conclusions about the results and the interpretation of what the respondents were describing and/or explaining. During these confirmatory re-interviews, the participant often expanded on their original response and even changed their mind. New questions were posed to make sure the language used in the online survey would be accurate, so these re-interviews are coded as separate responses to represent new data received.

Most of the government sector individuals interviewed came primarily from the combat support agency, National Geospatial-Intelligence Agency (NGA), while most of the private sector interviewed either came from software companies or DoD contracting companies. Between both data collection methods, there was a very limited participation (5%) by the local and state government sector.

There was similar sample representation between both managers and analysts in the interviews and survey; however, there were significantly more participants categorized as “other” in the survey. This may have occurred since the individuals were responsible for categorizing themselves in the survey; while, during the interviews, the researcher categorized the participant based on the interviewees’ description of their respective role.

Most of the respondents had between 10-15 years of experience with the second most number of respondents having between 15-20 years of experience, which was also the median. The distribution of the years of experience for all respondents was almost normal. Most of the participants entered the GIS field between the years 1994 and 1998, during a time when significant advancements in the field were taking place. Of significance overall was that most of respondents were from the DoD and U.S. Federal Government; however, due to the researcher’s professional network and snowball sampling, this was logical.

Ideally the sample would have been larger and more stratified; however, due to the exploratory nature of the study and grounded theory approach, this particular sample provides an adequate baseline for future studies to take place.

Strengths and Limitations of the Research

Lincoln and Guba (1985) proposed four criteria for evaluating interpretive research work: credibility, transferability, dependability, and confirmability. Credibility refers to the “adequate representation of the constructions of the social world under study (Bradley, 1993, p. 436)." Transferability refers to the extent to which the researcher's working hypothesis can be applied to another context. Dependability refers to "the coherence of the internal process and the way the researcher accounts for changing conditions in the phenomena (Bradley, 1993, p. 437)." Confirmability refers to "the extent to which the characteristics of the data, as posited by the researcher, can be confirmed by others who read or review the research results (Bradley, 1993, p. 437)." Dependability is determined by checking the consistency of the study processes, and confirmability is determined by checking the internal coherence of the research product, principally: the data, the findings, the interpretations, and the recommendations.

There were some sample limitations, as all the participants were arbitrarily solicited from conferences the researcher attended, and even with the survey, the researcher distributed the link to those within her professional network requesting snowball sampling and forwarding on of the survey link. Sample bias could influence a number of the results and conclusions and impact credibility. There was also a lack in respondents working in both the state and local government sector and those with a remote sensing or imagery background, which could have influenced the responses. Very few respondents discussed commercial satellite imagery companies as key actors in the evolution of GIS as a professional field, but it is evident they have been a crucial component in building a digital earth. The only individuals that did voice remote sensing or satellite imagery had experience with the imagery (raster) component of GIS in lieu of vectors (points, lines, and polygons). Many participants may not credit commercial satellite imagery companies as key actors, as the respondents may have associated the DoD with conducting the R&D behind the advent of satellite imagery. Many other sub-sections within the GIS field may not have been adequately represented in the sample as well. There may also be a power limitation for statistical power, as there was a relatively small sample size (N = 97), with the survey with 58 respondents and 39 respondents from the interviews.

This research does lend itself to transferability, as the hypothesis could be applied to other contexts, especially the group behaviors within GIS professionals. Of course, there are questions on both the internal and external validity of the results since the primary participants interviewed were in the researcher's professional network; however, the survey was designed to help provide the ability to generalize the results obtained from the interviews with methodological triangulation.

Dependability, or consistency in the research process, was maintained by following the protocol approved by the IRB during the data collection process in both the interviews and the survey. There is potential measurement limitation in the manner in which some of the survey questions were asked with ranking, checking all that apply or supplying textual responses. The allowance of textual responses may have contributed to a lesser degree of convergence for several questions within the survey. There was an effort made to control "response bias" by randomizing the order of the survey responses. Categorical responses may also limit some of the analysis that could be performed had the data been more ordinal or interval.

There were several questions on fit [**Fit**], promoting GIS within their organization [**PromoGIS**], and intra-organizational [**Intra**] structures that were only asked during the interviews given that the question was unclear to the participants. The inter-organizational [**Inter**] question from the interviews somewhat morphed into three separate questions on the survey. From both data collection methods, not all the variables were recoded, even with thin cells, which could also invalidate some of the statistical measurements; however, due to the medium richness obtained from the interviews, the researcher believes the representation was valuable to include in the study results.

Confirmability in this study can be achieved with the adherence to standards followed in the data collection process and maintenance of the data used in the statistical analysis upon which results and conclusions were developed. The researcher is herself a GIS professional involved in multiple applications of the technology, along with possessing the knowledge, skills, and abilities to conduct this research. She had access to an extended network of GIS professionals to contribute to the richness of the study and the contribution to knowledge. Furthermore, the researcher worked with two dissertation advisors, one of whom has an extensive background and rich experience in remote sensing and another whom has an unparalleled grasp on research design and application that provided the most useful assistance in tackling this research.

Although credibility could have been increased with a more representative sample of GIS professionals by having a more stratified representation, all processes and standards were strictly adhered to as outlined in the IRB protocol, which lend to both dependability and confirmability in this study. With a grounded theory and exploratory approach, transferability is most essential in application to other contexts, which this study does in providing an appropriate baseline for future studies to take place.

CHAPTER FOUR: HISTORY OF GIS

Development Milestones of GIS as a Professional Field

During the last half of the century, essentially from the late 1960's, GIS has undergone significant growth and development and evolved into what it is today. Roger Tomlinson's GIS developed for Canada's Federal Department of Forestry and Rural Development in 1962 (Fu & Sun, 2011) was the first computer-based GIS, as Tomlinson is commonly referred to as "the father of GIS." Roger Tomlinson did publish an historical account of much of the early work of GIS with Barbara Petchenik in a special issue of American Cartographer in 1988, including his work with Canada Geographic Information Systems (CGIS) (Tomlinson, 1988).

Coppock and Rhind's (1991) chapter on the "History of GIS" cuts across many institutions and attempts to describe the activities involved in the evolution of GIS by many individuals and organizations. This literature is more of a historical account with little analysis of the social context. Pickles (1995) developed one of the first attempts at placing the developments in GIS into an interpretative framework in "Ground Truth," and Timothy Foresman (1997) edited a compilation of chapters on perspectives written directly by the pioneers involved in development of GIS. The sequential stages of GIS as identified by Foresman (1997, p. 333) were:

- Stage 1: Innovation (1960-1980)
- Stage 2: Integration (1980-1990)
- Stage 3: Proliferation (1990 and beyond)

These stages additionally fit along with the GIS eras identified in Foresman

(1997) as well:

(1) Pioneering Age

(2) Research and Development Age

(3) Implementation and Vendor Age

(4) Client Application Age

(5) Local and Global Network Age

Innovation

Using Foresman's (1997) framework, two eras occurred within the innovation stage: the "Pioneering Age" and the "R&D Age." Innovation early on concentrated on technology development, and there were several isolated initiatives at different companies and organizations. Primarily GIS was leveraged on isolated systems with narrow applications comparatively to the present (Foresman, 1997). Most GIS moved forward due to informal committees and working groups (ibid.). GIS was expensive, and with a lack in data availability, growth was limited due to the especially high costs. The dominant products were maps and charts, essentially paper or digital products that could not be manipulated but provided a static assessment of some geographical area for a particular purpose.

During the Pioneering Age, the foundation for GIS was built and the most innovation occurred essentially from 1960-1980 (ibid.). The R&D Age consisted of a lot of work at universities. The G.I. Bill created a huge increase in student enrollment and began a trend to democratize what had been an elitist society in universities (Chrisman, 1997). This increase in enrollment increased demand for faculty and permitted greater specialization in ensuing studies, which the field of computer cartography was born from. John K. Wright at the American Geographical Society contributed to geographic measurement in cartography from 1920s to 1950s (Chrisman, 1997). The first course on geocoding and mapping techniques (computer processing of geographic information) was offered by Dr. Edgar Horwood, who ended up founding the Urban and Regional Information Systems Association (URISA) in 1963 (Chrisman, 1997). URISA is a nonprofit association of GIS professionals whose mission is to solve local or state governmental urban and regional environmental issues with GIS (URISA, 2012).

A monumental technological event occurred in April of 1964, when most engineers were using slide rules; IBM introduced its 360 line of multi-purpose computers (McDaniel, Howard, & Emery, 1997). Computers helped engineers see that computers and database systems typically used in accounting systems for billing and financial records could be used for developing decision support tools (McDaniel, Howard, & Emery, 1997), although it took years before the ideas became a reality. Computer Aided Drafting (CAD) systems began to emerge in the late 1960s (McDaniel, Howard, & Emery, 1997), which could be incorporated as a foundational basis for the GIS. Over the years, the U.S. Geological Survey (USGS) made public-domain GIS software available; however, they did not provide much support for any of the software provided (Greenlee & Guptill, 1997).

One of the attendees of Dr. Horwood's weeklong workshop in Chicago in 1964 was Howard Fisher, who then went on to found the Laboratory for Computer Graphics at Harvard in 1965, and led an effort to develop a "synagraphic" mapping package (SYMAP) (Chrisman, 1997). Probably some of the most well-known GIS developments occurred at the Harvard Lab. The Harvard Lab for Computer Graphics was reorganized as the Harvard Lab for Computer Graphics and Spatial Analysis in 1968 (Steinitz, 1993) and was central to the development and advancement of GIS in the early years with SYMAP in 1966. A key student, Jack Dangermond, came out of this Harvard Lab and began one of the pioneering companies in GIS, Environmental Systems Research Institute, Inc. (Esri) (Dangermond & Smith, 1988) which is still considered the predominant leader in GIS software. Chrisman (1988) published an overview of activities at the Harvard Laboratory for Computer Graphics and Spatial Analysis, and Rhind (1988) reviewed the activities at the Experimental Cartographic Unit in the United Kingdom. Undoubtedly the greatest legacy of Harvard Lab was the contributions of several of the students.

Another key event was the publication of Ian McHarg's (1969) discourse on map overlay techniques for landscape architecture, as it generated the legitimacy of overlay techniques to addressing compatibility issues geospatially in land planning. The Topologically Integrated Geographic Encoding and Reference (TIGER) system, implemented by the U.S. Census Bureau, was very influential and effective, as it allowed business users the capability to essentially forget about the map and concentrate on business problems they are trying to solve (Cooke & Maxfield, 1967). The National Environmental Policy Act (NEPA) of 1970 led to a plethora of mandated programs that both fostered and funded GIS programs and technological development (Foresman, 1997). The DoD was also a huge proponent of the automation of GIS, as there are so many applications internally, e.g., environmental compliance, civil engineering, missile siting, and air-defense strategies (Parent, 1988). Carl Steinitz and colleagues (1976) indicated the historical use of hand-drawn overlay techniques, a fundamental GIS process, to be "a logical and obvious basis for analyzing relationships among different elements of the landscape." The overlay techniques involved in the manual process established the foundation for GIS as it is today.

Based on this history of innovation in GIS, the researcher expected the participants to identify some of the key actors, especially from academia, who contributed greatly to the growth of the field. There were also significant technological advances that should be noted in automation and IT that would foster collaboration. The researcher expected some of the barriers in technology and costs to be recognized by the participants as well.

Integration

This stage ties to the era of "Implementation and Vendor Age" and lasted from approximately 1980 to 1990 (Foresman, 1997). During this stage, the developments were in both data and technology integration along with corporate and enterprise GIS strategies, with multiple participants involved in GIS within the organization (ibid.). There was a movement to reduce costs, make data more available, and create new and improved applications (ibid.). The dominant products were geographically referenced information. Tying geospatial coordinates to almost anything geospatially enabled the data for use in overlays or layers.

From 1979 to 1981, research at Earth Resources Observation and Science (EROS) Data Center, a government repository for satellite (mainly Landsat) imagery and analysis, was expanded to investigate the utility of "geoscience data bases" for mineral resources exploration (Greenlee & Guptill, 1997), and in the early to mid-1980s, the

National Mapping Division was developing vector data, and Water Resources and Geologic Divisions were digitizing maps of geology, hydrology, and other ancillary data (ibid.). From 1982 to 1983, EROS and Geologic Divisions staff evaluated raster based GIS techniques applied to the Rolla Quadrangle in Missouri (ibid.). The study compared results from a GIS-based approach and those obtained from conventional approach of overlaying geologic, geophysical, geochemical, and other hardcopy maps and manually delineating favorable environments for specific types of mineral deposits (ibid.). This was one of the first studies showing the value of GIS.

The Bureau of Land Management (BLM) became a player in the early 1980s coincidentally when the Fish and Wildlife Service (FWS) introduced GIS (ibid.). In early 1985, the BLM and FWS teamed up to develop a joint procurement of computer hardware and a conversion of MOSS software (ibid.). The Bureau of Indian Affairs (BIA) used a "systems approach" to resource management that utilized GIS technology, and the Geographic Data Service Center (GDSC) developed a "client focus" to help tribes build databases and conduct applications on tribal lands (ibid.). The National Park Service (NPS) became involved as one of the primary players in the mid to late 1970s, and in 1985 the use of GIS and remote sensing became critical on project funding and successful implementation by higher level management (ibid.). The latter half of the 1980s led to co-development and co-support of a suite of public domain software, based primarily on GRASS (Geographical Resources Analysis Support System), SAGIS (System Applications Group Information Systems), and ELAS (Earth Resources Laboratory Applications System) for predominantly UNIX workstations (ibid.). The suite was also leveraged on enhanced personal computers (PC) with very inexpensive software for DOS-based systems (ibid.). The complementary combination of raster and vector based GIS and image processing software with straightforward data interchange capability greatly facilitated the goals of the NPS (Cibula & Nyquist, 1987).

The integration stage consisted of assimilating the technology, software applications, and the data to make the systems useful. The researcher suspected for this dissertation that software and data would be discussed as either contributing factors to collaboration or barriers to evolution as time progressed due to the systems just beginning to work more efficiently together during this era.

Proliferation

Proliferation is the latest stage, beginning roughly in 1990 and continuing to the present (Foresman, 1997). The Internet really assisted in advancing the propagation of GIS as a technology. Most of the trends in GIS proliferation are system integration, the creation of a mass market, universal application and access, industry-wide standards, high data availability and low cost (ibid.). Essentially all the issues recognized during the integration stage were resolved in the proliferation stage. GIS is now the expectation, and value-added services, decision support systems (DSS), executive information systems, and geographically enabled applications are the primary products. GIS facilitates generalization (Goodchild, 1997) in five different ways by allowing:

- Temporal incorporation (Langran, 1992)
- Z-factor (vertical integration) with geology, terrain, etc. (Turner, 1992)
- Scale, moving between and handling data at multiple levels (Muller, Lagrange, & Weibel, 1995)
- Curvature of the Earth’s surface

- Handling of uncertainty – data modeling

During the “Client Application Age,” Army leadership seemed to view GIS as simply a tool to help installation personnel perform current duties rather than technology to transform information flows and processes and therefore requires extensive planning, coordination, and leadership for successful implementation (Goran, 1997). It is difficult for leadership to sometimes understand the versatile applications of GIS from installation management, to operations, to intelligence without actually seeing first-hand relevant examples.

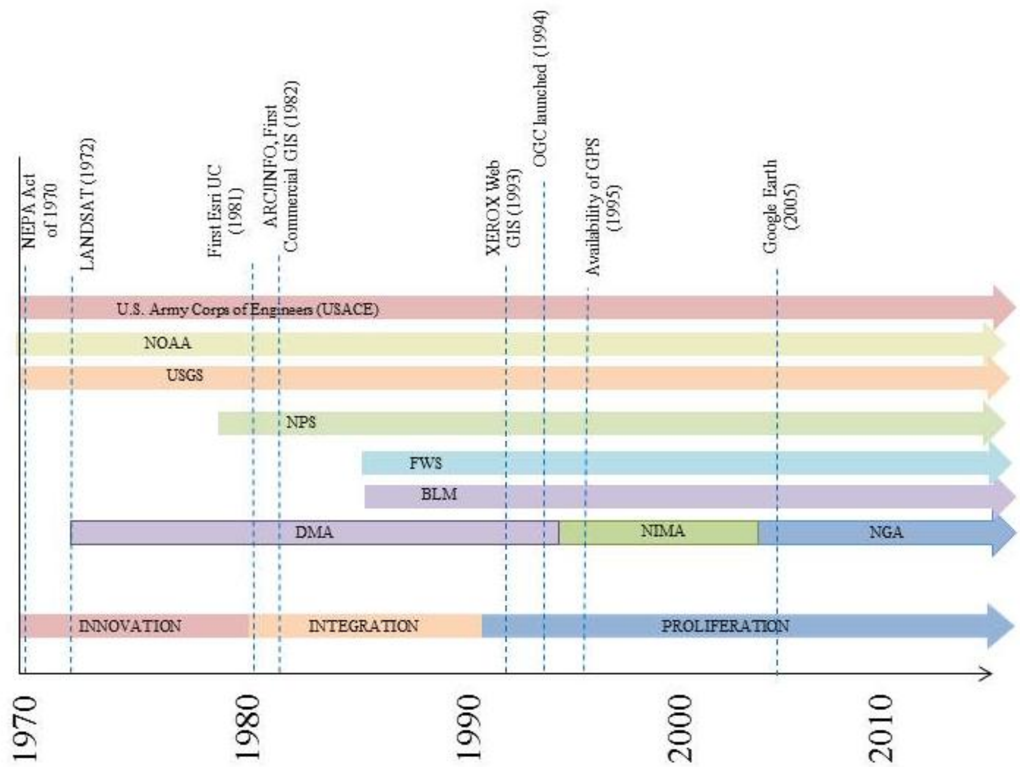
The “Local and Global Network Age” consisted of bringing GIS into the World Wide Web (WWW), especially post-Cold War (Foresman, 1997). The earliest Web GIS was developed by the Xerox Corporation Palo Alto Research Center (PARC) in 1993, which pioneered the approach that you could run a GIS within a web browser so users could access the data without having the GIS software and data locally installed on their workstation (Fu & Sun, 2011). In the 1990s there was also a “move to integration,” as previously there were computing issues related to distributed systems and user interfaces (Foresman, 1997). “Open systems” architecture became prominent (O’Callaghan, 1990; Ackland et al., 1994). Larger databases that were more and more complex had instigated issues, and the lack of standards for geographic data, which had been recognized as a priority for action in the National Strategy, was a major obstacle to development of a national spatial data infrastructure (Clarke, 1991). Integration of GIS and remote sensing also became a priority in the later 1980s and intensified in the 1990s; applications based on integration of two technologies became increasingly common (Zhou & Garner, 1990).

With the move to the WWW during the proliferation stage, the researcher had expected that some of the respondents would indicate the Internet as a significant milestone, since it led the way in making GIS available to everyone. Within this new frontier, the researcher had anticipated participants' discussion of both benefits and challenges to utilizing GIS services on the Internet.

GIS in the DoD Context

GIS in the DoD typically consisted of installation management, although the government saw back to at least the 1960s the value of satellite imagery and remote sensing to build an enhanced visual picture of the earth (NASA, 2012). Molding together remote sensing and GIS data took time, especially due to the bureaucratic red tape affiliated with most government entities. Within the government there are several endeavors – installation management, e.g., GeoBase at the U.S. Air Force (USAF), (Cullis, 2003), Defense Logistics Agency (DLA), U.S. Army Corps of Engineers (USACE), and mapping within the intelligence field, through NGA, formerly National Imagery and Mapping Agency (NIMA), and prior to that Defense Mapping Agency (DMA) (NGA, 2012). Figure 5 shows an overlapping timeline of when some of the primary U.S. Government agencies or organizations entered the GIS field over the last 50 years, along with a few key milestones.

Figure 5: Primary Federal GIS Users' Timeline.



DMA was established in the DoD, from the Mapping, Charting, and Geodesy Division of the Defense Intelligence Agency (DIA), by DoD Directive 5105.40, on January 1, 1972 (NGA, n.d.). DMA evolved into NIMA in 1996, when the DoD combined America's most advanced imagery and geospatial assets under a single umbrella (NGA, n.d.). As a result, the intelligence community was able to take its geospatial products to a new level. With the creation of NGA in 2003, this area of intelligence took another leap forward, allowing for integration of multi-sourced information and intelligence to create an innovative new discipline that then NGA director James Clapper formally designated as geospatial intelligence (GEOINT) (NGA, n.d.).

The term “geospatial intelligence” means, “the exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features and geographically referenced activities on the Earth. GEOINT consists of imagery, imagery intelligence, and geospatial information (Title 10 U.S. Code 467).” The change of name from NIMA to NGA was not for semantics, but there was a desire to bring GEOINT into the forefront with an agency name aligned with the strongest output (NGA, n.d.). Using the GEOINT paradigm, intelligence professionals are better able to exploit and analyze imagery and geospatial information to describe, assess and visually depict physical features and human activity on the Earth, which enables national leadership to make the best policy decisions possible (NGA, n.d).

The researcher expected the DoD would continue to innovate new ways in which to utilize GIS, as they have played the parts of either the innovator or the early adopter during the first portion of the last 50 years. Many ideas may have been funded by the U.S. Government, but the new concepts seem predominantly to be exploited by the private sector.

GIS Milestones

Research Question 1: What are the perceived significant milestones in GIS development?

The most significant milestones identified by the participants in the progression of GIS as a professional field in this study were (1) automation, (2) enhancements in software, and (3) the proliferation of the Internet. The primary milestones and themes “discovered” during process tracing, interviews, and survey were:

- Automation – movement from manual transparent overlays to automated processes with computers
- Windows, graphic user interface (GUI), and software – making GIS easier to use to perform geospatial analysis, software improvements – ease of use
- Global Positioning System (GPS) – allowing for easier data collection and providing a geospatial reference to all data collected out in the field
- Imagery – availability and allowing us have a better "look" at our world
- Standards – making data more sharable and interoperable
- Internet – pushing GIS out to everyone, allowing for more people to use it, discoverability of data and geospatial services

All of these themes have helped build GIS so that it can provide a backbone for organizations, as it is a fundamental Decision Support System (DSS).   Initially GIS was a manual process, using layering with transparencies, as the French Army did, as one interviewee mentioned, while another interviewee (Batcheller, 2011) cited John Snow's technique for manually mapping cholera to determine the source of infection in Central London and how it represented a pioneering example of the type of geographical analysis that would later be used to characterize GIS.

Automation

Respondents to the surveys and semi-structured interviews were asked to identify the most significant milestone in GIS development. Out of 97 respondents, 45 indicated that automation was the most important. When asking to provide more in-depth information about why automation was the lead milestone, one interviewee, Mona Holm, observed "…the ease of use with automation, it is much less technical without the manual process of engraving." Of the 39 interviewees, 18 identified automation as the most important milestone and gave reasons that were very similar to the quote just presented.

The computer allowed the manual overlay process to move to a digital process. Moving from a mainframe environment to the widespread adoption of the PC was a significant milestone in the late 1970s (Sellekaerts, 2012). Another interviewee, Jonathan Soulen, stated, "Initially data was big, and the computer was small." There was not enough processing power and disk storage, and what was available was very expensive – command line workstations were big ticket items.

Among the 58 people who completed the online survey, 47% identified automation as the most important milestone. This group of respondents was more likely to be in the U.S. Federal Government or DoD than the private or commercial sector. In the survey, 18 out of the 25 respondents who chose automation as the most significant milestone were from the government sector. This may explain why they more highly rank automation as a milestone than do the interviewees alone. Or this could be because interviewees were allowed multiple responses and typically provided them. All government, along with interviewees that had more than 17 years of experience, recognized moving from manual to electronic cartography and indicated the ease of use for GIS in the current environment. There was a high degree of convergence between process tracing, the interviews, and the survey on selecting automation as the single most important milestone in the development of GIS, as the ability to be digital put the "systems" in GIS.

Windows/GUI and Software

The first graphics-based user interface was Xerox in April in 1981 (Lanter & Essinger, 1991). When IT development went from command line to GUI and was more Windows-based, GIS opened itself up for many more users with less specialized skills and experience. This made GIS more readily available. Esri developers began formulating the concepts that ultimately led to the release in 1982 of ARC/INFO, the first commercial GIS (Esri, 2012). Since the 1990s, the ability for a non-GIS person to do GIS has increased as Esri updated the user interface of ArcGIS software. After moving into a GUI environment, the analyst could spend more time on complex analysis, including geoprocessing and dynamic analysis with a temporal element.

During the survey, the respondents were not allowed to select enhancements to GIS software as the most significant milestone, unless they textually entered it as other, which five respondents did. However, 42% of the interviewees mentioned software or tools in some form, and almost 20% of the total respondents indicated that GIS software, predominantly Esri products, was the most significant or leading listed milestone in the development of GIS as a professional field. Since interviewees were allowed to expand and respond with multiple milestones, there were many more milestone variables included to capture all of the responses.

Global Positioning System (GPS)

On June 26, 1993, the U.S. Air Force launched the 24th Navstar satellite into orbit, completing a network of 24 satellites known as GPS (Pace et al., 1995). This would allow users of handheld GPS devices to realize their exact location on Earth, to within a few hundred feet (USNO, 2012). GPS was originally developed for the DoD for military requirements; however, its usefulness and application was very apparent after it was first utilized. In March of 1995, U.S. President Bill Clinton affirmed that the U.S. will support providing GPS signals to the international civilian population in a letter to the International Civil Aviation Organization (ICAO) (Pace et al., 1995). The availability of GPS was colossal and providing the data outside of the survey world allowed GIS analysts to georeference about any piece of data to tie the geospatial component and make the data interoperable.

GPS was another milestone that was discussed during the interviews; however, since it wasn't one of the top two mentioned, as only three of the interviewees cited GPS, it was not available as an option on the survey. Only one of the survey respondents textually input GPS as a significant milestone for other, but its applicability and usefulness are almost a given as a significant milestone within the field. Without GPS, much of the data out there would not be geospatially referenced and lend itself to application for GIS.

Imagery

In 1972 the U.S. began a remote sensing program known as Landsat, jointly managed by National Aeronautics and Space Administration (NASA) and the USGS, which at that time was the largest program for acquisition of imagery of Earth from space (NASA, 2012). When the government moved from satellite film to digital, it was a major milestone, as imagery digitization allowed for access and availability for many analysts. In 1993, the U.S. Department of Commerce granted DigitalGlobe (then called WorldView), the first license allowing a private enterprise to build and operate a satellite system to gather high-resolution digital imagery of the earth for commercial sale (DigitalGlobe, 2012).

After successfully launching the QuickBird satellite, DigitalGlobe began building a professional network to include both government and commercial markets. DigitalGlobe made an agreement to provide high-resolution imagery to Keyhole Corporation, subsequently acquired by Google in 2004 (ibid.). This agreement has helped build a digital globe picture of the Earth and has offered much to the commercial success of Google Earth and beginning the proliferation of online mapping portals (ibid.). GeoEye is a close competitor of DigitalGlobe and both companies have made access to sub meter (in some cases, half a meter) resolution commercial satellite imagery easier and have provided a better picture of our Earth available to the regular citizen, who would not have access to view the aerial imagery otherwise.

Less than 20% of interviewees mentioned satellite imagery as a major milestone in GIS, which could have been due to the prevalence of non-imagery respondents interviewed. However, none of the survey respondents textually responded with satellite imagery as the most significant milestone either. Like GPS, satellite imagery may be taken for granted by most GIS professionals, due to so many of them either seeing the imagery readily available on Google Earth or other online map services, or it could be the lack of involvement in remote sensing or satellite imagery collection within the sample population.

Standards

The establishment of geospatial data standards was also identified as a major milestone in GIS evolution. Standards allowed for the sharing of data between organizations and allowed for non-proprietary systems to interchangeably ingest, read, and utilize the same data. A few organizations had a primary role in this development. The Open Geospatial Consortium (OGC) was formally launched in 1994 and provides geospatial standards that collectively comprise the platform of interoperability using OGC-compliant data, e.g., shapefiles, for working with different sourced datasets (OGC, 2012). Additionally the Federal Geographic Data Committee (FGDC) and Spatial Database Standards Facilities Infrastructure and Environment (SDSFIE) provided data standards for other areas, which made it easier for many users from different sectors to acquire data that they could use for their own application (Goran, 1997). The FGDC was also responsible for coordinating the U.S. Federal Government's development of a National Spatial Data Infrastructure (NSDI), an electronic index to spatial data collected across the United States, including GPS-based data (Pace et al., 1995).

Of the interviewees, only five said geospatial data standards were a significant milestone in the evolution of GIS as a professional field, and none of the survey respondents indicated. Although geospatial data standards were not recognized as the most significant milestone [**MileSt**], geospatial data standards were declared by 71 of the 97 (73%) of the total respondents as one of the factors contributing greatly to collaboration and interoperability between organizations. They were ranked second highest, next to enhanced communication systems, as the greatest factor contributing to collaboration currently. This is probably because without the standard shapefiles, organizations would not be able to utilize one another's data residing in a proprietary format for proprietary software.

Internet

Many enhancements to current GIS, i.e., the movement of flat files to geodatabases into spatial database engines (ArcSDE) and utilizing of Internet mapping systems (ArcIMS) or ArcGIS Server, allowed for analysts to focus on analysis and production in lieu of cartography. The Internet also allowed these analysts to publish their products out to the WWW and get maps, data, and services out to the users. GIS had also moved to a more SOA, which allowed for services for mobile devices and for the consumption of other services into the business intelligence platform. As one interviewee declared, "the Internet has helped get GIS out of basement and into the boardroom (Hill, 2011)," as essentially any organization can use GIS as a backbone. It is much easier now to access and compile data and more efficient to get it out to the masses. Since so many services and pools of data are available on the Internet, another great quality of GIS is "scalability." One of the interviewees, Todd Smith (2011), stated, "Any organization can use it to make a map – no matter how big or how small." Smith, a former GIS analyst at MapQuest, helps his local church use freely available online GIS to create related map services for members.

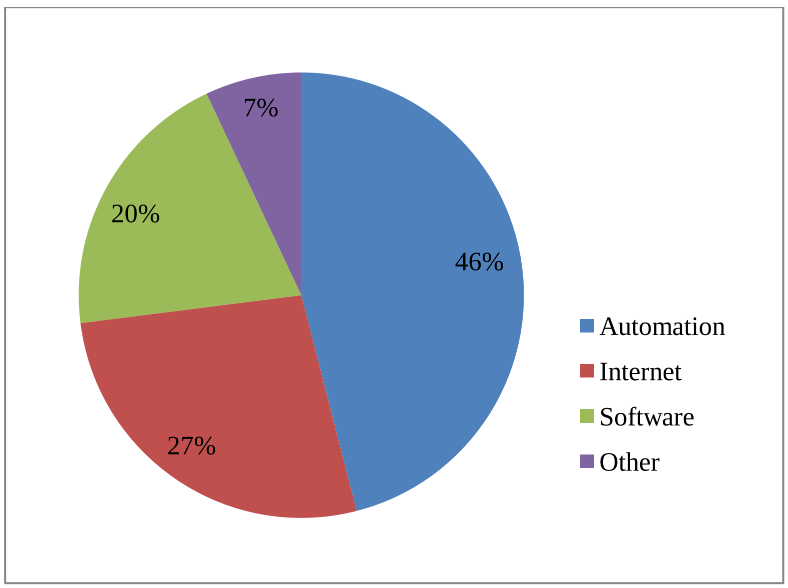
The proliferation of Web GIS (Fu & Sun, 2011) and movement into a cloud environment has opened up access to the public. Google's entry into the market with both Google Maps and Google Earth has increased public awareness and demonstrated the ease of use. GIS is much less technical now, so it has moved more from a specialist to everyone. As one of the interviewees stated, "Google Earth opened GIS up to everyone, who now understand the world from new perspective and became GIS savvy without even knowing it (Stout, 2011)."

Only 27% of the 97 respondents said the Internet was the *most* important milestone in the evolution of GIS as a professional field; however, almost half of the interviewees believed the Internet to be a major milestone in the development of GIS – just not the *most* important. Thirty-five percent of the survey respondents and only 15% of the interviewees believed the Internet was the most significant milestone. This is most likely due to the availability of the interviewees to again designate multiple responses, and the propagation of GIS as services for the Internet, as it is fundamentally the most prominent aspect of GIS currently. An interesting result is that the few state and local government respondents who participated believe the Internet is the most important (60%), whereas only 21% in private and 26% in DoD and Federal Government sector indicated this ranking. This may be due to the significant degree in which most local and state governments are providing web-based viewers to communicate geospatial data to their communities or residents.

Comparing the historical evidence to the data gathered through the interviews and survey, it was anticipated that software would be recognized as a more significant milestone because the interviewees said things like "the ease of use of software tools (McLaughlin, 2011)" and "with software tools, GIS has moved from a specialist to everyone (Neuner, 2011)." However, very few of the interviewees indicated GIS software as a significant milestone, which was also mirrored in the surveys with less than 20% of the total identifying it as the most significant milestone. Perhaps this is due to the respondents seeing other milestones as more monumental, while GIS software has been evolving slowly over the years since its inception, from the command line to the Windows GUI analysts are now using.

To summarize what was learned from the interviews and surveys, the variable milestones [**MileSt**] was created to rank the milestones perceived as most important in the progression of GIS as a professional field. Of the 97 responses, the breakout of the distribution is listed in Figure 6. Other responses accounted for 7% of the total responses. These responses included things such as specific hardware enhancements, geoprocessing capabilities, GPS and satellite imagery.

Figure 6: Significant GIS Milestones [**MileSt**] Distribution



Participants also had the ability to identify as many milestones as they wished. All participants identified at least one significant milestone, while 40% listed two and 10% listed three. One participant listed *eight* significant milestones. Comparing the responses obtained from both the interviews and survey to what was reported in the literature, we find a high convergence in the results. Automation essentially led the charge to making a lot of other things happen in GIS. Software tools have brought GIS a long way, and now the Internet is making everyone a GIS analyst, from essentially performing route analysis for driving on their next vacation to geospatially analyzing voting trends on a state by state basis.

There were statistically significant correlations between the [**Sector**] independent variable and dependent variables [**MileSt1**] and [**MileSt**] with Spearman's correlation coefficients (r_s) of 0.60 (p = 0.04) and -1.17 (p = 0.06), respectively. More of the private sector respondents chose both automation and the Internet, while more of U.S. Government respondents chose enhancements in software, as shown in cross-tabulation. There was also a slight significance shown (p=0.06) when cross-tabulation of years of experience [**YrExp**] and [**MileSt1**] was performed, with a Spearman's correlation coefficient (r_s) of 0.26. Essentially this demonstrates that almost half of the respondents indicated the Internet as the secondary milestone.

CHAPTER FIVE: RESULTS

This chapter describes the results, perspectives of the participants, and conclusions of the researcher. The primary actors influential to the evolution of GIS are identified and discussed, as well as collaborative structures and implications of Web GIS. Barriers that have been prohibitive to innovations in GIS and change management are also presented, as well as obstacles specific to the DoD for GIS services. Organizational structure and informational power are also addressed in these results and conclusions.

Actors in GIS

Research Question 2: Who have been the leading actors in GIS development?

During the survey, the researcher left the question open-ended as to who have been the leading actors; however, the researcher applied a temporal component to the question during the survey and asked the respondents to state the leading actors when the participant entered the field, and additionally who they believe to be leading actors currently. The responses from the interviews were all categorized as actors then. The actors then [**ActTh**] variable represented actors (individuals, organizations, companies, etc.) perceived as important or significant when the respondent entered the GIS field. The actors now [**ActNow**] variable characterized actors perceived as significant currently in the development of GIS as a professional field.

Within the survey, 53 out of 58 respondents included a textual response for the [**ActTh**] variable. Since the respondents were allowed to textually respond with as many actors as they desired, the first entry was the primary actor categorized for statistical comparison, although all were analyzed. Most respondents indicated at least two actors, with 89 and 59 responses, respectively for the first two actors then categories. The confirmatory interviewees support the survey responses as can be seen in this claim (Rundle, 2011), “I think if Esri were not in the business, we’d be light years behind.”

For the second actors then variable, other GIS software companies effectively garnered 25% of all responses. The other three [**ActTh**] variables had less than 30 responses, so the descriptive statistics were not included.

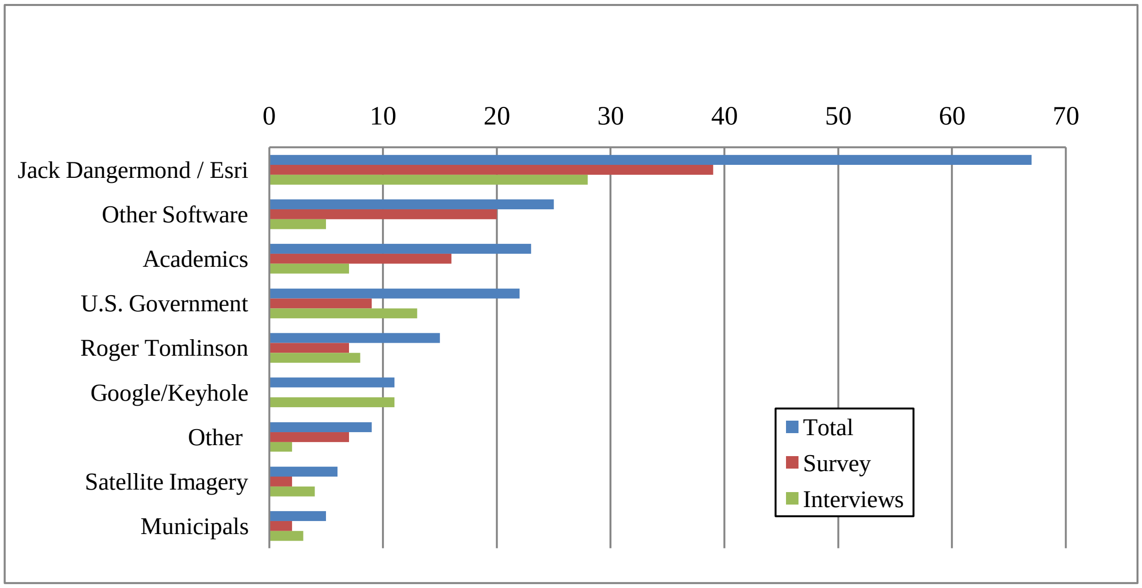
Actors Then

Although many more pioneers have made lasting contributions to GIS as a professional field, historically, these individuals have been noted as contributing greatly as pioneers to the field:

- Roger Tomlinson, considered to be the “father of GIS” for his implementation of the first operational GIS, called CGIS in 1962 (Fu & Sun, 2011)
- Jack Dangermond, a student from Harvard Lab for Computer Graphics, and founder of Esri in 1969, with a mission to make GIS available to everyone (Esri, 2012)
- Ian McHarg, Scottish founder of the Department of Landscape Architecture at the University of Pennsylvania in 1954 and writer of *Design with Nature (1969),* one of the most revered landscape architecture books of all time (CSISS, 2012)

From this research, the individuals or organizations described below are denoted as significant actors then or contributors to the field and evolution of GIS by the research participants. Due to the multiple responses received for actors then in both the interviews and the survey, a consolidated distribution was created to allow for multiple responses per subject. Figure 7 displays the consolidated distribution in highest to lowest frequency values for [**ActTh**], showing very clearly that Jack Dangermond/Esri is undoubtedly the most important actor and other people, organizations and software fall distantly behind.

Figure 7: Consolidated [**ActTh**] Frequency Distribution



<u>Software Companies</u>

The most frequent response (58%) for the first actors then [**ActTh**] variable was either Jack Dangermond or Esri, the company he founded and still operates. Esri is currently the world's 5th largest privately-owned technology company (Palmer, 2010), and when Jack Dangermond was asked in an interview why he never went public with the company, he stated, "You have to decide who you are going to serve – stockholders or your customers (Palmer, 2010)." The only debt Jack Dangermond ever took on in building Esri was a $5,000 loan from his mother (ibid.). Jack Dangermond has always made a point of taking care of his customers first. His parents emigrated from Holland and operated a plant nursery, which Jack began helping to manage at age 16 (Bryant, 2011). Jack's father taught him early on to not walk by a wilting plant (ibid.) – or a customer who needs assistance. Jack Dangermond has been instrumental in the vision for GIS, and essentially all of his "descendants" greatly value his contributions to the field. Allen Carroll, chief cartographer at National Geographic, was quoted (2009) discussing Jack's contribution to the field, "One of the things I admire most about Jack is by making GIS such a commonly used tool, he has literally changed the world (Howell, 2009)."

When consolidating all responses for the actors then variable, almost 70% of the total respondents indicated Esri or Jack Dangermond as a leading actor. Much of the research behind Esri's revolutionary software, ARC/INFO, was done at the Harvard Graphics Lab in the late 1970s on the Odyssey software project (Esri, 2012). Scott Morehouse, a lead developer on the project, joined Esri in 1981 as chief programmer (ibid.). ARC/INFO was released in 1982 as the first commercial GIS, with graphic displays of points, lines, and polygons along with a database for the feature attributes (ibid.). ARC/INFO has now evolved into ArcGIS, a platform that can be used as both a desktop application and software that can be used across the enterprise (ibid.).

In the consolidated responses, 34% of total respondents referenced other software companies by name as leading actors then. Honorable mentions for other influential and pioneering software companies went to Earth Resource Data Analysis System (ERDAS) (est. 1978), which led the way in imagery processing and handling raster data (ERDAS, 2012), and Intergraph (est. 1969) which released the first computer graphics terminal to use raster technology in 1980, which established the industry standard for high-resolution displays (Intergraph, 2012). In fact, Esri recently acquired

Lori Jordan from ERDAS to help improve Esri's imagery handling process. A few respondents mentioned CAD technology; however, it was more like electronic drafting without a spatial reference for a graphic display (Cowen, 1988). There was no real geographical analysis occurring on any maps created in CAD.

Another key response was Google, who years earlier would have not even been considered. In October 2004, Google acquired Keyhole, a digital mapping company which became the underlying the framework for Google Earth (Google, 2012). Jonathan Rosenberg (2004), VP at Google said, "This acquisition gives Google users a powerful new search tool, enabling users to view 3d images of any place on earth as well as tap a rich database of roads, businesses and many other points of interest. Keyhole is a valuable addition to Google's efforts to organize the world's information and make it universally accessible and useful." Keyhole's technology combined an enormous database of digital data and images collected from satellites and airplanes with a straightforward software application for visualization. This is another example of an effort researched by the U.S. Government and exploited by the private sector. Google Maps came online in February 2005, and Google Earth was released in June 2005 (Google, 2012). The primary contributions Google made was getting the public involved and making GIS relevant.

The researcher observed that both Roger Tomlinson and Google effectively obtained the same number of responses during the exploratory interview phase. During the confirmatory interviews, the researcher asked the interviewees if they believed it was fair to compare Roger Tomlinson and Google. One interviewee (Irvine, 2011) stated, "Tomlinson laid down the foundation and theoretical framework that Google would not be able to operate without." Another interviewee (Jalbert, 2011) said, "I worked for a Canadian company where he [Tomlinson] was a god…Google Earth is a tool, but he was an individual," contributing to the field. Most true, original GIS professionals would not consider Google a leading actor in any way, shape or form; however, its past is similar to a lot of the DoD-led efforts to create a digital world. Google has discovered its niche in GIS, as one of the interviewees (Robinson, 2011) attributed another colleague as stating, "Google provides visualization while ArcGIS provides the analysis."

GPS

The DoD within the U.S. Federal Government took the lead on GPS with the launch of satellites to establish the framework. Only two of the interviewees indicated GPS as one of the leading actors then, and NAVTEQ was the only company involved in GPS mentioned by name. From historical literature, there were two commercial companies identified that greatly contributed to actually using the data produced or referenced with GPS:

- NAVTEQ, founded in 1985 in Silicon Valley, California, focused on reality of the road network to enable dynamic turn-by-turn routing (NAVTEQ, 2012)
- TeleAtlas, a Netherlands-based company founded in 1984, delivered digital maps and other location-based services, manufacturer of TomTom (Esri, 2005)

Potentially more respondents could have inferred GPS as part of the U.S. Federal government's contribution to GIS, as 23 of the 97 respondents (24%) noted the DoD or U.S. Federal Government as a leading actor for when they entered the field of

GIS. GPS *was* acknowledged to be a critical milestone, so it may have been somewhat confusing for the participants as whether to identify it as a milestone or actor.

U.S. Government/Military/DoD

Agencies (e.g., USGS, NGA) within the U.S. Federal Government and DoD for support of the military, have made many rich contributions to the professional field of GIS, including but not limited to the availability of satellite imagery, access to GPS, and establishing the requirement for geospatial data standards, along with coordination with many software companies for GIS application refinement. Many of the tools available today would not be possible without DoD requirements in R&D. More sustainable funding also provided for the substantial contributions by the DoD to the professional field of GIS. During the exploratory interview phase, all government sector interviewees, except for one, indicated that NGA was a leading actor, while only one quarter of the other respondents indicated that the DoD or NGA was a leading actor. Overall 25% of the total respondents for both interviews and the survey recognized the DoD as a leading actor. It is somewhat ironic that software application versions in use on government networks are typically much further behind due to slowness from strict IT governance and red tape, since the government has been on the leading edge in innovating most of the technologies contributing to R&D for GIS.

Commercial Imagery Companies

Both DigitalGlobe founded in 1993, along with Walter Scott (founder), and GeoEye formed in 2006 (GeoEye, 2012) were noted by six of the 97 respondents (6 %) as key actors in the evolution of GIS as a professional field; however, most of those individuals had prior or current experience with the imagery component of GIS in lieu of points, lines, and polygons for other geospatial information & services (GI&S). The lack of respondents indicating imagery companies as a key actor could be because the DoD conducted the research to implement satellite imagery, so it may be known more as a DoD initiative.

Academia

Most of the legendary pioneers began shining in academia, including Jack Dangermond (Harvard Lab) and Ian McHarg (U of Penn); however, some of the pioneers spent almost exclusively their entire careers in academia. David DiBiase, the former director of Penn State's John A. Dutton's e-Education Institute within the College of Earth & Mineral Sciences and principal designer and manager of Penn State's GIS certificate and Masters Programs online, has recently joined Esri in late 2011. Michael Goodchild remains a professor of Geography at the University of California at Santa Barbara and director of the National Center for Geographic Information & Analysis (NCGIA) (Foresman, 1998). Mark Monmonier, professor at Syracuse University and author of many well-known books, including *How to Lie with Maps* (1991, 1996), and Michael Worboys (University of Maine) were also mentioned as leading actors.

Also receiving honorable mentions from the European academic world were the co-authors with Michael Goodchild of a predominantly used textbook, *Geographical Information Systems and Science* (2010, 3rd ed.): Paul Longley (University College London), David J. Maguire (University of Leicester, UK), and David Rhind (City University London). Additionally Stewart Fotheringham, formerly of University at Buffalo, is currently teaching in Ireland. Max Craglia (formerly of University of

Sheffield) is still making huge advancements in the field as a senior researcher at the Joint Research Centre of the European Commission, which coordinates the Infrastructure for Spatial Information in Europe, the INSPIRE initiative (INSPIRE, 2012).

In collectively looking at all the actors then mentioned by the respondents, 24% noted individual professors, universities, or collective groups of academics as leading actors then. Comparing the list of actors between the interviews and the surveys there is high similarity, perhaps due to the question being asked in an exploratory manner in both the interviews and the survey, in which the respondents were requested to input a textual response.

Country of Canada/Roger Tomlinson

Unless newer GIS professionals have a degree in Geography, they may not have heard of Roger Tomlinson, although he is still considered to be the "father of GIS." Only 25% of the interviewees indicated Roger Tomlinson as a leading actor in GIS – the same percentage as Google (or Google Earth). While this percentage appears low, only 10% of the survey respondents textually input either Roger Tomlinson or the country of Canada. The country of Canada played a part in GIS evolution as well, for supporting his implementation of the first operational GIS, CGIS, at Canada's Federal Department of Forestry and Rural Development in 1962 (Fu & Sun, 2011).

Technology Companies

Without the IT backbone, GIS would not have been able to progress as rapidly from manual to electronic, and the software would not have been up to par with its current status. Only four of the total 97 respondents stated IT firms as a leading actor in the field of GIS; however, they did note that developments in IT were the most significant milestone in GIS development. Clearly the GIS professionals participating in the study separate themselves from other IT specialists. Only one of the interviewees mentioned Bill Gates as a leading actor. However, it is arguable to also include Steve Jobs, with the Apple and iPod, iPhone, and iPad technology's functionality, as it has been somewhat of a model for other IT firms involved in GIS applications – especially with mobile device GIS technologies.

Consortiums

Four of the 97 respondents indicated several consortiums, of particular note the NGCIA formed in 1988 by National Science Foundation (NSF) funding, which is dedicated to basic research and education in GIS (NGCIA, 2012) with three member institutions: University of California, Santa Barbara; the University at Buffalo; and the University of Maine. Additionally, the OGC was formally launched in 1994 and provides geospatial standards to ensure interoperability (e.g., shapefiles) in order to work with datasets from different sources (OGC, 2012). A more recent addition to the consortium list, primarily due to the nature of the crowd-sourced contributions, is OpenStreetMap (OSM) since the public contributes directly to the map. Since 2004, OSM prefers that the public responds to whether the streets are right in their neighborhood to form a common base map. It provides free geospatial data for users to incorporate into their own project without legal or technical restrictions (OSM, 2012). Open access and crowdsourcing contribute to the success of OSM with both advantages (currency) and challenges (unvalidated data). Crowdsourcing allows for the "collective intelligence" of the local public to provide native, non-vetted data to the pool of information already available on the Internet (CBS, 2012).

Other Actors

The media began bringing GIS into everyone's homes, as one interviewee stated, when "CNN began showing maps for election coverage (Sheridan, 2011)." Additionally, GIS was popularized by the media during the war in Iraq beginning in 2003, as it helped Americans geospatially visualize a very unfamiliar country and region to better understand the situation. Some private sector companies realized they were more profitable and made better business decisions when they utilized GIS.

There was a weak correlation ($r_s = 0.21$, $p = 0.06$) between the data collection method [**DCIType**] and the second most predominant actors then [**ActTh**] dependent variable. It appeared that the interviewees were a lot more likely to volunteer other GIS software companies as leading actors then, than were those surveyed. This most likely is because interviewees were allowed to designate more than one actors then response, while the survey asked the respondent to rank the provided responses, unless the respondent textually entered a response under other.

Actors Now

The actors now question was asked differently during the survey, in that the respondents were provided with five choices to rank in order: Roger Tomlinson, Jack Dangermond/Esri, Google, U.S. Government, and other (textual responses). With the addition of the textual responses for this question, some respondents ended up entering up to seven [**ActNow**] responses. The results for the rankings of [**ActNow**] are shown in Figures 8-12 (below).

Jack Dangermond/Esri collected over 53% of the 55 survey responses for the most significant contributor for actors now, with Google accumulating the 2nd most at 22% for the number one ranking, shown in Figure 8. The U.S. Federal Government or DoD jumped from 14% to 25% between the number one and number two leading actors now rankings, while Google stayed consistent at 22% for number two slot (Figure 9). Jack Dangermond/Esri decreased to 31% for the second [**ActNow**] variable, as most of the respondents already ranked this response as number one. Google gathered over a third of the respondents for ranking third as a leading actor now, while the DoD stayed consistent at 25% (Figure 10). The most predominant response for the fourth ranking is Roger Tomlinson (45%), as that is last place besides other, which makes sense since he would be considered an actor then and should probably not have been included as a choice. Other textual responses are the majority (64%) of the 5th ranking of [**ActNow**].

Figure 8: Pie Graph for Actors Now [**ActNow**] Survey Rankings (First)

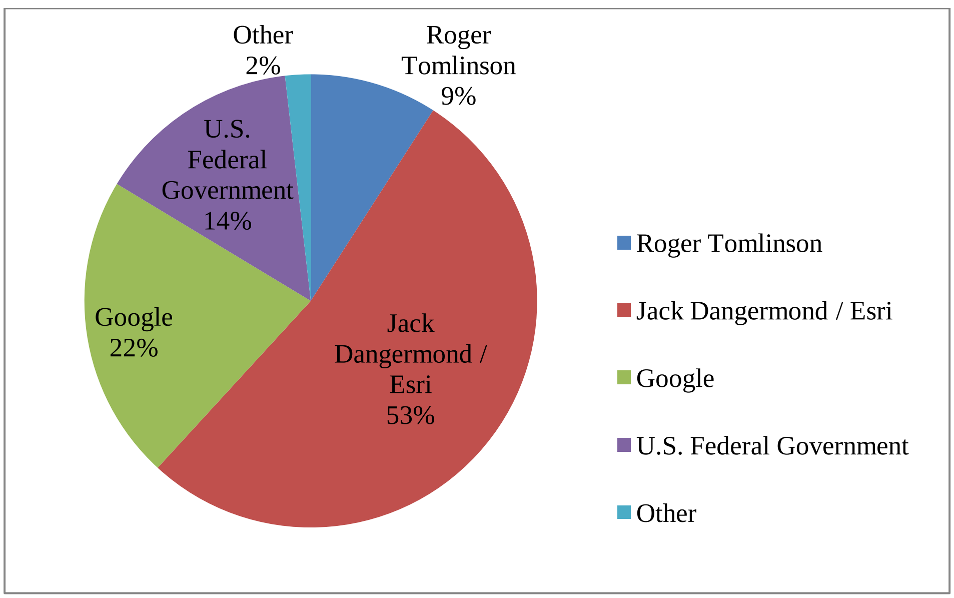


Figure 9: Pie Graph for Actors Now [**ActNow**] Survey Rankings (Second)

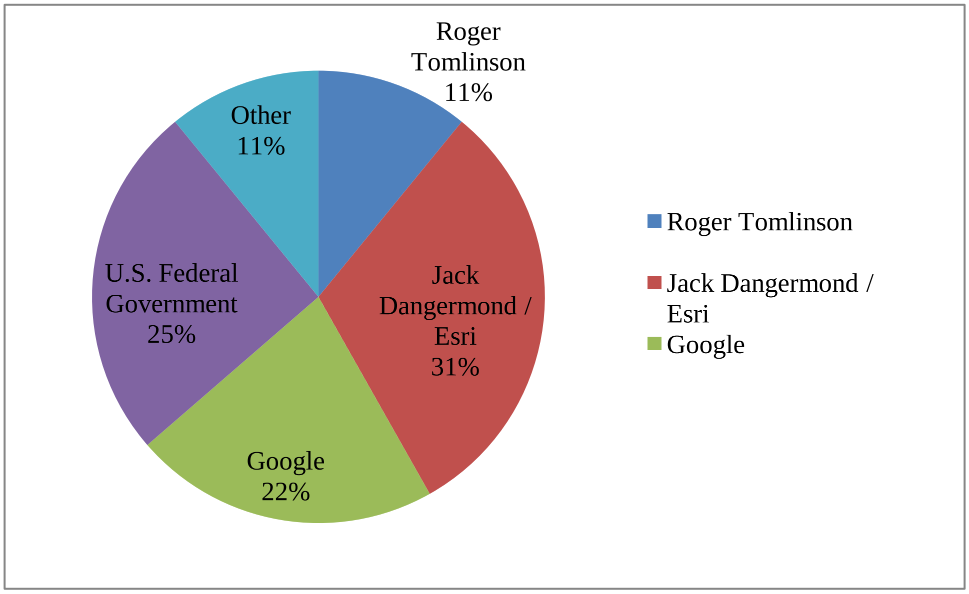


Figure 10: Pie Graph for Actors Now [**ActNow**] Survey Rankings (Third)

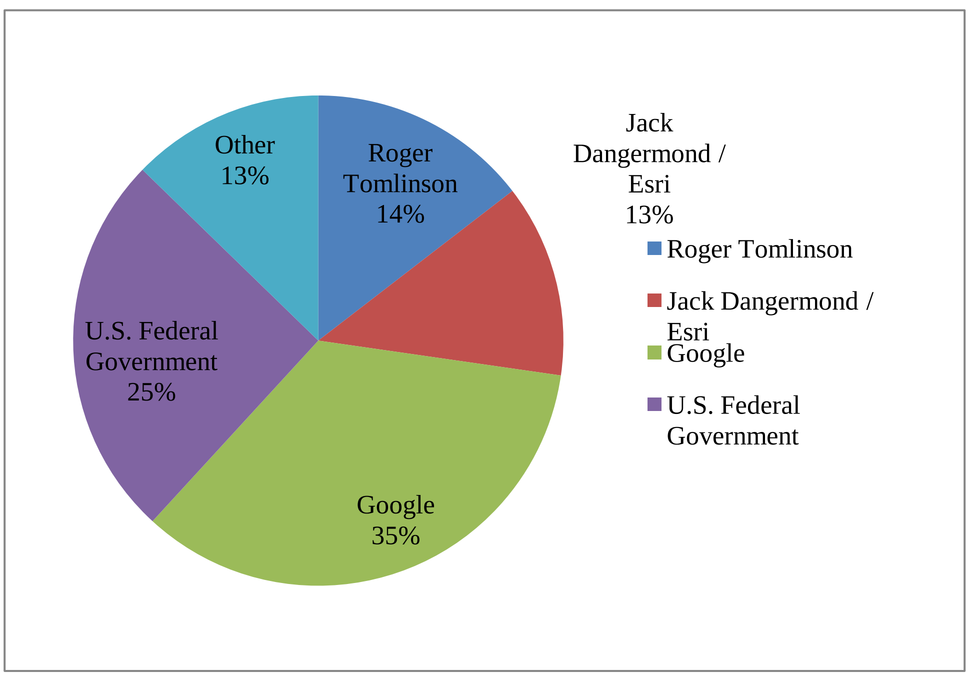


Figure 11: Pie Graph for Actors Now [**ActNow**] Survey Rankings (Fourth)

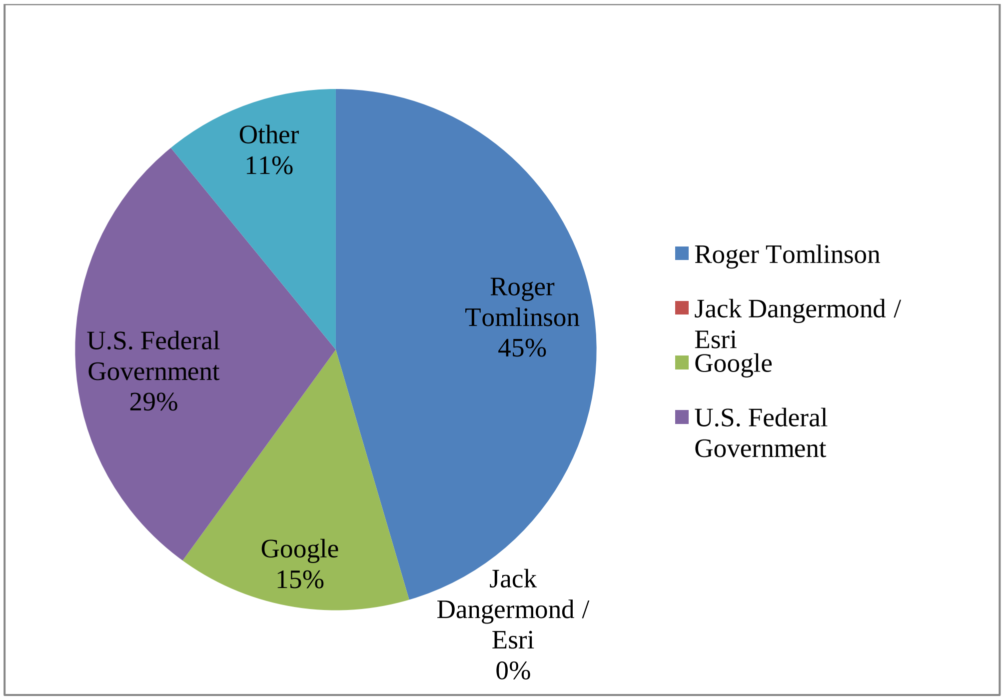
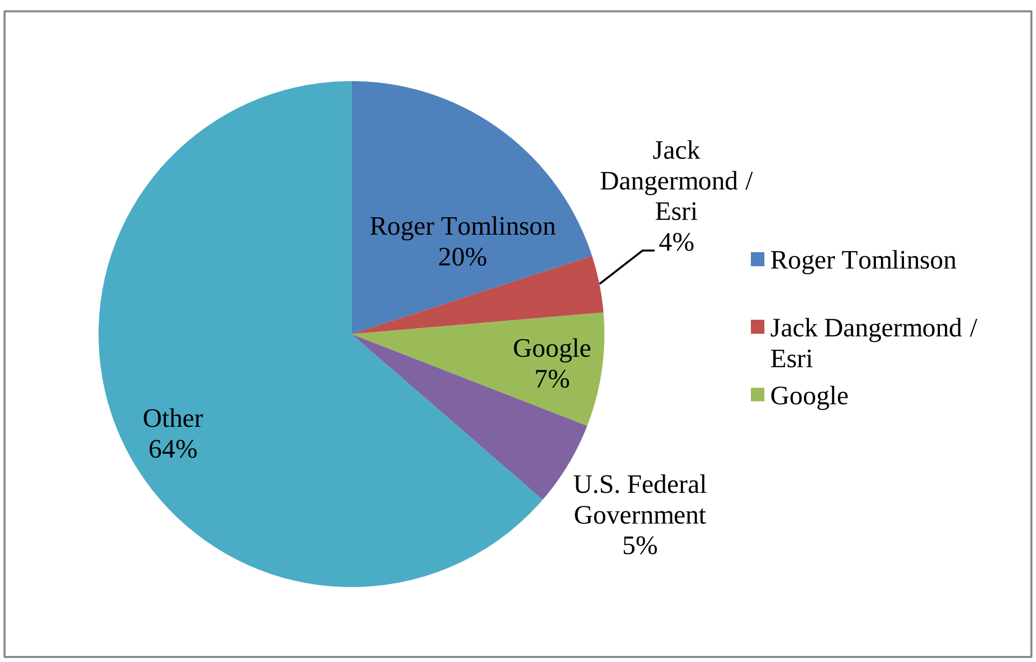


Figure 12: Pie Graph for Actors Now [**ActNow**] Survey Rankings (Fifth)



Analysis of Actors in GIS

In ranking the [**ActNow**] variable within the survey, for the top spot, twice as many private sector respondents chose both Roger Tomlinson and Google than expected in cross-tab calculations, whereas the U.S. Federal Government or DoD sector respondents chose primarily Jack Dangermond. The expected responses appeared to line up for most of the Esri rankings for each of the ranked items. Considering the bivariate relationships between [**YrExp**] and [**ActNow**], for respondents with less than 10 years of experience, there was a count of twice as many as expected for both Esri and academia. In the 10-15 years range, there were also twice as many as expected for both Google and other GIS software companies. This was probably a generational effect, in that when respondents with less than 15 years of experience entered the field, Esri tools, Google, and other software companies were already well established and recognized. Those with the least amount of experience (less than ten years) probably also considered contributions from the academic world paramount, as these participants are right out of school themselves.

None of the other independent variables, e.g., [**Role**], [**FavRole**], or [**Sector**] showed any strong correlations with either the [**ActTh**] or [**ActNow**] dependent variables. Principally the actors then and now were identified either through process tracing or through frequency distributions associated with univariate analysis from both interviews and survey. The predominant [**ActTh**] identified were Jack Dangermond/Esri (by an overwhelming majority of the respondents), other GIS software companies, and both academia and the U.S. Government with a small representation of the votes. Both Esri/Jack Dangermond and the U.S. Government were the only actors with endurance that stood the test of time and recognized still as a leading actor [**ActNow**], as was Google as a new player.

Collaboration Factors

Research Question 3: Have the nature of relationships and collaboration between many of the primary actors changed over time?

The interviewees were asked this question directly during the interview portion; however, the question was broken out into three questions for the survey. The respondents were asked to respond to the following true/false statement: Collaboration is better now than in earlier years between organizations/individuals doing GIS work. The response to this statement helped to frame whether the participant believed collaboration as good now [**ColGood**]. The participants were then asked to textually respond as to which factors they saw as contributing the most to collaboration when the respondent began working in the field [**ColFacTh**], and then they were asked to rank order the responses for factors contributing to collaboration now [**ColFacN**].

Almost 90% of respondents characterized collaboration as "good" [**ColGood**], or believed it has improved over time, when describing the relationship between different organizations performing GIS. Most people indicated more sharing, collaboration and communication for the overall greater good of GIS is achieved in lieu of solely for each company's bottom line

Collaboration Factors Then

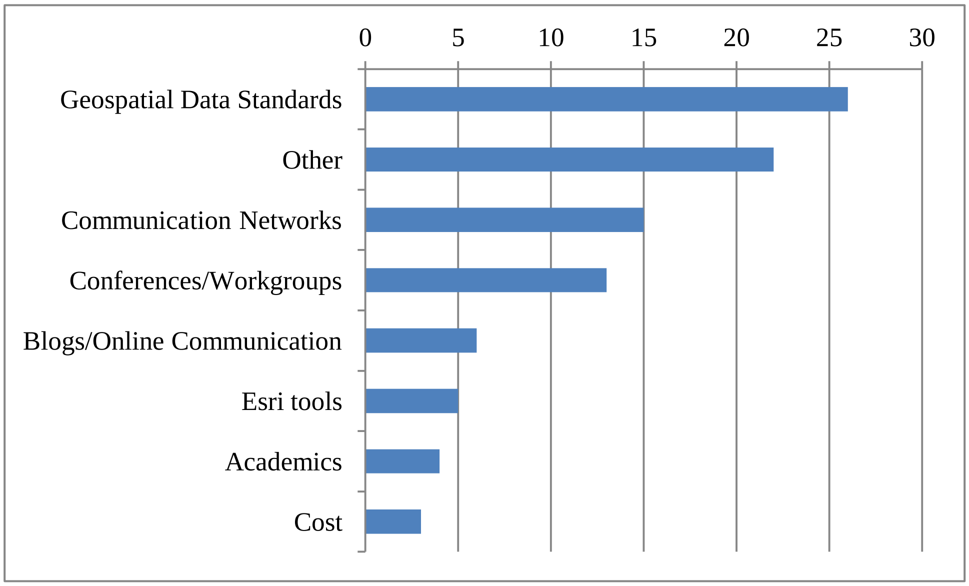
Since the question about inter-organizational structure was difficult for the interviewees, survey respondents were asked about historical collaboration factors [**ColFacTh**]. The qualitative interview responses were then recoded to conform to the wording of the survey question. It should be noted that 53 out of 58 survey respondents textually responded to this question, and 65 out of the total of 97 respondents were represented. There were a lot of diverse responses for this variable, which did not lend itself to much categorization. The allowance of textual responses contributed to a lesser degree of convergence for this question.

Almost 34% of the respondents referenced geospatial data standards first as the primary factor contributing to collaboration between organizations. One interviewee cited, "GIS software companies accept one another, even if they do not necessarily 'like' one another. The software companies used to be very overprotective of data and standards (Smith, 2011);" however, with open geospatial standards, they are essentially encouraged to work together.

Network communication systems accounted for almost 32% of the secondary responses for increased collaboration factors then [**ColFacTh**]. Initially there was a lack of IT infrastructure, but since that problem has been resolved, there has been a major move to more collaboration. In the past GIS has been served up in stovepipes, and the move to a more automated IT allows for better communication and more openness for collaboration, especially on large-scale, global projects.

Thirteen of the 65 responses for the question mentioned working groups and conferences as contributing to collaboration factors then. Esri has helped to foster good partnerships through their large, international conference, the Esri UC, and their software tools. One interviewee (Sellekaerts, 2011) stated, "There used to be a closer relationship between academics and Esri and other GIS software companies." Maybe there still is a close relationship, but since the software has already enhanced to such a high degree, perhaps there is less of a way to go. A consolidated frequency distribution of all responses for the [**ColFacTh**] is shown in Figure 13, below.

Figure 13: Consolidated [**ColFacTh**] Frequency Distribution



The sector in which the respondent worked was likely to influence views of collaboration, with those in the government sector most likely to agree that collaboration is good, while private sector respondents seemed to be less enthusiastic (λ = -0.23, p = 0.01). Additionally, participants with less than ten years of experience as a manager believed geospatial data standards to be the strongest factor contributing to collaboration in the past [**RYrMgr**] and the [**ColFacTh1**] (r_s = 0.29, p = 0.02). This may be an artifact of history since the Internet, and the corresponding enhanced network communication system that comprise it, have not been in place for that long.

Collaboration Factors Now

Collaboration factors now [**ColFacN**] were only addressed in the survey portion of the study, and 56 out of 58 survey respondents chose at least one relevant factor contributing to collaboration currently. This question was included to essentially acquire a temporal context as to whether the factors contributing to collaboration between individuals and organizations had changed over time. One interviewee (Irvine, 2011) noted, “Before it used to be a GIS black box, where it took a GIS person to understand and present geospatial data…essentially GIS and related IT has been simplified and exposed to a larger programmer and developer community to exploit geospatial data without specialized GIS knowledge.” GIS *has* been quite dependent on advances in IT to improve the services and capabilities and make them accessible. The factors were ranked by the survey respondents with 17 out of the 56 respondents (30%) placing enhanced network communication systems as the greatest factor contributing to increased collaboration between organizations and individuals in the GIS field, which in essence, mirrors the ranking for collaboration factors then [**ColFacTh**]. In fact, network communication systems ranked within the top three of all factors for 86% of all respondents.

One quarter of the respondents ranked geospatial data standards as the most important collaboration factors now [**ColFacN**]. This representation is slightly reduced from the 34% for collaboration factors then. However, it is higher than the 15% obtained in the interviews that said data standards contributed to inter-organizational collaboration and communication. This slight difference from then to now may indicate the influence of the temporal context since data standards have been established for a long period of time.

The third highest ranked choice was user conferences and working groups for [**ColFacN**] with 20% of the respondents, which is consistent from those obtained for collaboration factors then [**ColFacTh**]. It is interesting that these percentages reflect less than half of the 41% from the interviews that mentioned conferences and working groups for the inter-organizational structures variable; however, this may be due to the interviewees' limitless responses and lack of ranking. There are still internal and external organizational conflicts within and between DoD agencies (e.g., NGA and DIA), as far as who is doing what type of GIS support for the DoD. Even with the enhanced network communication systems, there is frequently a duplication of efforts within the DoD. A lot of information, processes, and data are sequestered away from a large majority of the other professionals engaged in GIS within the DoD. There has been a move to use classified working groups and conferences to support increased collaboration within the DoD, but the researcher has observed some territorial issues still between the functional services and some three-letter agencies within the larger DoD context.

Online communication technologies have helped foster collaboration in the GIS field with email, Jabber (DoD instant messaging), and video teleconferencing (VTC), allowing users to communicate in real-time over mediums other than the telephone. This factor was mentioned by three interviewees in the exploratory interviews for inter-organizational collaboration; hence, it was included in the selections for ranking for collaboration factors now [**ColFacN**]. This response was the lowest ranked specified factor of all provided responses, as only ten out of the 58 survey respondents (17%) ranked it first. This is slightly unusual as GIS professionals are problem solvers and collaborators by nature, so it should have ranked higher on the list. However, the enhanced communication infrastructure system, which was ranked higher, essentially is the backbone that allows the online communication to occur.

Another interviewee noted, “A big shift over time has also been the move from justification to do GIS to solving problems (Bowersox, 2011)” and actually performing geospatial analysis. With the increased collaboration between software companies, better tools have emerged. In fact, eight of the 56 responses (14%) to this question noted software tools, particularly Esri’s ArcGIS, as a factor contributing to greater collaboration. Since Esri was and is the strongest, largest, and most competitive player in GIS software, there may have been an imperative to other GIS companies to do it the “Esri way” as one interviewee stated. Companies who diverged from this direction were sometimes excluded from other opportunities, which could negatively impact collaboration.

The top three ranked distribution of responses for [**ColFacN**] variable is shown in Figures 14-16, below.

Figure 14: Pie Graph Displaying [**ColFacN**] Frequency, Ranked First

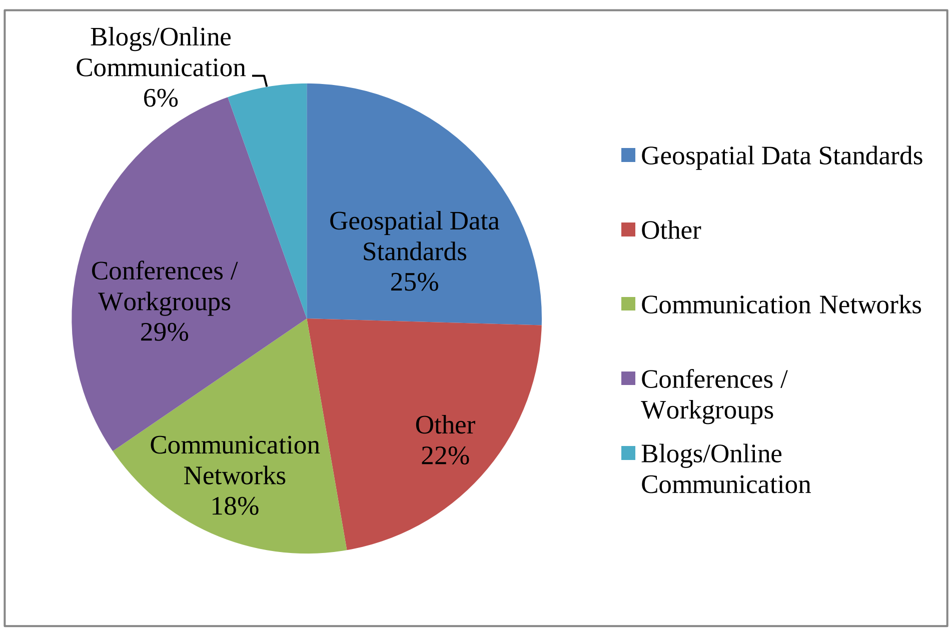


Figure 15: Pie Graph Displaying [**ColFacN**] Frequency, Ranked Second

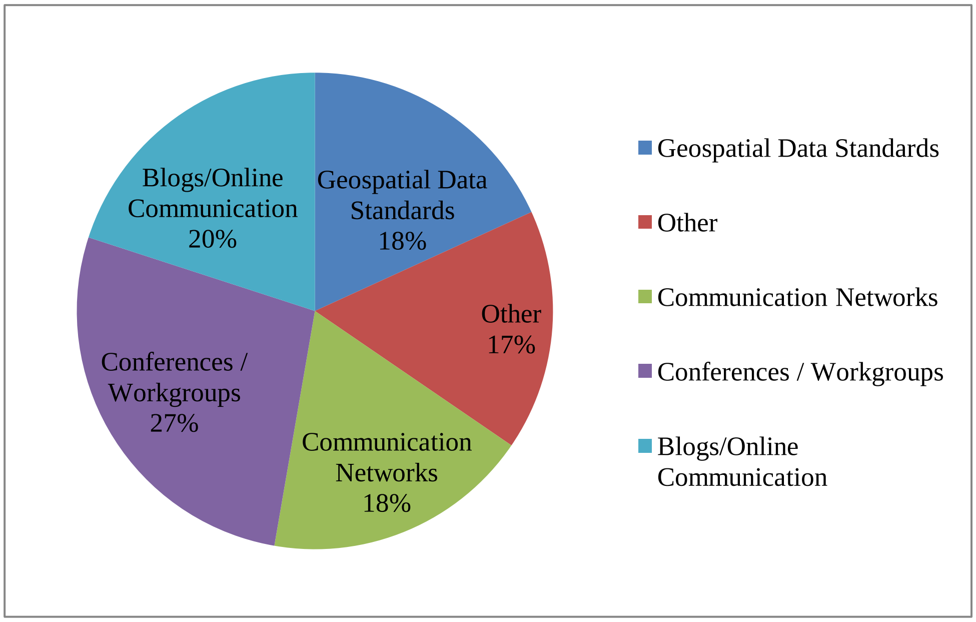
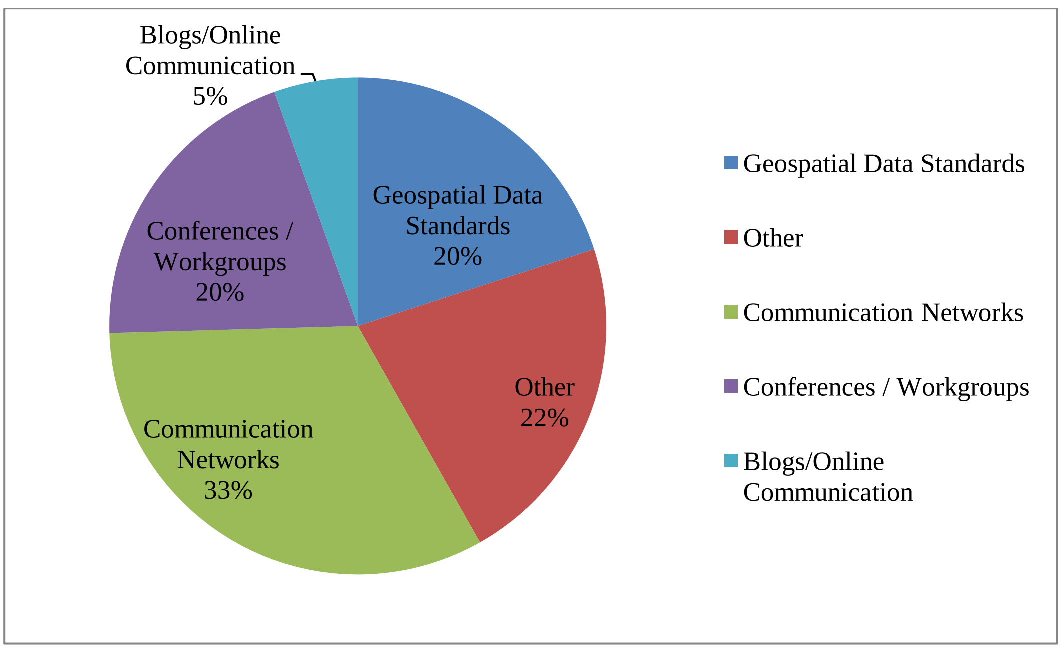


Figure 16: Pie Graph Displaying [**ColFacN**] Frequency, Ranked Third



Perhaps one of the best improvements to the GIS arena was the entry of Google Earth and Google Maps. Another interviewee noted, "It was interesting watching Esri deal with Google…Google Earth helped Esri not be complacent." Google was actually *doing* what Esri sought out to do…making GIS available to everyone, as "Geography – opening the world to everyone" was the theme for the Esri UC in 2010. Though the target audiences were and remain very different, the Esri/Google dynamic bred more competitiveness. Esri products are more for an analyst type, and Google services are more for the common person. Jack Dangermond has even commented on Esri's stance on Google and Bing map services in a 2010 interview (Palmer, 2010), "We don't really compete with them, but it has done our business good because it has helped people know more about geospatial analysis." GIS is becoming more available to a larger footprint of individuals, as Google and Esri are both more concerned with making people more geographically literate. One of the more cosmopolitan GIS professionals interviewed commented, "The outcome is overall less quality people dabbling in GIS." This statement may be because the professional dislikes less skilled individuals involved in his or her line of work.

Overall, most respondents believed that collaboration is good currently, and that it has improved over time. For [**ColFacTh**], most respondents chose geospatial data standards as the most important contributing factor to collaboration. The second most mentioned response was the enhanced network communication systems, but this is probably because the Internet, in its current state, has not been around that long, and it would be seen as contributing to collaboration when the respondent entered the field. Conferences and workgroups were also noted for collaboration factors then. For [**ColFacN**], conferences and workgroups were the highest ranked contributing factor with both geospatial data standards and enhanced network communication systems as a close second and third, respectively.

Implications of Web GIS

Research Question 4: What are the opportunities/benefits and risks/challenges in exploiting and consuming free commercially available services?

The interviewees were asked about the opportunities and benefits and, conversely, risks and challenges for organizations exploiting and consuming free commercially available services. However, in the survey, the researcher focused on the risks associated with online services [**OLRisk**] by allowing the respondent to select the greatest detriment to using freely available online GIS services from a list of: (1) data integrity, (2) reliability of the service, (3) loss of control/privacy, or (4) other, where the respondent could textually respond.

Capitalizing on GIS Services

For opportunities and benefits, most people (60%) indicated accessibility as the primary benefit, and almost 60% indicated reduced costs or freeness as a benefit. Only 10% mentioned application to mobile services. One individual responded that it would allow people to see what has already been done to reduce duplication of efforts. The researcher thought the “efficiency” perspective from private sector respondents was interesting. For risks and challenges, there was a capitalist, business opportunity risk, as 60% of the private sector respondents indicated this type of risk, whereas none of government sector respondents identified it. Almost 60% believed data integrity to be a risk, and reliability of service (e.g., uptime) was noted by 25% of overall respondents. Loss of control was another risk with over 25% of the overall respondents. Only one individual responded with "lack of privacy" – which may be the demographic, and most individuals within GIS field do not see issues in privacy with GIS data. A few DoD/U.S. Government types indicated another risk is the attribution on the public Internet – that people would know what you are looking at (related to privacy) but more on the crawler versus the data being crawled.

Benefits and Opportunities

The benefits and opportunities of online GIS services seem to go hand-in-hand with the benefits of informational power. The most important benefit of informational power was the *access* to information previously unavailable, as 42% of the total respondents indicated. The benefits and opportunities of online GIS services were specifically questioned during the interview phase; however, this variable was somewhat absorbed by the benefits of informational power [**InfoPB**] in the survey portion. Another obvious benefit that 22 out of 38 (58%) interviewees indicated was blatantly obvious: the services are free. Although, one interviewee (McLaughlin, 2011) believes all free GIS has a cost, "…typically there are advertisements…where the data resides." Two other interviewees indicated efficiencies are a big benefit of freely available online GIS services since operational costs can be reduced by using what is already out there and saving resources for other expenditures or tasks. The element that it is free also increases public awareness and utility of GIS, as one interviewee responded, "…it broadens people's understanding of GIS. If it costs, people wouldn't learn what it does...its usefulness (Wright, 2011)." Six interviewees also mentioned the application of GIS on mobile devices and opportunities for crowd-sourcing, and in a recent article for a DoD journal, NGA's current director, Letitia Long (2012), made the statement, “I believe mobile apps are a game-changer for our mission partners, for our customer set.”

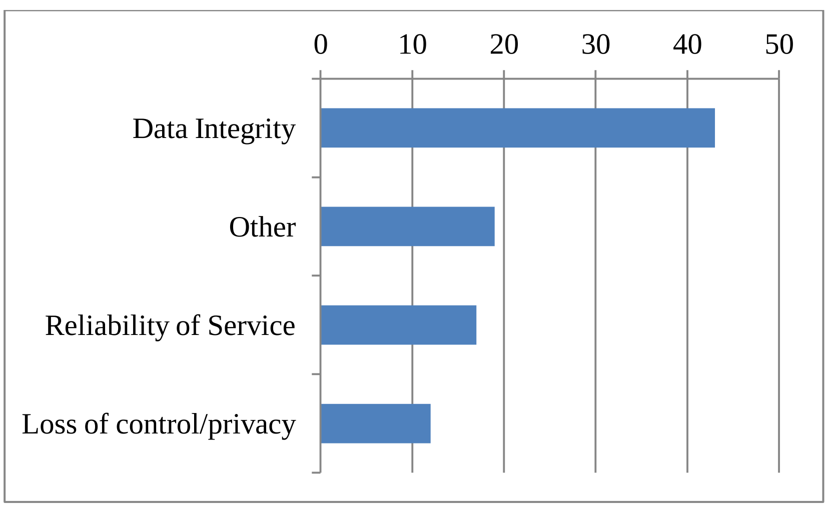
There were three government sector interviewees that negatively perceived any benefits of these services, as one interviewee stated, “The DoD doesn’t really get to capitalize on a lot of what is out there due to the closed networks (Hall, 2011).” NGA realizes the direction is to be able to move geospatial data between networks without compromising classified information (Ackerman, 2012), but until there is an IT architecture in place that supports this, it will have to wait. This is just another example of how GIS is fundamentally dependent on developments in IT.

Risks and Challenges

There were 91 responses received for the first online risk [**OLRisk**] and 19 responses for a secondary risk of using or consuming free online GIS services. Of the 91 total respondents, 47% believed the primary risk to be data integrity. This risk actually corresponds with inaccurate results, which were identified by 23% of the respondents as the greatest negative effect of informational power [**InfoPN**]. Data integrity, or the lack of it, could easily lead to a flawed analysis and inaccurate results. One interviewee responded with, “[GIS services] could be misleading…some people put a lot of trust in freely available GIS services (Stout, 2011).” Reliability of the service was identified by almost 20% of the respondents as a primary risk of online GIS. One private sector interviewee commented, “Some customers require more uptime than ArcGIS Online can provide (Neuner, 2011).” Another interviewee noted, “…no access to infrastructure or support means there is nothing to leverage or guarantee of the service (Bowersox, 2011).”

Depending on the customer or how the GIS data and services are being utilized could indicate whether a *free* solution would fit the requirements leveraged by the customer. Loss of control or privacy gathered 13% of the primary online risks, which was slightly less than the 25% obtained for the negative effects of informational power. Almost 21% of the respondents specified other unrelated risks for online GIS services, and the responses gathered for a secondary risk were predominantly split evenly across the board. There were some interesting responses for other risks, especially from private sector respondents, as one GIS consulting firm interviewee remarked about time being of the essence, "if you don't move fast on developing [GIS] solutions, someone else is going to come up with *another* solution…if it takes longer than 6 months (Levine, 2011)." Figure 17 displays the most frequent responses from both the interviews and the survey as the most significant risk of utilizing online GIS services.

Figure 17: Bar Graph for [**OLRisk**] Frequency Distribution (First)



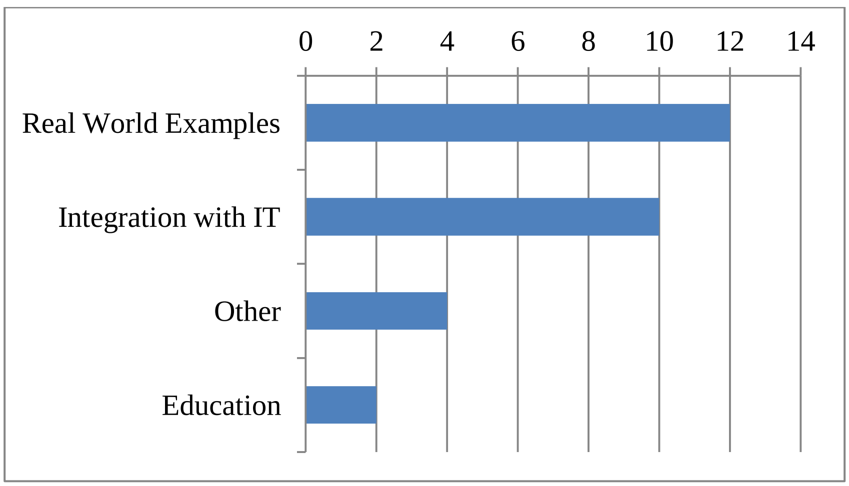
Data integrity seemed to be a stronger issue than loss of control or privacy for respondents in [**RYrMgr**], with more than ten years in a management role ($r_{s} = 0.48$, $p = 0.08$). Managers were more likely to state data integrity and reliability of the service;

however, analysts were more likely to state something else as a risk of using online GIS services. Perhaps managers were more aware of the fundamental requirements (data integrity, reliability of service) of their customers for GIS services. With data integrity lacking, there would be potential for misinterpretation and inaccurate results.

Promoting GIS

Another question that was asked during the exploratory interview phase of the research was how interviewees would recommend promoting GIS within their respective organization. The promote GIS [**PromoGIS**] variable was only asked of 28 respondents, and the most frequent type of response, with 11 of the total responses (40%) from GIS professionals, was to demonstrate GIS with real world examples. One interviewee stated, "Show real-world issues solved with GIS (Hall, 2011)." Another respondent declared, "Tie analysis to real metrics to show value (Bowersox, 2011)." Most of the participants interviewed believed that GIS would promote itself given the platform to stand upon. Although not really considered a true analytical GIS tool by most professionals, Google Maps and Google Earth were cited repeatedly throughout all the interviews and the survey due to the exposure they are bringing to the GIS profession through geospatial awareness. One respondent expressed how, "the web helps…provide awareness of geo capabilities (McLaughlin, 2011)." Five government sector interviewees believed GIS-specific education would help promote GIS. As one interviewee noted, "Educate people how to use GIS for their applications to see true value." Five others believed GIS should be more integrated with the IT department within the organization or allowed more R&D time for problem-solving. One interviewee advised, "Ensure GIS is part of mainstream IT technology; ensure data is accurate and timely, and then you show your [return on investment] ROI (Mims, 2011)." There were seven (25%) other suggestions as well which ranged from providing lightweight mobile GIS solutions, to allowing employees to spend up to 10 hours per week on creative ideas and GIS solutions (Stout, 2011), with one respondent (Irvine, 2011) even believing that, "Esri should reduce the annual personal subscription fee to $10, in order for young and talented 'kids' to play with the software and see what they can do." Figure 18 displays the most frequent responses from the interviews on promoting GIS in the respondent's organization as the professional field evolves.

Figure 18: Bar Graph for [**PromoGIS**] Frequency Distribution



Although the question generated somewhat predictable and relevant responses with real world examples, IT integration and education, the researcher felt the question was not necessary to include for methodological triangulation in the survey since it didn't really address any of the research questions proposed by the researcher.

Barriers

Research Question 5: What have been the barriers or sources of resistance over time in GIS development and evolution?

This question was asked in both the interview and the survey; however, during the interviews, there was not a temporal component associated. Within the survey, for both barriers when the participant entered the field [**BarrThen**] and barriers currently [**BarrNow**], the respondents were provided a list to choose one response from as to which was the *most* significant barrier to the development and evolution of GIS. The provided responses included: (1) lack of understanding/people issues, (2) technology, (3) lack of standards, (4) data availability, and (5) other, in which the respondent could textually insert a response.

GIS enacts and helps support change management. GIS allows for visualization of not merely geospatial factors as they are, but moreover geospatial factors temporally (either through a past or future lens). GIS helps justify making changes in organization, as it increases transparency and allows for visualization of decision making based on geospatial data. One could also look through the lens of changes in technology as a primary driver in making subsequent changes in the evolution of GIS as a professional field; however, as with any evolving technology or system, there were barriers that were required to be overcome in order to evolve.

Barriers or sources of resistance that have inhibited the development of GIS over time were predominantly identified as:

- Lack of understanding or people issues
- Data availability, policy, and standards
- Technology issues
- Costs

There was no temporal component to this variable when asked during the interview phase, but in the survey the question was broken into two separate inquiries. All the responses obtained from the interviews were categorized as [**BarrThen]**. Barriers then [**BarrThen**] is defined as barriers the respondents identified as the primary sources of resistance to the development (with 91 survey respondents agreeing) and evolution of GIS as a professional field when he or she entered the profession (with 19 survey respondents agreeing).

Barriers now [**BarrNow**] refers to barriers perceived as hindering the progression and development of GIS as a professional field currently. Since the interview responses were all categorized as [**BarrThen**], data was only collected from 53 of the 58 survey respondents for [**BarrNow**].

Lack of understanding

Management has not always seen GIS as a "must have" for the organization (King, 2011), especially in the past. Lack of understanding or people issues ranked first in both barriers then and barriers now variables. Leadership was needed to enact change for those afraid of the technology or transformation. Most GIS professionals believe there is a need to educate external customers for them to have a better understanding of the benefits of a GIS, as almost all GIS professionals believe that GIS is of utmost importance. One interviewee described the, "…significant time lag in customers understanding…now everyone is geo-enabling their data (Mims, 2011)." It is interesting that such a high percentage still perceives people issues or lack of understanding as the most significant barrier, as Google Earth and Google Maps have helped bring more of an awareness, but perhaps not understanding, to geospatial data.

There have been struggles with the utilization of GIS within the government and the DoD. Although the DoD was responsible for many of the advances in the technology of GIS, one of the more experienced DoD sector interviewees described how they were not always working entirely well with their commercial counterparts early on. The DoD probably saw a lot of what they did as requiring security and didn't believe commercial software companies could provide much benefit. Eventually academic individuals and commercial companies played a bigger part in GIS application within the DoD, and then the analysis that could occur with the software progressed.

Data

Eighteen of the 53 survey respondents indicated data availability as the most significant barrier then. Data availability, now or then, was not as much of an issue. This is most likely due to the increase in availability of data with online web services. Early on, there was a significant lack of data, and much of the data that was available was in a proprietary format. One interviewee (Sellekaerts, 2011) commented that currently there is too much data, and "the pedigree is unknown as many don't provide adequate metadata."

Lack of data standards was not noted as a significant barrier in either time frame; however, there is more concern looking to the future. Interoperability came with geospatial data standards set by the OGC; however, there are still not decisive standards for every industry. The shapefile is the predominant interoperable standard, but it lacks a significant amount of attributes and metadata that one would find in a feature class (Esri's standard data type). Even so, not all GIS software can ingest all the attribution that accompanies the shapefile, as noted in surveys and interviews. However, standards are still an issue today as they have been in the past. This wasn't foreseen by the researcher, as standards and policy have only improved over time, but with improvements come more expectations.

Technology

When GIS initially emerged, hardware, processing power, and software were archaic compared to today's IT standards and the technology that was available then was very expensive. GPS was also unavailable in the early years, which made it difficult to georeference the data that was available. Ten out of 53 survey respondents chose technology as the most significant barrier for when they first entered the field. Thinking back to the process tracing evidence, this makes sense, since in the past technology *was* a significant impediment.

Even after the PC was available, as one interviewee described, "ten years were wasted converting systems and data from UNIX to Windows (Sellekaerts, 2011)." Esri was the undeniable market leader in GIS software, but as another interviewee pointed out, "One single company dominating the entire industry wasn't good for development…lack of real competition allowed Esri to be more complacent." Initially GIS was not considered in the overarching IT development and infrastructure. As one interviewee noted, "technology was changing so rapidly, it limited the players since there was such a significant financial requirement to keep up with the technological changes (Sheridan, 2011)." Another interview commented, "GIS software evolved from a command line tool to a GUI…and with software so easy to use, many people shouldn't be [using the software or performing geospatial analysis] (Hill, 2011)," as they lack the skills and education to fully understand the tools.

Technology has undoubtedly improved more than any other of the concepts discussed as barriers, which would also correspond with why less than 2% of respondents chose technology as a barrier now. As noted in the factors contributing to collaboration, the communication infrastructure is perceived by over 30% of total respondents as the primary reason GIS has progressed so much. However, since GIS capabilities are now so prevalent, any lacks in the capabilities – especially within the DoD – are also considered a hindrance.

Costs

Cost and technology really went hand-in-hand in the early years, as there may have been a technological solution, but it was not affordable. One quarter of the interviewees noted costs being "prohibitive to entry" and the "scalability" factor; however, when choosing just one as the most significant, only one survey respondent indicated costs as a textual response for other. Most of the Federal Government sector respondents did not see money as being an issue, since typically the U.S. Government (or DoD) tends to have a lot to spend. A couple of the private sector respondents did not believe costs to be the biggest hurdle either, as one interviewee said about IT and GIS being so related, "The IT budget can typically absorb the costs for a GIS (Odom, 2011)." Conversely, another interviewee (Soulen, 2011) indicated a growing concern about organizations allowed to do an initial outlay of capital funds for a GIS several years ago, which will need a technology refresh in the next couple years. "Funding for refreshes will need to come out of Operations & Maintenance (O&M) portion of the budget – which may present a funding challenge. If they don't upgrade, these organizations will all have antiquated equipment for their GIS to ride on (Soulen, 2011)." Since there is such a large financial burden of getting in, companies and organizations need to prioritize what becomes a GIS. [**BarrThen**] and [**BarrNow**] variables ranked as the most significant are shown below in Figures 19 and 20.

Figure 19: Bar Graph for [**BarrThen**] Frequency Distribution (First)

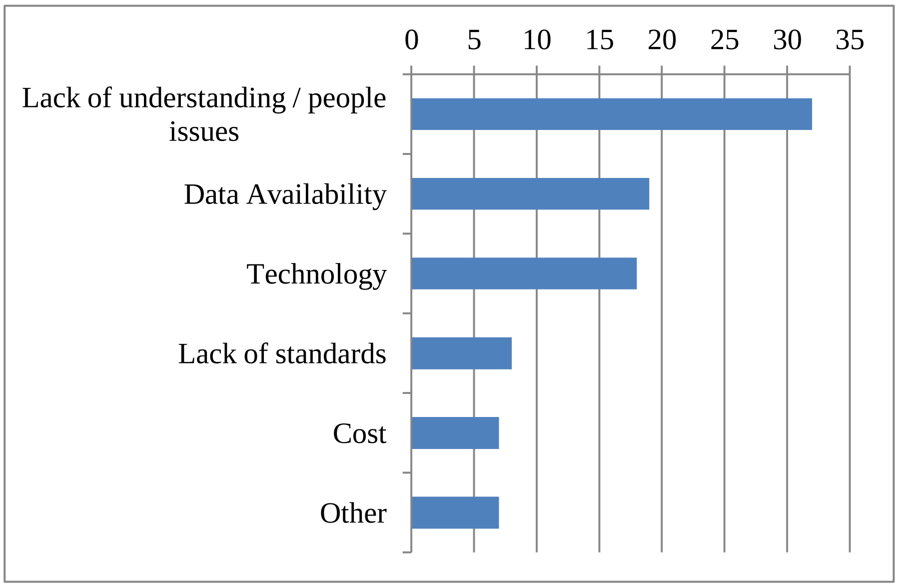
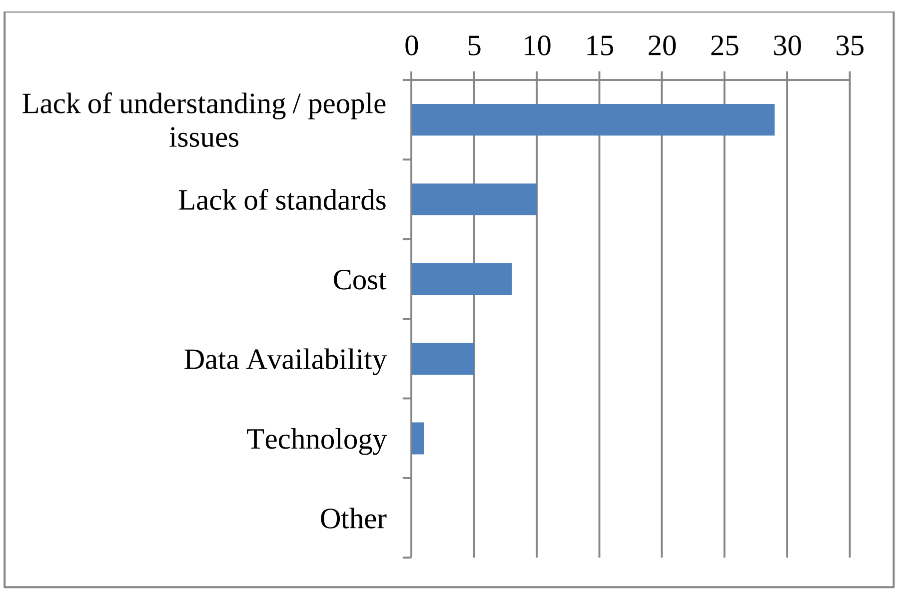


Figure 20: Bar Graph for [**BarrNow**] Survey Rankings (First)



For both [**BarrThen**] and [**BarrNow**], the most significant barrier by an overwhelming majority was lack of understanding or human factors. For [**BarrThen**], both technology and data availability were considered the primary impediment; however, for [**BarrNow**], both technology and data are very low on the list, and the lack of data standards moved into second place. This was probably because the population is fairly confident in the technology currently in place. The researcher thought it was interesting but also logical that, both then and now, human factors cause the most problems in change management – even when incorporating or adopting technology.

DoD-specific Challenges

Research Question 6: What are the issues the DoD may be required to overcome to capitalize on the freely available online GIS services, which is the direction in which the field is trending?

The DoD issues variable [**DoDIssue**] is defined as challenges with the DoD exploiting free commercially available GIS on the Internet or any other issue in progressing forward with GIS as the field evolves. It was asked directly in the survey, but the respondents were presented with responses to select from. Those responses were: (1) inability to access data from a closed system, (2) lack of interoperability between systems, and (3) reliability of services – with the additional option of selecting other and textually inserting a response. This question was only specifically asked during the online survey; however, one interviewee described one challenge for capitalizing on the online services within the DoD, "It gives [people] knowledge of what you are looking at…attribution of web searches (Holm, 2011)," which directly ties to this variable. Operational security (OPSEC) could also present concerns with using online GIS data and services if operating on an unclassified network.

Of the 58 total respondents who answered this question, 40 (69%) stated the inability to access data from a closed system, and even if the data and the user do reside on the same domain and network, there are other compatibility issues as in multiple different software platforms, e.g., ArcGIS versions, Google Earth, and various customized stovepipe systems. There are costly solutions for providing data interoperability when the dataset is too large, but most users do not have access to the tool.

Almost two-thirds (65%) described a DoD issue as the lack of interoperability between systems, with no DoD wide solution. NGA has been tasked as the lead on making GEOINT data available, but NGA is a combat support agency (CSA) and has no jurisdiction over the local network communication systems at each installation and Command within the DoD.   It is difficult to enact change from the current position, due to the fact this is not a GEOINT issue, but a network issue for the DoD. A movement has begun to get away from minor agency-specific networks at each classification level. With more consolidation and less firewalls, resolving connectivity issues should be closer to attain. There is also not one authoritative source of GIS services and data, as there are too many government agencies duplicating efforts. Many GIS data and services that *are* available are not discoverable (or easy to find). There are many different data sources for imagery or vector data that are specific to a particular agency or mission within the DoD and require a separate username and password through web-based access.   If the user is unaware of the existence of a dataset, the probability is extremely low that they will ever find it. NGA's Online GEOINT Services portal was intended to accomplish discovering all relevant GEOINT data for multiple intelligence missions, but it isn't there yet.

Only 27 (47%) respondents indicated reliability of services as a primary [**DoDIssue**], as there is no commercial incentive to continuously provide the GIS services. The researcher believes fewer survey respondents chose the reliability response, as they may not have direct contact with GIS within the DoD and do not understand that there are very few service level agreements (SLA) between the agencies or within the DoD to have a certain percentage of uptime, as there are in the private sector. For the most part, all services on the public Internet are going to be more current than what would be available on a DoD network. There were discussions recently in trying to bring in unclassified data (e.g., OSM) onto classified networks. Most users were quite satisfied with a monthly update, as that is much better than most of the stale data that tends to reside on the secure networks.

Four of the survey respondents also indicated security as a DoD issue. The DoD is unable to utilize mobile and Web GIS to their best ability, as security and information assurance strategies are not agile and responsive to the military needs. The disallowance of external hard drives and flash drives on DoD networks, put in place for network security reasons, is hampering the mission and preventing GIS from being effectively utilized by the Warfighter or deployed service members. One interviewee (Rashed, 2011) discussed the excellent GIS tools his firm could present to the DoD, but without appropriate or adequate clearances, they cannot succinctly explain to the DoD how to use the tools on the DoD networks.

The DoD has secure networks for protecting information, and allowing access to this information defeats the purpose of the established networks; however, the inability to access the GIS services and data available on the Internet was considered the most significant impediment. There has been direction ay the highest levels within the DoD to build and support an IT infrastructure which would be conducive to providing access to data and transferability between the networks, while not compromising the classified information.

DoD solutions [**DoDSol**] was a variable created to capture recommendations from survey respondents on how to better address the DoD issues [**DoDIssue**] mentioned above and to successfully capitalize on Web GIS. Of the 38 textual responses received, the most frequent categorical response (47%) had to do with connecting and communicating with the outside world and services available on the Internet. Improved security considerations and encryption standards was the second most frequent response (16%); however, there were many more varied responses (37%) that could not easily be categorized.

There were no statistically significant relationships identified for the [**DoDIssue**] dependent variable. However, the following table (Table 3) displays three statistically significant correlations for the [**DoDSol**] variable with respect to sector, years of experience, and the recoded variable for years as a manager.

Table 3: Statistically Significant Relationships for [**DoDSol**] Correlations*

Bivariate Combinations	Spearman's Correlation Coefficient	One-tailed Significance
RYrMgr x DODSol	0.30	0.03
Sector x DODSol	-0.24	0.07
YearsExp x DODSol	0.38	0.01

**Correlations are significant at 0.05 level (one-tailed), and values denoted in gray are statistically significant at 0.10 level.*

Essentially none of the respondents with less than ten years of management experience responded with "increased security methods" or "better encryption," as they all observed the need only to connect with the outside world. Both those with less experience and those with more experience were twice as likely to respond with "increased security methods" or "better encryption." The government sector participants were also more likely to respond with connecting to the outside world in lieu of better encryption and security methods than private sector participants. This may be in fact due to the government respondents' familiarity with the DoD networks and the security measures enacted already, while the private sector respondents were only speculating.

GIS Placement and Location in Organizational Structures

Research Question 7: Does an advanced technology like GIS fit into a bureaucratic, hierarchical organizational structure like the DoD?

This question was only asked during the interviews. The researcher also asked about intra-organizational structures and collaborative structures as well during the interviews to understand how the individual perceived GIS to fit both internally and externally to the organization.

Most respondents believed that GIS could fit into any organization, so a bureaucratic one would be no different. GIS inherently spans across boundaries within organizations. GIS allows for access to data and information for functional or authoritative sections within the organization, which permits decentralization of decisions, and thus the organizational structure. Geospatial information is the type of data, which can easily be communicated upwards and laterally, as well as downwards. GIS easily allows for upward communication, in which individuals at lower levels are allowed to share ideas on how things can be improved since the data is easily discoverable. GIS in itself intrinsically violates the rules governing a traditional bureaucracy, as it allow specialized skills and information to travel across internal organizational boundaries.

Fit

Fit used in the context intended for the fit of GIS to an organization, refers primarily to whether GIS could fit in an organization or how it best fits into the organization. Fit was only addressed during the interviews, as it was apparent early on the confusion it induced in the interviewees. Most interpreted this question during the exploratory phase as, "Could GIS fit into a bureaucratic organization?" to which there was a resounding, "Yes, it fits!" by 53% of respondents, as these GIS professionals enthusiastically saw GIS fitting and benefitting any organization.

When the researcher asked the question during the confirmatory phase, the researcher emphasized to the interviewee to respond as to whether they believed a hierarchical or bureaucratic organizational structure would be the best way to manage GIS, but there was still a multitude of various responses ranging from, "Yes, GIS is flexible enough to fit any organization," to, "No, it doesn't fit because GIS is enabler across the organization." This is probably due to the fact that the interviewee was not prompted to respond in any particular way. It may also account for the difference in questioning between the exploratory and confirmatory phase.

One interviewee, Hal Rundle (2011), described GIS as, "an amazing tool if users are educated in use," but he also noted that it would probably best fit in "a functional or flat government." Over 75% of the interviewees indicated that GIS could help decision making if integrated effectively across the organization and could really enhance "business intelligence" (King, 2011) and the DSS.

Previously GIS was considered a complicated technology, and some of the problems were in lack of leadership understanding. However, the Internet has helped leaders in organizations see the value of GIS, so it may be more acceptable currently than in the early 1990s. Google has helped bring GIS into almost any organization because it allows basic Internet users to visualize geospatially, providing situational awareness, and conduct simple GIS-like analysis. This allows leadership and most other members of the organization to see the benefits of GIS. Therefore it is "no longer a niche technology as GIS is flexible enough to fit into any organization," as another interviewee (McLaughlin, 2011) commented, but it may require "a champion to promote and show how it integrates with other IT systems (Levine, 2011)."

Eleven of the 39 interviewees did say that a bureaucratic structure is not the best organizational structure since GIS crosses internal organizational boundaries. A lot of information can be stranded in sensitive compartmented information facilities (SCIFs) within the government and DoD in the Intelligence Community (IC) and not shared with logistics or other directorates who could benefit from the GIS. It may be best to integrate GIS with both policy and decision makers, along with the IT department in order to obtain the technical support, software updates, etc., pertinent to an efficient and effective organizational GIS, in a matrix structure. One interviewee indicated, “GIS can work in stovepipe or any environment, as it helps show cracks in the structure (King, 2011)” which would benefit the organization overall. A couple of the interviewees emphasized that smart, skilled GIS professionals must be retained for organizations to glean the most value out of their GIS, as GIS consists of software, hardware, data, methods, and *people*.

Intra-organizational Structures

In the context intended for the interviews, intra-organizational structures should have been described with terms specific to “centralization,” “formalization,” and “patterns.” These types of organization are usually defined as functional, divisional, matrix or other internal configurations of people within the organization. However, the researcher did not prompt the interviewees consistently or adequately to allow for sufficient responses for a majority of the interviews. Hence, intra-organizational structures were only questioned during the exploratory interviews, as it was evident early on that the respondents did not have a full understanding of the organizational structure’s “configuration” and “complexity (Jablin, 1987).”

Although most interviewees were not familiar with “organizational structures” explicitly, in 50% of the exploratory interviews, there was a general consensus that the organization should be flat, focused on GIS with educated, talented, skilled, smart individuals, whom are also integrated with IT or other business units they are supporting as the best intra-organizational structure – essentially a matrix organization, by definition.

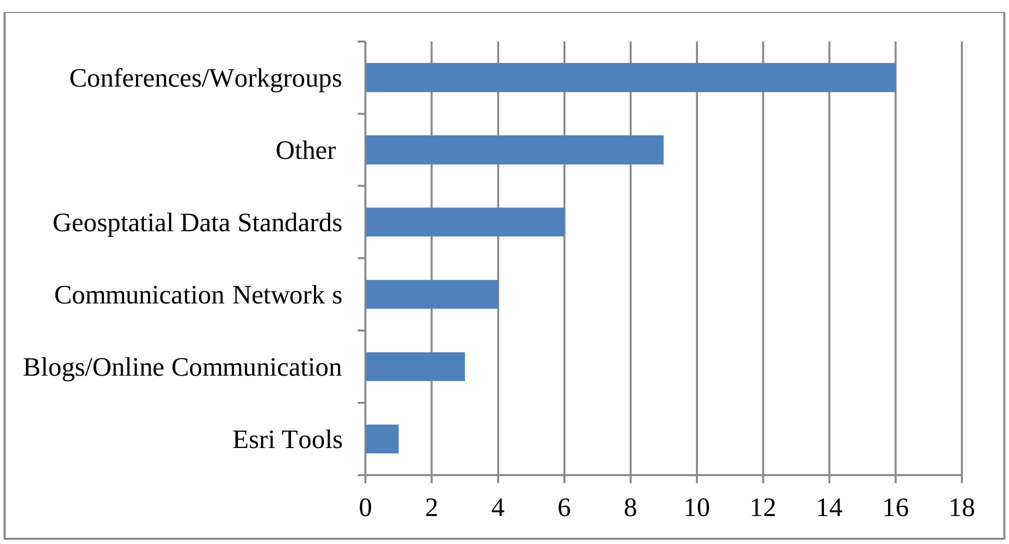
There was not a high consistency or convergence in many of the responses obtained for this variable in the interviews. Responses ranged from integrating with IT; to being small, focused, or flat; to embedding GIS professionals in other organizations. Perhaps the researcher could have collapsed the categorical responses to find more convergence, but the extraneous responses appeared to lack a common theme. As the most probable response was essentially "other" not aligning with the predominant responses the researcher intended to solicit. This is most likely due to the lack of definition of the terms explained by the researcher.

A couple of the interviewees discoursed on the organization in micro terminology and went as far to discuss individuals within the organization and how databases should be managed by authoritative data owners and ArcSDE, or a central database repository. There was also mention of the overall makeup of the organization, in that there is a need for more people to intellectually own concepts of GIS and "think geospatially." Some of the interviewees also presented ideas on how to more effectively manage GIS internally within the organization, as Tim Hill (2011) said to "involve stakeholders from different departments, such as a steering committee who owns the data to leverage, as they would have a vested interest in the GIS." Another interviewee involved more on the commercial side of GIS mentioned, "[subject matter experts] SMEs should meet with other SMEs at proposed clients, in order to determine the *real* needs (Neuner, 2011)." One of the government interviewees suggested, "GIS should be built on validated requirements – not the technology itself (Filler, 2011)," when developing internal GIS solutions. Another respondent expressed a need in an organization solely concerned with GIS to allow for more time for R&D, training, and experts providing mentorship to promote GIS internally.

Inter-organizational Structures

For the purpose of the interviews conducted in the study, inter-organizational structure referred to methods in which organizations communicate or share data and/or information amongst themselves. The inter-organizational structure variables were questioned during both the exploratory and confirmatory interviews. However, the researcher consistently needed to explain the question's intent to the interviewees, so it was evident this was not the most effective way to discover methods contributing to collaboration or communication between organizations. Hence, this direct question was not included in the survey, but a variation on the question for collaboration factors was included, which was discussed above. A bar graph is displayed below (Figure 21) to show the extent and frequency of the categorical responses obtained for the [**Inter**] variable.

Figure 21: Inter-organizational [**Inter**] Frequency Distribution



Working Groups and Conferences

The most probable response was user conferences and workgroups, with a mode of 21 responses (41% of interviewees) as the best way for collaborating between organizations as the field evolves. Since primarily DoD participants were interviewed, most indicated benefits of DoD-related or sponsored working groups or conferences that focused on GIS missions within the DoD – essentially any groups that get together to collaborate and talk about GIS. Another predominant response was the Esri UC held annually in San Diego, California, which allows users from all over the world to share ideas in GIS. The first Esri International UC was held in 1981 with 16 attendees, and it has grown substantially over the years, today attracting more than 14,000 attendees (Esri, 2012) and is noted as the largest GIS conference in the world.

Standards

Geospatial data standards were the second most predominant response for the inter-organizational question at 15% of respondents. There was also a consensus that Esri helped justify standards, but that the standards still need improvement. Standards board organizations, such as the OGC, allow people to agree on and understand what each other's data means.

IT Relationship

Twelve of the 39 interviewees mentioned that GIS teams should maintain a strong working relationship with IT services and management. Collaborating with IT, data sharing, and understanding links in other organizations' IT architectures, will help organizations work together more seamlessly. From a commercial perspective, there is definitely a need to work with and sell to both the business unit and IT unit to approve and integrate the technology.

Database or Cloud?

There was a lot of discussion on where the geospatial data should reside. Almost 15% of the interviewees believed data should reside in either ArcSDE or a cloud environment with interoperable web services (real-time, crowd sourcing, fusing data) to best collaborate externally or inter-organizationally. Some people also believed that centralization would help in the government, as currently there is a lot of duplication of resources. There was a perception by one interviewee that smaller, private sector companies typically use lower tech solutions in lieu of enterprise systems, but that typically the lower tech solutions provide all the capability they need, in comparing enterprise DoD systems to private sector GIS applications.

Role of Geospatial Information Officer (GIO)

There was a concern about the lack of individuals involved whom are technical and understand the vision, as GIS implementations need strategic and fairly technical leaders to drive. Two of the interviewees believed in taking a more defined and pragmatic direction and establishing a central GIO role to collaborate with the chief information officer (CIO). One interviewee believed the support of the CIO would allow the GIO to push out geospatial policy to business units on how to collaborate better (Jalbert, 2011). GIS itself could be the linking pin to maintain and create relationships across the organization because GIS does cross organizational boundaries. As one interviewee responded, “Most people, places, things, ideas within an organization have a ‘where?’ component (McLaughlin, 2011).”

Social Media and Networks

Social media and networks with email, chat and Internet blogs and posts all help the technical GIS professionals collaborate, share trouble-shooting solutions, and discuss common issues in order for all to benefit for the greater good of GIS. Three interviewees of the 28 exploratory interviews conducted voiced social media as a great way to collaborate and communicate between users and organizations. Geospatial data standards help these techies talk the same language about GIS data and issues with software. Since Esri is the dominant player for analytical software, users from across the world are able to collaborate on solutions for one GIS software company.
This question *is* similar to the collaboration factors now question in the online survey which read, "At this time, what has been the greatest factor contributing to increased collaboration between organizations/individuals in the GIS field?" The survey respondents ranked online communication as an important factor, but not the greatest factor, as it was ranked 4th out of five responses for the number one collaboration factor now [**ColFacN**]. However, due to the manner in which the question was asked in the interviews and the survey, it remained a separate variable from factors contributing to collaboration in the results. Due to the wide range of categorical responses that could not be collapsed, the variable was not analyzed any further.

Informational Power

Research Question 8: How does "informational power," which is enhanced by GIS, affect decision making in DoD organizations?

This question was asked directly during the exploratory interviews; however, similarly to the manner in which the collaboration and evolution of relationships was handled, this question was broken into three sections for the survey. The respondents were initially asked to characterize informational power as positive or negative [**InfoPower**], with an option to state, “it depends,” and textually insert a response. Secondly, they were then asked to select the primary benefits of informational power [**InfoPB**] for the following options: increased transparency, ability to make better decisions, access to information not previously available, and improved situational awareness; they were allowed to check all that apply. Thirdly, the respondents were asked to textually respond to the primary disadvantages of informational power [**InfoPN**].

Informational power is distinguished from expert power (French, 1965) and is defined as power that comes from information (Forsyth, 2009); people and organizations can gain power from access and control over information. GIS enhances informational power, as it helps organize geospatial information and provides it to people who may need it. Though this question was addressed in both the interviews and the survey, a response was not always received, with 91 valid responses out of 97 total responses. Three of the survey respondents did not answer this question, and the researcher could not ascertain a definitive response to code from three of the interviewees to include in the statistical analysis. Of those that responded, over 75% believed informational power [**InfoPower**] to be positive, while only 6% observed it as negative. There were several respondents (almost 18%) who said, “It depends.” Those that believed it was positive verbally made remarks like, “GIS forces transparency (Sellekaerts, 2011)” or, “seeing data geospatially puts truth to the numbers.” Most believed it could help make better decisions quicker, increase transparency, and improve situational awareness. One interviewee identified the misuse of information and acknowledged data hoarders as the culprit and stated that government or people could do, "…profiling on geographic data." One of the textual responses input for a respondent choosing "it depends" was, "…depends on the user's and the audience's perceived intent." Three of the survey respondents indicated that they did know what the phrase or term, informational power, was defined as. This was an oversight on the researcher to not more clearly define the term. Responses were generally positive in the survey until they were specifically asked what detrimental effects could be foreseen with informational power.

One interviewee noted regarding informational power, "It is required for private companies to be competitive (Rundle, 2011)," as it is opening up to make decisions visually and geospatially. GIS has the unique ability to allow for spatial pattern analysis in lieu of a strictly financial analysis. It incorporates a third dimension into a DSS. One private sector interviewee heavily involved with facilities and infrastructure with the DoD spoke about a geospatial analysis the U.S. Marines conducted to actually *see* where their money was being spent (Mims, 2011), which helped make decisions for base realignment and closure (BRAC). GIS provides a way to visually see what is on the ground and allows for identifying patterns that may not have been identified if the layers were not overlaid in a GIS.

Informational Power Benefits

The question regarding informational power benefits was not directly asked during the interviews; however, if the interviewees made verbal comments about one of the predefined benefits of informational power included in the survey, the data was coded accordingly.

Due to the manner in which the survey respondents were asked to check all that apply for information power benefits, these four variables were dichotomous. [**InfoPB1**] is defined as increased transparency, while [**InfoPB2**] is the ability to make better decisions. [**InfoPB3**] is access to information not previously available, and [**InfoPB4**] is improved situational awareness. Almost 53% of the total respondents believed that the ability to make better decisions was a primary benefit of informational power, with 40 out of the 54 (74%) that responded to this question in the survey. One interviewee discussed the lack of an efficient and robust GIS in planning the Allied Invasion at Normandy (Robinson, 2011) and how the planning process could have taken substantially less time, been more thorough, and saved many more lives. One interviewee (Bowes, 2011) noted, "With regard to military operations, rarely do you know the true impact of remote sensing or GIS. Many times there is not a linear, direct impact that GIS makes. However, the impact of more informed decisions on the battlefield is exponential." The more relevant the data or information for the decision to be made, the more informational power it possesses.

Almost 49% of the overall participants believed improved situational awareness to be a benefit, as 74% of the survey respondents indicated this. One interviewee (Jalbert, 2011) noted, "Leadership across multiple organizations desires improved situational awareness with the dashboard methodology ever since Google and Yahoo maps were exposed to the masses." Any service type company where location is relevant for situational awareness is really at a disadvantage to not have a robust GIS.

There was a weak correlation for the relationship between sector and improved situational awareness response for [**InfoPB**] variable ($r_s = 0.14$, $p = 0.09$). More of the government sector respondents than expected additionally selected situational awareness as a benefit of informational power. This may be due to familiarity with the phrase “situational awareness,” since it is an expression used daily within the DoD.

Access to information not previously available was communicated by 42% of the total respondents as an informational power benefit, although the hoarding of data is not as much of an issue as it was previously. In older generations, there was a sense of power loss with providing too much information to the lay workforce, which is explained by Emerson’s (1962) power dependency. Subsequently, a plethora of data is publicly available currently, which decreases any *one* person or group’s power since the masses are empowered with informational power. There was concern from two of the interviewees from government sector, referencing operational security (OPSEC) as a potential issue with the increased access. Within the DoD context, there is some sensitive data that should not be shared for mission data sets, e.g., explosive radius for munitions, utility lines, and deployed units. If the “bad guys” had possession of the data, they could target the U.S. Military more accurately.

The least prominent response was increased transparency for informational power benefits with 30% of total respondents. Three of the interviewees mentioned transparency as important but not necessarily in this context. Another interviewee stated, “There is too much transparency in the current technological environment to really use GIS for power anymore (Jalbert, 2011).” This statement is essentially supported by Emerson’s General Dependency Postulate (1962). The lack of responses related to transparency may be due to the interpretation of the term, as increased transparency significantly helps decision making – but many respondents chose the post-benefit of the increased transparency.

Table 4: Statistically Significant Relationships for [**InfoPB**] Correlations*

Bivariate Combinations	Spearman's Correlation Coefficient	One-tailed Significance
RYrMgr x InfoPB3	-0.23	0.05
Sector x InfoPB2	0.17	0.05
Sector x InfoPB4	0.14	0.09
FavRole x InfoPB2	-0.23	0.08

**Correlations are significant at 0.05 level (one-tailed), and values denoted in gray are statistically significant at 0.10 level.*

Less experienced managers (with less than 10 years in management) are statistically more likely to see access to information not previously available as a benefit of informational power. Those in the government sector also had higher levels of agreement that improved situational awareness was a benefit. Those whose favorite role was manager and those in the government sector were more likely to see the ability to make better decisions as a benefit.

The researcher believes that those with less than ten years of management experience have not had experience with the *lack* of robust GIS services. More of the government sector respondents than expected saw better decision making and improved situational awareness as benefits, which could be, as mentioned earlier, that the government (especially the DoD) uses the expression for situational awareness in their daily operations and may be more familiar with the jargon. GIS was primarily implemented into the DoD for the sole purpose of enhancing decision making, so that may also be a goal of which the government sector participants are more cognizant.

Informational Power Negative Effects

Only six of the 97 total respondents perceived informational power as being negative. The informational power negative effects [**InfoPN**] were only questioned during the survey. This question required a textual entry response, and there were only 45 obtained. However, if the responses from the interviews for the informational power question resembled a majority of the responses from the survey, they were coded accordingly. The first most frequently mentioned negative effect was inaccurate results and potential misrepresentation of the data with 12 out of the 53 responses (23%). Some of the weaknesses of having access to an overabundance of geospatial data could be construed that public could be too trusting and don't understand the underlying assumptions going into map creation, as in Monmonier's (1991) *How to lie with maps*. A skilled GIS analyst can manipulate symbology or extent that would not provide the true context or representation of the data. The second and third most predominant responses for informational power negative effects were data quality and abuse or lack of privacy. Of all the consolidated responses, 26% believed there could be data quality or integrity issues in identifying authoritative data sources. Another quarter of the respondents were fearful for the loss of control of the data since once it is out there, it may be used for analysis for which it was not intended. This effect was coupled with abuse of the information and lack of privacy, as GIS-savvy criminals could profile victims based on geographic data on public websites. Ten of the total respondents also indicated there is potential for information overload with all the data and sources already out there. The only statistically significant relationship identified for the [**InfoPN**] variable was the years as a manager [**RYrMgr]** ($r_s = 0.07$, $p = 0.02$).

Respondents with the least amount of time in managerial roles believed data quality was the predominant negative effect of informational power, whereas the respondents with more than ten years of managerial experience were less concerned with data quality as a negative effect. This may be because those that have been around long enough realize that some data is better than no data to use in performing geospatial analysis, so they may be less concerned with the quality and are happier with the availability.

Most participants agreed that informational power should be characterized as positive. Improved decision making was the main response attributable to informational power as it decentralizes the information and allows the data to be seen by decision makers for the respective area, with increased situational awareness as the second most common response. The most significant negative effect of informational power indicated was the potential for inaccurate results and misinterpretation. Informational power is not as strong as it previously was for any individual use, but it is significantly greater for the wider population. IT has allowed for GIS to become accessible to the masses, so relative power has been decreased. Informational power for the everyday user is significantly enhanced by the availability of GIS services and directly contributes to an improved understanding and awareness of the situation. As the professional field of GIS evolves and is incorporated into organizational activities and decisions, the relative benefit or advantage will decrease, as it will be *expected* to be included in any decisions made due to the increased availability of the services.

CHAPTER SIX: GIS EVOLUTION

This chapter applies several different elements to the evolution of GIS as a professional field. The research explored sectoral structuring and differences, along with amount of experience, type of roles, group behaviors, and associated perceptions of the evolution of GIS. The research also observed organizational structures and the role of technology and its impact on the development and evolution of GIS. The intent of the research was to discover whether there were any control factors that were particularly important in understanding the evolution of GIS. To verify this, the variables: participant sector [**Sector**], time as manager in field [**RYrMgr**], years of experience [**YrExp**], role type [**Role**], or preferred role type [**FavRole**] were tested.

The study intended more decisively to determine whether there are distinct qualities in a GIS professional that distinguish them from a typical IT professional, applying group behavior theories, or whether categorization of the types of professionals could be possible. There appears to be a distinctive quality regarding the individuals and their passion for this profession that makes them a little different, and this study sought to describe those differences and how they contribute to the growth and development of GIS as a professional field.

GIS Evolution and Sectoral Structuring

Research Question 9: Are there fundamental significant differences between GIS professionals in the private sector versus the DoD?

This question was not directly inquired of the participants; however, the researcher intended to decipher an answer through culmination of the statistical analysis from observing the independent variable, [**Sector**], versus the dependent variables.

Although there were some noticeable patterns for sector, there was not an excess of statistically significant relationships.

The research explored and confirmed that, regardless of sector, Jack Dangermond and/or Esri was explicitly the leading actor and organization in GIS and its evolution as a professional field. There were differences in secondary actors, as more of the government sector respondents than expected chose the U.S. Government and other software companies versus private sector respondents.

Automation was identified as the most important milestone by almost half of the participants, but this group of respondents was more likely to come from the government sector rather than the private sector. All the U.S. Government interviewees recognized moving from manual to electronic cartography and indicated the ease of use for GIS in the current environment. The Internet was the most important milestone by more than half of the state and local government respondents. Many state and local governments are moving towards providing web-based viewers to communicate data geospatially to their communities or residents, so that may be a reason for the strong partiality towards the Internet. There were some evident relationships between [**Sector**] independent variable and dependent variables [**MileSt1**] and [**MileSt**], as more of the private sector chose both automation and the Internet, while more of government sector chose both automation and enhancements in software.

During the exploratory interview phase, all government sector interviewees, except for one, indicated that NGA was a leading actor, while only one quarter of the other interviewees indicated that DoD or NGA was a leading actor. This may be due to private and state/local government sector interviewees not realizing the foundational efforts the DoD has contributed to the development of GIS, or it may be that government sector interviewees' window of reality is limited in scope to their own organization's influence. Additionally, when ranking the [**ActNow**] variable within the survey, for the top position, twice as many private sector respondents chose both Roger Tomlinson and Google than were expected, while the government sector respondents chose only Jack Dangermond. Esri is the software principally used by the DoD, as there are enterprise license agreements (ELA) with the company in order for the DoD to maximize use of their software, which may be a contributing factor, as Esri may be the most relevant and well-known GIS software package for this sector.

There was a statistically significant relationship between sector and whether the respondent believed that collaboration was good, as slightly more than expected government sector respondents believed that collaboration has *not* improved over time, while private sector respondents were a lot more likely to say, "it depends" when responding to this question. The difference in opinions may be due to the government sector respondents noting that, internally there still lacks significant collaboration within and between DoD-affiliated agencies. The private sector experiences some lack of collaboration due to competitiveness. However, overall they believe with standards, blogs, and sharing at related user conferences, there is a good amount of collaboration. There was another strong correlation, as more of government sector than expected selected the benefit [**InfoPB**] of making better decisions and situational awareness as a benefit of informational power [**InfoPower**]. As mentioned previously, this may be due to the DoD participants' familiarity with decision making and related jargon like "situational awareness."

Government respondents did not see money as being an issue as much as private sector respondents, since typically the U.S. Government's budget easily absorbs costs associated with a GIS. Private sector respondents also specified "efficiencies" when discussing opportunities and benefits of online GIS services, which were not stated by U.S. Government sector respondents. For risks and challenges of online GIS services, the private or commercial sector also acknowledged a capitalist, business opportunity risk, with 60% of the private sector respondents indicating this type of risk, while *none* of the government respondents identified. This shows that there is definitely a different frame of reference in which the participants by sector operate. The primary risks recognized in respective order were data integrity, reliability of service, and loss of control. A few DoD/U.S. Government types indicated another risk as the search attribution on the Internet, which is related to privacy on the GIS researcher. There were three government sector interviewees that negatively perceived any benefits of these services since they believed it is too difficult for the DoD to capitalize with closed networks. The government sector participants were also more likely than private sector to respond with connecting to the outside world in lieu of better encryption and security methods for DoD solutions [**DoDSol**]. Most likely this is due to the government respondents' experience with the DoD networks and related security measures, and the private sector respondents lack of knowledge or understanding of classified networks.

Differences in sector were noted in the research, as these did contribute to differences in responses, and as the researcher indicated, there does seem to be an alternate frame of reference or window of reality depending on the respondent's sector. Frequently the participants had both private and government sector experience, so the researcher was forced to categorize the respondent into one sector or another, typically on length of time spent in sector. This may have contributed to the spanning perspectives across sector. It may have been more effective to only select respondents from one sector or the other, to create another category for respondents with experience in both, or to further segment by those who are in contractor roles within the U.S. Government.

GIS Evolution and Amount of Experience

Two variables were established to measure the effect on length of time in the field and amount of experience. These variables were denoted as years of experience [**YrExp**] and a recoded variable for years as a manager [**RYrMgr**]. The distribution for both variables is shown in Table 5. The years of experience as a manager had a smaller sample size since the data was only gathered from the survey participants.

Table 5: Amount of Experience Frequency Distributions

Amount of Experience [**YrExp**], N=93		
Less than 10 years	17	18%
Between 10 and 15 years	26	28%
Between 15 and 20 years	26	28%
Between 20 and 25 years	9	10%
Greater than 25 years	15	16%
Amount of **Management** Experience [**RYrMgr**], N=53		
0 years	25	47%
0-10 years	21	40%
> 10 years	7	13%

Twice as many as expected in the category with less than ten years of experience [**YrExp**] chose both Esri and academia [**ActNow**], and in the 10-15 years range, there were also twice as many as expected choosing Google and other GIS software companies. All the interviewees with more than 17 years of experience recognized automation as a significant milestone, but this is probably due to their own experience in the field. There was also a slight significance shown between [**YrExp**] and [**MileSt1**] in which the ordinal levels of experience were fairly stratified. This significance demonstrates that almost half of the respondents indicated the Internet as the secondary milestone. Ironically, it appeared that those respondents were either much younger or much older since most of the respondents had either ten to 15 years of experience or over 25 years who selected the Internet.

Respondents with the least amount of time in managerial roles [**RYrMgr**] tended to believe data quality was the predominant negative effect of informational power [**InfoPN**], where the respondents with more than ten years were less concerned. This may be because those with more years in management roles have been in the field long enough to understand how important data pedigree is; however, having data of slight questionable integrity is better than not having any data at all. Respondents with longer tenures in managerial roles may be less concerned with the quality and are happy with just having access to data. Data integrity seemed to be a stronger issue [**OLRisk**] than loss of control or privacy for respondents in [**RYrMgr**] with more than ten years in a management role. It seemed managers were more likely to state data integrity and reliability of the service, while analysts were more likely to state something else as a risk of using online GIS services.

Essentially none of the respondents in the middle range for amount of experience, with 15-20 years, responded with better encryption or security methods for DoD solutions [**DoDSol**], as they all observed the need *only* to connect with the outside world. Both those with less experience and those with more were twice as likely to respond with improved network security or encryption methods. Fewer of the respondents than expected with more than ten years of experience in management saw access to information not previously available as a benefit of informational power, as they declared that in the current environment, there is already too much transparency due to GIS. The differences noted between years of experience and/or amount of time spent in a managerial role were minimal, and probably have more to do with the age difference among the participants for what the participants personally experienced more than anything else.

GIS Evolution and Roles

Roles were captured in a variety of ways in this study, as there was the direct variable for role [**Role**], but there were also variables introduced for favorite role [**FavRole**] and why that role was their favorite [**WhyFav**]. These variables were established not only to identify the role of the participant, but to also group the respondents by somewhat of a personality type.

The only real relationship identified was a loose statistically significant correlation between [**FavRole**] and the benefit of informational power to make better decisions. Most of the respondents who selected decision making as a primary benefit also enjoyed more technical roles. This is probably because those in technical roles feel successful when their analysis can be used instrumentally for making a better decision. This independent variable could easily have been segmented in more ways (e.g., GIS discipline, preferred type of analysis) to help identify other correlations had this data been collected from the participants from the onset of the study.

GIS Evolution and Group Behaviors

The research looked at similarities and dissimilarities within groups and their respective behaviors with Gouldner's (1957) cosmopolitans and locals by constructing an index variable. For the respondents who would be characterized as having the most cosmopolitan characteristics [**Cosmo**], the researcher selected responses from eight variables including sector, role, milestones, collaboration factors then, collaboration factors now, barriers then, barriers now, and perception of informational power that best represented Gouldner's ideas. An additive index variable was created using a dichotomous approach with a score of one (1) indicating the cosmopolitan characteristic was present, thus the highest potential score for the [**Cosmo**] variable was seven (7). The range of values for [**Cosmo**] was 0-6 with a mean of 2.34 and standard deviation of 1.30.

The same approach was used to construct an index variable for [**Local**], with the exception that informational power negative effects was substituted for perception on informational power. The range of values for [**Local**] was 0-6 with a mean of 1.97 and standard deviation of 1.38. The highest potential score for the [**Local**] variable was six (6). Figures 21 and Figure 22 display the index variables for [**Cosmo**] and [**Local**], respectively as a percent of the maximum that each respondent scored. Reviewing these two figures, there is no discernible difference in the distribution of responses, suggesting that the respondents, as GIS professionals, cannot neatly be categorized using Gouldner's framework.

Figure 21: [**Cosmo**] Frequency Distribution Histogram

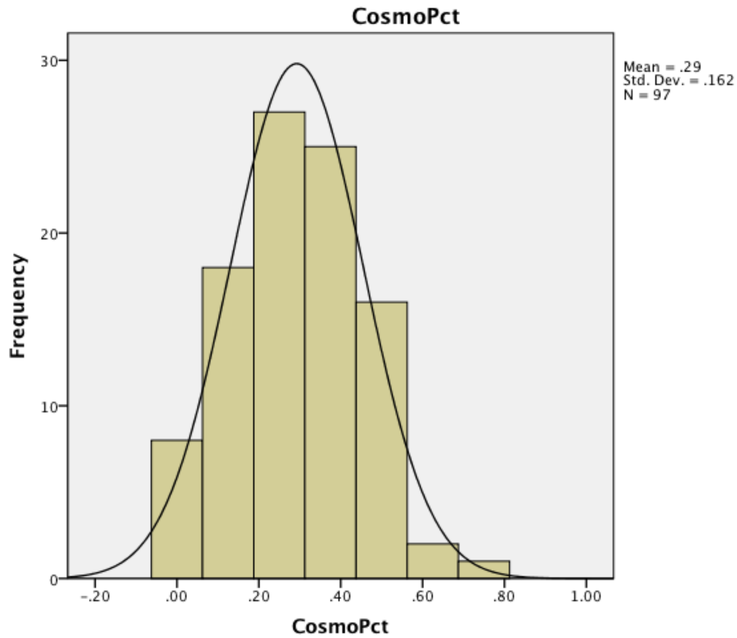
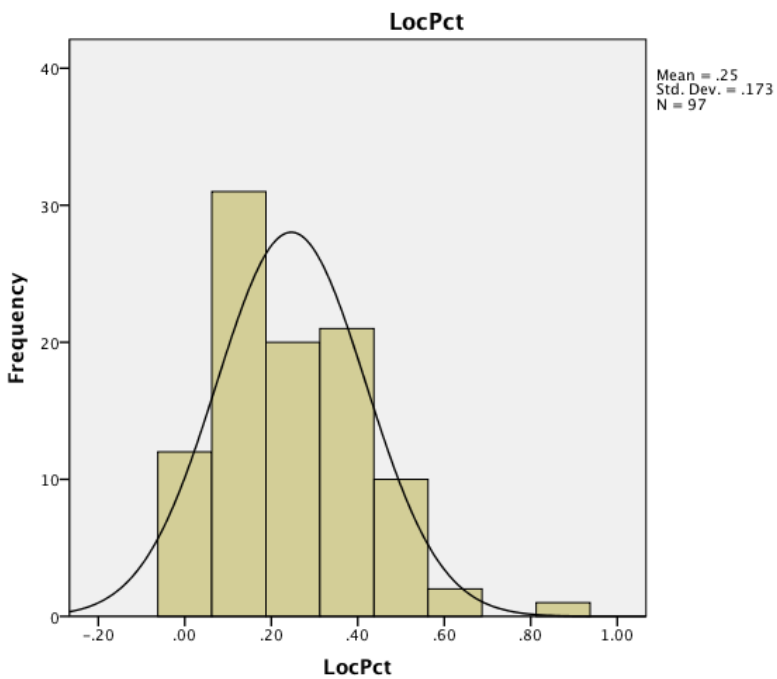


Figure 22: [**Local**] Frequency Distribution Histogram



The researcher expected to see correlations between the local [**Local**] variable and believing that automation was most significant milestone and rudimentary standards contributing most to collaboration. The researcher anticipated that due to the locals' allegiance to the government, they would have preconceived beliefs regarding informational power could provide too much information or it contributed to a lack of privacy. Potentially the local would not see lack of privacy or access to information as issues, since they are so loyal to the government. The cosmopolitan [**Cosmo**] variable was expected to describe the Internet as a more critical milestone and online communication and conferences/workgroups contributing most to collaboration. There was also expected to see a relationship between [**Cosmo**] and inaccurate results and misinterpretation for negative side effects of informational power [**InfoPN**].

Cosmopolitans are professionals in every sense of the word, with typically a significant amount of formal training contributing to their expertise. They do not appreciate people lacking true GIS skills involved in *their* field. There were no statistically significant relationships detected for the index variables [**Cosmo**] and [**Local**] with respect to the other dependent variables. There are definitely frames of references that exist for differing perceptions; however, the research found that while these roles may be applicable generally, they did not lend themselves to testing empirically as this study intended to do.

Very few respondents stated IT firms as leading actors in the field of GIS; however, they did state that developments in IT were the most significant milestone in GIS development, with automation and as collaboration factors with enhanced network communication systems allowing for GIS to proliferate. Clearly the GIS professionals participating in the study separate themselves from other professional association aligned experts. Essentially none of the respondents categorized themselves as an IT professional when discussing role descriptions. The researcher felt a strong sense of belonging and loyalty to the GIS profession from most of the respondents, especially during the interviews. Although the researcher did not collect any data on general or other professional association aligned experts, the intergroup differences between GIS professionals and these other experts would be interesting to study more in depth. Applying social identity theory (Tajfel & Turner, 1979), the GIS professional group is part of who the individuals are. Although GIS professionals use the communication systems, program data, and leverage the WWW, they do not exemplify the IT profession as much as the geographical aspect of their position. GIS professionals have contributed to meaningful changes in the IT profession and have demanded that other changes be made to accommodate; however, the end goal is minimally different. IT firms have visions like Google, and their mission "to organize the world's information and make it universally accessible and useful (Google, 2012)." While the mission of a GIS firm would be more along the lines of Esri's early mission in 1969, "to organize and analyze *geographic* information to help land planners and land resource managers make well-informed environmental decisions (Esri, 2012)." This minimal group difference for social identity theory is the *type* of information, the *end users* of that information, and what the information is used for (or *fit for use*).

GIS Evolution and Organizational Structures

Most respondents in the study felt that GIS could fit into any organizational structure, as it provides relevant, actionable information for individuals in any organization to do their job. GIS disregards chain of command in a hierarchical organizational structure and allows any size organization to scale a GIS for application. A bureaucratic organizational structure is not the most efficient way to manage a GIS since the geospatial infrastructure spans boundaries within organizations. One-third of the respondents indicated geospatial data standards, and essentially another one-third said enhanced network communication systems were the strongest contributing factors to inter-organizational collaboration. Improved decision making was seen as the primary benefit of informational power, which in essence, supports the fact that decentralization in an organizational structure allows for better decision making. Decentralization allows relevant decisions to be made at the appropriate level by the managers closest to the data. It was interesting to see that such a high percentage of the respondents still perceives people issues or lack of understanding as the most significant barrier to the progression of the field, as Google Earth and Google Maps have helped bring more awareness, but perhaps not understanding, to geospatial data.

GIS Evolution and Role of Technology

Renis Likert's (1961) linking pin theory was extended in this study, as GIS is seen as establishing this geospatial infrastructure and establishing permanence and stability for organizations and individuals to capitalize on. GIS is a linking pin fundamentally as it crosses boundaries within the organization, so individuals performing this type of work could be seen as a linking pin as well within a communication network. Communication networks have undoubtedly helped both instigate and facilitate changes within organizations. Undoubtedly enhancements in IT have allowed for integration of information and sharing of explicit geospatial knowledge. The Internet communication system has helped share information, and it also makes it discoverable and retrievable.

GIS, when internalized with business processes and functions, aids in reengineering an organization. It can help facilitate change management in a way like no other IT system, as it provides transparency to the data when visualized geospatially. Most would agree that GIS helps promote understanding of the information and why a change should occur or how a business process could be improved. GIS promotes decentralization within an organization, as coupled with IT, it gets the information to the users or decision makers who would benefit most from the knowledge. The two predominant responses as to how to promote GIS within the respondent's organization as the environment evolves were demonstrating GIS with real-world examples and integrating efforts with IT. The more IT progresses, the more GIS will continue to evolve. It is essential for GIS to remain or become integrated with IT in order to leverage the technology most effectively. Additionally, any time true geospatial analysis or statistics can be performed to show people throughout the organization how to apply GIS for cost savings, etc. – GIS will show its true value.

CHAPTER SEVEN: SUMMARY AND THEORETICAL CONCLUSIONS

The objective of this exploratory study was to observe in detail how GIS has evolved as a professional field. Similar to what is reported in the extant literature, the participants in this study confirm that the evolution can be divided into three main phases: innovation, integration, and proliferation. Nine different research questions were tested to put this evolution into context and identify key factors that have and will continue to influence the evolution of GIS.

Responses to the Research Questions

Research Question 1: What are the perceived significant milestones in GIS development?

The most significant milestones identified in the progression of GIS as a professional field in this study were (1) automation, (2) enhances in software, and (3) the proliferation of the Internet.

Research Question 2: Who have been the leading actors in GIS development?

Jack Dangermond and Esri were the most acknowledged leading actors in GIS development; however, others identified were other GIS software companies, the U.S. Federal Government, and Google. Additionally mentioned were those from academia, GIS consortiums, GPS firms, and satellite imagery companies.

Research Question 3: Have the nature of relationships and collaboration between many of the primary actors changed over time?

Most respondents believe that collaboration is good currently, and that it has improved over time. Most attribute the improvements to geospatial data standards and enhanced network communication systems.

Research Question 4: What are the opportunities/benefits and risks/challenges in exploiting and consuming free commercially available services?

Opportunities and benefits seem to again be the ability to make better decisions and have better situational awareness through capitalizing on the freely available, online GIS services. The primary risk and challenge associated with online services was data integrity. With questionable data integrity, there is potential for misinterpretation and inaccurate results derived from the analysis.

Research Question 5: What have been the barriers or sources of resistance over time in GIS development and evolution?

The most significant barrier described was lack of understanding or human factors both then and now. Other barriers included lack of data, technology (or computer power), and high costs – especially for startup in the past.

Research Question 6: What are the issues the DoD may be required to overcome to capitalize on the freely available online GIS services, which is the direction in which the field is trending?

The DoD has secure networks for protecting information, and allowing access to this information defeats the purpose of the established networks. There has been direction as the highest levels within the DoD to build and support an IT infrastructure which would be conducive to providing access to data and transferability between the networks, while not compromising the classified information.

Research Question 7: Does an advanced technology like GIS fit into a bureaucratic, hierarchical organizational structure like the DoD?

The respondents believe that GIS can fit into any organization, so a bureaucratic one would be no different. GIS inherently spans across boundaries within organizations. GIS helps decentralize information and allows decisions to be made most effectively at the appropriate levels.

Research Question 8: How does "informational power," which is enhanced by GIS, affect decision making in DoD organizations?

Improved decision making was the main response attributable to informational power as it decentralizes the information and allows the data to be seen by decision makers for the respective area. Advances in IT have helped GIS enact Emerson's General Dependency Postulate, reducing dependencies on one information source, allowing access, and creating less of a relative advantage since GIS has allowed information to propagate out to the masses.

Research Question 9: Are there fundamental significant differences between GIS professionals in the private sector versus the DoD?

There are definitely frames of references that exist for differing perceptions between sectors; however, the local and cosmopolitan index variables for group behaviors between private and federal sector were not empirically supported by the statistical results. Categorization may be possible utilizing alternate theoretical approaches, like social identity theory or comparing a group of GIS professionals to an external group.

Practical Implications and Theoretical Contributions of the Study

The researcher applied group behavioral theories and compared nuances between subgroups within the overall population of GIS professionals. This research determined that there are distinct qualities in a GIS professional that distinguish them from other professional association aligned experts. There appears to be a unique quality regarding the individuals and their passion for this profession that makes them a little different, and this study described those differences and how they contribute to the growth and development of GIS as a professional field.

Though the "information systems" component of GIS makes it a sub discipline of the ever evolving IT field, most GIS professionals would agree that the geographic element is a much stronger aspect of their chosen profession. This researcher confirms there may be approaches to categorization of GIS professionals by various qualities exhibited, especially between those coming from the private and the government sector. Initially, it appeared most technical, problem-solving GIS professionals were cosmopolitans (Gouldner, 1957), referring to an inner circle of other professionals, with the same education and institutionalized training, both internal and external to their respective organization. While the researcher tried to infer this categorization between those coming from the government and private sector, it was apparent that the profession or social identity (Tajfel & Turner, 1979) is much more within the individual, regardless of sector. There may be some slight connection to the government or DoD, but NGA appears to offer that which a private sector organization offers: autonomy, prestige, and professional association, which are characteristic of the profession as a whole. The distinction between locals and cosmopolitans theorized by Gouldner (1957) didn't play a significant role either in classifying the sub groups. This connection with the profession and role, in lieu of the organization or management within it, leads to better collaboration and rapport with the outside world of other GIS professionals.

There was discussion about having an internal champion to help promote GIS and assist in the innovation adoption (Rogers, 1962) process. Although GIS has been significantly influenced in its evolution by enhancements in IT, most GIS professionals would agree that GIS does not fall under IT. It is a separate entity. GIS professionals, though similar to other professional association aligned experts in the technical and complex technologies in which they manage, are fundamentally different. GIS professionals tend to identify more with one another and self-categorize than they do with other IT professionals – perhaps due to the vastness of the general IT profession. For example, many GIS professionals publish web map services, but they do not consider themselves to be a web developer. They are a GIS professional. While the IT profession has Microsoft’s Bill Gates and Apple’s [former] Steve Jobs, as the fervent champions of the technology, the GIS profession is fortunate to have Jack Dangermond, founder and president of Esri, as their evangelical leader. With Jack’s vision, ArcGIS software, and the annual Esri UC, his contributions and efforts to the profession are unequaled.

There was an expectation to see more dialogue and inclusions regarding the contribution the DoD has made on the technology and for R&D in GIS; however, fewer than expected discussed these contributions. This led the researcher to believe that it is possible that many of the participants do not either see the background technology the DoD has contributed to, or that they just take these developments for granted. GPS, geospatial standards, satellite imagery, and the Internet are all the expectation now.

Conceivably this is due to the DoD being a leader in the R&D of GIS; however, most of the utility and functionality has been refined and exploited in the private sector. GIS crosses organizational boundaries due to the nature of the data and systems, and it is still struggling with being integrated and leveraged as successfully in the DoD as it is in the private sector. This could be due to the placement of GIS within the bureaucratic organizational structures inherent to the U.S. Government.

It was interesting to note how established theories that were conceptualized and intended to be applied to individuals within the organization, like Likert's linking pin model, are now applied to objects or groups. Companies, e.g., software and search engines, were all seen as "actors" by the respondents, and the profession as a whole. GIS in itself could be characterized as an actor linking and providing overlap between different work units. There was also consideration by the researcher as to whether most of the respondents were truly qualified to assess and provide feedback on the organizational and professional evolution of GIS. These participants typically had formal training, licenses, and allegiance to their profession, but did they have a complete understanding of where GIS fits into the overall picture? It appeared that many live and operate within a more parochial view of the GIS, responding contextually, as in what is most relevant to them and their own corner of the world, without necessarily visualizing how it could or does fit into the global scheme of things. GIS managers and other leaders in organizations were not sought out for this study since they typically were not GIS professionals themselves; however, these individuals may have a better understanding of GIS and its application and relevance in the big picture. It would make sense to expand this study beyond GIS practitioners, as the barriers identified in this study tended to be more people issues in lieu of technical hurdles.

The lack of understanding identified as a significant barrier also had implications for enhancements to curriculum at academic institutions. In order for Geography or GIS students to help break down this barrier and be able to better communicate with management, relate to actual users of the technology, and understand how GIS fits into the big picture, the researcher recommends three focus areas for a "Management for GIS" course be included in the curriculum:

(1) Technical communication

(2) Human Computer Interface (HCI) design

(3) Economics for logistics

The technical communication component would consist of both the verbal and written communications skills, where the primary focus would be on translating technical information into ordinary language. The HCI design would consist of testing and observing "people issues" related to web sites and software development. In order for the technical GIS professionals to see the value of location or geographic placement, an economics course with a logistics component would help them understand what type of geospatial analysis would be helpful to management in making decisions.

As the research revealed, GIS continues to evolve and become more relevant in many peoples' lives. In Jack Dangermond's plenary session from the Esri UC in 2009, he stated one of the most common questions a GIS professional gets asked when looking at a digital earth is, "Can you show me my house?" This one question is indicative of a greater need for everyone to feel connected to the world or society as a whole (Dangermond, 2009). GIS provides informational power, puts the individual into the more mainstream environment, and establishes a connection to the outside world. This is the direction where GIS is heading, and there will be more and more expectations leveraged on the GIS professional to have a better understanding of the world. The world is getting smaller, and the public will want a greater understanding of the intricacies of it and what geospatial analysis can bring to the table.

Methodological Concerns or Considerations

The three qualitative methods chosen for data collection for this study helped to provide some ability for the methodological triangulation and resulting conclusions. Initially the researcher began process tracing to identify irrefutable key actors and milestones within the historical context of the study. The data collected from process tracing was then comparatively analyzed to new data collected from subjects participating in the study. The interview method was very exploratory in nature and helped ascertain themes and directions indicated by the respondents. The researcher then followed up with confirmatory interviews to help solidify these themes before moving on to developing the survey questionnaire.

There was a high degree of convergence between process tracing, the interviews, and the survey on selecting automation as the single most important milestone in the development of GIS, as the ability to be digital put the "systems" into GIS. There was a loose correlation between the qualitative method used and the actors then response noted second (after Jack Dangermond/Esri). It appeared that the interviewees were a lot more likely to volunteer other GIS software companies as leading actors then, than were those surveyed. This may be more due to a methodological difference, since interviewees were allowed to designate more than one actors then response, while the survey asked the respondent to rank the provided responses, unless the respondent textually entered more under other. Essentially the same could be said about the milestone variable, as the interviewees were not required to choose only one significant milestone, they were allowed multiple responses and typically provided them. Almost all of the interviewees mentioned the Internet – just not *first*. The propagation of GIS as services for the Internet is fundamentally the most prominent aspect of GIS currently.

The slight difference between interview and survey responses on collaboration factors now for selecting geospatial data standards could indicate the influence of the temporal context. Data standards have been established for a long period of time, and the survey asked then versus now in two distinct questions on collaboration factors in the survey, while the interviews did not take the sequential context into the question. The third highest ranked choice was user conferences and working groups for collaboration factors now with 20% of the respondents, which is consistent from those obtained for collaboration factors then. It is interesting that these percentages reflect less than half of the percentage received from the interviews that mentioned conferences and working groups for the inter-organizational structures variable; however, this may be due to the interviewees' limitless responses and lack of ranking.

Future Research

Due to the exploratory nature of this study, several things learned could be applied to future research. More demographics data could be gathered to try and categorize more accurately the independent variables and how they are influenced by demographic characteristics of the respondents. A larger sample size of local and state government could also be gathered to prevent the need for recoding due to thin cells. A higher degree of categorization based on industry specialty could also be used to categorize the respondents better, which may also help in empirically analyzing groups of GIS professionals with social identity theory or as locals or cosmopolitans. Of interest to some in the IC would be the differences, if any, between GIS (or GEOINT) professionals and other Intel analysts in the DoD. A geographical assessment component could also be incorporated to help measure the respondents' skill level, as to also better categorize the respondents' technical capabilities to group by roles.

This research explored how GIS has evolved as a professional field. The study exposed perceptions of GIS professionals from both the private and public sectors on the fit of GIS within organizational structures and its impact on communication. It recognized and categorized significant milestones in GIS, identified key actors, and acknowledged obstacles GIS has overcome in its development and evolution. Since GIS naturally spans boundaries, it appears as though the typical bureaucratic government structure has inhibited leveraging GIS in a more effective approach in the public sector. The research also identified the most important factors contributing to collaboration for GIS. The study determined that although qualities are present in GIS field that represent Gouldner's (1957) locals and cosmopolitans group behaviors, it is more difficult to empirically analyze these group categorizations. The research discussed how Tajfel & Turner's (1979) social identity theory could be applied with the minimal group differences to help categorize GIS professionals and other professional association aligned experts. This study also addressed the role of technology, including the movement to Web GIS, on the field. This study hoped to capture the uniqueness of the GIS professional and their love for this profession that makes them a little different and how it has contributed to the growth and development of GIS as a professional field.

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APPENDIX 1: INTERVIEW PROTOCOL

University of Oklahoma – Norman Campus
Institutional Review Board
Description of Study Protocol

Submission of a copy of a grant application does not replace completion of this form. Please respond to each item. Incomplete submission forms will be returned to you.

1) Click below to describe the research design of the study.

In this research design, we explore the development of the Geographic Information Systems (GIS) field and document major milestones and actors involved.

This research will consist of interviewing up to 50 GIS professionals that I know in my professional capacity from a variety of organizations based on their background and expertise in the GIS field. The interviews will consist of asking participants background information about their years of experience and specific expertise. Then they will be asked several exploratory, semi-structured interview questions.

The second stage of data collection will be an online survey found at: GIS Development as a Professional Field. If it does not work, copy and paste this into your browser:
http://oucas.qualtrics.com/SE/?SID=SV_aWfKBexIBcWwgpS

2) In the input area below, describe the recruitment procedures. Attach a copy of any material used to recruit subjects (e.g., informed consent forms, advertisement, flyers, telephone scripts, verbal recruitment scripts, cover letters, etc.) Explain who will approach potential participants to request participation in the research study and what will be done to protect the individual's privacy in this process.

The PI will contact the participant over the phone and/or in person (recruitment script #1) or via email (recruitment script #2) and request participation in research study. The participants' addresses and contact information are publicly available, and the PI knows the participants through personal and professional network. The PI will use a snowball sampling technique asking them for referrals to any other GIS professionals.

At the time of recruitment, each prospective participant will be provided an Informed Consent form. Participants can read the informed consent form while the verbal or email recruitment process occurs and participants will be able to elect their preferred level of elements of confidentiality, including: Consent (or not) to being quoted directly and consent (or not) to have name reported with quoted material. They will also be able to refuse audio recording of interview. Participants will be allowed time to ask questions before data collection begins. There is no compensation or inducements in this study.

For the anonymous, online survey, the participants will be drawn from the list of 500 participants at the Intelligence Community (IC) section of the Esri conference in San Diego in the summer of 2011. The email recruitment message with the website link will be sent to the section chair who will forward to the list of approximately 500 GIS experts at the conference drawn from the public, private, consulting and not for profit sectors.

3) Below, list and describe the tasks that participants will be asked to perform, including a step-by-step description for each procedure you plan to use with your subjects. Provide the approximate duration of subject participation for each procedure.

Listen to verbal recruitment or read email recruitment, read informed consent form and ask questions (5 minutes).

Participants will be asked background questions to get them to talk about themselves and get comfortable with the idea that they are experts that have something important to say (5 minutes).

Participants will then be asked the several exploratory, semi-structured interview questions according to the attached interview protocol. (20 minutes)

The general approach will be to ask the participants to describe the facts, why they believe the facts are facts, and their respective opinions.

After reading an information sheet, the participants will complete an anonymous, online survey at the qualtrics.com website.

4) Describe your data collection procedures. If data collection instruments will be used, indicate the time necessary to complete them, the frequency of administration, and the setting in which they will be administered, such as telephone, mail, or face-to-face interview. (You must submit a copy of each study instrument, including all questionnaires, surveys, protocols for interviews, etc.)

Data collection will be conducted through face to face interviews lasting no more than 30 minutes.

The anonymous, online survey has 17 questions and can be completed in 15 minutes. It will be completed one time at the location of the participant's choosing.

5) Click below and provide background information for the study including the objective of the proposed research, purpose, research question, hypothesis and other information deemed relevant. Include up to 5 references from the literature.

The objective of the proposed research is to better understand the development of Geographic Information Systems (GIS) as a professional field. The ultimate goal of this research study is to provide recommendations on how to promote the technology of GIS as the environment evolves and moves forward. This study will explore the following hypotheses:

Ha1: Key actors involved in the development of GIS as a professional field include members from private, public and commercial sectors.

Ha2: The milestones in the GIS field have typically been initiated by the government and exploited by private or commercial sectors.

Ha3: "Informational power," which is enhanced by GIS, affects positively decision-making.

The development of GIS as a professional field will be explored in a temporal context. The most appropriate and effective organization structure for the development of the GIS technology will be explored. The research will also address challenges/risks and opportunities/benefits to capitalizing on GIS development.

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APPENDIX 2: QUALTRICS SURVEY

GIS Development as a Professional Field

Q10 Good day, I am Tara Mott, a PhD candidate in the Political Science Department at the University of the Oklahoma. I am requesting that you participate in a research study titled "Evolution and Development of GIS as a Professional Field". You were selected as a possible participant because of your association in the field of GIS and your experience with the DoD.

Purpose of the Research Study: The purpose of this study is to quantitatively validate and assess results on the development of GIS as a professional field.

Procedures: If you agree to be in this study, you will complete a survey after reading this page.

Length of Participation: Less than 15 minutes.

Risks and Benefits of Being in the Study: The study has no risks or benefits.

Compensation: You will not be compensated for your time and participation in this study.

Voluntary Nature of the Study: Participation in this study is voluntary. Your decision whether or not to participate will not result in penalty or loss of benefits to which you are otherwise entitled. If you decide to participate, you are free not to answer any question or discontinue participation at any time without penalty or a loss of benefits to which you are otherwise entitled.

Confidentiality: Your responses are anonymous. The records of this study will be kept private and your supervisor will not have access to your responses. In published reports, there will be no information included that will make it possible to identify you as a research participant. Research records will be stored securely. Only approved researchers and the OU-NC IRB will have access to the records. Contacts and Questions: If you have concerns or complaints about the research, please contact me at + 49 171 216 3171, or tara_mott@ou.edu. You can also contact my faculty supervisor, Dr. Aimee L. Franklin at 405-325-5216 or alfranklin@ou.edu. In the event of a research-related injury, contact the researcher(s). You are encouraged to contact the researcher(s) if you have any questions. If you have any questions, concerns, or complaints about the research or about your rights and wish to talk to someone other than the individuals on the research team, or if you cannot reach the research team, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at (405) 325-8110 or irb@ou.edu. Please print this page for your records.

- ❍ Yes, I will take this survey. (1)
- ❍ No, I will not take this survey. (2)

If Disagree Is Selected, Then Skip To End of Survey

Q3 Which milestone do you believe has made more of a difference in the evolution of GIS as a professional field?

- ❍ Manual to electronic cartography (1)
- ❍ Availability of the Internet to expose GIS services (2)
- ❍ Other: Please describe in the text box below. (3) ____________________

Q17 When you began working primarily in the GIS field, who were the leading actors in the development of GIS? Type your response in the text box below.

Q4 At this time, who are the leading actors in the development of GIS? Rank in order from 1 as the most significant contributor to 5 as the least significant contributor. To rank the actors, just click and hold on their name and drag the row to the proper position.

______ Roger Tomlinson (1)
______ Jack Dangermond/Esri (2)
______ Google (3)
______ US Government (4)
______ Other: Please type in another actor. (5)

Q5 True or False: Collaboration is better now than in earlier years between organizations/individuals doing GIS work.

- ❍ True (1)
- ❍ False (2)

Q18 When you began working primarily in the GIS field, which factors did you see as contributing the most to increased collaboration between organizations/individuals in the GIS field? Type your response in the text box below.

Q6 At this time, what has been the greatest factor contributing to increased collaboration between organizations/individuals in the GIS field? Rank in order from 1 as the greatest collaboration factor to 5 as least collaboration factor. To rank the factors, just click and hold on the words and drag the row to the proper position.

______ Data Standards (1)
______ Blogs/Online Communication (2)
______ User Conferences/Workgroups (3)
______ Enhanced Network Communication Systems (4)
______ Other: Please type in another factor. (5)

Q19 When you began working primarily in the GIS field, what do you think was the most significant barrier to the development and evolution of GIS? Select one choice from the following list.

- ❍ Lack of understanding/people issues (1)
- ❍ Technology (2)
- ❍ Lack of standards (3)
- ❍ Data Availability (4)
- ❍ Other: Please describe in the text box below. (5) ____________________

Q1 At this time, select from the following list the most significant barrier to the development and evolution of GIS.

- ❍ Lack of understanding/people issues (1)
- ❍ Technology (2)
- ❍ Lack of standards (3)
- ❍ Data availability (4)
- ❍ Other: Please describe in the text box below. (5) ____________________

Q2 Select from the following list the greatest detriment to using freely available online GIS services.

- ❍ Data Integrity (1)
- ❍ Reliability of service (2)
- ❍ Loss of control/privacy (3)
- ❍ Other: Please describe in the text box below. (4) ____________________

Q7 When you hear the phrase "informational power," would you characterize it as positive or negative?

- ❍ Positive (1)
- ❍ Negative (2)
- ❍ It Depends: Please describe the conditions that influence your characterization below. (3) ____________________

Q8 What would you consider to be the primary benefits of "informational power"? Check all that apply.

- ❑ Increased transparency (1)
- ❑ Ability to make better decisions (2)
- ❑ Access to information not previously available (3)
- ❑ Improved situational awareness (4)
- ❑ Other: Please describe in the text box below. (5) ____________________

Q20 What would you consider to be the primary disadvantage of "informational power"? Type your response in the text box below.

Q9 What are the main issues for closed (internal or classified) DoD networks for capitalizing on Web (cloud) GIS or mobile GIS? Check all that apply.

- ❑ Inability to access data from a closed system (1)
- ❑ Lack of interoperability between systems (no DoD wide solution) (2)
- ❑ Reliability of services within DoD (no commercial incentive to continuously provide services) (3)
- ❑ Other: Please describe in the text box below. (4) ____________________

Q11 How would you suggest the DoD overcome these issues in order to benefit from the direction GIS is evolving towards?

Q12 How many years have you worked in the GIS field?

- ❍ Less than 10 (1)
- ❍ Between 10 and 15 (2)
- ❍ Between 15 and 20 (3)
- ❍ Between 20 and 25 (4)
- ❍ Greater than 25 (5)

Q13 How would you characterize the primary sector in which you have worked in the GIS field?

- ❍ Private/Commercial (1)
- ❍ Local/State Government (2)
- ❍ DoD/Federal Government (3)
- ❍ Other: Please describe in the text box below. (4) ____________________

Q14 Which role best describes you?

- ❍ GIS Manager (1)
- ❍ GIS Analyst (2)
- ❍ Other: Please describe in the text box below. (3) ____________________

Q15 How many years have you spent in each of these roles/positions?

______ GIS Manager (1)
______ GIS Analyst (2)
______ Other Position (3)

APPENDIX 3: ACRONYM & ABBREVIATION DICTIONARY

APA – American Psychological Association

BIA – Bureau of Indian Affairs

BLM – Bureau of Land Management

BRAC – Base Realignment and Closure

CAD – Computer Aided Drafting

CGIS – Canada Geographic Information Systems

CIO – Chief Information Officer

CSA – Combat Support Agency

DIA – Defense Intelligence Agency

DLA – Defense Logistics Agency

DMA – Defense Mapping Agency

DoD – Department of Defense

DSS – Decision Support System

ELAS – Earth Resources Laboratory Applications System

ERDAS – Earth Resource Data Analysis System

EROS – Earth Resources Observation and Science

Esri – Environmental Systems Research Institute, Inc.

FGDC – Federal Geographic Data Committee

FWS – Fish and Wildlife Service

GDSC – Geographic Data Service Center

GEOINT – Geospatial Intelligence

GIO – Geospatial Information Officer

GIS – Geographic Information Systems

GI&S – Geospatial Information & Services

GPS – Global Positioning System

GRASS – Geographical Resources Analysis Support System

GUI – Graphic User Interface

IC – Intelligence Community

ICAO – International Civil Aviation Organization

IMS – Internet Mapping Systems

INSPIRE – Infrastructure for Spatial Information in Europe

IRB – Institutional Review Board

IT – Information Technology

NASA – National Aeronautics and Space Administration

NCGIA – National Center for Geographic Information & Analysis

NEPA – National Environmental Policy Act

NGA – National Geospatial-Intelligence Agency

NIMA – National Imagery and Mapping Agency

NPS – National Park Service

NSDI – National Spatial Data Infrastructure

NSF – National Science Foundation

O&M – Operations & Maintenance

OGC – Open Geospatial Consortium

OPSEC – Operational Security

OSM – OpenStreetMap

PARC – Palo Alto Research Center

PC – Personal Computer

R&D – Research and Development

ROI – Return on Investment

SAGIS – System Applications Group Information Systems

SCIF – Sensitive Compartmented Information Facility

SDE – Spatial Database Engine

SDSFIE – Spatial Database Standards Facilities Infrastructure and Environment

SLA – Service Level Agreement

SME – Subject Matter Expert

SOA – Service-Oriented Architecture

SPSS – Statistical Package for the Social Sciences

SYMAP – Synagraphic Mapping Package

TIGER - Topologically Integrated Geographic Encoding and Reference

UC – User Conference

USACE – U.S. Army Corps of Engineers

USGS – U.S. Geological Survey

URISA – Urban and Regional Information Systems Association

VTC – Video Teleconferencing

WWW – World Wide Web