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University of Redlands

**Modeling Television & Radio Broadcasting System Infrastructure within  
a Prototype Enterprise Geospatial Information System**

A Major Individual Project submitted in partial satisfaction of the requirements  
for the degree of Master of Science in Geographic Information Systems

by  
Daniel Kaare Flatla

Douglas M. Flewelling, Ph.D., Chair  
Mark P. Stewart, M.S.

August 2008



Modeling Television & Radio Broadcasting System Infrastructure within a Prototype  
Enterprise Geospatial Information System

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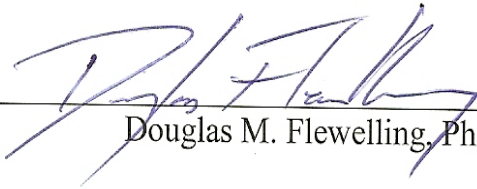




The report of Daniel Kaare Flatla is approved.

A handwritten signature in blue ink, appearing to read "Mark P. Stewart", written over a horizontal line.

Mark P. Stewart, M.S.

A handwritten signature in blue ink, appearing to read "Douglas M. Flewelling", written over a horizontal line.

Douglas M. Flewelling, Ph.D., Chair

August 2008

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Thirty years from now in 2038: *"So there I was! Trapped in Redlands! Drinkin' Kool-Aid..."*

## ABSTRACT

### Modeling Television & Radio Broadcasting System Infrastructure within a Prototype Enterprise Geospatial Information System

by

Daniel Kaare Flatla

Since the beginning of the modern American Intelligence Community apparatus, the need to understand how people communicate via their media has been important. The need to locate television and radio infrastructure and the extent of effects have been required in government to learn about the understandings, feelings, and values of other cultures to support clear and thoughtful communication with other nations. The Open Source Center (OSC) within the Office of the Director of National Intelligence has monitored global media sources for almost seventy years, and recently has begun to locate and analyze the geographic extent and effects of these sources. This report describes the creation of a prototype geographic information system which models the television and radio broadcast system infrastructure and broadcast areas of OSC sources. The project reviewed the social and interactive processes of media to learn about the spatial relationships between objects such as stations, towers, broadcast transmitters, and owners within the broadcasting system. The project prototyped a GIS which modeled these features and relationships in a ESRI-based geodatabase. The prototype utilized the ArcGIS suite of tools from ESRI to perform database management, analysis, and to implement Web-based Open Source Consortium Web services. The resulting prototype GIS provided OSC a platform which it could learn from and later implement.



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## List of Acronyms & Terms

ADO.NET	Microsoft Active Data Objects for the .NET Framework
AFIF	NGA Aeronautical Flight Information File
Arc2Earth	ArcGIS Software Extension to Export GIS Data to Google Earth
ArcGIS Desktop	ESRI Desktop-based GIS Software
ArcGIS Server	ESRI Server-based GIS Software
ASP.NET	Microsoft Active Server Pages for the .NET Framework
BBC	British Broadcasting Corporation
BBCM	British Broadcasting Corporation Monitoring Service
BigTable	Internal Google Application
CIA	Central Intelligence Agency
COMPASS	Map Library Catalog Management Database
CSPT	Communication Systems Planning Tool
dBi	Decibel
DBMS	Database Management System
DOD	U.S. Department of Defense
DreamSpark	Microsoft Student Discount Software Program
DTED	Digital Terrain Elevation Dataset
ERP	Estimated Radiated Power
ESRI	Environmental Systems Research Institute, Inc.
FBIS	Foreign Broadcast Information Service
FCC	Federal Communications Commission
FOCAL	Canadian Foundation for the Americas
GAO	Government Accountability Office
GEOINT	Geospatial Intelligence
GeoMedia	GIS Software
GeOS	OSC Geospatial Online Services
GIS	Geographic Information System
GML	Geography Markup Language
GRASS	GIS Software
IIS	Microsoft Internet Information Server
Intelink-U	A Government Computer Network
ISO	International Standards Organization
KML	Keyhole Markup Language
KMZ	Keyhole Markup Language–Zipped
LandScan	A Population Data Product from Oak Ridge National Laboratory
LTC	Lieutenant Colonel
Manifold	GIS Software
Mapstraction	Web-based Map Viewer

Mapufacture	Web-based Map Viewer
Microsoft SQL Server	Database Management System Software
MMA	Mapping the Media in the Americas Project
MS GIS	University of Redlands Master's of Science in Geographic Information Systems Program
MSC	OSC Map Services Center
MXD	ArcGIS Map Exchange Document
NGA	National Geospatial-Intelligence Agency
NSA	National Security Agency
ODNI	Office of the Director of National Intelligence
OGC	Open Geospatial Consortium
OpenLayers	Web-based Map Viewer
Oracle	Database Management System Software
OSC	Open Source Center
OSINT	Open Source Intelligence
OSS	Office of Strategic Services
PLC	University of Princeton Listening Center
PostGIS	Open Source Spatial Data Engine Software
PostgreSQL	Open Source SQL Database Software
QA	Quality Assurance
qGIS	Quantum GIS Software
RDBMS	Relational Database Management System
SDE	Spatial Data Engine
SPLAT!	Radio Frequency Modeling Software
SRTM	Shuttle Radar Topography Mission
TagIConnect	Social Bookmarking Web Application
TFL	Tobler's First Law of Geography
TNEP	OSC Terrorism Near East Program
uDIG	GIS Software
USIA	United States Information Agency
VMWare	Virtual Machine Software
VPN	Virtual Private Network
WebADF	Web Application Development Framework
WGS84	World Geodetic System 1984
WMD	Weapons of Mass Destruction
WMS	OGC Web Mapping Service
WMS-T	OGC Web Mapping Service–Transactional

## **1.0 Introduction**

Since September 11, 2001, the United States has been engaged in what the Army calls the Long War (formerly known as the Global War on Terror) with Al Qaeda and its associates, battling to exert their military, diplomatic, and economic influence (Graham & White, 2006). The United States has been successful compared to Al Qaeda with its military operations in Iraq, Afghanistan, and Somalia where it can project power and money to try to rebuild these nations, but it lacks engagement on what was coined as the "The Fourth Front" in 1941 during World War Two (Graves, 1941) or the "struggle for the minds and wills of men" as President Eisenhower once put it (Bowie & Immerman, 1998).

Intelligence and the news report the impact Al Qaeda's As Sahab Media Center is having within Muslim countries and their ability to recruit new supporters while the United States is having difficulty to begin a successful "strategic communication" strategy to counter As Sahab's influence. It is the fourth front that encompasses social processes of media and information which influence understanding, feelings, and values. Understanding the effects of media on various cultures—as social and spatial processes—is critical for the United States to understand and to engage this fourth front.

### **1.1 The Problem**

"I believe the geospatial framework is essential to understanding and acting upon media ecology from an intelligence perspective. Finding Osama [bin Laden] may well be important but the key to the problem is really understanding how the message is delivered and how and why it affects populations, small and large, and where these populations are located. In order to drain the swamp you not only have to know where the swamp is but what are the sources of its swampiness." (P. Reid, senior OSC Editor, email, October 9, 2007).

Understanding social and cultural change is a challenging task for all aspects of government and the Open Source Center (OSC) is no different. Its partners want to understand the effects of media. For instance, an open source intelligence analyst who uses publicly available compared to classified information is researching a businessman turned politician in Iraq. The analyst finds information about the politician, and his family, who are known to own a television station and a radio station in a city in Kurdistan. The analyst wants to know the impact of the man's media ownership on the surrounding population. Did it affect voting habits, purchasing habits, women's rights, or civil order in the politician's media sphere? Currently, OSC can manually place the pieces of this puzzle together in the form of textual reports, stringing together hundreds of information sources. This results in analysts printing out and stacking report upon report on their desks and forcing them to perform an exercise in paper management to link content together to identify key concepts and relationships in their research.

"[...] My biggest problem was volume, context, source and intended audiences... basically the "so what" of the story." (LTC W. Riggs, U.S. Army, U.S. Joint Information Operations Warfare Command, email, October 12, 2007)

The problem for those studying media environments at OSC and elsewhere is rather a matter of storage, retrieval, and updating of local events and sources of information, not a matter of content. They require a means to locate and discover spatial and social relationships. LTC Riggs, as a typical consumer of open source intelligence, spent four to six hours per day culling through a volume of information consisting of news, rumors, and intelligence reports that were overwhelming. Users have the challenge to connect their sources, influencers, and the events of the day to maintain situational awareness to support their superiors' decision making processes. The U.S. Government has

applied systems for information acquisition problems years ago with systems designed to manage and store text documents; today the problem is a matter of discovering the "so what" users are trying to acquire from government information systems. With even larger databases of event reporting in cultural spaces coming online, and a larger push to collect "human terrain" data in the future, information overload may cause analysis to grind to a snail's pace. Because of the time and resources required to sort through that information, the future outlook doesn't make a typical user's job any easier.

## **1.2 The Client**

The primary client for this project was the Open Source Center in Reston, Virginia. The mission of the Open Source Center is to monitor and analyze publicly available information. Specifically, the Open Source Center analyzes international media such as press, broadcast, geographic information, and other forms of public communication. The OSC provides support to senior policy makers and to the U.S. Intelligence Community regarding current events and detailed research. The client requested the design of a prototype enterprise GIS to enable its staff to model the infrastructure and phenomena of television and radio broadcast systems. The client intends to explore the application of an enterprise GIS to enhance its methods of collection and analysis to support its clients.

## **1.3 Audience**

This paper is intended to be for Open Source Center personnel such as managers, engineers, and analysts who are involved with OSC's media sourcing activities. It is also intended for OSC's partners: BBC Monitoring Service, and employees from the U.S.



Departments of State and Defense who are involved with international public diplomacy programs. Military personnel who are also involved with information operations, open source intelligence, public affairs, human terrain analysis, and civil affairs will find this document as a supplement to support counterinsurgency operations per needs in Army Field Manual 3-24 (U.S. Army, 2006a).

#### **1.4 Scope**

The scope of the project focused to develop prototype GIS architecture around the Environmental Systems Research Institute's (ESRI) geodatabase technology. The project's scope included the development of a basic analytic component to provide users the ability to search for features geographically or by their attributes. The project limited itself to implementing desktop GIS and Web-based mapping tools to perform the basic analysis and query functions, as well as the editing of features in the geodatabase. Finally, the project also provided access to its geodatabase via Open Geospatial Consortium Web service standards to other GIS systems to support inter-agency collaboration.

The project's intended timeframe of completion was eleven or twelve months, which it takes to complete the MS GIS program at the University of Redlands. Project resources were also constrained to hardware and software provided by the University of Redlands, the client, and ESRI. The study area was also constrained to the television and radio media infrastructure within the country of Iraq due to the availability of data from OSC's previous work.

Limitations to the scope of the project did not allow for content analysis, or the typical analysis of media content conducted by OSC and its partners. The project scope

was constrained to modeling the media infrastructure of Iraq (Figure 1) with data provided by the client and not to discover or collect any data. The basic overlay analysis included limited information from country-level population density, tribal and ethnographic data sources. While more complex analysis could have been conducted, it was not within the scope of this project as additional resources would have been required to collect more precise geodemographic data for Iraq.



**Figure 1. Map of Iraq.**

## **1.5 Solution**

The project explored methodologies which support media researchers and analysts in understanding international media and culture with the creation of a geodatabase to model the infrastructure of television and radio. The places of distribution were modeled to assist in furthering the examination of complex social impacts the media has on society. The project took into account various organizations' media monitoring activities and data to model media sources in Iraq, to deliver a prototype geodatabase for global access to the OSC and its partners. The application of the GIS tools created in this project helped to manage and describe the infrastructure and the electromagnetic areas of broadcast systems. Tools such as the Department of Commerce's Communication Systems Planning Tool (CSPT) were used to model the electromagnetic propagation of transmissions areas of these systems to support visualization and analysis. These elements contribute to the spatial analysis of media and identifying factors contributing to a culture's identity and ideas.

The project architecture supports the enterprise need of the OSC by focusing on common features and attributes that describe the terrestrial television and radio environment. The project creates a number of basic analytic models and tools to calculate values of media penetration within a country or market. Although the analytic output is quantitative and describes the patterns of media and cultures, it is by no means indicative of the processes of media and society that are occurring in the study areas. The project's basic analytic components assist with the discovery of spatial patterns that can help inform

research on the advanced, complex analyses of the social, cultural, and psychological processes that factor into studying media environments.

## **1.6 Outline**

This paper outlines the project and partnership with the OSC to prototype a GIS architecture demonstrating the capability of an enterprise GIS. The goal was demonstrate the capabilities of an enterprise GIS to enable OSC and its partners to collect and aggregate information about the physical infrastructure of media sources to further understand the role of media by using spatial methods. The application of GIS to study media is intended to identify the places of media OSC and the Intelligence Community collect, thus allowing users to apply spatial methods and information to identify the effect of the media sources they monitor.

The project studied the spatial characteristics and the relationships of media infrastructure to create a data model the utilizing ESRI ArcSDE geodatabase technology. The model focused on storing the location of radio and television stations, along with their related transmitters and towers. Stations and towers were stored as points. Transmitters, owners, managers, and alternative names were stored in tables. Relationship classes connecting the features and tables to one another were the primary reason for using ArcSDE to emphasize the interconnectedness of the infrastructure. ArcGIS technology allows for specific behavior, such as relationships, to be stored in the geodatabase allowing stations, for example, to be linked to multiple transmitters on specific towers. The infrastructure behaves in a particular way that is best suited for an object-relational database management system such as ArcSDE and Microsoft SQL Server 2005. Also, the

utilization of this technology in the project was intended to be an example of how common commercial hardware and software could be applied and potentially be transferred to OSC after the project's completion.

The project's efforts resulted in the design of a system architecture that included workflows around a geodatabase to store a media infrastructure model and associated data. The project design was prototyped using university and client resources such as servers, software, and data. A geodatabase was successfully created that ArcGIS desktop users could connect to using a direct connection protocol or an Internet protocol feature. The geodatabase was also accessible to other GIS clients via Open Geospatial Consortium Web services. Web-based applications, such as an editing tool and a viewer, were created. The Web-based editing application was limited to editing simple geographic features, such as points, where this shortfall in the ArcGIS Server technology was mitigated using ArcSDE's geodatabase versioning feature. Workflows for users were created to integrate the users, the technology, and the data together to form the prototype system.

## **1.7 Summary**

This paper discusses the creation of a prototype GIS to model media infrastructure. The project's background is discussed in chapter two and provides a discussion of the organizations and the history involved with modeling media infrastructure. Chapter two also lays out the concepts involved with the geography of media, social scientific research, and the complexity that involves society and media. Chapter three discusses how the project was managed and how design decisions were made. Chapter four is a discussion on the construction of the project and how it was physically created. The project results are

presented in the fifth chapter, focusing on the outcomes of system testing and operation. The paper concludes with chapter six where recommendations, follow-on projects, and alternative technologies are discussed.



## **2.0 Background**

### **2.1 The First Sixty Years**

Radio was in its infancy at the time of the Second World War. The Axis and Allies each used this medium to influence their enemies and potential allies around the globe with propaganda intended to lead, or counter, aggression in enemy countries. Broadcasts from Germany could be heard in Britain and the United States; British broadcasts could be heard in Africa, the Americas, and across Europe. Radio "annihilated" space, but also expanded it at the same time (Debord & Knabb, 2005). This war for the "minds and wills of men" (Bowie & Immerman, 1998), created what one American broadcaster (CBS) called the Fourth Front (Graves, 1941).

Propaganda was directed to specific audiences, but broadcast to everyone and little was known about how to engage this new front. How radio propaganda affected the target populations was unclear. Most countries who broadcasted propaganda had only a vague idea how to direct their radio waves at the country they wished to influence, and increasing their power to reach their intended audiences. Broadcasters also had listening posts around the world, to identify enemy propaganda for their own counter-propaganda broadcasts (Graves, 1941; Mercado, 2001).

Radio proved to be a powerful propaganda tool which warranted study. In the 1930s the Rockefeller Foundation funded The Radio Project supporting sociology, anthropology, political science, and journalism programs at Princeton University, and later Columbia University, to study the impact of radio. The leading media researchers at the time who started the field, Paul Lazarsfeld and Leo Lowenthal, had migrated from the



Frankfurt Institute of Social Research to schools in the United States. Lazarsfeld was put in charge of The Radio Project at Princeton, and created the Princeton Listening Center (PLC) (Livingstone, 1997). The PLC was formed to monitor and understand this new medium, detailing the extent and impact on those for whom the message is intended and not intended (Princeton University, 2006). Other aspects of The Radio Project focused on audience psychology and sociological studies of audiences, while the PLC analyzed media content and the medium. Employing a quirky group of world travelers and native speakers who knew the nuances of the broadcasts and the audiences (Mercado, 2001), the PLC could identify who broadcasts were intended for. The PLC also gauged the growth of media sources and the technology employed, keeping track of the direction of radio beams and their transmitting power. In his book, *War on the Short Waves*, Harold Graves (1941), the former director of PLC, provided figures about the growth of radio as a new medium around the world. He also included simple circular maps denoting the direction of BBC, Italian, and Nazi global broadcasts (Figure 2.1).



**Figure 2.1. Early Princeton Listening Center map of Italian short wave radio broadcasts from Rome during World War Two (Graves, 1941; used with permission from Questia).**

When the United States of America entered the Second World War in 1941, the PLC and CBS's monitoring activities were absorbed by the Federal Communications Commission (FCC) and renamed as the Foreign Broadcast Intelligence Service (FBIS). The mission of FBIS was to collect and monitor international media, and identify and analyze enemy propaganda; locations of new media sources and their content were passed to the Office of Strategic Services (OSS) to be countered around the world. As World War Two raged on, General William Donovan, the director of the OSS, sent compliments to the FCC director on the importance of the FBIS to war effort, and there was a direct line from FBIS to the White House. The FBIS reported the fall of Italy in September of 1943 well before the press. President Roosevelt, Winston Churchill and others gathered around a phone in the Oval Office to listen in as FBIS monitored the radio broadcast of Italian Marshal Pietro Bagdoglio declaring an armistice. It was reported that the FBIS staff could hear Churchill's jubilation in the background of the phone call (Foreign Broadcast Information Service, 1943, p. 1; Mercado).

When the war ended, the Foreign Broadcast Intelligence Service became the Foreign Broadcast Information Service (FBIS). The FBIS was transferred to the newly created Central Intelligence Agency (CIA) in 1947, where it provided basic research and "open source intelligence"—intelligence derived from publicly available sources to include television, film, radio, press, and other media. During its association with the CIA, FBIS focused on providing translations of international news. The effects of media and the geographic location of sources became less important due to the demands of the Intelligence Community to translate foreign media rather than to attempt to fully understand it, as it had during World War II. This shift in priorities created an imbalance in

the use of analysts' time between understanding in-depth the impacts of global sources and focus on the events being monitored. This shift coincided with the United States' decline in strategic communications starting in the 1960s when the declining budgets of FBIS and the U.S. Information Agency (USIA)—the federal agency responsible for international communications and the Voice of America—were almost parallel. The transfer of USIA responsibilities to the State Department in the late 1990s has been cited as one of many factors in the criticism of the United States' lack of a coordinated strategic communications program and policy to support the messages and ideas that America values (Fitzpatrick, 2008). A nation who does not listen, or understand the world, cannot effectively speak to it or vie for the minds and wills of men.

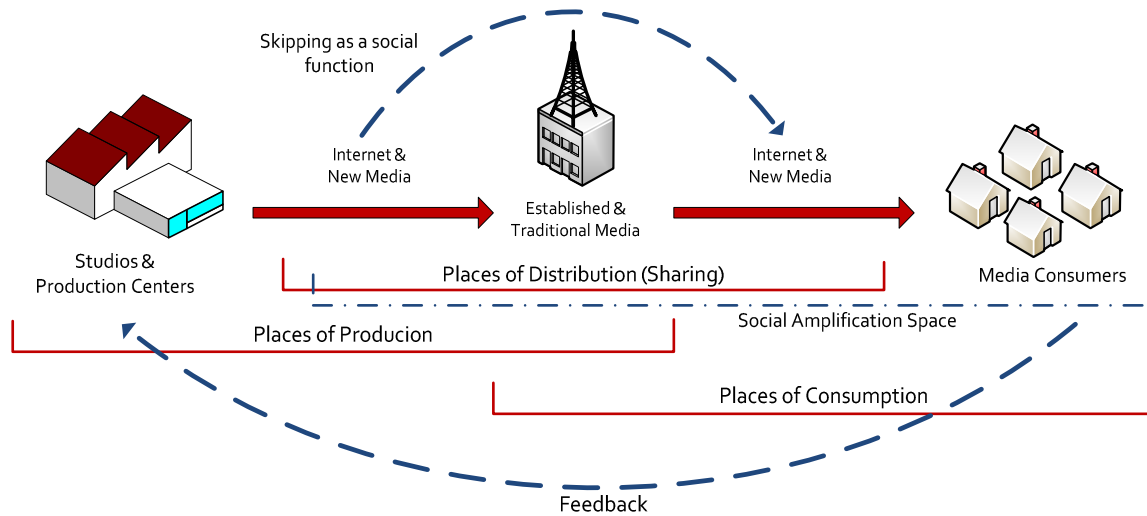
In 2005, FBIS became the Open Source Center (OSC). It remains as an office within the CIA, but is now considered a part of the Office of the Director of National Intelligence (ODNI). Association with the ODNI has expanded OSC's role in intelligence based on the 9/11 Commission and the WMD Commission reports. Open source intelligence (OSINT) is now a priority for the intelligence community, and OSC is at the forefront of leading the intelligence community in this area through educating others about how to use OSINT.

## **2.2 Geography of Media**

All media work us over completely. They are so pervasive in their personal, political, economic, aesthetic, psychological, moral, ethical, and social consequences that they leave no part of us untouched, unaffected, unaltered. The medium is the message. Any understanding of social and cultural change is impossible without a knowledge of the way media work as environment (McLuhan, Fiore, & Agel, 2001, p. 26).

The overall OSC project is attempting to re-establish the abilities that originated with PLC and The Radio Project, establishing a separate function studying international media as a whole, especially to focus on the places of production, distribution, and consumption of media. While the geography of media spaces have not been well researched (Couldry, 2001; Strate, 1999), previous media research has encompassed multiple disciplines—like sociology, psychology, and anthropology—to engage the subject in a critical manner focusing on audiences. Yet, these multiple disciplines remain segregated in academia with only a handful of researchers having managed to approach their studies with cross-discipline theories (Couldry & McCarthy, 2004; Livingstone, 1997). Only recently have the places of media been considered in media research and the work of researchers have begun to include spatial considerations that may have once been overlooked.

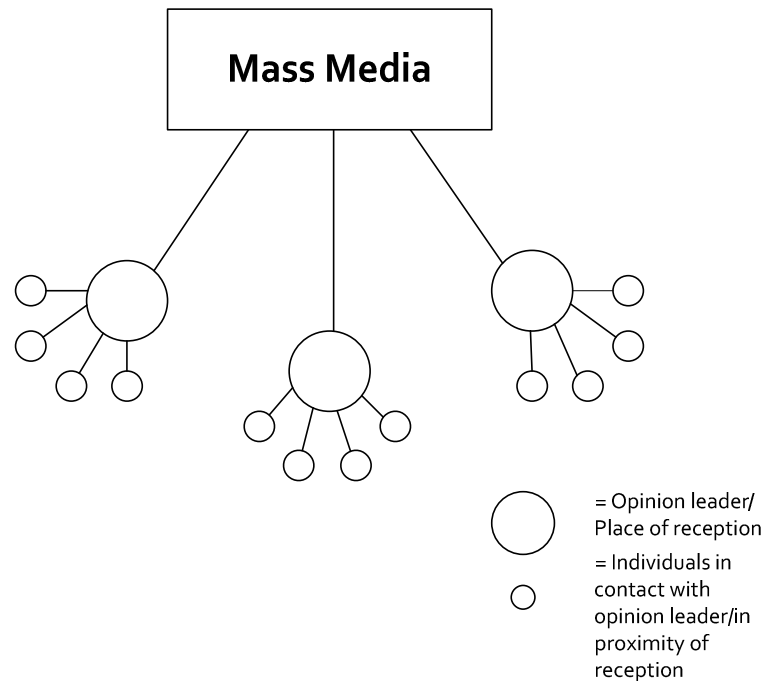
Couldry & McCarthy describe in their introduction to *Mediaspace* (2004) the five levels of media space: These levels include the representation of media space; the flow of data and how media space is reconfigured; the specific places at the ends of spectrum of media space (production and consumption spaces); the effects and complexity of geographic scale; and finally how media is understood at various scales (Figure 2.2). Understanding the geography of media contributes to representing media at different scales, applying a level of complexity that is not normally addressed in most listenership or audience studies. The relationships between source and receiver contribute to the flow of information and directly to their effects spatially.



**Figure 2.2. Geography of media. The social aspects of media, production, distribution, and consumption, occur in space**

In many studies Tobler's First Law of Geography (TFL), "Everything is related to everything else, but near things are more related than distant things" (Tobler, 1970, p. 236), could be applied to media research. Researchers often describe social processes spatially without knowing the effects of geography on media. For example, there is the separation between producer and consumer, where the places of production, like studios, are separate from the consumer's locale. The workplace or barber shops are other examples of the spatial aspect of the social process of media which are evoked (Ossman, 2004). In these places, personal, cultural, and historical factors apply to discussions about consumed media, which either amplify or dampen the effect at the local level of social space. This effect was modeled by Katz and Lazarsfeld (1955) with a Two Step Flow theory where the mass media is first received by opinion leaders, and secondly individuals in proximal social contact are influenced by the opinion leader. The social factors of influence then act according to geographic, social, cultural, and historical factors within the group of individuals. The Two Step Flow Model (Figure 2.3) focuses on social aspects, but is

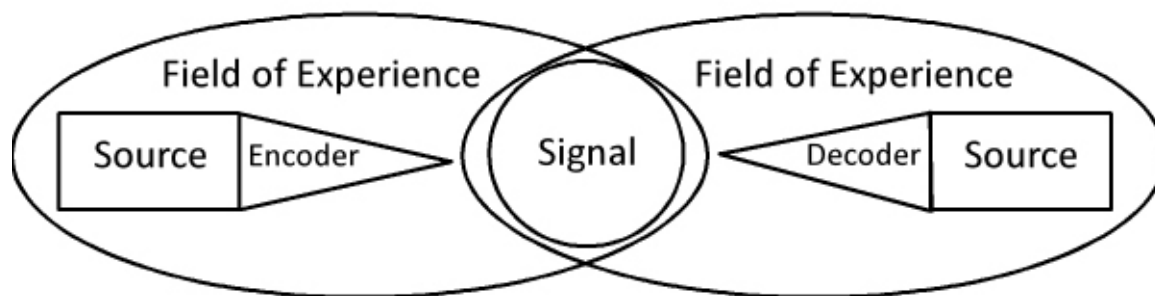
dependent upon proximity to media and interpersonal relationships rather than accepting previous assumptions that media had a direct effect on those it touched (Katz & Lazarsfeld, 1955). Applying TFL to the model, influence decays over distance—social, geographic, or temporal.



**Figure 2.3. Two-step influence model (Katz & Lazarsfeld, 1955)**

There are at more than three communication models referenced in texts on communication studies (Gerbner, 1956; Maletzke, 1963; Schramm, 1954) which imply that geographic processes are occurring in communications. One such model is Berlo's S-M-C-R Model (Berlo, 1960). It categorized elements of a medium such as the source (S), message (M), channel (C), and receiver (R) in a linear fashion and focus on the interpersonal relationship of communication. The Schramm Model (1954) is a modified circular model, it captures the cyclic nature of communication where there is a processing role within each receiver/transmitter and the application of feedback at multiple stages.

Schramm (1954) had also created a Field of Experience model (Figure 2.4). He posited that the overlap of an individual's experience with others contributed to the understanding between groups of people. This overlap makes it easier to communicate successfully with others, emphasizing a connection through likeness. Schramm's experience model exhibits elements of TFL, where, again, receivers closer in proximity are more related than receivers further away, or with less similarity in social space. There is possible application of the Field of Experience Model to further describe the social processes occurring at the second step of influence of Lazarsfeld's model where experience and proximity affect media's amplified social process.



**Figure 2.4. Schramm's "Field of Experience" Model (1954).**

Often influence or ideologies are primarily associated with the study of the media, limiting the approach to study what people do with the medium and the message. Individual perception of media and identity has been a factor that is overlooked in media research, and considered a possible area of further research (Corner, Schlesinger, & Silverstone, 1998). These processes of media creation, sharing, and consumption are self-selecting because of identity and geography. An individual determines what and with whom they are going to produce, share, or consume media based on their experience and place in the world. The use of behavior as an approach to study media implies application

of sociological, anthropological, and socio-psychological theories to explain an individual or group's rationale for producing, sharing, or consuming media. Nonetheless, many media researchers accept external factors may be at work—whether ideological, behavioral, or something completely different—adding to media's complex effects (Corner et al., 1998; Couldry, 2001; Katz, 1959; Livingstone, 1997; McLuhan, 1964). Using GIS to map patterns and processes could help to further the study of media effects as the social processes occur spatially, but may not ever be the definitive answer to fully understanding media effects.

### **2.3 Mapping the Media**

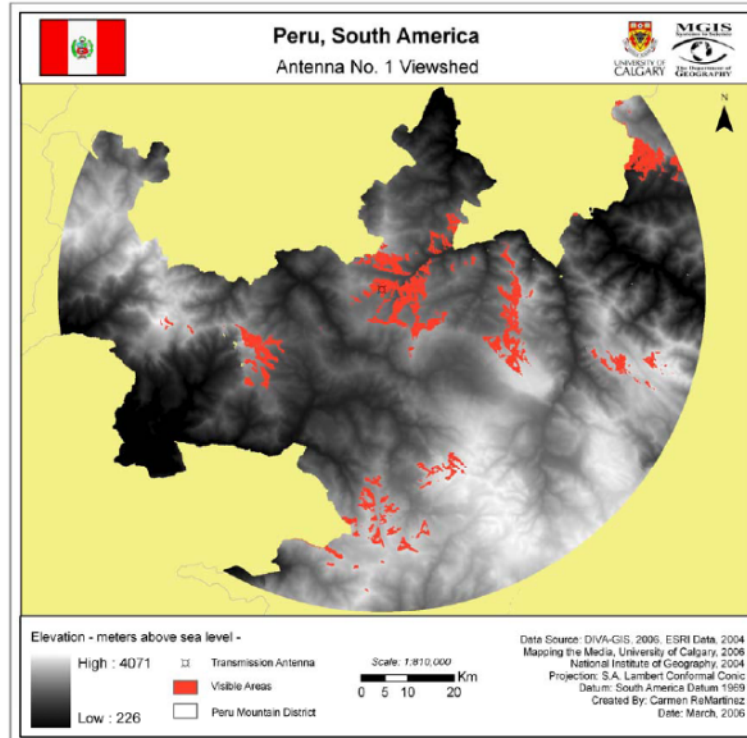
The literature with the closest comparison to the project was conducted by a team of researchers from the University of Calgary, The Carter Center, and the Canadian Foundation for the Americas (FOCAL) (Cole, 2005; Dowding, Hansen, Sun, ReMartinez, & Waters, 2006; McConnell, Hansen, & Waters, 2005; Waters, Hansen, Gao, Sun, & Palacios, 2006). In 2003, The Mapping the Media in the Americas (MMA) project was started to map access and ownership in the Americas. The project's intent was to provide insight for change into political campaign financing and political use of media.

The MMA utilized its partnerships with non-governmental agencies and the media of its study areas to collect international data, build a GIS, and to provide an Internet mapping site. The Carter Center and FOCAL conducted the data collection abroad, meeting with media sources, government agencies, and journalists to collect media ownership data. This data not only consisted of who owned radio stations, but the locations of who owned a radio. The GIS was built and utilized by the University of Calgary, where the data were processed, analyzed, and maps were generated. The University of Calgary



also designed an Internet mapping site for the MMA project allowing for the project's intent of providing greater transparency into political financing of media during elections.

The methods used in the MMA's GIS and analyses consisted of locating media sources, potential receivers and comparing them to election outcomes. The comparison was performed by modeling the range of broadcast signals of stations (Figure 2.5) to determine potential listenership in an area. The MMA researchers performed geographically weighted regression (Fotheringham, Brunson, & Charlton, 2002) on election results to determine where political parties did well or not to account for regional differences. Geographically weighted regression also was performed to calculate an estimate of radio owners throughout the country and was determined by the researchers to be successful in predicting election outcomes (Dowding et al., 2006).



**Figure 2.5. Example of the output of mapping media by University of Calgary research**

The MMA effort was started before this project and the Open Source Center's initiative to start mapping their resource. While both projects cover the same topic of mapping media sources, media consumers, and the influence of media, the MMA project focused on working with sources and non-governmental organizations to promote democracy and social change. The Open Source Center's intent was to enhance their analysis and to integrate GIS into their workflows to understand the effects of media beyond elections. Both projects do overlap in design and methods, but the intent and scope of the projects differ due to the needs they were implemented for.

## **2.4 A Partnership and a Beginning**

In 2006, OSC started its media mapping effort with its media analysts and its geographers. The geographers acted on the suggestion in a 2006 internal email from a

branch chief who recommended the two groups "do something together." The geographers from wrote a proposal to locate OSC media sources, and with help from media analysts, picked Iraq as prototype area. The OSC used their sources and those of the BBC Monitoring Service, to include the World Radio and Television Handbook to populate a table of attributes about the available sources in Iraq. The table consisted of over 30 attributes and over 400 stations, many duplicates, and the aggregated data were difficult to pull together, due to the varying methods the sources used to describe the information. There were no coordinates for the locations of broadcast towers, only addresses for studios and the name of the location where the broadcast tower might be. A join between the location attribute of the transmission sources table and a populated places GIS file provided the probable point location for the transmitter data.

While creating the data for Iraq, the OSC team placed station locations as accurately as they could. This process introduced errors into the data because locations were not exact. It was later determined that scales larger than 1:250,000 were ineffective to support analysis at larger scales. When users zoomed into the data, the data would begin displaying errors at larger scales due to the production method of placing features manually with GIS tools. For instance, if zoomed into Baghdad, transmitters created for the project would look like they are randomly distributed through the city, but they are not. The original data creation process introduced spatial errors that, at large scales, display significant inaccuracies which could be misconstrued as accurate (Figure 2.6). Nevertheless, the fact that OSC could plot the locations of sources in a GIS was a tremendous step toward integrating different aspects of the Center to reinvigorate the collection and analysis processes. By working together, the two OSC groups demonstrated

that media analysis has a geographic component, and that OSC's corps of geographers could do more for the Center than just manage a map library.



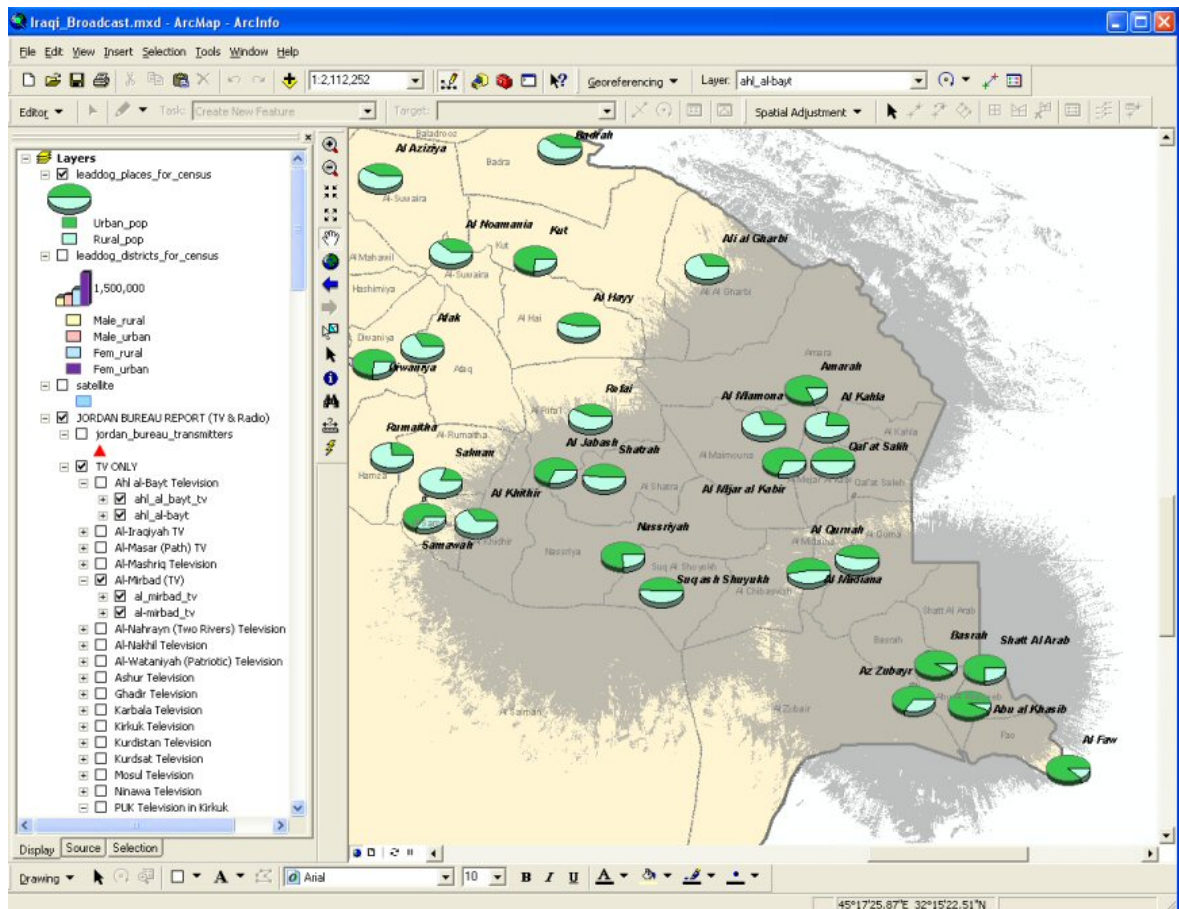
**Figure 2.6. Uncertainty of original method of placing transmitters. Notice the stations placed in the river. (Image: DigitalGlobe 2002, Google 2008)**

During this phase, OSC geographers thought to also map broadcast areas of the Iraq sources with information about their transmission signals. At the time, OSC did not have the tools to model radio frequency propagation; 1941 appeared to be the last time OSC mapped any extent or direction of media. Using OSC's geography blog, "Why Geography Matters," the geographers posted a question to the greater Intelligence Community asking what tools were available to model radio frequency propagation in a GIS. The US Army and the National Security Agency (NSA), responded regarding a tool called the Communication Systems Planning Tool (CSPT), developed by the Institute for Telecommunication Sciences within the Department of Commerce's National

Telecommunications and Information Administration. OSC partnered with both groups and forwarded the shapefile of Iraqi media sources off to be modeled (Flatla & Blinde, 2007).

Because the transmitter shapefile had incomplete technical data about transmitter attributes, the NSA and the Army both used default parameters for the CSPT tool. They generated the 180 broadcast ranges in ESRI GRID raster format that were sent back to OSC for inclusion into the project. The default values created broadcast ranges approximately the size of a large metropolitan area at a scale of 1:2,000,000, a typical ratio for the type of stations OSC is attempting to model (Figure 2.7). These default values, mixed with real values, are approximations and they had to be declared as such, which was acceptable to OSC. For the size of the area involved, any analysis conducted would include metropolitan-sized study areas or smaller scale areas. Similar analysis conducted over Western areas, like the United States or Western Europe, could be conducted at larger scales, but in the case of Iraq the error at larger scales skewed local analysis because of the coarseness and lack of data. Hence, a country-wide display of the ranges overlaid on tribal, ethnicity, and population density data was provided as a demonstration to OSC senior management detailing views about the places of distribution that OSC sources cover.





**Figure 2.7. Generated broadcast ranges for OSC by NSA. (Source: OSC)**

Senior OSC managers asked after the demonstration how to integrate the project into OSC's daily workflow and how it would help OSC. Managers are weary of additional strains placed on their analysts to use new software and new tools. For one, analysts already conducted source assessments qualitatively by producing media guides. The earlier project to map media offered a different approach to creating media guides and to diversify the type of analysis OSC conducts. Understanding the extent and reach of media in their locales extends analysts' understanding of the source and media. Visualizing the media and its effects extends analyzing media content for nuanced statements directed towards groups or individuals that act in a local capacity. This added context develops an analyst's

knowledge about the culture and geography of an area and aids in determining the changes occurring in a given location. Both aspects multiply the organization's knowledge and understanding of media and societies, which contributes to the overall purpose of intelligence and geography—to understand people.

The Internet and other media generate an amount of information comparable to the size of the Library of Congress daily (Roberts, 2002). The databases and collections that OSC has are substantial and continually expanding. Knowing the geographic extent of media can help relate information and knowledge through various geographic search techniques, and even spatial analysis of data that was once thought to be non-spatial. That vision is possible, but OSC has to start somewhere and mapping their media sources is it.

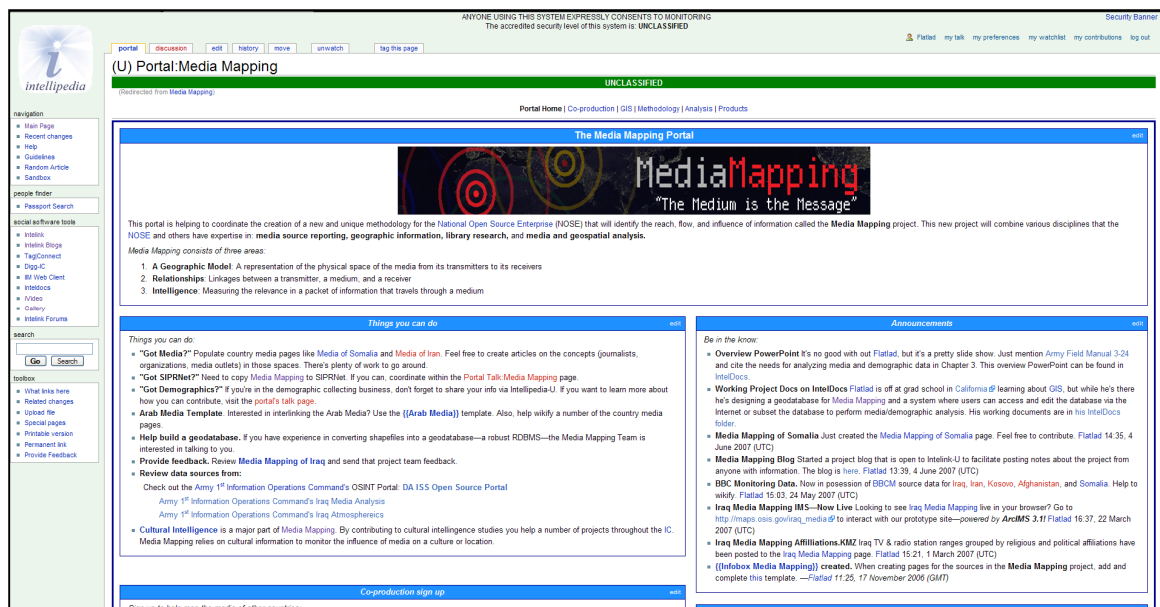
Prototyping the beginning of a new age of media analysis can motivate OSC to implement follow-on and complementary projects to transform itself and the open source intelligence community, providing deeper analysis to their partners while continuing to provide the same traditional services. The potential growth fulfills the task set by the Director of National Intelligence and the United States Congress.

Other potential users of the analysis and data include U.S. embassies, military organizations, and OSC's international partners like the BBC Monitoring Service. The global distribution of these users maximizes the need to understand local media. By leveraging this network, users can be significant to a project like this, providing near-real time changes to a global project with access to local media sources. This arrangement with users maximizes the information about media sources around the globe.

Previous work on the project had attempted to interface with potential partners by using various ways to describe and showcase the project. From a GIS perspective, an ArcIMS site was a Web map of media in Iraq. The mapping Website on the Intelligence Community's unclassified network, Intelink-U, proved to be of little use to partners who work on distributed secure networks. The Website did not offer much interaction with the data, but helped to distribute data to some ArcGIS Desktop users for viewing. The Web mapping site did garner support for the project from OSC's overseas bureaus that collect the information about the media sources in the project.

Another project Website was created on Intellipedia, the Intelligence Community's enterprise wiki, to share methods and data (Figure 2.8). The Intellipedia portal and pages are some of the most popular pages on Intellipedia with over 50,000 views, but this platform only offers to organize current information about the project as shapefiles, KML file for Google Earth, tables and images have been uploaded for users to download and use. The wiki pages are an important part of the project to communicate results and have been used to manage the project from an information sharing standpoint.





**Figure 2.8. View of the project's wiki on Intelink-U**

To add another increased level of transparency to the project, a blog was created to communicate with partners and to capture project thoughts and ideas. The blog has an important relationship with the Army Information Operations and public diplomacy communities who actively read and participates with the blog. Project direction, methods, theory, and results are posted; as are related datasets, information about new media sources, and technologies related to the project. This active participation has helped to coordinate user needs for the project and to legitimize the need of the project.

The blog has been one of the more popular elements of the project, where users and project team members have established a dialog with partners throughout the Intelligence Community (Figure 10). Yet, one finds that most partners are only interested in obtaining data and not sharing data, but love to access the Intellipedia page and blog on the secure networks. All of these interfaces are good for establishing presence, but what the project lacks is persistence that lives within the OSC and Intelligence Community enterprise.



**Figure 2.9. View of the project blog on Intelink-U.**

## 2.5 Summary

Mapping media sources have been an often asked question with little research conducted. The history behind current effort to map media sources in government has resulted in almost no body of knowledge that has persisted through the years and is not a wide researched subject in academia. The history and known efforts were reviewed to advance this project's capabilities of understanding of media and how mapping it has been conducted in the past.



## **3.0 System Design & Architecture**

### **3.1 Introduction**

This chapter follows the activities in the project schedule and explains how design and configuration decisions were made to create the prototype GIS. Focus was placed on the design of a GIS built around a geodatabase to describe the geography of terrestrial television and radio infrastructure. Just as important as the geodatabase was the prototype's system architecture, where data, applications, and users interact to model media infrastructure and measure media impact.

User requirements were gathered and validated through interviews with the client and through documents that outlined project needs such as required data and user activities; these activities described needs for project elements within their own process models. Examples of partner workflows, such as those used by the U.S. State Department for public diplomacy, were used to support client needs, which in turn support the client's partners. The U.S. Army's information needs, stated within its own field manuals, were also used to validate client requirements, which heavily supported Army public affairs and information and civil affairs operations.

This chapter also describes the system architecture of the project used to meet the client's requirements. The architecture at its core relied on the geodatabase. Concepts and elements that make up the geodatabase are described in detail to show their intended use and how they relate to the description of media infrastructure in a geographic context. Tools and workflows surround the geodatabase; they are dependent on the users to

accomplish the tasks to support the overall activities of mapping the media through mapping applications. These workflows and applications, such as geodatabase versioning, were recommended to OSC and its users and were not intended to be static due to the nature of OSC's business.

Finally, the identities and roles of users are described. The user is the priority in the project's architecture and determines data input, use, modification, and output. User roles, such as the database administrator, SDE administrator, GIS manager, editors, and readers, are mentioned throughout the project and are not defined in this report. User roles can be determined and changed by the client at any time. Without users, the project would never have functioned and would have contributed nothing to the OSC and its partners' operations.

### **3.2 Requirements Analysis**

The first step of the project was to gather user requirements from the client to determine the functionality of the prototype. The project team interviewed the client to understand its workflows and processes regarding how it needed to map its media sources. These questions, along with doctrines and processes from the client's partners, were used to form the system requirements of the prototype.

Once the client interview and the processes from the client's partners were reviewed, requirements were derived and broken down into two categories: functional and nonfunctional requirements. The functional requirements outlined the capabilities the project prototype needed to address in the project's design and implementation. Nonfunctional requirements did not necessarily support functionality but addressed

aesthetic and specific needs like scalability and software types. The requirements were then written into the project's requirement management documentation and applied to the system design plan.

The client's geographers and open source officers responded to interview questions via e-mail. They often explained their jobs and roles, but also provided questions they and their partners often asked during their source analyses activities. These questions ranged from basic look-up questions to questions about spatial analysis as well as nonspatial questions. Basic queries were often about where a station was located. More complex spatial analysis questions addressed the broadcast areas and the underlying demographics of the affected population; for example, "What is the geodemographic makeup of listeners within the broadcast range of a specific radio station?" Other questions submitted by the client included nonspatial questions that asked about features of a station such as the language in which it broadcast or who owned or operated the station.

Similar questions or requests for data were described as information needs in the doctrine and field manuals of the client's partners; these needs drove the client's collection and analysis of its sources. The U.S. State Department's model for implementing public diplomacy campaigns included multiple needs to identify media sources and their potential audiences and to measure the effects of their outreach (Government Accountability Office, 2006). From a military standpoint, the U.S. Army addressed specific needs for data to conduct operations that included combat, information, public affairs, intelligence, counterinsurgency, and reconstruction operations. The military doctrine cited similar needs to collect, manage, and disseminate information about media infrastructure, information about programming and ownership of the media, and the makeup of the affected

population of those media (Department of Defense, 2006; U.S. Army, 2006a, 2006b, 2008). The documents and manuals from the State Department and military referenced the need to use knowledge management systems to address their needs, as well as the client's, to support their partners.

The client interviews and their partners' documentation were then reviewed, sorted, and broken down into functional and nonfunctional requirements. The questions from the client were analyzed using a word-noun-verb method which discerned objects from nouns and relationships from the verbs acting between the objects. Current client processes and technology were reviewed to understand how they managed and analyzed their information. It should be noted that the project had to validate every requirement the client provided; many times, the client would request something that was outside the capabilities of the project team or outside the time frame of the project. Some requirements and requests, such as integrating a broadcast area generation tool into a geoprocessing task, were either beyond the capabilities of the project team or would have lengthened the project significantly, and such requirements were omitted. The project acknowledged the need to use such data and worked with the client to redefine the requirement so as to satisfy the client. The majority of the prototype's needs were about functionality, although scalability, accessibility, and specific tools to which the user had access were organized as nonfunctional requirements.

The following concerns addressed the required functionality of a typical GIS. These requirements had functions that focused on the workflows of the users and the phenomena that the project modeled. They were organized into groups, such as the inputs, tasks, and outputs, which described the system.

**Table 3-1. Functional Requirements—Inputs**

<b>1.1</b> The system shall have a database.
<b>1.1.1</b> The system database shall be a container for user data that describes the location and attributes of objects and relationships apparent in radio and television communication systems. These attributes contain:
<b>1.1.1.1</b> Station location, station name, station address, station phone, owner, manager, whether it is licensed or not, station e-mail, station Web site, primary broadcast media, and the network affiliation.
<b>1.1.1.2</b> Transmitter owner, type, model, manufacturer, power in kilowatts, channel (if television), band, transmitter ID, elevation, antenna pattern, antenna orientation, frequency, and gain in decibels.
<b>1.1.1.3</b> Tower ID, latitude, longitude, location, address, owner, height in feet and meters, base elevation, the tower's vertical obstruction ID in any aeronautics database, structure type, and structure manufacturer.
<b>1.1.2</b> The database shall record or provide the ability to record the ownership and management entities of radio and television stations and their infrastructure.
<b>1.1.2.1</b> The ownership and management records shall contain the minimum fields: name, phone, address broken down to its most atomic parts, Web site, e-mail, and fax number.
<b>1.1.3</b> The database shall contain the radio frequency propagation datasets created by a radio frequency propagation modeling software program.
<b>1.1.3.1</b> These radio frequency propagation datasets shall have the following attribution: name, tower ID number, transmitter ID number, the estimated decibel level of the signal, the signal-to-noise ratio measurement, line-of-sight values, station ID, and network ID information.
<b>1.1.4</b> The database shall contain a global elevation model with a post spacing of at least three minutes of arc.
<b>1.1.5</b> The database shall contain references to sources that are used to compile the features in the database for citation and accountability purposes.
<b>1.1.6</b> The database shall be constrained to the WGS 84 datum.
<b>1.2</b> The system shall make use of Web services that provide access to geospatial data as an input to the system.
<b>1.2.1</b> The system shall provide similar output access to other Web services.
<b>1.3</b> The system shall make use of geospatial data file formats for raster and vector input sources.
<b>1.4</b> The system shall make use of digital tabular data formats common to most enterprise applications as an import source.

**Table 3-2. Functional Requirements—Outputs**

<b>2.1</b> The system shall output the generated radio frequency propagation analysis as a raster and store it back in the database.
<b>2.2</b> The system shall be able to manage vector data such as point, lines, and areas and their complexities.
<b>2.3</b> The system shall be able to manage raster data in the database.



<b>2.4</b> The system shall be able to create a map and export it as an image.
<b>2.5</b> The system shall be able to create a map and export it—with its symbology—as a KML or KMZ file for viewing in Google Earth.
<b>2.6</b> The system shall be able to export data as shapefiles.
<b>2.7</b> The system shall be able to export data as tables.
<b>2.8</b> The system shall be able to output its data as a Web service for other services to consume.

**Table 3-3. Functional Requirements—Tasks**

<b>3.1</b> The system shall be able to perform queries on the database and return a list to the user.
<b>3.2</b> The system shall have many levels of access.
<b>3.2.1</b> The system shall be accessible from a desktop GIS platform.
<b>3.2.2</b> The system shall be accessible from a Web mapping application.
<b>3.2.3</b> The system shall be accessible as an OGC Web service.
<b>3.2.4</b> The system shall be able to access other Web and data services.
<b>3.3</b> The system shall be able to perform queries and spatial analysis.
<b>3.3.1</b> The system shall be able to perform database queries for multiple users from desktop GIS, Web mapping applications, and other Web services.
<b>3.3.2</b> The system shall be able to provide data to generate radio frequency propagation models with features from the data inside the database and save them back to the database.
<b>3.3.3</b> The system shall be able to return the location of a database feature.
<b>3.3.4</b> The system shall be able to return a query on any attribute in the database.
<b>3.3.5</b> The system shall be able to determine what languages a station is broadcasting in.
<b>3.3.6</b> The system shall be able to return a query on the technical attributes of stations, transmitters, and towers and how they are related.
<b>3.3.7</b> The system shall be able to return information about who owns or manages a station or elements of the communication system infrastructure.
<b>3.3.8</b> The system shall be able to return information about what stations can be received at a particular location the user determines.
<b>3.3.9</b> The system shall be able to determine the area and perimeter of a station's broadcast signal.
<b>3.3.10</b> The system shall be able to perform analysis within broadcast areas on any system or user-provided geodemographic data.
<b>3.3.11</b> The system shall be able to determine areas where station signals overlap.
<b>3.3.12</b> The system shall be able to determine what urban population centers are within a broadcast area.
<b>3.3.13</b> The system shall be able to perform overlay analysis, spatial joins, hot spot analysis, and other spatially analytic capabilities that are common in most of today's GIS software applications.
<b>3.4</b> The system shall be able to perform common operations that are typical of spatial databases.
<b>3.4.1</b> The system shall be able to let the user create a new feature in the database.
<b>3.4.2</b> The system shall be able to let the user read and access features in the database.
<b>3.4.3</b> The system shall be able to let the user update features in the database.
<b>3.4.4</b> The system shall be able to let the user remove features from the database.

<b>3.4.5</b> The system shall be able to archive changes made to the database for redundancy and analysis.
<b>3.4.6</b> The system shall be able to allow specified users to accept or roll back changes to the database.
<b>3.4.7</b> The system shall be able to subset a portion of the database for a user to replicate to allow for times when the user will not have access to the database.
<b>3.4.8</b> The system shall be able to accept replicated and edited subset versions of the database from users who previously did not have access to the database.
<b>3.5</b> The system shall be able to allow users to build analytic models, run them, and publish the models for other users to use for common analysis tasks.
<b>3.6</b> The system shall create and manage metadata with inputs from the user.

The following nonfunctional requirements focused on the performance, standards, and technology needed for the project. They addressed the need to use commercial GIS software, database technology, and Web servers for the prototype. The client also required the prototype to theoretically support five hundred users, be globally accessible, and have the ability to scale with regard to size and users. The client also required the implementation of industry approved security practices to protect its prototype and the data within it.

**Table 3-4. Non-Functional Requirements**

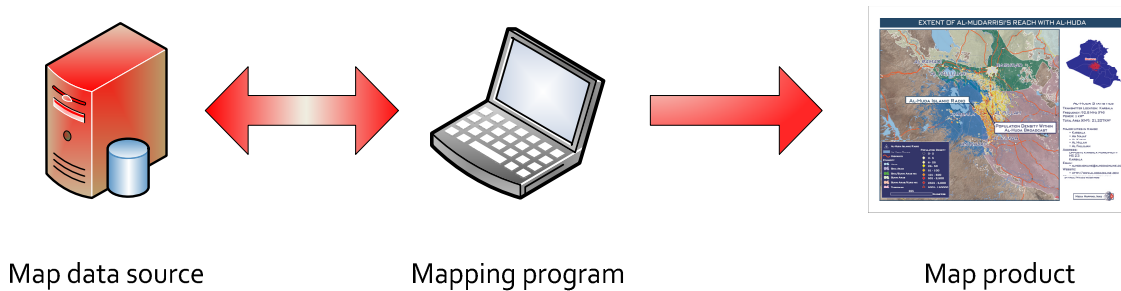
4.1 The system shall support five hundred concurrent users.
4.2 The system shall be supported by an industry-approved database.
4.3 The system shall use a commercial GIS software platform.
4.4 The system shall use industry-approved Web server technology.
4.5 The system shall use client and industry security practices.
4.6 The system shall be globally accessible.
4.7 The system shall be able to manage user accounts and access to the system.
4.8 The system shall be accessible 99% of the time on a 24-hour, 365-days-per-year basis.
4.9 The system shall be able to scale upward for the inclusion of users, tools, or formats, or the inclusion of new platforms.

The project and the client derived the project requirements to describe the needs of the project prototype. These were collected through interviews, reviews of workflows, and conversations with the client's partners to enable the needed capabilities of the prototype. The requirements were also validated and recorded in the project's documentation. Once they were collected, recorded, reviewed, and validated, the project team used them to create the prototype system for the project.

### **3.3 System Description**

To meet the needs of OSC and its partners, the project prototype design focused on providing users with the capabilities to contribute and manage spatial, technical, and organizational data about the infrastructure of radio and television sources they monitored around the world. The system was designed to perform queries of the data, to enable users to work collaboratively, the goal being the creation of radio frequency propagation models to support the analysis of media environments and populations. The same data was also intended to be available to advanced users and other enterprise tools via Web services. For

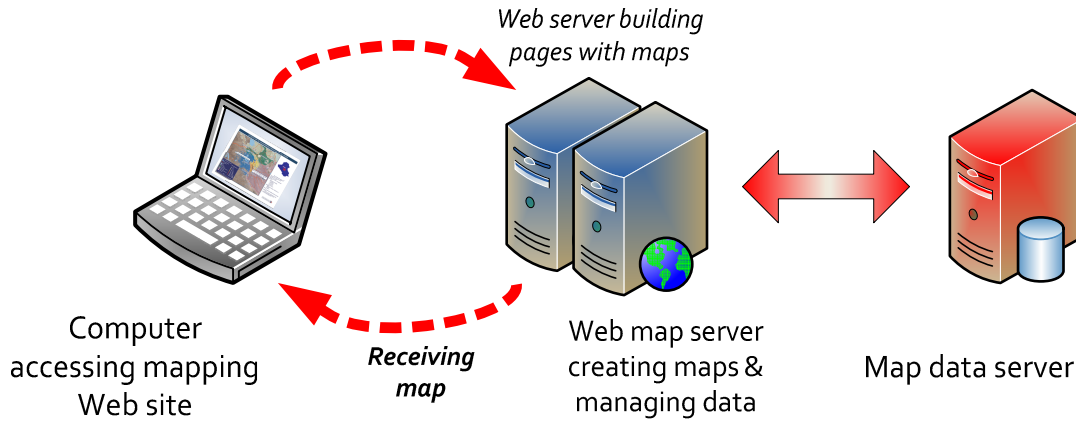
users who were less familiar with desktop GIS, the system was designed to include database editing via Web mapping applications. These decisions were based on the roles of open source analysts, public affairs officers, and others who could potentially contribute to the project's geodatabase. The system included commercial off-the-shelf technology and third-party GIS applications in the prototype architecture, giving all users the ability to create maps and communicate via formats like KML for Google Earth (Figure 3.1).



**Figure 3.1. Illustration of elements a mapping program needs to access map data to create a map**

The question, "Where is the station I heard on a specific frequency when I was at a specific location?" was commonly asked by users. The system prototype was able to help answer such questions from users who had observed a frequency at a location through a spatial query that was built as a project analytic model with ModelBuilder. Users are now able to access the data via desktop GIS or through a Web application, where they can perform the query against the enterprise database. Users were able to create a local copy for the area they were working on to edit or analyze data through their replicated geodatabase. The users' mapping applications—Web or desktop—allowed them to perform a query against data attributes within the database (Figure 3.2). The query returned a map with a list of stations that met the users' search criteria. They employed the returned

information for their needed purpose, whether it was to make a map, provide the list in a report, or identify the station to make changes to the database.



**Figure 3.2. How a mapping Web site interacts with the end user and the back-end programs on the servers**

The system provided the capability to add, change, or remove records or attributes of features in the geodatabase. If the above query against the database was being used to update information about the particular station of interest, the user was able to enter a database edit session from a desktop GIS or Web application to add information about a station's address or a tower location or an attribute of an observed increase in a station's broadcast power. The user could also add information about the organization or individual who owns or manages a station or multiple stations. These edits are also stored in a version to be approved by a project manager, who verifies the data and posts the edits to the enterprise database for access by all users.

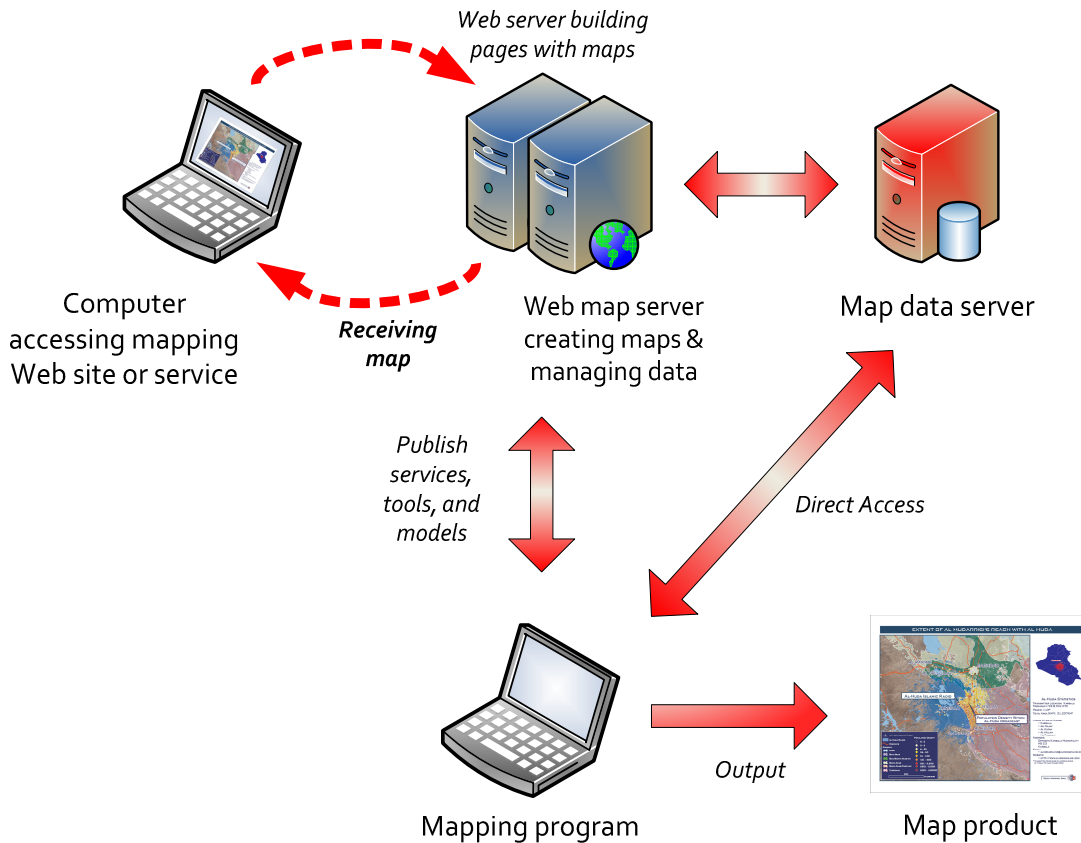
In addition to queries and adding data, the system provided the user with analytic capabilities for using spatial analysis tools commonly found in most GIS software. Associated workflows enable data to be provided to the National Security Agency or other

partners who use specialized radio frequency propagation software to create raster data and polygon features of the transmitter propagation areas. These features are stored in the enterprise geodatabase, supporting the analysis of media sources and their impact in an area by all users.

In an example of an analysis scenario of the system, a user monitors the media in a specific country (Country X) where the local leader had given a radio address. The user knows that the leader is affiliated with a group in Country X with a specific agenda. The user analyzes the impact of the local leader's speech to map the potential influence the speech had on the population in a certain region of Country X. The user identifies the parts of the population that were more receptive than others in the region. Employing the project's system, the user queries and identifies radio stations that broadcast the speech and determines the listening areas. With human and cultural geography ("human terrain") data such as population density, tribal, ethnic, language, employment, and other types of geodemographic and lifestyle data, the user deployed GIS analysis tools and applied overlay analysis, spatial joins, and other relevant analytic methods against the data. The user identified the market penetration of each station, determined the demographic makeup of the audience, and segmented the most likely groups of listeners. The user created maps and exported the information for later presentations including reports, Intellipedia pages, other graphics software, or to KML (Google Earth).

Users often performed repeat analysis over different geographic areas, requiring the system to have their methods stored and served to other users. The system provides the capability to save and distribute the methodology for repeatable analytic tasks. The system

is able to access the analytic models directly or via the Web, which enabled analysts to create repeatable work (Figure 3.3). Basic analytic methods were developed by the project, although there is the capability for users to link to other services and use different tools for future tasks.



**Figure 3. The combined Web and desktop system environments**

The system functions include asking simple questions of the project data, contributing data found in researching and monitoring sources, and in-depth analysis of a media environment using geoprocessing tools to generate data views. These system capabilities provide answers to questions often asked by analysts, diplomats, and policy makers.

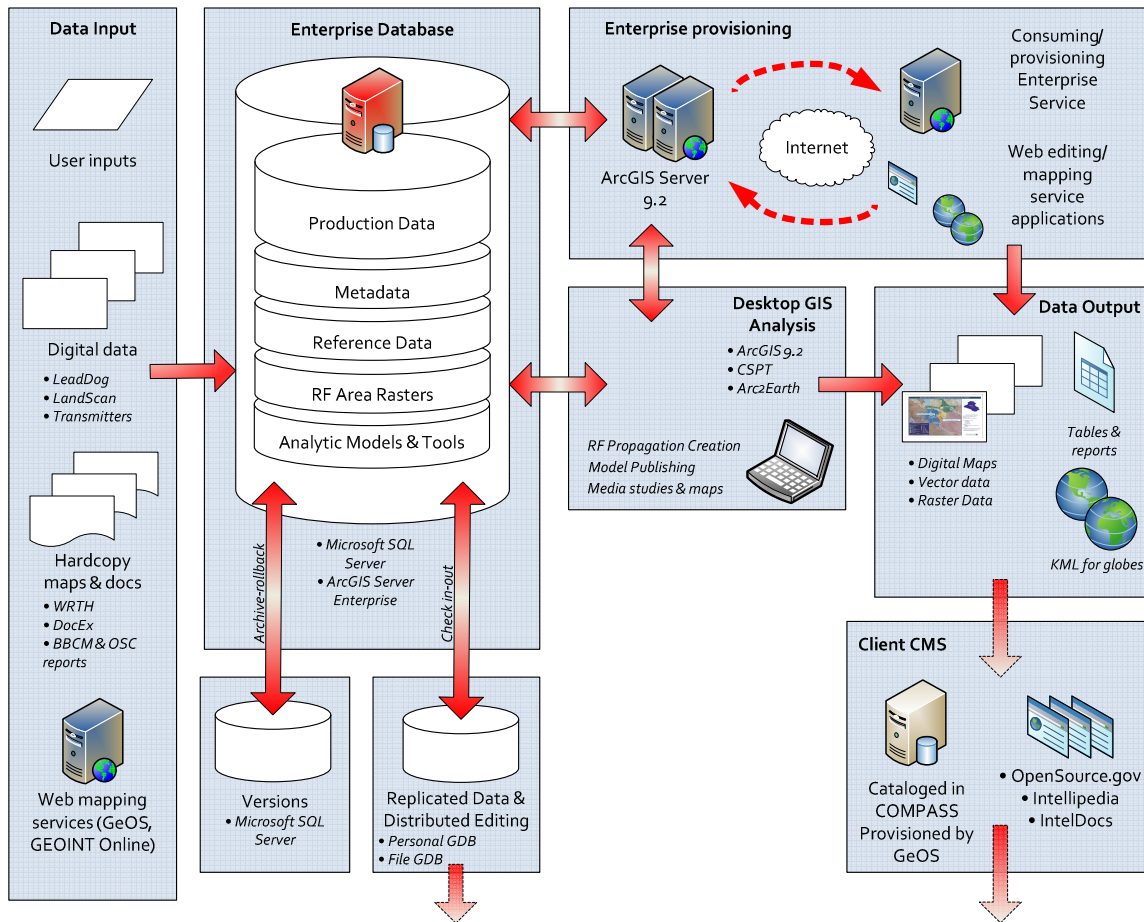
### 3.4 System Architecture

The system architecture (Figure 3.4) was a framework for the project that used technology to focus the interaction between the user, methods, and data. As with all systems, the prototype system architecture had inputs, information storage and retrieval, application processes, component connectivity, and outputs. For the project, the prototype incorporated GIS applications, relational database management systems, and Web servers as the vital components for processing, storing, and distributing data. Final outputs and Web services were implemented to share information, which supports other enterprise information systems and user processes. All of these elements supported the client's needs and formed the framework architecture for the system.

The system integrated the ArcGIS suite for the server and desktop platforms with Microsoft's SQL Server (2005) product based on the project's requirements and constraints. The enterprise database is managed using ArcGIS Server (ArcSDE) and ArcCatalog, which publish map services, models, and tools. The use of ArcGIS Server allowed the system to ingest data from other enterprise databases and Web services. ArcGIS Server also provided data to other enterprise Web services, which helped meet the system's requirement to implement Web-based editing. The desktop GIS analysis component of the architecture used the ArcInfo license of ArcGIS Desktop to perform the needed geoprocessing capabilities on local computers. Coupled with the CSPT radio frequency propagation modeling software and Arc2Earth extensions, the desktop component was intended to generate the radio frequency propagation datasets required of the project to drive further analysis. Output from these tools in various workflows produced maps and exported data to Google Earth's native format, KML, for ingestion into other lightweight



geobrowsers. The Web application component of the project used the ArcGIS Server Web Application Development Framework (WebADF), which created Web-based mapping applications capable of querying and editing the geodatabase.



**Figure 4. Project's prototype system architecture**

The system ingested data from multiple sources of various types such as terrain data from NGA services or maps from OSC data sources. The formats ranged from common vector, raster, and tabular formats to Web services and user inputs from editing sessions. The system's enterprise RDBMS used Microsoft SQL Server 2005. The RDBMS was configured with ArcSDE as the enterprise geodatabase for a less complicated integration. SQL Server 2005 was also chosen because of its robust body of documentation

for administrators and its integration with ArcGIS, which included support for ArcSDE and SQL Server Express 2005 to replicate and archive geodatabases.

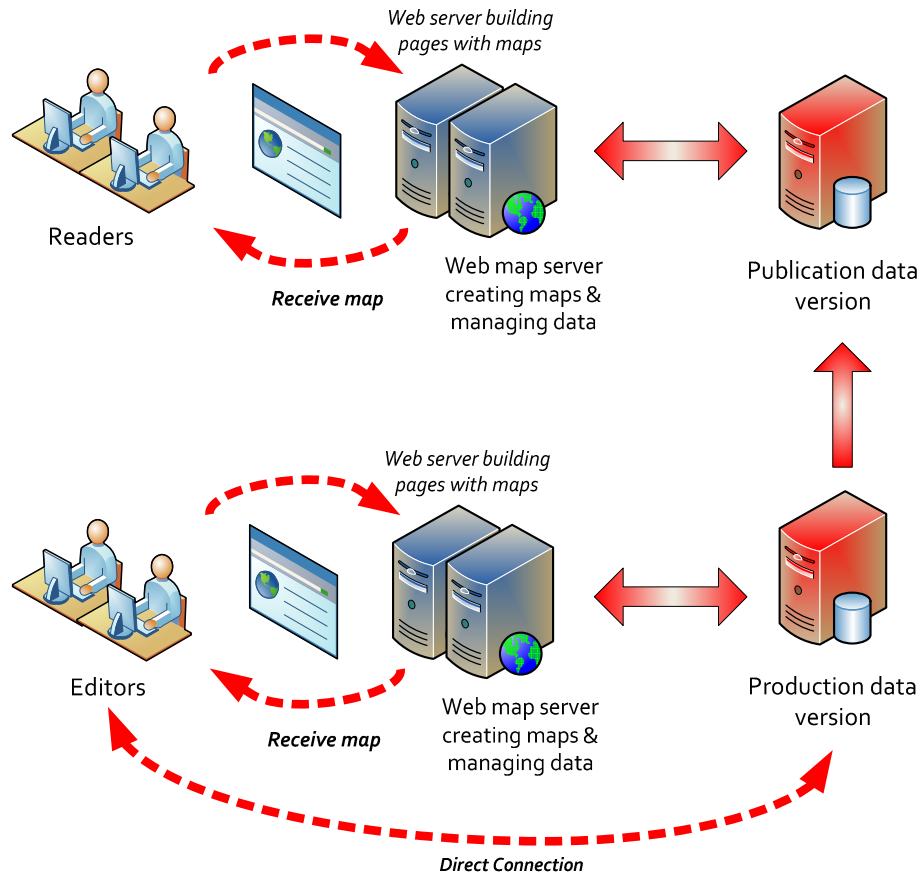
The system was also capable of archiving and versioning with each edit session of the database via features in ArcGIS. The ArcGIS and Microsoft integration allowed the differences between edit sessions to be saved and archived. In the event that the database needs to be recovered or that some edits need to be removed, the system is capable of performing such tasks. Historical archives can also be created and exported to support government archiving practices and analysis between historical versions. The ArcGIS geodatabase supported these features, which helped to secure its use in the project.

ArcGIS geodatabase technology was implemented to support the system's ability to create subsets of data to be exported to other geodatabases. A personal geodatabase, a file geodatabase, or database replication to another enterprise geodatabase via disconnected export enabled information sharing between multiple users and enterprise systems. This capability was especially useful for the individuals who could not access the Internet or who needed to focus on a country or region. The replicated database worked with standard ArcGIS Desktop software, but an ArcEditor license was required for editing the geodatabase and synchronizing with the enterprise geodatabase.

The system provisioned data from the enterprise database via Web services and direct connections to desktop GIS applications. These services utilize ArcGIS Server's proprietary format for use with other ArcGIS tools and implemented the Open Geospatial Consortium (OGC) Web Mapping Service. In addition to ArcGIS and OGC services, users

accessed data from the enterprise database via ArcGIS Server, which implemented a KML data service for Google Earth-like geobrowsers.

The technology behind Microsoft SQL Server and ArcSDE allowed ArcGIS Desktop users to directly connect to the enterprise database to access and manage data. User accesses were managed by the database and SDE administrators for database security purposes using Windows Authentication and SDE logins to assign roles and privileges. Security features were applied not only to the DBMS software but also to different versions of the geodatabase through provided privileges. For example, a "WEB\_EDITOR" version of the geodatabase was created specifically for the Web editing application of the project, which did not affect other versions or the DEFAULT version of the geodatabase. This meant that the edits Web users made were not database-wide but isolated until the SDE administrator or GIS manager could perform quality assurance processes on the data and integrate information across the entire geodatabase. Security profiles created during the prototyping were limited to the database administrator, the SDE administrator, editors, and readers (Figure 3.5). User roles specified user types, which ranged from system administration and quality assurance to editing and reading tasks.



**Figure 5. Geodatabase versioning supports different accesses and tasks, for example, the difference between Web viewing and editing.**

The desktop analytic component of the system prototype is composed of ArcGIS Desktop (ArcInfo license) with the CSPT and the Arc2Earth extensions. ArcGIS Desktop provided the necessary geoprocessing capabilities for GIS analysis. ArcGIS Desktop, with its ArcMap and ArcCatalog applications, has the ability to create, read, update, and delete data inside the enterprise database as well as the ability to read and output data in the common formats the client uses.

ArcGIS also provided the capability to create custom and repeatable geoprocessing tasks via ModelBuilder. With ArcGIS Server, ArcGIS Desktop can publish tools and

models—via ArcToolbox—to the enterprise database for other users on the network to implement with the same data. ArcGIS Desktop also consumes external system data sources like the future services from OSC Map Services Center's GeOS and NGA's GEOINT Online services; the ability to integrate information from other data sources and services extended the utility of publishing analytic services and applications for users on demand to the client.

It should be noted that the desktop component can vary greatly between users because additional third-party applications which can be utilized on the desktop, can provide processes and methods that are beyond the scope of this project. The use of the CSPT and Arc2Earth extensions were two out of many other applications that were available to extend the capabilities of ArcGIS Desktop. These two extensions were provided to perform specific tasks at hand such as modeling and symbolizing data for analysis and dissemination.

The CSPT extension is a third-party application for ArcGIS Desktop that created radio frequency propagation datasets. An element of the project's workflow was to create the propagation data with CSPT and to store the output to the enterprise database as a raster dataset. This raster dataset was processed by a geoprocessing task from ArcScan, which comes with the ArcEditor and ArcInfo licenses of ArcGIS Desktop; this created a polygon feature for each propagation area and stored it as feature dataset.

Previous OSC work with CSPT was a partnership with the National Security Agency, which had experience with the propagation tool at the time. This was still the case for the project. During the project's implementation, CSPT tool was determined not to be

compatible with the enterprise geodatabase. Features and tables that made up the project's geodatabase were needed to be joined in ArcMap and exported to shapefiles for the CSPT tool to generate broadcast signal propagation generation. NSA continues to use the tool and support OSC work to generate the data. Another shortcoming of the CSPT extension, due to its creation, is that it cannot be used in ArcToolbox as a server-based geoprocessing task at this time. A possible follow-up project would be to develop a server-based geoprocessing version of CSPT, which was discussed with the client and was determined to be outside the scope of this project. The CSPT tool was still a useful component to the project; broadcast areas were generated through a workflow with NSA, which included data transformation. Through its data access capabilities, the system architecture would have provided data access to NSA to perform the broadcast area generation with CSPT.

The Arc2Earth extension allowed users to convert and publish ArcGIS map documents (MXD) to KML files for Google Earth (Figure 3.6). The use of Arc2Earth applied the representations created within ArcMap for display in Google Earth. The methods to export data to KML were through the 3D Analyst extension for ArcGIS and the ArcGIS Server KML service. These two methods lacked the capability to represent data in the way the user created it in ArcMap. The use of Arc2Earth overcame these representation problems when exporting to KML and supported sharing views of the geodatabase and any analysis via e-mail or posting to Intellipedia.



**Figure 6. Example of Arc2Earth. Pie chart symbology was transferred from ArcMap to a KML file for viewing in Google Earth. Pie charts represent the percentage of the Iraqi population that is urban or rural in each district. (Source: Google, DigitalGlobe, Government of Iraq)**

The system provided output via raster, vector, and tabular formats commonly provided by ArcGIS Desktop, ArcGIS Server, and Microsoft SQL Server 2005. The user saved data to the enterprise database and created geodatabase replicas for archiving or for other uses. Users were able to create and print maps with the desktop tools and print maps and reports from their Web browser when using the Web mapping applications. The system provided a KML service via ArcGIS Server and allowed the user to export KML with Arc2Earth. All content generated was capable of being published or uploaded to any of the client's content management or knowledge management systems.

Although not formally part of the architecture, there are additional content management systems—OpenSource.gov, COMPASS, and GeOS—and knowledge

management systems—Intellipedia and IntelDocs—that the client must consider. These external systems accepted published maps, reports, and content generated by the project's prototype system. They were considered the external "sneaker net" component where users transferred the data manually to share information across the Intelligence Community.

Finally, Microsoft's Internet Information Server (IIS) Web server technology was used in the prototype system architecture. The use of Microsoft-based servers and database technology, and the use of ArcGIS Server, meant IIS was the primary Web server of choice for the project. The IIS application was required to support the Web mapping and editing applications of the project. With ASP.NET technology and ArcGIS Server, the Web applications were created and designed using Microsoft Visual Studio and the ArcGIS Server WebADF. Visual Studio and the WebADF assisted in the design of the user interfaces of the Web applications. These applications were then compiled and served to the system's network. The IIS Web server is standard with Windows operating systems and is coupled with ASP.NET and ADO.NET technology. Further development of applications can be accomplished with these tools, which could support client and partner applications.

### **3.5 Geodatabase Design**

At the core of the system and its architecture is the geodatabase, which is the focus of this project. The geodatabase stored the information from users and external sources and drove the interaction of technology and social processes. As a media source, the contents of the geodatabase modeled television and radio broadcasting infrastructure and related features. This section describes the concepts behind the geodatabase design and how it was logically organized and physically implemented. The geodatabase was created from the previous work of OSC with a better understanding of the spatial relationships learned from



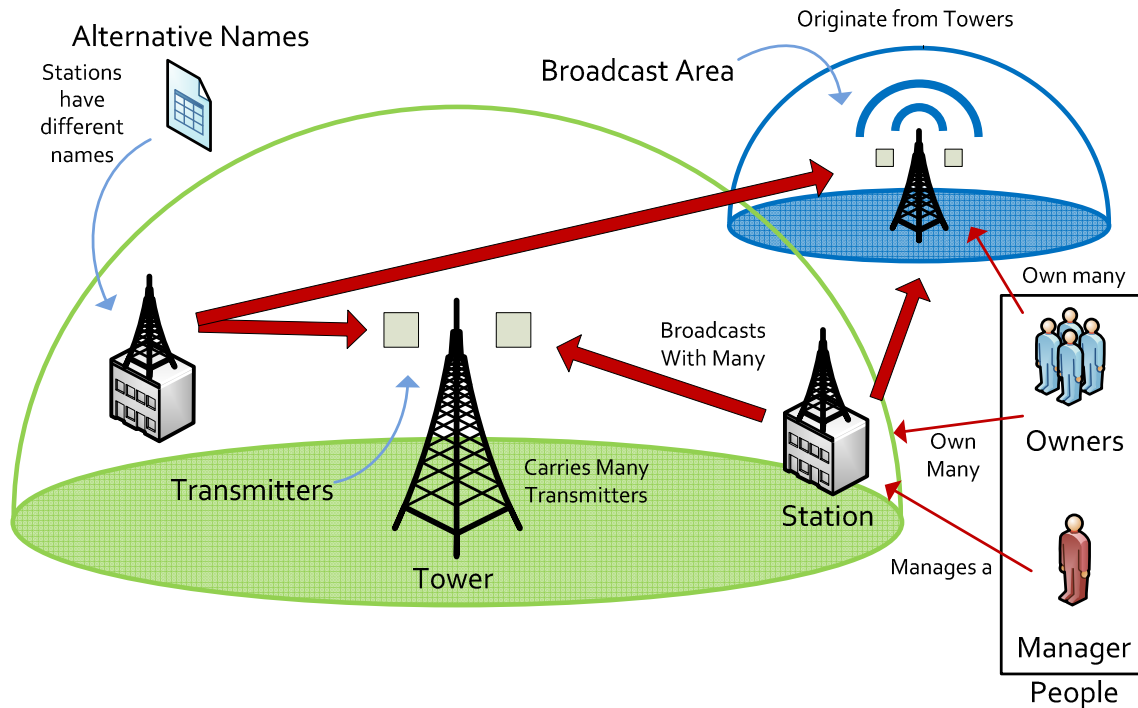
an exploration into how media worked as a whole, as noted in Chapter 2. Physical design and implementation lessons were learned from ESRI courses and documentation, which helped to structure hardware and software to work effectively within the system architecture (Peters, 2007). The geodatabase, being based on ESRI technology, was not without issue where geodatabase design did not work perfectly with the initial implementations. The project overcame these issues while implementing the geodatabase and made slight design changes to the data model, which resulted in a functioning geodatabase. The project relied on the geodatabase for its design and implementation to support the overall project effort and is documented in this section.

### **3.5.1 Conceptual Design**

The concepts this prototype modeled were the features and relationships of terrestrial radio and television broadcasting infrastructure. This effort included the locations and attributes common to the infrastructure of broadcasting systems including stations, transmitters, towers, individuals associated with the infrastructure, and the relationships between these elements. Previous data from OSC consisted of a shapefile which had only a simple point to locate a media source and was estimated to be the origin of a broadcast signal. As the project explored the components that constituted the infrastructure of a broadcasting system, a single feature point was not an accurate description of phenomena OSC had previously mapped.

A systematic review to identify the processes and technology composing media infrastructure supported the conceptual design of the project's geodatabase. Background material, some of which is described in Chapter 2, such as communication models and the social processes of media, helped to identify objects and relationships to be modeled. If

people produced, disseminated, and consumed media, then those activities occurred spatially somewhere and were objects to be modeled (Figure 3.7).



**Figure 7. Concept of television and radio infrastructure with managers and owners**

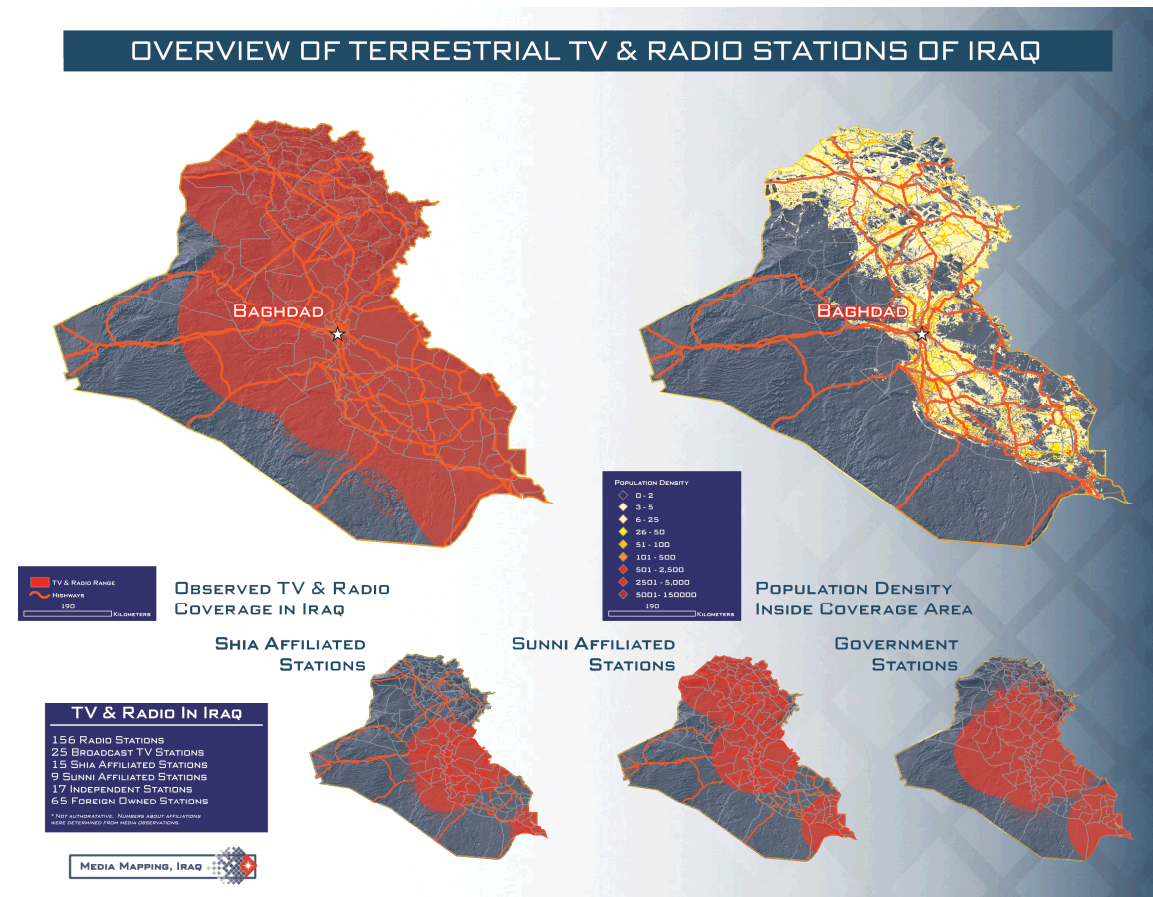
Individuals owned the networks, station, studios, and production centers that created media. Those places were typically office buildings or houses, and these places of production were linked to a method or technology to disseminate their media: transmitters broadcasting signals over the terrain to be consumed. Yet multiple transmitters, in the typical places of dissemination within television and radio industry, are placed on broadcast towers either within an urban area, like Baghdad Tower, or in the rural areas as seen in Figure 3.8. Relationships such as these were important concepts included in the design of the geodatabase, since stations can have multiple transmitters, each transmitter is on a tower, and towers often have more than one transmitter. The infrastructure—stations,

transmitters, and towers—had several types of relationships described as one-to-one, one-to-many, and many-to-many, which needed to be understood and modeled.



**Figure 3.8. The arrangement of transmitters on a tower (Logan, 2007)**

Relationships regarding media ownership were also required to be modeled; users had previously asked OSC who owned and managed media outlets and networks. Ownership was an important part of the geodatabase, for open source analysts were evaluating sources for credibility purposes. If the ownership structure of OSC media sources could be captured, analysts were enabled to join data external to the geodatabase and conduct expanded analysis. Analysis of organizational affiliations could be mapped and visualized, depicting associated groups who could potentially influence local media. Previous OSC work explored this type of analysis, which was captured in products such as, "Overview of Terrestrial TV & Radio Stations of Iraq" (Figure 3.9). The geodatabase had to incorporate ownership and other relationships to support the systematic analysis of a media system.



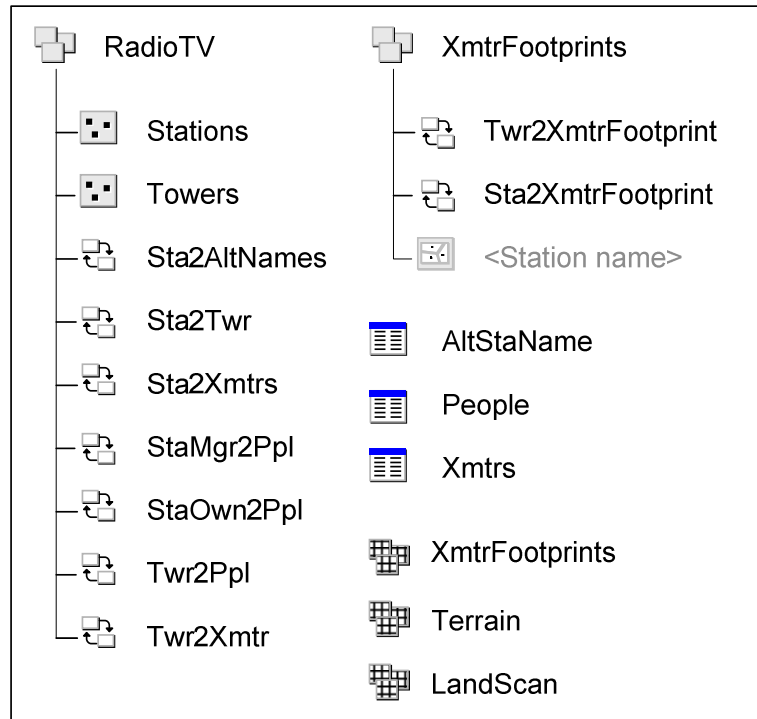
**Figure 8. "Overview of Terrestrial TV & Radio Stations of Iraq," which incorporated ownership relationships and group affiliations to categorize Iraqi media. (Source: OSC)**

### 3.5.2 Logical Geodatabase Design

The geodatabase was logically designed with the concepts noted above, which assisted the project in modeling the infrastructure of media. The geodatabase's physical design used ArcGIS technology with ArcSDE, which had the capability to model complex relationships within the geodatabase to support the concepts that needed to be modeled by the project. The ArcSDE geodatabase relationship class provided the project with the needed complex relationship behavior to model the relationships between simple point features such as those between stations and towers. The ArcSDE geodatabase behaviors also supported the complex relationships, which were also modeled with tables that

described how people, transmitters, alternative names, and different information sources were related to the features. The capability of mapping relationships between features and tables maintained the logical geodatabase integrity of the phenomena modeled for the project.

The geodatabase model consisted of two feature datasets (Figure 3.10). The first was "RadioTV" which included the stations and towers feature classes and nine relationship classes. The second feature dataset, "XmtrFootprints," contained the polygon feature classes of the broadcast areas created from the CSPT raster outputs using the ArcScan tools. The geodatabase contained three tables, which described television transmitter information (XMTRS), owners and managers of stations and equipment (PEOPLE), and alternative names for stations (ALT NAMES). The geodatabase's logical design included two raster catalogs for elevation data and radio frequency propagation data, as well as a raster dataset for LandScan™ population density data from Oak Ridge National Laboratory. These raster catalogs were intended to support local storage of raster datasets within the project prototype, as the project was disconnected from NGA and OSC geodata services and their corporate networks. Tables included in the database are for people, citation look-ups, and transmitter information.



**Figure 9. Contents of the project's prototype geodatabase**

The radio and television feature dataset, "RADIOTV," was the container for all station and tower geographic point features as well as the nine relationship classes within the project's geodatabase. This feature dataset was created to organize the television and radio features and relationships of the project in one place within the geodatabase. It was determined to be a logical organization of the features for terrestrial communications infrastructure, as it was assumed by the project that any expansion in later projects could create feature datasets for the infrastructure of other media such as satellite television, cell phone networks, wireless Internet, cable systems, and others.

Television and radio infrastructure were paired together, since their equipment and patterns were similar. Both features have stations, transmitters, and towers. The ownership and management of the features were similar as well, and the previous OSC work had paired the two features together in the same shapefile. The "RADIOTV" dataset was kept

together for the prototype, while a future iteration of the project might separate the two features.

The "STATIONS" feature class (Figure 3.11) was a point feature that contains attributes about a radio station and did not contain the attributes of related transmitters or towers. Attributes in this feature class included the station's name, address, phone, building number, street, district, city, state/province, country, postcode, owner, station ID, country issuing the license, whether the station was licensed or not, URL, e-mail, call sign, manager's name, fax number, and network ID. Many of the feature class attributes also acted as keys within the geodatabase to support relationship classes and any external spatial joins which might occur.



Simple feature class <b>sde.SDE.Stations</b>						Geometry <i>Point</i>	
						Contains M values	<i>No</i>
						Contains Z values	<i>No</i>
Field name	Data type	Allow nulls	Default value	Domain	Precision	Scale	Length
OBJECTID	Object ID						
Stat_name	String	Yes					254
stationID	String	Yes					254
networkID	String	Yes					254
callSign	String	Yes					254
ADDRESS	String	Yes					254
bldgNum	String	Yes					254
street	String	Yes					254
district	String	Yes					254
city	String	Yes					254
stateProv	String	Yes					254
country	String	Yes		Countries			254
postCode	String	Yes					254
owner	String	Yes					254
licensed	String	Yes		Boolean			254
ctryLic	String	Yes					254
email	String	Yes					254
website	String	Yes					254
phone	String	Yes					254
fax	String	Yes					254
mgrName	String	Yes					254
mgrEmail	String	Yes					254
mgrPhone	String	Yes					254
cite	String	Yes		CitationSrc			254
programmin	String	Yes					254
onAir	String	Yes					254
startBC	String	Yes					254
endBC	String	Yes					254
duration	Double	Yes			19	6	
language	String	Yes		Languages			254
Shape	Geometry	Yes					
GlobalID		No			0	0	38

**Figure 10. The STATIONS feature class**

The "TOWERS" feature class (Figure 3.12) was a point feature that contained attributes about a radio tower and did not describe the transmitter or station itself. Attributes of the feature class included: a unique identification number, latitude, longitude, address, building number, street, district, city, state or province, country, postcode, owner, height, NGA AFIF vertical obstruction data identification number, structure type, and structure manufacturer. The TOWERS feature's unique identification number was used as a database key for relationship classes within the geodatabase, which helped to describe a tower's relationship to stations, transmitters, owners, and managers. Latitude and longitude

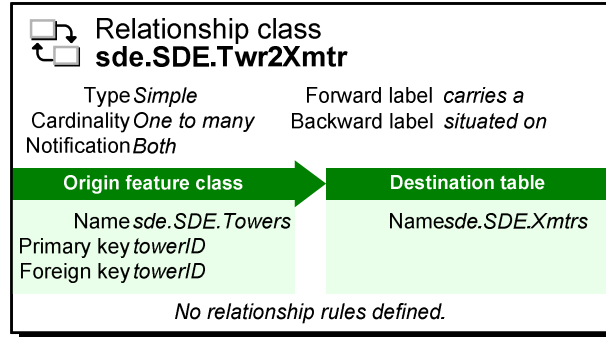
fields were included to verify the exact location of the tower, which might be read by other applications, such as the CSPT tool, which does not read the feature class geometry directly.

Simple feature class				Geometry Point	
<b>sde.SDE.Towers</b>				Contains M values	No
				Contains Z values	No
Field name	Data type	Allow nulls	Default value	Domain	Precision Scale Length
OBJECTID	Object ID				
towerID	String	Yes			254
latitude	String	Yes			254
longitude	String	Yes			254
address	String	Yes			254
bldgNum	String	Yes			254
street	String	Yes			254
district	String	Yes			254
city	String	Yes			254
stateProv	String	Yes			254
country	String	Yes		Countries	254
postCode	String	Yes			254
owner	String	Yes			254
height	String	Yes			254
baseElev	String	Yes			254
vertObstDa	String	Yes			254
structureT	String	Yes		Structures	254
structureM	String	Yes		Manufacturers	254
cite	String	Yes			254
Shape	Geometry	Yes			
GlobalID		No			0 0 38

**Figure 11. The TOWERS feature class within the geodatabase**

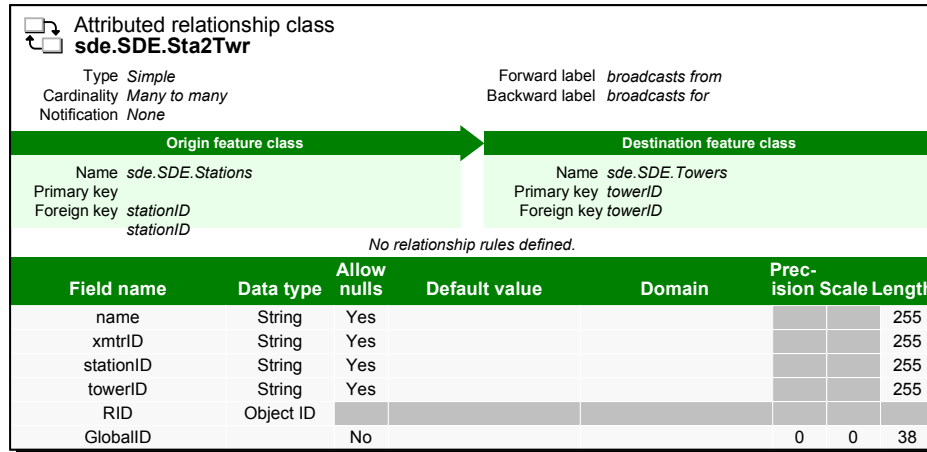
The relationship classes of the "TOWERS" feature class focused on how transmitters and towers are related. In the real world, multiple transmitters sit atop a single tower to broadcast a station's signal out across the landscape. The "XMTRS2TWR" relationship class was created through the "XMTR" table and the "TOWERS" feature class "TOWER\_ID" attributes, linking multiple transmitters to a single tower (Figure 3.13). A simple relationship was used due to the uncertainty of transmitters being on towers. If a tower were to no longer exist in a composite relationship, the transmitters would also be

removed. To account for this uncertainty the relationship class was designed as a simple relationship type.



**Figure 12. The "XMTRS2TWR" relationship class was another one-to-many relationship class within the geodatabase**

Another relationship class was created to depict the links between stations and towers. This was a relationship class that included an intermediate table to link the two feature classes together. The decision to create this relationship class was made to provide the client the option to use a direct relationship between the features. The relationship was also possible through the two other relationship classes in the geodatabase, "STA2XMTR" and "TWR2XMTR." This relationship class was also used as a comparison to understand which relationship class configuration would help keep the integrity of the geodatabase. At the time of review with the client, it still was not clear which arrangement of relationship behavior between stations, transmitters, and towers would be the best fit for OSC. Both arrangements were kept in the geodatabase, specifically the "STA2TWR" (Figure 3.14) relationship class, since they had addressed user requirements to find which stations broadcast from which towers.



**Figure 13. The STA2TWR relationship class with relates the STATION and TOWER feature classes**

The other relationship classes within the "RADIOTV" feature dataset included "STA2ALT NAMES," "STAMGRS2PPL," "STAOWN2PPL," and "TWR2PPL." These relationship classes focused on ownership and alternative names for stations. The client tracks ownership as part of its source management process, which determines the external credibility of the source. Ownership information is also used to describe links a source may have to outside organizations that might have influence over it. At the least, the "OWNER\_NAME" and "MANAGER\_NAME" attributes within the "STATIONS" and "TOWERS" feature classes enable the client to link outside data to the features associated with those for mapping and analyses purposes. These relationships, coupled with the broadcast area polygons within the geodatabase can model the extent of influence a persons or organization has through the use of radio or television as a medium.

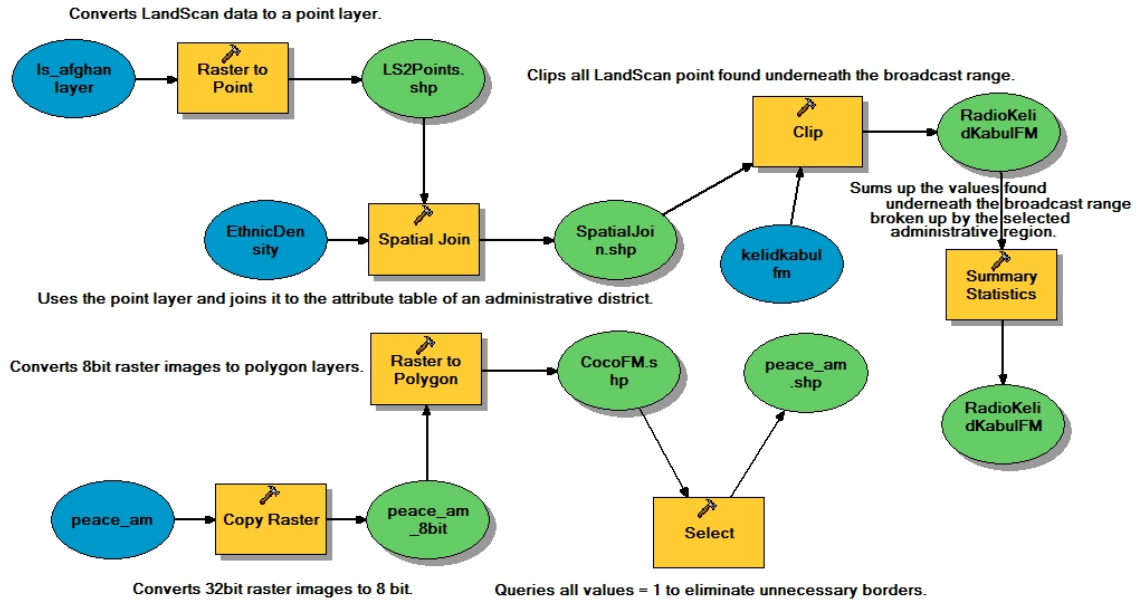
The "STA2ALT NAMES" relationship class was a mechanism for the client to record alternative names for a station. Station names changed over time or were known to the local population by a different name. This relationship class utilizes the "ALT NAMES" table, which captured these different names, as well as names in the vernacular script, to

enable search capabilities by other users. With "STATIONS" and "ALT NAMES" linked, alternative names can be added in the client's editing process and can facilitate an improved search capability for the prototype system users.

The "RADIOTV" feature dataset was the core of the prototype geodatabase. It was the heart of the project, facilitating many of the capabilities the client required. The complex relational behavior of the objects that were in this feature dataset was best modeled with the ArcGIS Server (ArcSDE) geodatabase capabilities. It was the complexity that was essential to be modeled within the geodatabase, as it pertained to how radio and television infrastructure is in the real world. The broadcast areas, though not part of the infrastructure modeled in "RADIOTV," were important and have a spatial relationship with the infrastructure and the populations they cover. The broadcast areas and their relationships were captured elsewhere within the project prototype geodatabase.

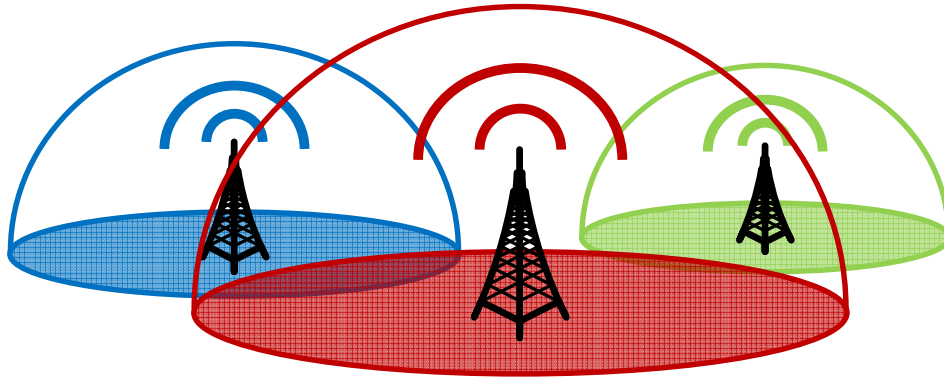
The second feature dataset, "XMTRFOOTPRINTS," contained broadcast area polygons created by CSPT and other communication system planning tools used by the NSA in the project's workflow. The feature dataset helped to organize the broadcast footprints within the geodatabase to support vector overlay analysis to utilize other vector data when analyses were required. The transmitter footprint polygon features are multipart features, which are an effect of the transformation from raster to vector. The feature classes of broadcast area footprints served only to model areas which had coverage or no coverage as calculated by CSPT extension. The ArcScan process modeled into ModelBuilder transformed the transmitter footprint raster to a feature class, removed the "no coverage areas," and rewrote the feature to the feature dataset within the geodatabase (Figure 3.15). The broadcast area feature classes were created from the raster data of the same

phenomena, which was a continuous surface of signal strength, and enabled additional relationship classes and analytic processes.



**Figure 14. OSC-provided broadcast raster to vector and reporting model**

An additional manual process was required to assign three attributes to the broadcast areas: "XMTR\_ID," "TOWER\_ID," and "STATION\_ID" attributes. These attributes enabled the "TWR2XMTRFOOTPRINT" and "STA2XMTRFOOTPRINT" relationship classes and gave the potential for others relationships to be created. The "TWR2XMTRFOOTPRINT" relationship class was intended to support the relationship between the individual broadcast area footprint feature class and the tower feature class from which the signal emanates (Figure 3.16). This was to ensure integrity of the location between the two features. The "STA2XMTRFOOTPRINT" relationship class matched the signal to the station, which supported analyses of ownership, affiliations, languages, and the program content of stations. These relationships and attributes were intended to support processes which were meant to join broadcast area features with other data sources.



**Figure 15. The relationship between Tower Transmitters and broadcast areas**

The "XMTRS" table included information describing radio and television transmitters separately from the station and tower feature classes. The "XMTRS" table contained attributes that provided the technical specifications of television and radio transmitters. The origins of these fields were taken from previous OSC and BBC Monitoring Service work. Attribute fields, and later data, were also influenced by a crowd-sourced publication called the World Radio Television Handbook (Hardyman, 2008) and Web sites such as <http://FMScan.org>. The attributes of the "XMTRS" table were heavily influenced by the CSPT tool and its interface. The CSPT extension for ArcMap required specific fields needed to generate the broadcast area footprints such as "ERP" (Estimated Radiated Power) or "dBi" (decibels). These fields, along with band, type, model, manufacturer, power, channel, "XMTR\_ID," altitude, antenna pattern type, antenna orientation, beam widths, frequency, and gain, were available to the user to populate. The client and the project understood that these attributes are difficult to obtain and are included because they described the object.

The "XMTRS" table and the other tables within the geodatabase were intended to be related to the feature classes within the geodatabase. A transmitter is an object in space,

but in the case of this project and the scale of the geodatabase, the location of the transmitter would be similar to that of the tower it was attached to (Figure 3.17). The difference between separate transmitters and the towers would be measured in elevation and inches. This difference was miniscule for the purpose of this project and it was thus decided to model transmitters within the geodatabase as a separate table; the transmitters depend on the tower they were related to for their location through a relationship class.

Table								
sde.SDE.Xmtrs								
Field name	Data type	Allow nulls	Default value	Domain	Prec-	ision	Scale	Length
OBJECTID	Object ID							
name	String	Yes						255
xmtrID	String	Yes						255
stationID	String	Yes						255
towerID	String	Yes						255
frequency	Double	Yes				15	6	
freqUnits	String	Yes		FrequencyUnits				255
channel	String	Yes						255
band	String	Yes		BAND				255
power	Double	Yes				15	6	
powerType	String	Yes		PowerType				255
type	String	Yes		AntennaTypes				255
model	String	Yes						255
manufacturer	String	Yes		Manufacturers				255
pattern	String	Yes		XmtrPattern				255
orientation	String	Yes		Orientation				255
lineLoss	String	Yes						255
gain	String	Yes						255
gainUnits	String	Yes		GainUnits				255
AGL	String	Yes						255
h_width	String	Yes						255
v_width	String	Yes						255
front_to_back	String	Yes						255
cite	String	Yes		CitationSrc				255
GlobalID		No				0	0	38

**Figure 3.17. The XMTRS table within the geodatabase**

The "PEOPLE" table included information on people associated with the ownership and management of stations and towers. The table included the name, address, phone and fax numbers, address, URL, and e-mail addresses of the individuals recorded therein. The

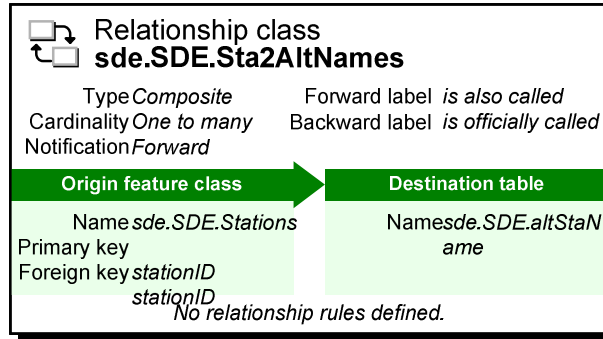


use of this table was previously explained as it related to the station and tower feature classes and is included to facilitate future analyses regarding ownership, affiliation to other organizations, and influence.

Often, stations change names or are known by a different name by the local population. Additionally, differences in native spellings can contribute difficulties when searching for the name of a station. The "ALTSTANAME" table listed alternative names for stations. This table was intended to record common alternatives or local slang names for a station for open source analysts. It included language support for the vernacular spelling of the station to assist in future link analysis and relates to other databases that include various spellings of the same sources in their metadata. The relationship class associated with the "STATIONS" feature class and "ALTSTANAME" table (Figure 3.18) was the "SAT2ALTNAMES" relationship class (Figure 3.19). This class captured the behavior within the geodatabase that assigns multiple names and spellings to one station to assist with search and editing.

Table sde.SDE.altStaName							
Field name	Data type	Allow nulls	Default value	Domain	Prec-	ision	Scale Length
OBJECTID	Object ID						
stationID	String	Yes					255
altName	String	Yes					255
GlobalID		No			0	0	38

**Figure 16. The alternative names table within the geodatabase**



**Figure 3.19. The relationship class, which provided alternative names to be related to the stations feature class**

Raster catalogs are containers within an ArcGIS geodatabase that hold multiple raster datasets, which are often referred to as images. Raster catalogs within this geodatabase helped to organize specific types of raster datasets such as the broadcast range footprint output generated by the CSPT extension at NSA, LandScan™ population data, DTED digital elevation data, or scanned maps. Raster catalogs within ArcGIS are used to store and display overlapping raster datasets without mosaicking, which is a process of combining the multiple datasets into one large dataset.

The "XMTRFOOTPRINTS" raster catalog, not to be confused with the "XMTRFOOTPRINS" feature dataset, was a collection of raster datasets generated by the CSPT tool. Each transmitter broadcast area footprint generated was stored in this raster catalog and included attributes describing the tower ID, station ID, transmitter ID, network ID, the gain in decibels, the signal-to-noise ratio, and line-of-sight values. The raster datasets within the raster catalog modeled the continuous values associated with radio frequency propagation, which are able to be visualized as such. The raster datasets within "XMTRFOOTPRINTS" are used for raster analyses with others such as the LandScan™ population dataset, which calculated the number of potential listeners of a station or

highlighted the densest areas of potential listeners. The raster datasets within the raster catalog were exported to the "XMTRFOOTPRINTS" feature dataset through a conversion process utilizing ArcScan. Relationship classes could have been created, but were not done so for the raster datasets of the broadcast areas because the project and the client felt the feature class sufficed for the prototype.

The "LandScan" and "Terrain" raster catalogs were included within the geodatabase due to the project's lack of access to NGA and OSC enterprise databases. These additional databases were included due to their relevance to visualizing and supporting processes within the prototype, but would not be included in a full enterprise deployment. If an enterprise deployment of the project is implemented, data services from NGA, OSC, and other organizations will have enabled the project and the creativity of its users to conduct analyses not conceptualized within this report. The "TERRAIN" and "LANDSCAN" raster catalogs were included to illustrate how similar data would be exported or replicated to a Personal ArcSDE geodatabase.

The "TERRAIN" raster catalog and datasets were intended to be used for radio propagation modeling and analysis. The raster catalog contained DTED1 or SRTM1 terrain data covering the Middle East. This data was downloaded from the NGA Data Bundler Web site via the Intelink-U government computer network, which through its encryption methods disables GIS Web services from NGA and OSC. The users could have had better data locally on their computers if they were in a position to access and use the data with ArcGIS Desktop and CSPT. In a full production environment, terrain data would not be part of the geodatabase because Web services from NGA and other organizations would be available. For the prototype, ArcGIS Desktop and ArcGIS Server accessed local

ArcSDE enterprise and personal geodatabases to consume terrain. Terrain data was included in the geodatabase for prototype purposes only and would not be included unless the geodatabase were to be replicated for use without access to a computer network.

Similar to the terrain data, population and demographic data were not necessarily elements that needed to be stored in the prototype geodatabase if they were to be implemented at the client's site. Demographic and ethnographic data is collected from multiple sources and varies in its fitness for use and scale. Often, population data and demographic data are incomplete and are accessed from different sources required by users for different areas and projects. For the purpose of this project, demographic data consisted of LandScan™ global population datasets stored in the "LANDSCAN" raster catalog. LandScan™ is created yearly by the Oak Ridge National Laboratory.

Additional tribal and ethnographic data covering the prototype's geographic area was obtained from the Central Intelligence Agency, and the 2006 Iraq Population Estimate was obtained by OSC from the Iraq Central Office of Statistics and Information Technology Web site. Administrative and transportation data for Iraq was provided by LeadDog LLC; all are available via the NGA Web services if the project were to be connected to the NGA network. This information was stored in separate feature datasets within the prototype geodatabase. Similar to the LandScan™ and "TERRAIN" raster catalogs, these datasets were included to provide additional information for the prototype to simulate a connection to geodata services from NGA and OSC.

The prototype geodatabase included additional software features, which helped to maintain the data integrity of the geodatabase through the use of coded value range

domains. The ArcGIS geodatabase included each of these features, which the project used in its prototype geodatabase. These domains were important and served a number of different tables and feature classes within the geodatabase.

Coded value domains are sets of codes that help to maintain specific range of acceptable attributes in the geodatabase. For example, the prototype geodatabase has a "COUNTRIES" domain which was applied to several feature classes and tables. The "COUNTRIES" domain included a list of countries and their International Standards Organization 3166-1 standardized country codes, which provided international country codes for the entire world (Figure 3.20). A coded value domain such as "COUNTRIES" was designed to assist—or prevent—users spelling country names, which was also included in a drop-down list when the table or feature class was edited.

Coded value domain	
<b>Countries</b>	
Description	<i>ISO 3166-1 Country</i>
Field type	<i>codes</i>
Split policy	<i>String</i>
Merge policy	<i>Default value</i>
Code	Description
IRN	Iran
IRQ	Iraq
JOR	Jordan
SAU	Saudi Arabia
TUR	Turkey
KWT	Kuwait
SYR	Syria
GBR	United Kingdom
USA	United States

**Figure 3.20. The COUNTRIES coded value domain used ISO 3166-1 country codes to support editing**

Several coded value domains were created for the prototype geodatabase, especially for the "XMTRS" table, which included attributes and values specified by the CSPT tool. If data from the "XMTRS" table and any of the other geodatabase's feature

classes were to be used with CSPT, the attributes needed to conform to the tool. The best way to maintain the integrity of the geodatabase in its work with CSPT was to use coded value domains. Many of the coded value domains included information on antenna types, radio frequency bands (such as FM or AM), Boolean codes, codes for citation sources, specific units of measure, and specifics associated with antenna equipment. Coded value domains such as "COUNTRIES" and "LANGUAGES" utilized International Standards Organization codes for their inputs, which are also utilized within the client's other information systems. When these coded value domains were designed along with their tables and feature classes, information in the client's other information systems was kept in mind to support the possibility that the client may join data from other systems in the future.

A range domain within the geodatabase defines a range of acceptable values a user can enter into a field within the geodatabase. Range domains are numeric, and in the case of the project were applied to the "CHANNELS" and "FREQUENCYRANGE" range domains. The "CHANNELS" domain limited the range of values entered within the geodatabase from 0 to 999. This range of values for channels was implemented to support cable or satellite channels in the future. The "FREQUENCYRANGE" domain also limited the numeric values, which were entered into the geodatabase; these values ranged from 0 to 108000 to cover the high frequency, or HF, radio spectrum in the "XMTRS" table in kilohertz. Again, range domains were applied to maintain the integrity of the geodatabase. If values are not within the ranges at the time edits are made, ArcMap will notify the editor of the out-of-range value. This feature is intended to alert the editor that the value may be incorrect and that a review of the data may be required.

The logical design of the geodatabase was supposed to organize the concepts the geodatabase was to model. The project's prototype geodatabase design focused on television and radio infrastructure and the extent of its broadcasting capabilities. The logical design also focused on maintaining the integrity of the geodatabase and the editing to be done by the client and the geodatabase users. The geodatabase may have had only a few feature classes and raster datasets, yet the most important aspects of the geodatabase were the relationships within it. The relationships, which occurred in the real world, were modeled in the project geodatabase and provided the links necessary to allow the features within the geodatabase to be broken down into specific parts. The logical design also provided a prototype framework for modeling other media infrastructures such as satellite television or wireless cell phone networks and press distributions. Different media will require further exploration as to how they should be modeled if they are to be included in a geodatabase similar to the project prototype.

### **3.6 System Design & Architecture Summary**

As the heart of the system, the project's geodatabase modeled the concepts of television and radio infrastructure. The logical design, which utilized information about media infrastructure and previous work done by OSC, led to a data model that captured the behavior and relationships within the system. The design of the geodatabase was an exercise which brought the prototype geodatabase and the system to life. The physical geodatabase powered the rest of the project with its hardware, software, data, and network connections. The rest of the system revolved around the geodatabase, where other applications and user roles and workflows were based on what could be done with it.

## **4.0 Project Planning & Management**

### **4.1 Introduction**

This project created a prototype GIS that followed a project management plan to ensure it met the client's needs. This chapter discusses the stated goals and objectives related to the perspective of the project. The management plan addressed how the project was to be conducted and used a project schedule, project work plans, and risk mitigation plans. These plans ensured that the identified needs of the user were incorporated in the project solution within the scope of the time and resources.

With guidance from the client, specific goals and objectives were identified and incorporated in the plan. A scope of work was written to manage expectations and set limitations to the work to be done. Tasks were defined within the scope, and time frames for each were documented. With a time frame set, the project initiated a work plan and work schedule. The work plan identified all the work to be done and created a simplified work breakdown structure for the project. The structure was linked to the project schedule, which tracked both when work tasks were started and their expected duration. A Gantt chart was created to visualize the schedule and track progress. All of these management tools kept the project on a successful path to creating a prototype GIS for the client.

### **4.2 Project Work Plan**

The project work plan supported the overall management of the project. The work plan consisted of six grouped tasks that covered work from requirements analysis, system design, system configuration, user interface and analytic model design, system testing, and



project close-out. These six areas helped to break the tasks down into functional areas that were used to schedule tasks and track performance. Tasks were broken down further into subtasks, which focused on the accomplishment of specific components such as the geodatabase design, hardware configuration, and software configuration. The work plan also outlined the project's objectives and scope of work to meet the needs of the client.

The first area specified within the work plan consisted of the requirement analysis of the client's needs. The project team worked with the client to review workflows and processes, interviewing users and writing up use case scenarios of the system. These elements were discovered in the review process, analyzed, and then broken down into functional and nonfunctional requirements that were used for the project's design.

Following the requirement analysis with the client, an acquisition and procurement process was scheduled to analyze the hardware, software, and data that were needed to design and prototype the system. This analysis focused on the technology used by the client and available to the project team, as resources were limited for procurement. Data was already provided by the client and the MS GIS program provided the hardware and software. This arrangement was adequate for the needs of the prototype and was within the scope of the project.

The platform design and configuration process was the third area of work accomplished. Designing the system architecture and geodatabase and implementing the prototype were involved in this area of work. A virtual server that the geodatabase, spatial data engine, ArcGIS Server, and Web server resided on was the prototype. The project's core focus was on the geodatabase and the modeling of media infrastructure, where

desktop software and Web users of the prototype were provided with accessibility to create, read, update, and edit the geodatabase.

The final development aspects of the work plan focused on how to use the geodatabase to answer users' questions and meet their needs. The users' interaction affected the workflow design that supported modeling media infrastructure and user queries. The design process included the use of query attribute tasks and ModelBuilder to support users' queries. Data creation and output needs were met with external tools and workflows that included applications such as CSPT and Arc2Earth. Web-based mapping applications were also designed, created, and tested during this activity.

The work plan outlined the scope of work that needed to be completed, but it was the project schedule that kept the work on task and on time. The work plan was used by the project team and client to adhere to the scope of work and only the work to be completed. The work plan and with the schedule were the two driving factors that made the project successful.

### **4.3 Project Schedule**

The schedule included a breakdown of all tasks associated with the project and the estimated durations for each task. The initial schedule was created with Microsoft Project 2003 to create a Gantt chart visualizing the start and duration of work. Within Microsoft Project, the work day was scheduled to last for two hours and excluded weekends and holidays, including the MS GIS Program's three week-long breaks. The work day and time off were determined to be a valid estimate that included external influences such as MS GIS class work and work-life balance issues to support project team morale.

Morale and time management notwithstanding, the schedule enabled the project to validate all the tasks that needed to be accomplished to create the prototype. While creating the work plan, the schedule broke larger tasks with many components down into smaller tasks. The extent of the work plan and schedule did not create a comprehensive breakdown structure with itemized work packages, nor was that its intention. While many projects benefit from itemized breakdown structures, they were not required to create the prototype. The work completed was documented for the client to learn the intricacies of the technology applied to the project, which is discussed in Chapters 5 and 6.

The schedule also included milestones and events, which were important for the project's success. Milestones and events were often the start and end dates of tasks, dates to review work before proceeding to the next task, or deliverables. These milestones were intended to keep work on task and on time within the schedule; sometimes milestones were pushed back due to external influences. The amount of padding included within the schedule compensated for the tasks which were pushed back. Any delays were rescheduled and accomplished over the final MS GIS program break. Throughout the final break, eight-hour days were spent finishing the system configuration and data preparation tasks to return the project to the schedule.

The original schedule gave an estimated 156 days to complete the project, encompassing 312 hours of work according to the method in which work days were measured. The amount of time in the sprint period over the final MS GIS break validated this estimate, as the tasks caught up to the original schedule. The schedule was an invaluable component managing the project, which helped to achieve its deliverables.

#### **4.4 Project Deliverables**

The project deliverables included the prototype to the client, which demonstrated how to model media infrastructure in an enterprise geodatabase. The project, per the MS GIS program, was also required to deliver design documents, this report, a final presentation, a poster, and all deliverables on a CD or DVD. The work plan addressed these requirements and estimated deliveries via the work schedule.

#### **4.5 Project Assumptions**

When the project plan was created, a number of assumptions were identified that affected work tasks and design criteria. Many of the assumptions were related to data from sources, such as from the client, or about data completeness. An assumption about the amount of time per day spent on the project was outlined as well. Assumptions about hardware and software, their cost, and whether the client would pay for them were also included.

Data for the project was assumed to be provided by the client, and it was. The assumptions about the completeness of the client's data, however, were true in that not all cells in the data attributes of the features were provided. This fact caused minimal impact to the project. The data provided was incorporated into the geodatabase design process as well. The shapefiles and tables in the data preparation process had to be cracked to be extracted, transformed, and loaded into the project's geodatabase. The client made an attempt to supply the database schema for the BBC Monitoring Service's media database but was unsuccessful. The lack of the BBC database proved to be of no consequence, as it was not required to be applied to the geodatabase design process. There were no overall issues regarding the availability of data, either.

Hardware and software assumptions were a different matter regarding the project. Initially, the project assumed that it would be based on ESRI's ArcGIS technology, which includes ArcGIS Desktop 9.2 and ArcGIS Server 9.2. It was also assumed the project would utilize Microsoft SQL Server 2005. These assumptions regarding the software caused no issues, since the ESRI and Microsoft software were provided by the University of Redlands and through the client's enterprise license agreement. The hardware assumptions were unclear at the time the project plan was written. The assumption early on was that a stand-alone server would be provided by the client, which was not the case. Coinciding with the project was an MS GIS course on Internet mapping services, where students utilized a virtual server using VMWare™ to configure its server-based applications. It was then decided to use a virtual server for the prototype.

Project assumptions were both overestimated and underestimated. A lack of communication between the client, University, and project team became a risk. It was fortunate the risk was mitigated from the use of the virtual server and through increased communications with the client and University staff. The incident could have been avoided with additional exploration early on by the project team. These kinds of risks were unknown at the time, and should have been studied further with a more thorough analysis.

#### **4.6 Project Risks**

During the project planning stage, assumptions about the availability of materials or the occurrence of events were made, but more analysis was conducted to identify initial risks. A feasibility and risk assessment was performed, which looked at whether the project was technically, financially, and organizationally feasible. A risk assessment matrix was created that used the work plan and schedule to identify tasks which would have made

significant impacts. The matrix also measured the probability and severity of the risks, which were multiplied to determine the project's exposure to risk. Risks within the matrix also identified methods to mitigate them and to minimize the exposure.

The feasibility analysis first determined whether the project was technically feasible. Tasks were reviewed against the project team and client's level of knowledge and familiarity with the proposed technology. The technology that was recommended by the client was also reviewed for its abilities to accomplish the goals and to meet the client's needs. The technical assessment focused on familiarity with geodatabase versioning, the creation of analytic models, and discussion about whether Web services were able to be implemented. The project was feasible because of the skills the project team had acquired prior to the project and had applied during the project's implementation. The software met the client's requirements and was utilized for its intended purpose without major issue.

Due to material resources being supplied by the client and the University, the project was also feasible from an economic standpoint. Time was an additional economic factor that was reviewed. The project's scope and the MS GIS program schedule limited the project's time frame to the amount of work that could be done within nine months. The work plan and schedule reflected the scope of work and ensured economic feasibility.

The final factor the project reviewed was the organizational feasibility that determined whether the project team and client's organization could accomplish the project. The Director of OSC made himself a stakeholder when he allocated resources that included exploring methods to collect and analyze information about broadcast media infrastructure. The collection of media sources and infrastructure data continues at OSC,

which demonstrates a dedication to researching sources and their impact on the landscape. The information technology group within OSC is observing the work for this project and is looking forward to reviewing the prototype to consider a follow-up system. The project was considered organizationally feasible, and the stakeholders participated to share requirements, expectations, and a plan to communicate the project status to the appropriate partners.

The overall project was therefore determined to be feasible, and the risks were reviewed to identify any possible problems that may have arisen during the project. A risk matrix was created to identify areas of possible exposure to risk and ways which they could be mitigated. The severity and probability of the risks were measured on a scale of one to five, five being the most severe or probable measure. The severity and probability figures were multiplied to calculate the project's risk exposure. This helped to further explore the reasons why some tasks were riskier than others. This process identified the appropriate methods to mitigate risks associated with the project. Recommended risk mitigation techniques were then added to the matrix and included in the feasibility and risk assessment document. The feasibility and risk assessment was referenced during the creation of tasks, especially during the geodatabase design and system configuration tasks.

The risk matrix (Table 4-1) identified items such as the geodatabase design, the analytic methods, and the dissemination platform. The database design was considered a critical task, which resulted in a score of four on the scale of severity. This meant the improper design and configuration of the geodatabase would have made the project impossible to finish. The probability of the geodatabase design not being completed had scored even odds—a score of three—of not being designed properly. The initial risk

assessment regarded concern about the geodatabase design and its focus on how media infrastructure would be represented within it. The exposure to risk from the geodatabase design scored a twelve, the highest score of all assessed risks, which meant the risk was further reviewed and required strict methods to mitigate.

**Table 4-1 Project risk matrix**

<b>Risk</b>	<b>Severity</b>	<b>Probability</b>	<b>Mitigation</b>	<b>Exposure</b>
<b>Geodatabase Design</b>	4	3	Understand user problems; aggregate data from Phase 1; understand media models and incorporate into database design.	12
<b>Analytic Methodology</b>	3	3	Identify current tools that can be incorporated in ArcGIS; identify media models previously developed and port to ModelBuilder.	9
<b>Dissemination Platform</b>	3	3	Take ArcGIS Server training; purchase hardware/software early or leverage ESRI services.	9

The project team mitigated the risk posed by the geodatabase design by researching similar database models, took additional geodatabase design and management training, and developed a deeper understanding of how media worked socially and physically in geographic space. Self-prescribed ESRI instructor-led training regarding multiuser geodatabases gave the project personnel hands-on experience to conceptually, logically, and physically design and implement the geodatabase. The project team read several texts on media and its geographic extent, as noted in Chapter 2, to understand how media worked spatially and how it could be modeled in a geodatabase. The project team worked with the client to develop requirements for the geodatabase design and used client-provided data to assist in the identification of attributes the database would need to include. The expanded knowledge the project team added allowed it to utilize the appropriate



methods to meet the requirements of the client and mitigate any risks involved with the phenomena and technology.

The feasibility and risk analysis conducted early on, to both identify whether the project could be successful and mitigate any risks that arose throughout the project, led to the involvement of the stakeholders in the planning process to determine whether the project was feasible to conduct based on the client's requirements and the risks involved. Communication and thorough reviews of those risks involved sound practices in the design of the project plan, which contributed to the mitigation of project risks.

#### **4.7 Summary**

In the end, the planning process kept the project in a functional state. Without the implemented plan and project management techniques, the project would not have been able to stay within the scope of the work needed to be done and would not have been completed within the time specified. The work that needed to be completed was understood and its status was communicated to the stakeholders when required.

The core management documents of the project were the work plan and schedule, which outlined the work to be accomplished. The project work plan set clear goals and objectives, set the scope of the project, and estimated the types of tasks and amount of time spent on it. Equally important to the work plan were the project schedule and its Gantt chart. The Gantt chart visualized and organized the start and duration of each task. The Gantt chart also identified critical tasks and work scheduled in parallel and noted project milestones.

A successful project plan with clear goals and a thorough analysis of the risks associated with the prototype also contributed to the project's completion. With risks reviewed and evaluated, which helped to mitigate issues, the project could avoid any setbacks. Unforeseen and underestimated risks were minimal and were mitigated with similar techniques used in the initial risk assessment exercise.

These methods in project design emphasized focus on a small prototype project that, if expanded, would require significant project planning. If the project were to be implemented in the client's organization, any follow-up work would require a team of GIS professionals, information technology staff, and end users who would need to formulate a project plan. Any personnel added to the project would have required additional project management techniques such as team communication, system integration, and team management plans.

Overall, project management techniques succeeded in delivering the prototype GIS to the client. The tasks which were implemented are described in the next chapter, noting the issues and the associated risks related to the creation of the prototype GIS for the client. Project management skills were critical to the project, as were the technical skills involved in creating the prototype GIS.



## 5.0 Implementation

### 5.1 Introduction

The implementation of the project prototype revolved around designing a storage and dissemination solution from hardware and software that followed a recommended ArcGIS geodatabase enterprise architecture from an Environmental Systems Research Institute, Inc. (ESRI), white paper called *System Design Strategies* (Peters, 2007). Hardware, such as servers and network components, were provided by the University of Redlands via virtual servers and its network. The geodatabase consisted of a Microsoft SQL Server Enterprise 2005 and ArcSDE instance that followed the recommended settings from ESRI. The user required a specific configuration of the data such as storing the data in the WGS 84 coordinate system and setting the spatial resolution and tolerance of the geodatabase.

Once the project platform was built, configured, and loaded with data, the project implemented Web mapping services to support other desktop GIS and geodata users who were also on the prototype's network. These services consisted of ESRI's proprietary data services, which that were native to the ArcGIS suite of software, and two open source services—Web Mapping Service (WMS) and KML service—from the Open Geospatial Consortium (OGC). These services provided access to read data from the project's geodatabase in ESRI applications like ArcMap and ArcGIS Explorer. They also provided users with access to the geodatabase via tools such as Quantum GIS and Google Earth through the WMS and KML Web services. These services demonstrated the capabilities the client would have at its disposal to share and collaborate within its organization and

with its partners. Web-based applications that accessed the geodatabase services were implemented to provide the client and its users with an interface to access and edit the prototype's geodatabase through the Web browser.

## **5.2 System Implementation**

The geodatabase is the core of the system architecture and would drive user activities based on the data they entered into the geodatabase and could get out of it. The configuration and tuning of the geodatabase optimized its technical features for the project. Standard features of an ArcGIS geodatabase, such as loading and storing data, used the keywords feature; storage of transactional and historical views of geodatabase changes incorporated versioning; optimization of search and data access applied compression and indexing; and to support data sharing within or outside of the enterprise network, the replication feature were utilized. When the geodatabase was coupled with ArcGIS Server and the Web server, it enabled another set of functionality through geospatial Web services, which facilitated data sharing across the simulated enterprise network. These capabilities were implemented for the project and met its goals and the requirements of the client.

The University of Redlands provided hardware and network equipment for the prototype. The University provided students of the MS GIS program with a Windows Server 2003 and VMWare virtual server for class work and projects. This platform was utilized for the project and configured for use within the Redlands intranet, which also could be accessed externally via a virtual private network (VPN) connection. From a budget and configuration perspective, the choice to use this platform had a clear advantage over building an entirely new test network. Redlands owned and configured the virtual

machine and server as well as the network. This accelerated completion of the project by a week and made it easier to focus on installing and configuring the software for the geodatabase. The virtual machine had enough processing power with its multiple core multiprocessors and 16 GB of memory. The only problem that arose with the platform was that the virtual machine needed to implement a "shrinking" process occasionally to clear its memory cache, which had slowed its performance to support database services and Web-based applications. Shrinking the virtual machine would be a routine task that a database administrator or a server engineer would perform to maintain performance of the platform.

The software used for the geodatabase was the real workhorse of the prototype. The database management system software coupled with the spatial data engine was the combination which made the prototype possible. The choice was made to use Microsoft SQL Server 2005 to manage the database; this choice had been discussed previously with the client, which had an Oracle database implementation. Accessibility to Oracle Spatial Enterprise database software could not be obtained due to the cost, which would have been extremely high, quite possibly tens of thousands of dollars. The availability of Microsoft SQL Server 2005, through a Microsoft student discount program called DreamSpark, provided the project the with the database management software for free. Another factor in the decision to go with Microsoft SQL Server 2005 was the ease of integration with ArcGIS Server (ArcSDE) and the platform operating system, Windows Server 2003.

The use of Microsoft SQL Server will have to be discussed further with the client and its information technology staff if the project is to be taken from prototype to production at the client's site. The benefits the project experienced were the use of Windows operating system security features with the database software, the use of Visual

Studio 2008 to create server-based applications to view the data, and the ease of integration with ArcGIS Server. Installation and configuration were much easier than the project had predicted. This meant that, from a personnel staffing standpoint for the client, hiring personnel to support the database would be much easier due to the larger hiring pool of Microsoft engineers as compared to Oracle engineers. The client may encounter issues with its certification and accreditation or security processes for Microsoft SQL Server software when they decide to institute a production implementation, as it is not currently on its approved products list.

The spatial data engine software used for the geodatabase was ArcGIS Server, or ArcSDE, which is the spatial database engine within the ArcGIS Server software suite. The ArcSDE application is described as "sitting on top of the database" and acts as the intermediary between the database and the ArcGIS suite of software applications. ArcSDE manages the tables within the database that store information about the geometry, attributes, and behavior—such as relationships—of spatial data. ArcSDE also allows the geodatabase and its information to be accessed directly via ArcGIS Desktop or through a Web service. A direct connection to the geodatabase from ArcGIS Desktop utilizes the local network communications protocols and processing tasks on the client machine to manage the connection. A Web-based connection from ArcGIS Desktop to the geodatabase uses Internet protocols and a Web server to communicate to the desktop computers. The primary difference is the users' preference as to where they want to delegate processing tasks within the system. This decision depended on the size of the network and the processing capabilities of the client's machines, which would require further testing to optimize the system for the client.

Microsoft SQL Server 2005 and ArcSDE were placed on the same server for the configuration of the prototype. Initial system designs used multiple servers to manage storage and the data access processes of the geodatabase platform. This was not the case for the prototype, which was restricted to a single server; for the purpose of the prototype, the hardware and software configuration on the single server was sufficient to demonstrate a proof-of-concept to the client.

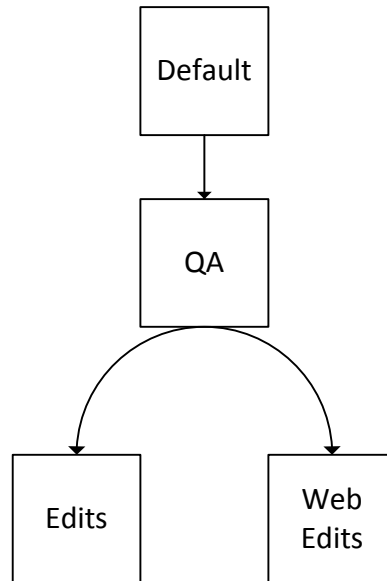
The geodatabase was installed on a single server and needed to be tuned and optimized. The server had greater processor and memory capabilities than the recommended specifications from Microsoft and ESRI; this helped immediately with initial performance. Microsoft SQL Server was configured to consume 55% of the server's memory and processes based on the ESRI recommendation to allocate 33% to 55% of it to server processes (Peters, 2007). The higher memory allocation was estimated to leverage at least 8 GB of memory for the server and split the other 45% with ArcSDE and the operating system. This would be enough to run the geodatabase processes so that users would not experience any performance issues.

Geodatabase performance depended on how data and features were loaded, versioned, compressed, and indexed. The keyword feature of the geodatabase was used with SQL Server and ArcSDE. The project allocated specific keywords for loading data that determined where data was to be stored and managed. For example, terrain data within the geodatabase utilized the "TERRAIN" keyword, which stored the data in a separate folder on the network from the rest of the geodatabase data. The keyword feature demonstrated the distribution of data within a geodatabase and how it was possible to store data elsewhere on the network. Keywords can be used to help ArcSDE transform and set



properties during data loading that might help in the performance of the geodatabase. For example, as a user loads a raster dataset, bands can be modified or data transformed to a different projection. The keyword feature could be useful in managing project data and bulk data loading if the project data were to grow too large or the network storage configuration were to change.

Geodatabase versioning was a concern in that it could have contributed to performance issues. Extraneous versioning was dealt with by limiting the number of users who could create versions through roles and privilege functions in ArcGIS. Additionally, workflow processes between the editors and the GIS manager or SDE administrator were developed to review geodatabase changes. These changes in child versions of the geodatabase would be integrated into the parent version from which it was created. From another standpoint, geodatabase versioning was important for geodatabase archiving and replication operations. Versions can be created for replication to include only part of an area that needs to be edited (Figure 5.1). These versions, where subsets of the geodatabase are included for editing, can be replicated to another enterprise geodatabase, file geodatabase, or personal geodatabase on another system or computer through the replication technology ArcSDE employs.

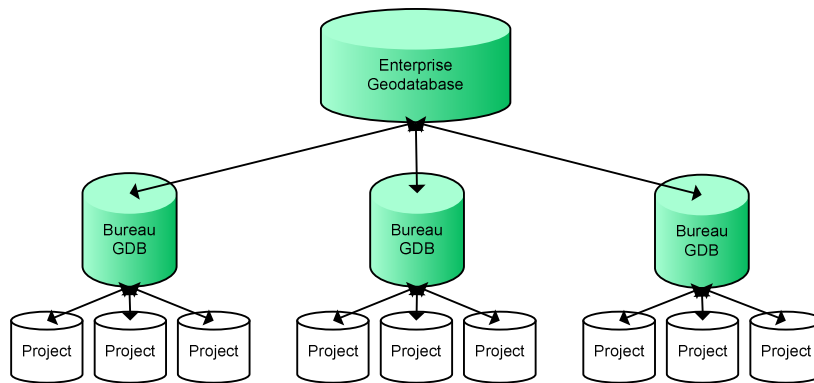


**Figure 5.1. Concept of geodatabase versioning where there is a parent to child relationship**

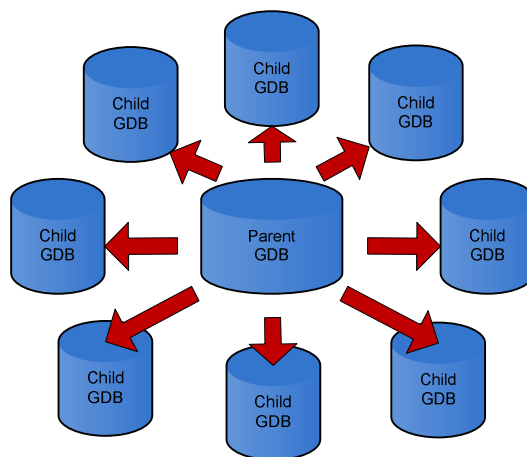
Data that was replicated and edited externally and which can be brought back into the geodatabase is another feature of the replication process. In the example of the client, its international bureaus can be provided a replica, or a portion, of the prototype's geodatabase for performing edits. The edits performed by the bureaus can be synchronized remotely or physically with the project geodatabase in Reston, Virginia, or vice versa. Replication can occur in any of three ways: Check In/Check Out, One-Way Replication, or Two-Way Replication. Within the context of this project and the nature of the client's work, all replication methods were available for any purpose that might arise in the future. A workflow process could be further developed to support various source collection and verification scenarios that the client and its partners might decide upon at a later date (Figure 5.2).

The entire geodatabase replication process relied on versioning (Figure 5.3). The project recommends that any follow-up work include in its design practical version

management workflows to support the project and the user needs within the project. The very nature of geodatabase replication in a disconnected enterprise can be very powerful. If mobile platforms were to be employed in the future, they could benefit from both the geodatabase information and the editing of the data they could conduct. Versioning and geodatabase replication is available, and the client will need to understand how it can benefit from that in the future.



**Figure 17. Hierarchical nature of geodatabase replicas, which is based on geodatabase versions**



**Figure 18. Versions are created for replicated geodatabases where updates can be sent from the parent to the child.**

A feature similar to transactional versioning utilized within the geodatabase was the archival version functionality. Archival versions in ArcSDE are separate from transactional versions, where users create a child version of the geodatabase to edit. An archival version can be created using tools within ArcMap to specify either when the archive version should be created or what actions dictated the creation of an archive. One benefit from an analytic standpoint is that geodatabase archive versions could be used for historical analysis of stations, towers, transmitters, and other features as they change over time. Archiving adds the potential to conduct historical source analysis for OSC and its partners, although no historical source analysis was conducted for this prototype. An archival version was only created once as a proof of concept. Due to government requirements to archive records, geodatabase archiving is recommended as a process to be implemented when the client deploys an enterprise geodatabase.

Storage capacity was provided by a network storage device greater than one terabyte that contained the project's geodatabase information. Storage was not an issue related to performance while the prototype was configured; there were methods performed which contributed to improving geodatabase performance. To improve storage and retrieval speed within the geodatabase, the project created indexes for specific attributes or the spatial extent of the features within the geodatabase that were commonly searched for. For example, the names of stations and the names of their owners and managers, or the location of features within the geodatabase, were indexed. The performance improvement realized by using indexes with the prototype's data saw minimal improvement due to the limited number of features. If the features were to have ten thousand more records, indexing would assist with improved performance.

Another method used to attempt to add increased performance to the geodatabase was the "Analyze" feature within ArcCatalog. This feature compressed and optimized the geodatabase by removing deleted records that remained in the geodatabase. When records are deleted, they persist in the geodatabase due to versioning, and the size of the database remains the same. Without periodic compressions that delete the persistent records, the performance of the geodatabase degrades. The Analyze function removes the deleted records, which creates more storage space and improved data retrieval performance.

Indexes and compresses were processes required to be performed by the SDE administrator or the GIS manager of the geodatabase. These features are required periodically to maintain the health and responsiveness of the geodatabase. ESRI geodatabase instructors have recommended that indexes should be recalculated when the location and number of records or attributes has changed significantly enough to affect geodatabase performance. Compresses were recommended based upon the frequency of edits performed within the geodatabase. The prototype geodatabase did not have a required schedule for rebuilding indexes or performing compresses. Indexes were built as data was loaded into the geodatabase, and compresses were performed on the data after the project data was loaded or after versions were created and edited.

Loading the data into the geodatabase was lengthier than it was difficult. The project data was delivered to the project in shapefile format, which had to be broken down into the separate feature classes and tables described in the geodatabase design of Chapter 3. The original shapefile was converted into a file geodatabase feature class to help facilitate the construction of the prototype geodatabase. Attributes from the original shapefile had been divided into their respective tables, where additional attribute fields

were added. Geometry was transferred from the original shapefile to the "STATIONS" and "TOWERS" feature classes in a file geodatabase with a spatial join to the geometry of the original shapefile. Fields such as the station's name or a tower's identification number from the old shapefile were included in the join, which included only a few exceptions, as most of the attributes were excluded. The accuracy of the station and tower location was highly uncertain, and the feature classes were moved to locations that were descriptive in their attributes. Some edits included the relocation of station studios that were outside the borders of Iraq in places such as London or Dubai, UAE. Towers were not adjusted and inherited the locations of towns and villages they were previously reported to be in.

The tables in the geodatabase were created from the original shapefile data as well. The relationship classes were created using the relationship class tools in ArcGIS. The administrative data, scanned maps, and terrain data were imported into the geodatabase using the "cut and paste" import method of ArcGIS. When the data ingestion had been completed, indexes and compression processes were performed. The "RADIOTV" and "XMTRFOOTPRINT" feature datasets and the tables within the geodatabase were registered for users to create versions of the data in the geodatabase. With the core data of the project versioned, this allowed for several processes and applications to be enabled with their own versions within the geodatabase.

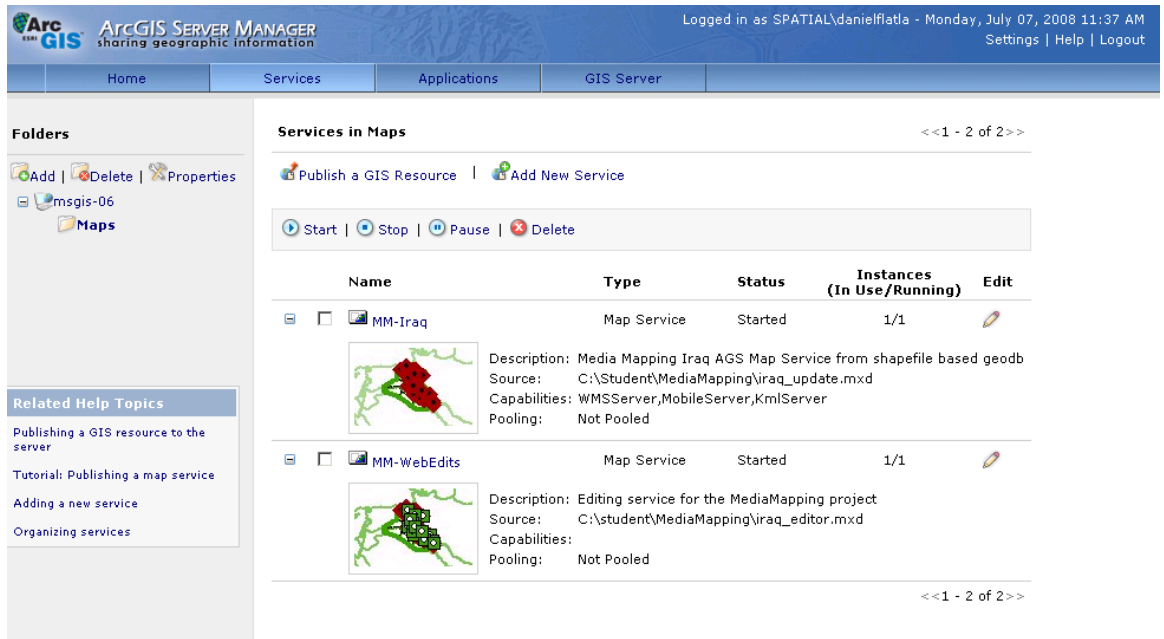
With the data loaded, the geodatabase was configured to mirror the projection, datum, and precision of the data it had ingested from the original shapefile. The client requested that the data be stored in the same spatial reference system in which it was created, the geographic coordinate system, and in the World Geodetic System 1984 datum. The client serves a number of its partners' data and felt that the datum and coordinate

system were generic enough to support a majority of uses. The coordinates within the geodatabase were also stored as decimal-degrees, for similar reasons as for the projection and datum.

### **5.3 Services**

The prototype used ArcGIS Server in its implementation, which provided the capabilities the client had required for managing and sharing data. Not only did ArcGIS Server provide the project's geodatabase technology to work with ArcGIS Desktop and its tools to access project data, but it was also able to create Web mapping services and data services for other applications and users to consume. The ArcGIS Server application provided the ability to share data via Open Geospatial Consortium (OGC) standards such as through the Web Mapping Service (WMS) and Keyhole Markup Language (KML) standards. These services were configured in ArcGIS Server to support the mapping applications and were intended to disseminate data to the client's partners.

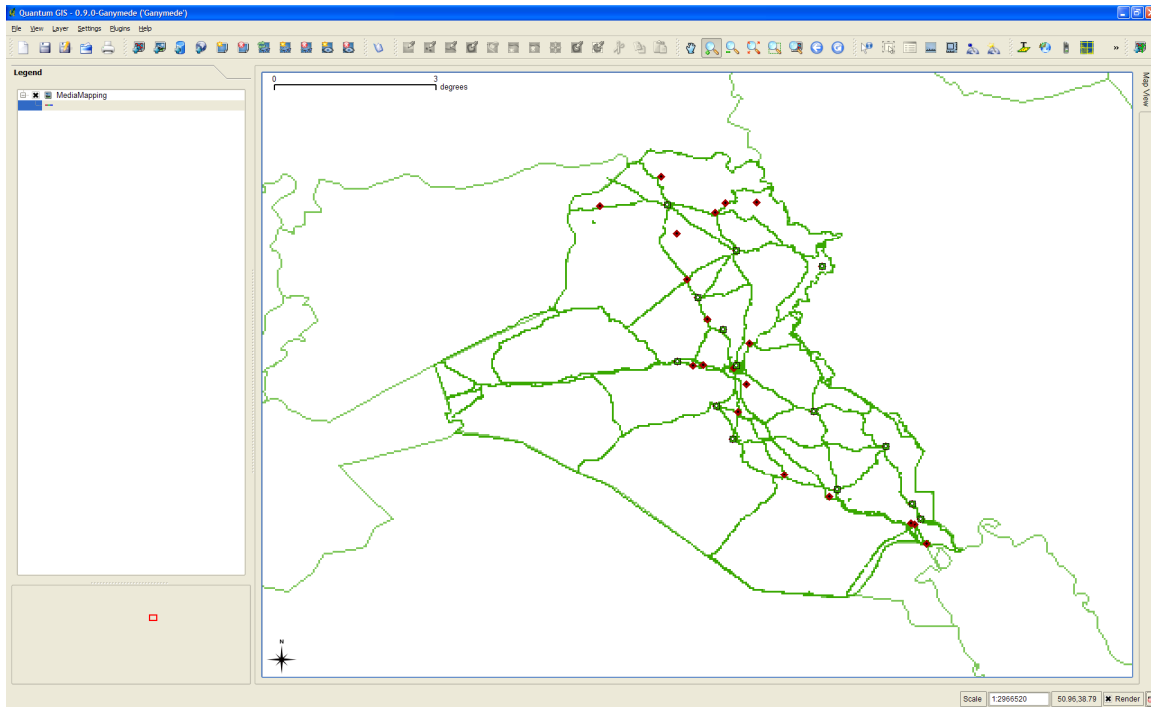
The ArcGIS Server application works in conjunction with ESRI's ArcGIS software suite, where it can be managed from a user's desktop to create map services, geodata services, or three-dimensional globe services through the ArcCatalog desktop application. ArcGIS Server's primary management application is Web-based and is called ArcGIS Server Manager; it provides additional control to generate map, geodata, and globe services. ArcGIS Server Manager also provides the capability to create Web mapping applications, which were used in the project to create a generic attribute query application and a Web editing application (Figure 5.4). Other dissemination services, such as WMS, KML, and mobile data services, can be enabled with ArcGIS Server Manager as well.



**Figure 19. The Services interface of ArcGIS Server Manager, where Web mapping services are managed**

The OGC Web Mapping Service (WMS) enabled the prototype to disseminate maps that were created with ArcGIS Desktop across a network. A WMS service allowed users to access maps in different applications. An example that was tested was with an open source GIS application called Quantum GIS, or qGIS. The intended use of WMS was to support partners which do not utilize ESRI-based applications but which still require access geographic data for their work. Some of these applications are desktop-based, like Quantum GIS (Figure 5.5), or Web-based. Layers from the project geodatabase can be accessed as overlays in other GIS applications. There are a number of applications that consume WMS services with which the users can access multiple services, thus creating an unknown number of uses and maps. Users of applications that employ WMS can also query different layers the service provides and aggregate them accordingly in desktop or Web-based applications.

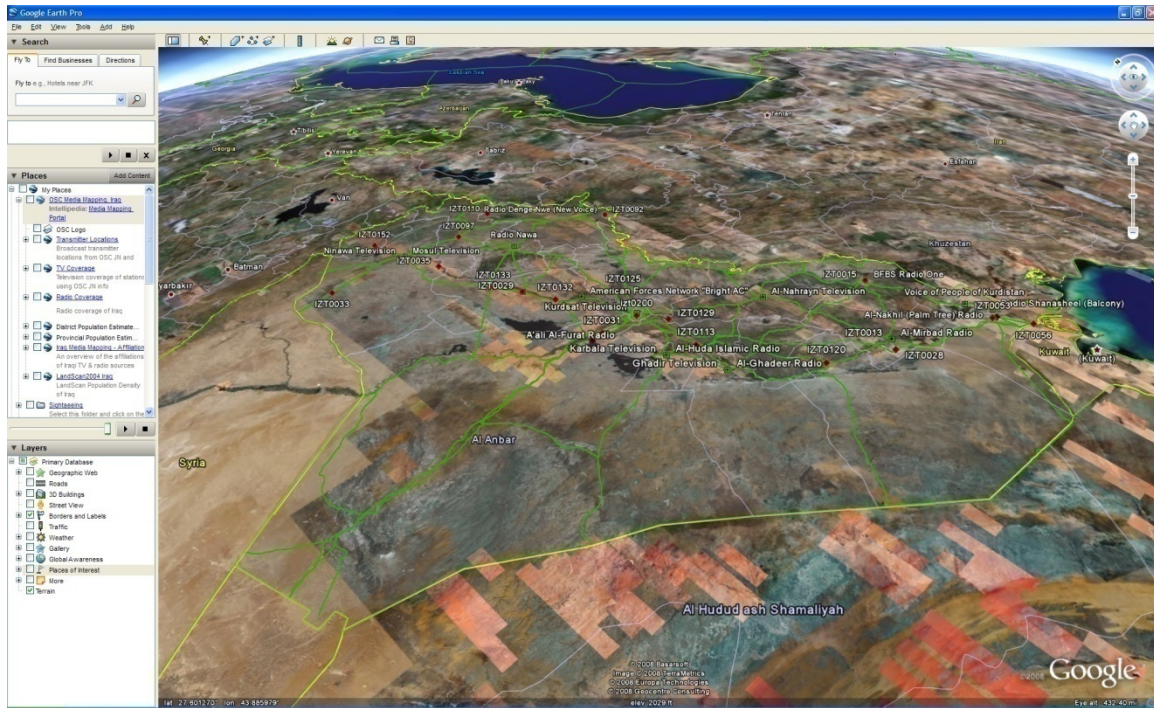




**Figure 20. The project's WMS service in qGIS**

The ability to access the project geodatabase via a KML service was implemented with ArcGIS Server's KML service. The service was activated in ArcGIS Server Manager with the selection of a checkbox. The KML service provided a URL for the system administrator to disseminate to users, which would create a networked link within applications like Google Earth or ArcGIS Explorer to display the project's data. There are three options in ArcGIS Server Manager about how ArcGIS Server renders KML. The first was a complete composite of the entire map service. This composite consisted of a large image file that would be overlaid in the application. The second option enabled layers to be created like the composite but consisted of the individual layers in the mapping service. The third KML service option in ArcGIS Server Manager enables the vector data of the map layers to be rendered in the application (Figure 5.6). The project selected the vector-only option to quickly render the prototype's data on the fly, as well as for speed and

aesthetic purposes. All the data is accessible and able to be queried via the KML application.



**Figure 21. The KML service from ArcGIS Server in Google Earth**

The services provided by ArcGIS Server demonstrated the prototype's capability to share data across a network to meet the client's requirements. These capabilities were to ensure data could be disseminated to a wide variety of users and applications that consume geographic Web services. Services provided by the project could have unknown but positive impacts when they become aggregated with other data services by users. Additional applications internal and external to the project could be applied to create maps, analyze information, and share data with these services as well.

## 5.4 Applications

Multiple applications were utilized and created to meet the requirements to manipulate data within the project's geodatabase. These applications ranged from the use of ESRI's ArcGIS Desktop application suite, which includes ArcMap and ArcCatalog, to Web sites that would query and edit the geodatabase. Other applications from ESRI, such as geoprocessing tasks, and third-party applications, such as CSPT and Arc2Earth, provided capabilities that attempted to meet the client's requirements. These applications were created as Web-based tools or deployed to the user's desktop.

Applications were created for different types of users within the client's organization that affected the tasks a user could perform. They manipulated data differently from other applications the project utilized, whether it was to manage the geodatabase, make maps, query the geodatabase, or edit the geodatabase. All of these applications and their specific uses and capabilities were intended to be the mechanisms with which the user would interface the geodatabase and the system.

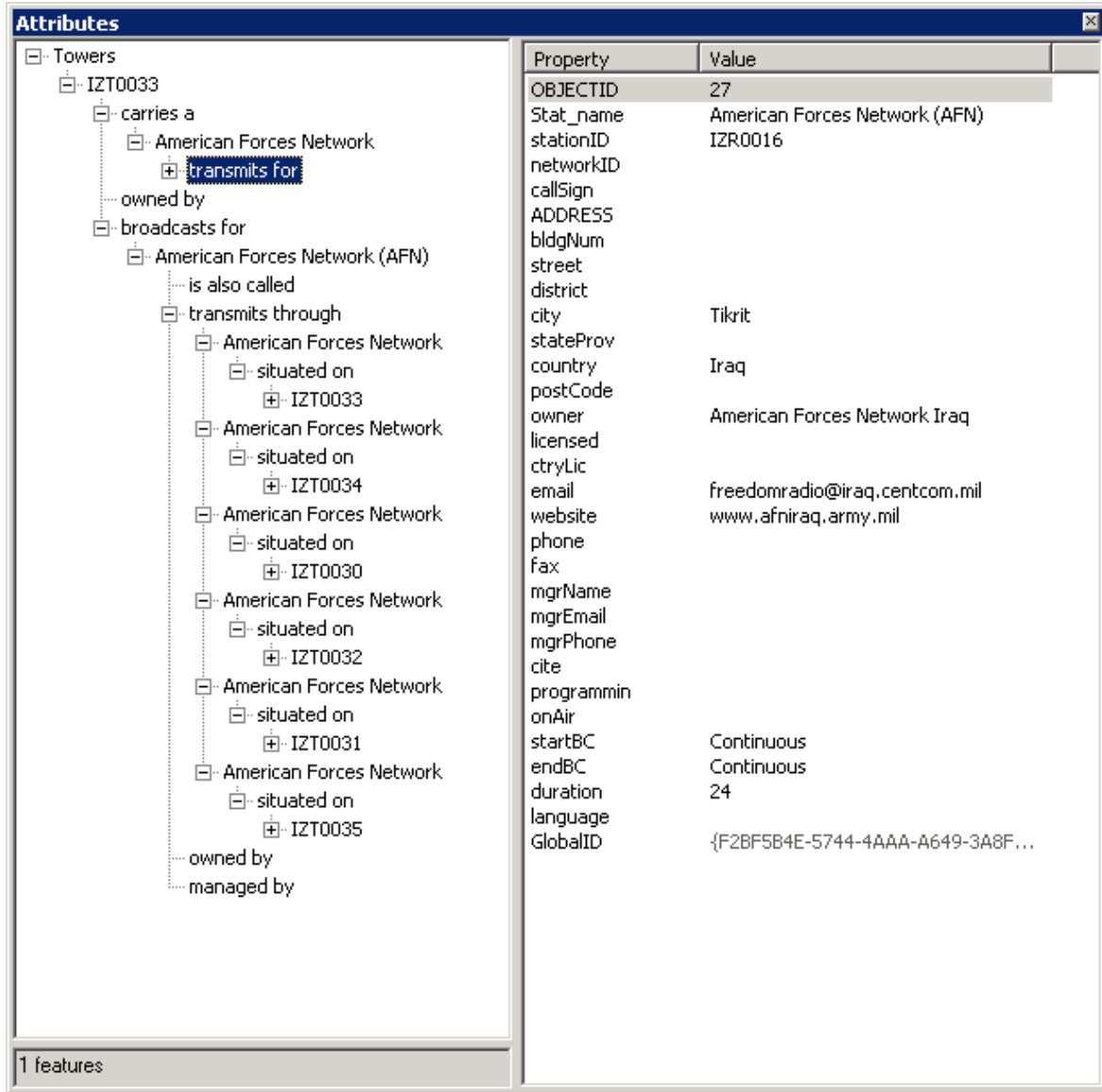
The primary user interface that was part of the prototype was ArcGIS Desktop. The ArcGIS Desktop suite was installed on user desktop computers to provide the ability to create maps, manipulate data within the geodatabase, access geographic information via Web services, conduct geospatial analysis, and generate metadata for data associated with the project. The primary applications within the ArcGIS Desktop suite were based in ArcMap, which could generate maps, perform analysis, transform and edit data, create geodatabase versions to include archival versions, and replicate the geodatabase.

The primary purpose for the use of ArcMap was for editing the geodatabase. Using the editing toolbar, features could be edited while the complex behaviors of the features with relationship classes were maintained (Figure 5.7). This meant the integrity of the geodatabase could be kept intact without much trouble; users involved in editing sessions could move features and update related attributes throughout the geodatabase and be alerted to their interconnectedness.

The client has already deployed ArcEditor licenses of ArcGIS Desktop to its overseas bureaus. It has been conducting training with its personnel in the use of ArcGIS Desktop to create and edit geodatabases; the client intends these personnel to become its experienced user base. In addition to creating geodatabases, the client's overseas personnel have already made maps and conducted basic analysis with ArcGIS Desktop. These users are intended to be the primary users of any future instance of the prototype's follow-up applications.

As ArcMap is considered one of the two primary interfaces in the ArcGIS Desktop suite, the other interface is ArcCatalog. The ArcCatalog program is the application that allows users to create and manage data and geodatabases. ArcCatalog performs functions similar to the Windows Operating Systems file explorer, except with functionality to manipulate geographic information in geodatabases and to act as a remote interface to ArcGIS Server. ArcCatalog also utilizes ArcGIS geoprocessing tasks in ArcToolbox, which manipulates geographic and tabular data. The geoprocessing tasks in ArcToolbox are also available for use in ArcMap. ArcCatalog is where SDE managers and GIS managers can administer the geodatabase, provide users privileges to specific datasets to view or edit, and build and compress the geodatabase. ArcCatalog also provides the user

with an interface to extract, transform, and load geographic data for the project.



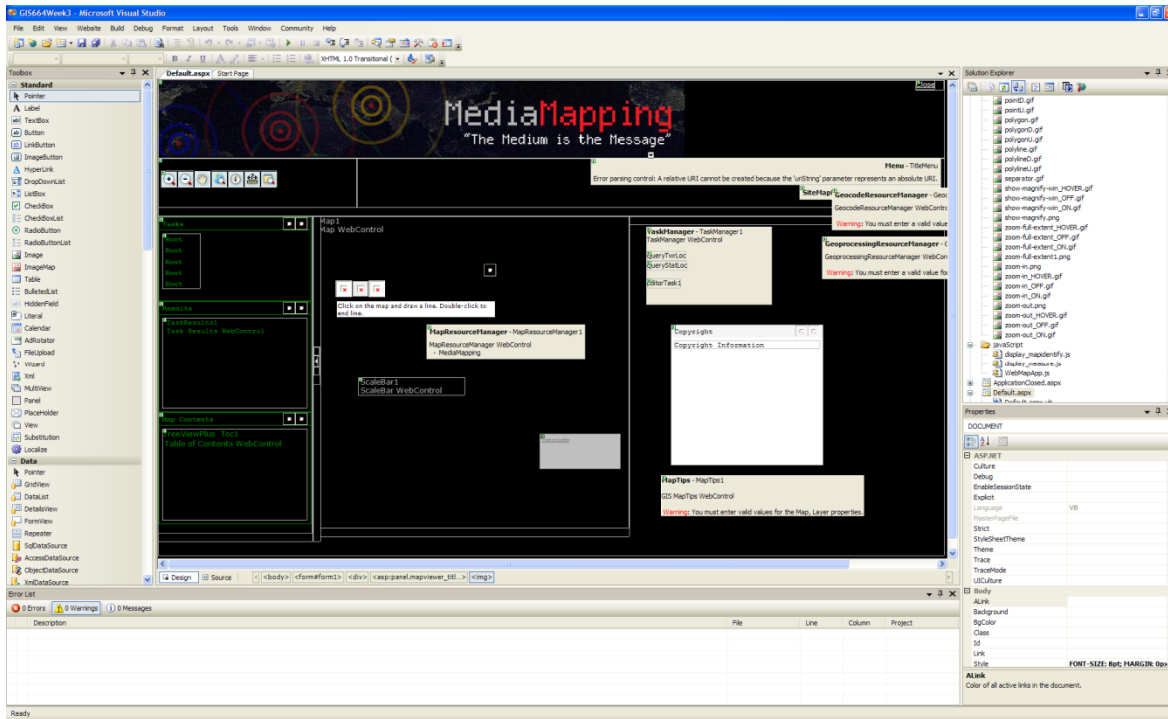
**Figure 22. ArcMap attribute editor maintained the complex relationships within the data.**

ArcMap is used to create an MXD project file, which is similar in nature to a file for Microsoft Word, to manage data layers, tools, scripts, graphics, and map layouts. An MXD file was created for the maps that were distributed online via ArcGIS Server.

Another MXD file was created for the overview map of Iraq in Figure 1 and was copied for similar maps. The MXD files and their graphic output can be published to a network as

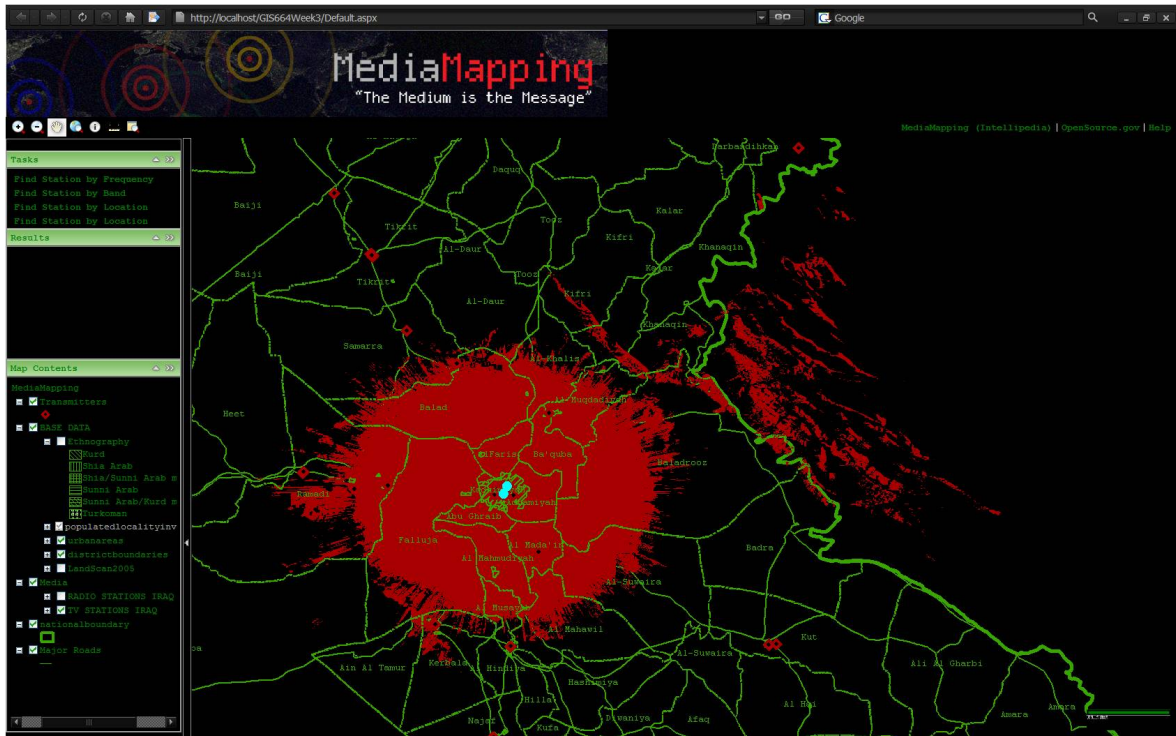
a map service via ArcCatalog directly or through ArcGIS Server Manager. MXD files were helpful when sharing data with the client and can be published to content management systems, such as Intellipedia, for others on the network to download and use. The file pathways to the source data must either be locally available or accessible via the user's network. In the context of the prototype, users on the network were able to share the MXD and access the project geodatabase via its ArcSDE Web service connection.

The geodatabase and ArcGIS Server provided a number of Web mapping services for users to access data with different applications that have different purposes. The project created two Web-based applications that accessed the native ArcGIS Server Web service. Both applications were initially created with the tools that ArcGIS Server Manager provided and were later modified using Microsoft Visual Studio 2005 and the ArcGIS Web Application Development Framework (Figure 5.8). Modifications to the Web sites were made with Virtual Studio 2005 to match the style of the maps created in ArcMap.



**Figure 23. The Virtual Studio development environment that was used to create the project's Web applications**

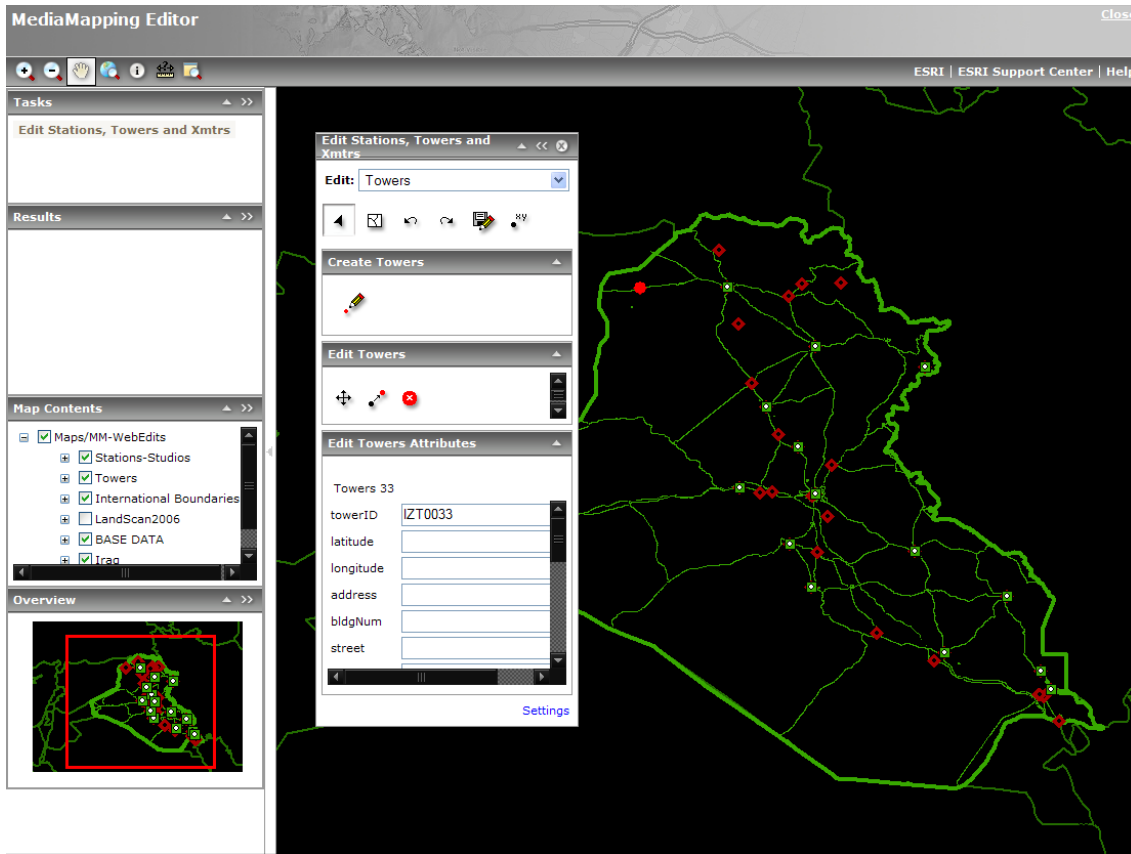
The first application focused on providing the ability to look up attributes about the stations and towers within the geodatabase. Queries were based on specific questions the client and its partners asked. These questions focused on searching for stations based on their bands, frequencies, names, content, language, and the names of the municipalities they were near. The user could use the find tool with the application, but specific attribute searches were provided through drop-down lists for places, frequencies, bands, and language. The Web query tool provided geographic search capabilities as well by selecting features using the selection tool, which was standard with the application created by ArcGIS Server Manager. Users were able to view station broadcast areas (Figure 5.9) and ethnographic and administrative data stored within the geodatabase. This application's layers and visualization were initially represented in an MXD file created with ArcMap and served by ArcGIS Server.



**Figure 24. The project's Web query tool used Virtual Studio to develop the Web site and an MXD for the map style.**

The second Web-based application provided editing tools for users to create, update, or delete station or tower features within the geodatabase online (Figure 5.10). The Web editing application was limited in its functionality compared to the editing capabilities of ArcMap. This deficiency in the Web editor was due to the construction of the Web editing task in ArcGIS Server's Web Application Development Framework, which is unable to handle complex behaviors in the geodatabase the way ArcMap does. The Web editor was only able to edit simple features, such as points, and unable to edit tables or relationship classes. The project provided the client information about this deficiency and made recommendations for follow-up work to enable the Web editor further. The client was open to continuing to prototype the Web editor, as it represented a capability that could be leveraged in other projects.





**Figure 25. The project's Web editor application could not deliver all the functionality of ArcMap.**

A "WEB\_EDIT" version was created for the Web editor. This specific version for the Web editor was used to demonstrate how adding new stations and towers with updated attributes would be useful to identify television and radio media infrastructure and other features. A GIS manager or editor with ArcMap could review changes to the "WEB\_EDIT" version and incorporate them into the parent versions of the geodatabase, supplying users with updated information. The client had noted that this modified process was not the easiest or most practical but would still be useful if it was the only Web-based editing tool the project could field.

Another area of applications implemented as part of the project was that of ArcMap extensions, or plug-ins. Extensions for ArcGIS and ArcMap are separate applications that are installed and incorporated into the ArcMap or ArcCatalog applications. The project attempted to incorporate two specific extensions that were thought to support the client's requirements. The first was the Communications Systems Planning tool from the Department of Commerce (CSPT) that creates the broadcast areas of the transmitters and imports them into ArcMap. The second was Arc2Earth, which exports maps created in ArcMap to a KML file format for viewing in Google Earth. Both were designed to support specific needs of the client, but as they were implemented and installed, the project discovered that some of the extensions would need another review for their inclusion in the project.

The first tool the client recommended that the project use was the CSPT extension from the Department of Commerce. The CSPT tool can generate broadcast areas for a number of different types of broadcast communication systems. The normal use of the CSPT tool revolves around data in shapefiles, personal geodatabases, terrain models, radio frequency propagation algorithms, and antenna characteristics. The CSPT tool is an old FORTRAN program enclosed within a Visual Basic application that provides a toolbar as an interface to ArcMap. This arrangement prevented the extension from being used with ModelBuilder and within the ArcGIS geoprocessing framework. In addition to being unusable in the geoprocessing framework, which could have natively interacted with the project's geodatabase, CSPT required data to be entered manually to create its own shapefile of towers that were joined with transmitter attributes. The tool was installed with ArcMap for the project but required extraneous training for a typical user of the prototype.

A business process modification was discussed with the client and a team of GIS professionals at the National Security Agency (NSA). The Web services of the geodatabase would eventually be made available to the NSA to generate broadcast areas. Geodatabase editor privileges would be provided to the NSA team, which could run a geoprocessing model to create the needed shapefile for its version of CSPT. The NSA team would then save the newly created broadcast area in the project's geodatabase. The client agreed to then transform the raster dataset of the broadcast area generated by NSA into a polygon feature class and add it to the "XMTRFOOTPRINT" feature dataset. The client and the NSA, in the name of interagency collaboration, worked to enable the use of a complicated tool through a change in business processes that benefitted both organizations through the use of Web services and common applications.

The second extension the project utilized with ArcGIS Desktop was the Arc2Earth extension. This is an ArcGIS extension that can export layers or the map layout of an MXD file with all of its symbology to a KML or KMZ (a zipped KML file). Arc2Earth allows ArcGIS users to export data to geobrowsers, like Google Earth or ArcGIS Explorer, as there are more Google Earth Enterprise application users in the Intelligence Community than there are ArcGIS Desktop users. The installation of Arc2Earth was a straight-forward process where users could install the extension like any other application. Additionally, Arc2Earth was able to be incorporated as a tool within ModelBuilder that could be useful for users to export maps for any task en masse via a script or batch file. The KML from Arc2Earth had previously been saved to the client's pages in Intellipedia for dissemination. These files can also be cataloged within the client's geographic information library catalog,

COMPASS, to facilitate search and dissemination for external users through the client's map library Web site.

The use of Arc2Earth and ArcGIS Server's KML service appeared redundant to the client at times throughout the project. The client had required the ability of the prototype to output KML. As it was explained to the client, the two did produce KML, but each implemented different capabilities, since, Arc2Earth was a desktop GIS tool and the KML service was a Web service. The Arc2Earth extension enabled desktop users to export maps and data, which they could manipulate, symbolize, and disseminate via e-mail, wiki, blog, or CD-ROM if they wished. The KML service from ArcGIS Server created a Web service that only geobrowsers on the network could access via a KML network link. The two provide access to the same data, but Arc2Earth addressed the ad hoc export of KML, whereas ArcGIS Server's KML Service addressed the capability to export a map service via the network.

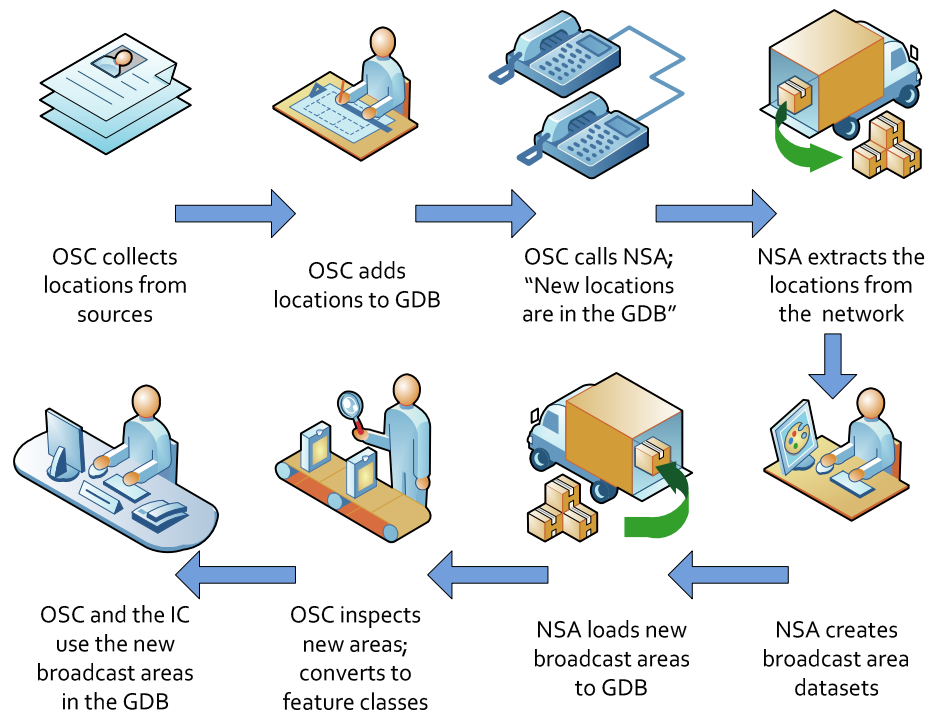
The applications, services, and extensions that were created were intended to be interfaces between the geodatabase and the users. The applications and extensions enabled the user to create, read, update, and delete information within the geodatabase. They also provided mechanisms to create maps and export information to other users or systems that could utilize the information. These applications helped to model and visualize television and radio media infrastructure to meet the needs of the client and its partners. These applications are dynamic and can be combined with other tools and data to perform spatial analysis and create new geodatabases and new maps and visualizations. Extensions for ArcGIS and the Web-based applications are able to be added and removed as they become available or as they are needed to enhance the needs of the client and its partners.

## 5.5 Testing

Testing of individual components was performed as they were constructed, which provided a way to ensure that the prototype functioned properly. The project plan had scheduled testing during the configuration and implementation of project components. No project test plans were written, as many of the tests were go or no-go tests that determined whether each component worked. Often, the hardware and software would provide the project team with error messages if components were not installed properly. The project team, when assembling and configuring the geodatabase components, followed the manufacturer's prescribed recommendations and procedures and did not have many issues. Software license files at one time did have to be updated for ArcGIS Server to work properly, but that was the only apparent issue that surfaced.

The installation of the third-party extensions, such as CSPT and Arc2Earth, initially worked. There were no problems testing Arc2Earth, since the manufacturer's directions created the appropriate output. The CSPT tool, upon installation and review, was more problematic for the project. First, there was an issue of the team not being able to use it in the geoprocessing framework with ArcToolbox. Other issues involved it being overly complicated and reliant upon settings the typical OSC user or open source analyst would not know how to perform. The previous method for developing broadcast areas had been to send the source features to NSA when they required updating. The amount of change to the broadcast area with the default parameters NSA recommended did not vary greatly over time unless additional power was added to a transmitted signal. The nature of the prototype itself was to share and disseminate data across a network within the Intelligence Community. Discussions with the client and the NSA resulted in a partnership where OSC

would contact NSA when the broadcast footprints needed to be updated. This workflow worked in the past, when the client would e-mail a shapefile to NSA for processing (Figure 5.11). No testing of this workflow was conducted during the project, but it was discussed with the client and the NSA.



**Figure 26. The OSC-NSA broadcast area generation process**

The Web applications were tested for their functionality as they were built with Visual Studio 2005 and with the ArcGIS Server Web Application Development Framework (WebADF). Modules in the WebADF provided development tools in Visual Studio 2005 to create the layout and behavior of the project's Web applications, such as map controls and tasks. The applications were tested as they were created on the development machine, where drop-down lists would have the proper information or produce the appropriate results. As previously noted, the Web editing application did not perform as expected, as it was unable to display the geodatabase tables and maintain the

relationships between the data. The Web editor was only able to create, modify, and edit simple feature classes within the geodatabase, which allowed users to add, move, and delete towers and stations in the "WEB\_EDIT" version of the geodatabase. This issue was brought up with the client with the recommendation that the situation with the Web editor would allow for Web users to continue to provide information to the project by mapping the locations of stations and towers. Information such as transmitter attributes could be collected and added by desktop GIS users, who were able to edit and manage the full behavior of the geodatabase. Another proposed solution to updating the transmitter attributes would be to use Intellipedia as a platform to update changes via the Web.

These applications were intended to be accessible globally, and the project was able to accomplish this test. The project team provided access to members of the Intelligence Community to the University of Redlands virtual private network, where the prototype resided. Testers were able to log on to the network and access the applications through a variety of Web browsers. Testers accessed the system with Windows and Mac-based operating systems and were able to use the Safari, Firefox 2.0, and Internet Explorer 7.0 Web browsers to access the project's applications without issue. Test participants were located in Washington, London, and Hawaii and provided feedback to the project team via instant messenger as the tests occurred. No significant problems arose with these tests, but load-testing the applications could not be performed on the prototype during its development.

The prototype system was tested as it was created. The project team ensured that the data organization and design worked and behaved as it was intended with regard to the geodatabase and the system interfaces. The architecture of the system performed as it was

designed to and provided the required functionality to the client. The mitigation of configuration issues and deficiencies were discussed with the client. Modifications to the configuration or workflow, due to the result of testing the prototype, were made per the needs of the client. Follow-up work with the client on a full-scale implementation will have to require a more thorough testing plan.

## **5.6 Implementation Summary**

This section described how the project was implemented with regard to the equipment and software that was used to create the prototype and how it was configured to meet the needs of the client. The project laid out its project plan and designs to prototype a system the client could learn from and implement themselves. The technology—servers, networks, database and database software, GIS software, and development tools—is commercially available for the project and the client to utilize.

The client has been collecting data that was reviewed, deconstructed, reassembled, and used to fill the prototype. The migration from shapefiles to geodatabases was demonstrated and the geographic relationships were reviewed and modeled within the geodatabase. The division of features and attributes into separate feature classes with the addition of relationship classes introduced the natural relationships between the objects connected as part of television and radio broadcasting infrastructure in the geodatabase. The data model and the geodatabase provided a place for the client to start exploring how it can model other media infrastructure such as satellite and cable television. The geodatabase and data model can now be referenced to expand the client's ability to understand its media sources and the populations it monitors.



Creativity and necessity helped create the prototype applications that enable the client to interact with the data and the platform. These objects combined to construct a proof of concept for the client to consider for a future implementation of technology and processes. The client can use the system to advance its knowledge about its sources and the geography of the phenomena it monitors daily.

The geodatabase and platform attempted to demonstrate the collaborative nature of GIS as well. The prototype is a platform where the client and its partners can come together to share and visualize information that is of a common concern. The project implemented technology with as many capabilities to access and share data with the client and its partners as it could. Web Mapping Service, the KML service, and the proprietary ESRI service contributed to the dissemination of information and the inclusion of users who work with desktop applications and Web-based applications. The technology implemented provides room for the creative nature of intelligence analysts to mix and match data from different sources as well. The prototype has the ability to apply a wealth of different tools and as many methods to discover information about an area as the user can apply. The project contributed to the growth of the client's capabilities through its demonstration of modeling media infrastructure to contribute to the geographic analysis of a region by systematically studying a specific phenomenon—media infrastructure and signals.

## **6.0 Discussion**

### **6.1 Introduction**

The project was an exercise in prototyping a system that could model the features and relationships of television and radio broadcasting infrastructure for the client. The project studied and researched the materials, structures, people, technology, and spatial characteristics which were part of television and radio broadcast systems. This small research project resulted in work related to human geography and communications studies, which were applied to the design and creation of the project's prototype geodatabase and GIS. With requirements collected from the client, its previous work, and its partners, the project was able to leverage knowledge and technology to create a prototype. The prototype met the needs of the client and also served as a proof of concept that it could learn from.

### **6.2 Media, Geography, and GIS**

The project was not without its difficulties. The project team had to learn about the client, the problem, the client's previous work, the field of geography that was to be modeled in a GIS, communications studies, and the technology involved in the project. A thorough interdisciplinary review of media studies, geography, and the client's own processes helped to design the project to meet the needs for the prototype. The project used this knowledge and the data previously collected to design the project geodatabase. Understanding the nature of the client's work helped to segment data from the previous efforts by the client and built the relationship classes apparent in the physical objects of a

broadcasting system, which included the people involved in the system as well. There were some discussions with the client about separating the "STATIONS" feature class into separate "TVSTATION" and "RADIOSTATION" feature classes. This was possible, although for prototyping, the features were similar enough to leave together. Separating the feature classes even further would help with being able to create separate applications or services for just those feature classes, but the client decided the prototype did not have to implement a separation of the feature classes at the time of design and implementation. The client said it wanted a prototype and would learn from the decision, so the design was left as such.

Additional training was provided for the project team to learn about the detailed aspects of multiuser geodatabases and the ArcGIS technology suite to counter any difficulties that may have arisen from a technology standpoint. The project team scheduled a number of ESRI instructor-led courses to bolster the project's knowledge of multiuser enterprise ArcGIS Server geodatabases. This training proved to be helpful, as the project team learned the intricacies of ArcGIS Server and the ESRI geodatabase, especially with regard to installation and tuning tips. This training assisted in the project implementing the installation of Microsoft SQL Server and ArcSDE on the University's virtual server and for configuring the project's geodatabase behavior. Capabilities such as versioning, replication, compression, and using keywords were better understood and utilized in the project to support the needs of the client.

### **6.3 Design Principles and the Geodatabase**

One aspect the project learned during the design and implementation of the prototype was how agile and dynamic the ArcGIS software suite was. The software could

have been configured differently had the client's requirements been more lax or more restrictive. Had the client not wanted to segment its previously created shapefile, the data could have been transferred to feature classes without relationship classes and been left as is. This would have enabled users to manipulate the data via the Web editor, but the client's intention to model the relationships in the geodatabase were greater than the Web edit task. The other alternative regarding the organization of the data would have been to break it down further into more features such as radio and television station feature classes or transmitter feature classes. This would have added more complex behavior to the geodatabase, and management would have become more complex as well. Similarly, relay transmitters were brought up in conversations with the client that were not fully understood by all parties. Further research into the subject provided knowledge that led to an understanding about relay towers and how they could be represented the same as the towers and transmitters in the project. The client decided to model the relays as such because it had not received any inquiries about relays before. If the client ever decided to model relay towers, it could easily do so by creating subtypes for the towers feature class and transmitter table. The flexibility of the ArcGIS geodatabase and software suite proved to be the best choice for the prototype for these reasons.

The system design was considered to be of a typical design recommended by ESRI (Peters, 2007). The basis of the GIS was that of a system where "stuff goes in, stuff happens, and where stuff comes out" that would support the needs of the client. The project implemented the ESRI ArcGIS suite utilizing the client's enterprise license to maximize tools the client uses and is familiar with. The core of the system, the geodatabase, consisted of ArcGIS Server (ArcSDE) and Microsoft SQL Server. This combination of

software and hardware was considered the least complicated configuration of the database and ArcSDE technology for the project to implement.

The client will face a more difficult challenge implementing a follow-up project of the prototype if it continues to use Oracle as a database within the enterprise. The intricacies of the Oracle database would have pushed the prototype back by an estimated month. The primary reason for the estimated setback would have been project team training and acquisition. Training would have been required by the project team nonetheless, and Oracle books and documentation (Loney, 2004; Loney & Bryla, 2005) were not as clear as the Microsoft SQL Server references (Stanek, 2005; Whalen, 2007). The project team was more familiar with the Windows platform, and the integration of SQL Server and ESRI on a Windows platform which was the choice platform to work with. This included the integration of ArcGIS Server (ArcSDE and the WebADF for Visual Studio) with Microsoft's .NET framework and Internet Information Services Web server. Much of the programming was done in Visual Basic or C# ("C sharp"), which are native to ArcGIS and SQL Server. Windows security and management features were enabled, which allowed a more integrated platform for the prototype.

Of note was the fact that Oracle was unable to be acquired for the project. An initial review of academic prices ruled out the use of Oracle Spatial Enterprise. The client did not want to incur the cost of the software, and neither did the University. Fortunately, Microsoft was distributing SQL Server and other development tools to students via the DreamSpark program. The project was able to download Microsoft SQL Server 2005 for free via DreamSpark and installed it on the virtual server the University provided, which enabled the project to continue.

There was the difference of database software between the client's site and the prototype. ArcGIS Server and ESRI's geodatabase technology allow the replication of the geodatabase on other platforms regardless of the database used. There are some differences in the capabilities ArcGIS Server can perform on Oracle and SQL Server, but these were negligible to the prototype. The cost and complexity of using Oracle was discussed with the client, and the recommendation was made to use SQL Server instead of Oracle for the prototype. It should be noted that there were other database alternatives to Oracle and SQL Server that ArcGIS Server could also take advantage of. Had the prototype been created in ArcGIS Server 9.3, the option to implement an open source solution with a geodatabase such as PostGIS would have been available. Upon any implementation by the client, it will need to conduct a cost analysis for its system. The client will be required to review how it will need to allocate its costs based on the skills of its personnel and the technology it wishes to implement, then select the best value for the project.

#### **6.4 Project Applications and Tools**

In addition to the difficulties of learning about the client and the phenomena, there were issues concerning some of the tools and applications the client had recommended the project incorporate into the prototype. Foremost, the Communication Systems Planning Tool (CSPT), an extension to ArcMap, presented an unforeseen risk that was mitigated through a modification in the client's workflow. Other problems, such as the Web editing application and its inability to edit relationship classes and tables, were also unexpected. Problems such as these were mitigated by working through and learning about their shortcomings and how they interfaced with the overall system of the prototype.

The Web services and Web applications of the prototype worked well as prototypes. Web services could be enabled with ArcGIS Server and its applications as well as by providing GIS data to non-ESRI desktop GIS clients. The Web Mapping Service (WMS) and KML services could be provided to a number of different applications if need be within the client's networks. Applications such as Google Earth can be used to view the data with relative ease within the client's community of users and partners. The only difficulty with these services is that they have to be announced and the Web address passed along to users. This can happen through bookmarking in a user's browser, posting the Web address to a wiki or blog, or by e-mail. In the case of the project, if the prototype were on the client's network, the project team would have posted the links to the Web services and applications on Intellipedia and the project's blog and would have bookmarked them using Intelink's social bookmarking Web site, Tag|Connect. These places on the client's network would have supported multiple methods of discovery, where each URL could be tagged with a descriptive word and then indexed by Intelink's Google search indexer.

The Web applications met the client's requirement to search for specific attributes and to perform Web-based edits. Development of the Web query tool was based on a similar Web tool the project prototyped with the client's original shapefile data. The project had to create spatial and attribute joins in the MXD files, which would provide similar functionality as the prototype query tool that used the shapefile. Once the original shapefiles and client data were broken down into their separate feature classes and tables within the prototype geodatabase, the joins had to be performed for the map service in ArcGIS Server and the Web site to work.

The Web-based editing application for the prototype geodatabase, as has been noted, had its own deficiency, where the Web edit task did not edit complex geodatabase behavior. Spatial joins in the MXD were attempted but failed to work in early iterations of the application. The MXD for the Web editing tool was based on MXD files of the query tool, which had the joins in ArcMap. Another attempt to edit tables had been brainstormed, and a proposed solution to enable users to edit tables in the prototype geodatabase would have attempted to edit the SQL Server database directly through the Web application.

The proposed solution for editing tables in the Web editor application would have used Microsoft's ADO.NET technology for application access to the database and ASP.NET technology, which was used to create the Web applications. By attempting to utilize ADO.NET to create a data grid element in the editor tool, the project would have opened the database to the users who would have the ability to corrupt the tables and relationships within the geodatabase. It should be pointed out that the geodatabase is a series of tables within the database that relate to one another. If those tables were to become corrupted in any way, errors would occur when attempting to use any ArcGIS tools and services. The users would also be editing the base tables of the geodatabase; if any versions were created, they would become corrupt and fail. This solution could have worked had the project not implemented geodatabase versioning, where all edits would be visible by all users. There would have been the possibility of edit conflicts as well that would have dictated that the last edit would be saved to the database. If this configuration had been implemented to meet the client's needs, it would have been a poor decision, but in a circumstance where there are minimal editors and only one version of the geodatabase with simple features, this solution could work.



The Web applications for the prototype were successfully created to meet the requirements of the client. They both served as proof of concepts for the client to learn from. These types of applications can be created in a short amount of time that could use data from the prototype geodatabase and other Web services to meet the needs of the client as they arise. One roadblock the client may have with its implementation would be its network security policies and certification processes. These processes would reduce any agility it would have with deploying applications that used any sort of Web services in a rapid manner.

The inclusion of the Communication Systems Planning Tool (CSPT) was per the client's recommendation, which brought some difficulties to the project. The tool itself uses terrain data to generate broadcast areas where radio frequencies propagate, and when visualized, they look similar to the impacts of paintballs. This data generation tool can be an excellent method for planning two-way communications systems or for communication networks in buildings or urban areas. In radio and television, the broadcast areas are so vast the detail may not be needed by users. A generalization of an ellipse could have sufficed, but was not desired by the client. The splat-like shape and the ellipse both include spatial uncertainties, either covering too much area or too little. One has to keep in mind the client is estimating a coverage area to analyze. The client's previous practice, in coordination with the NSA, has been to rely on CSPT for conservative estimates. These estimates allowed the client to generate maps and analysis that would include the least amount of people in an area with some accuracy to present to its customers. The intent of the project geodatabase and the attributes of the towers and transmitters were to gather as

much information about the broadcast information to improve the broadcast areas and their accuracy.

The use of the CSPT by the client has been difficult, and, as described in Chapter 5, the tool was implemented as an interagency process, which the NSA participated in. Until the CSPT tool can handle ArcSDE geodatabase information and be integrated into a geoprocessing task within the ArcGIS geoprocessing framework, it will continue to be utilized as a tool within a workflow process instead of a geoprocessing model.

#### **6.4 Project Implementation**

The project planning process was not as extensive as it could have been. The project team took planning seriously yet had not given the plan the appropriate rigor. Understanding and organizing steps in which to complete a project is an art. There is not only the analysis and implementation of the problem but also steps to plan for the project plan.

The initial problem had to be identified with the client and then refined. This included brainstorming and proposing a solution to the client, which then had to be turned into the project plan. Immediately the scope of work was created to restrict the work. From the start, the project was considered a prototype; this relieved it from a full implementation at the client site, which was not required. The other major element of the project's scope was the time frame in which the period of performance would occur; that is, within the period of nine months to a year, to coincide with the University of Redlands MS GIS program schedule. There was also the nature of the work to be conducted, which was neither content analysis as is done in traditional open source intelligence work nor content

collection. These three items were what defined the extent of the work to be done and kept the project focused.

The goals and objectives of the project were appropriate to the work that was done. They focused on creating a platform to map and study the geographic extent of OSC sources, thus expanding the capabilities of OSC. The project studied the phenomena of radio and television media infrastructure from a geographic perspective, but also did so from a multidisciplinary aspect. The project incorporated a review of communication models and the societal relationships within media as well. Otherwise, the project's geodatabase could not have been designed and built the way it was, which could have resulted in missing the understanding of the spatial relationships. The project demonstrated enough of an understanding of the phenomena to model it. This understanding was essential to the project and could be applied to other media and could support follow-up projects for the client.

The work plan focused on six major components of the project that were broken down into other work tasks, then broken down further to a third tier of tasks. The Project Management Institute teaches that a work plan is a document that describes all the work needed to be performed to accomplish the project (Project Management Institute., 2004; Schwalbe, 2006). This would have entailed the project team diving deep into planning the project to write work packages and establishing a comprehensive work breakdown structure for the work plan. This had not happened for the project; otherwise, the team would have been spending its entire time writing project documentation, ESRI help documents, step-by-step instructions on how to configure SQL Server and ArcGIS tools, and hardware and network components. The team believed it could accomplish creation of

the prototype without writing a detailed work breakdown structure. Major system components were reviewed, and a top-to-bottom approach to identifying the work to be done was taken. Design, implementation, and testing tasks were identified as the lowest order of work. There were no work packages written that said "plug in the server" or "switch power switch to the 'on' position." That level of detail was not required for the prototype and seemed inappropriate to include in the project work plan. A comprehensive work breakdown structure would be required if the client did implement an on-site solution due to the network and certification policies of the client's information technology group.

The project planning process utilized other planning and analysis documents such as a risk assessment and project feasibility analysis, project requirements, and design specifications. The project drafted plans for post-prototype system implementation, deployment, adoption, testing, and acceptance. These plans helped the team to understand the risks and the work to be involved with the project by organizing different components logically into tasks and processes.

The project risk assessment and feasibility study reviewed the potential the project had to succeed and if the project could be done at all. The study reviewed the project team and client's skills and abilities in performing the work needed to be done, the severity of risks to the client if the project wasn't implemented successfully or on time, and whether the technology existed to implement the project. Overall, the project risk was low, and it was also feasible to implement. The client and project team mitigated their lack of knowledge with training and education regarding media studies and GIS technology that the project was concerned with. The risk to the client was minimal, since the project was a prototype. The technology had also been used and implemented elsewhere in the federal

government at organizations such as the U.S. Geologic Survey and the National Geospatial-Intelligence Agency to some success. The system architecture reflected a typical ESRI deployment per Peters (2007) and his recommendations, which reduced the project risk and increased the feasibility of the project. Had the prototype been implemented on the client's site, the project's risk would have increased. The client had some experience implementing some GIS applications but not a full deployment based on an enterprise geodatabase infrastructure. The client will need to review its policies and processes to mitigate risks that may slow or prevent any future deployments similar to those of the project prototype.

## **6.7 Summary**

The project built a prototype enterprise GIS to model television and radio broadcasting infrastructure, which provided a proof of concept of the services and capabilities the client could learn from. Media infrastructure and geographic relationships were researched, not only for television and radio media but also for the sociocultural behavior and technology that make up a communication system. The concepts learned from this project can be applied to satellite, wireless systems, and the Internet if further research is conducted. The objects in a communications system can be modeled in a GIS and updated with a frequency that would keep up with the amount of change to the data to support analysis.

The system's design and architecture bore a resemblance to other GIS systems that implement similar technology. The *System Design Strategies* (Peters, 2007) paper provided a number of recommendations and introduced the project to multiple strategies that it used to implement a GIS. The project applied these concepts to meet the client's

need for a GIS that would involve data from multiple sources and provide collaborative access to its data with its partners. The decision to implement the ArcGIS suite of technology and provide data services for users of different GIS platforms like Quantum GIS or Google Earth proved to be a great example to the client of how it could support a large number of users and partners worldwide with its geospatial data and analysis.

The suite of tools and applications the project created were more examples of how users, both within and outside the client's organization, could use the data services from the project to create their own applications. All users with access to the geodatabase and its services can read the data and conduct their own analysis or create their own maps for their individual needs. Tasks like editing the geodatabase with tools such as ArcMap and the Web editor application are controlled by the client to implement through the management policies for its future system. There is the potential for more complex applications that could utilize the project's data and services that are beyond the scope of this project.

The execution of the project and the creation of the prototype were conducted in a way that was indicative of the work that was needed to be accomplished. The initial problem and the scope of the project's work were defined with requirements and the goals and objectives the project wanted to accomplish with the client. The client's problem and the project's proposed solution were reviewed for their feasibility and risks that could have prevented the project from succeeding in its prototyping effort. These efforts helped to plan the project and make the prototype a reality.

The problem, scope, goals, and risks impacted the project work plan and project schedule. The work plan consisted of six major areas, which were broken down to another

two tiers to outline the work which was needed to be done. The project had not fully implemented the practice of creating a comprehensive work breakdown structure with work packages. A comprehensive work break down structure would have extended the length of the project and would have been unnecessary for its size and scope. The project work plan also served as the foundation of the schedule, which helped to plan when and how long tasks were to be conducted. The combination of the work plan and schedule focused the project to complete the prototype to meet the needs of the client.

## **7.0 Conclusion**

### **7.1 Introduction**

This paper began with the need for the United States to engage the world on a fourth front, which encompassed the social processes of media and information that influence a culture's understandings, feelings, and values. The geographic extent of media needed to be understood more than it had been and the requirements to do so were scattered among agencies and organizations that focused on specific elements of understanding and collecting information on media sources. This disparate structure was an area the client wished to remedy through its sponsorship of the project to prototype a GIS to model television and radio infrastructure. The project prototype was a starting step to organize the open source intelligence and strategic communications communities to work together with the development of tools and methods that could effectively lead to an improvement for understanding and engaging the fourth front.

### **7.2 Review**

The ability to learn about media sources, the geography of television and radio media, and the modeling of relationships of objects within the geography of those media were the goals of the project's prototyping effort. The client required a prototype of an enterprise system which it could begin to use to explore a way to apply GIS in its organization for the study of the geographic impact of media. The prototype also provided the client and its partners a way forward to explore methods in which they could collaborate and coordinate the collection and analyses of media source information. The project demonstrated that by applying an enterprise GIS solution to questions that have



been asked for almost seventy years (Goldberg, Magruder, & Rogers, 1943), the potential to collect and analyze this data can be accomplished with tools that can enable a community of users who are interested in a similar topic.

The design and architecture of the project was similar to other enterprise GIS platforms that focused on the geodatabase and the user as the core elements of the system. The ArcGIS suite of enterprise tools, along with Microsoft SQL Server, combined to be the heart of the geodatabase, which stored the locations of stations, towers, and broadcast areas. The combination of ArcGIS and SQL Server supported the complex behavior of relationships that were part of the project's data model for television and radio infrastructure as well. The rest of the system supplied access to the project's data through direct connections from the desktop or through Web services and applications to users. The applications on the desktop, such as ArcMap, and the Web applications enabled the creation and management of data within the geodatabase while allowing access to other enterprise data services within the client's network or from the National Geospatial-Intelligence Agency.

The project performed an exercise in problem solving that required project management techniques. These techniques helped to plan for all the work that needed to be done. A project work plan was created to identify the work while project management documents such as scope statements, project schedules, risk assessments, feasibility studies, requirements analyses, and design documents complemented the work plan. These items kept the project organized to implement the prototype to meet the needs of the client. The work plan created a framework for the project team to successfully build the prototype.

The implementation of the project brought the prototype to life, which created a platform to meet the needs of the client. The prototype demonstrated the capabilities of technology and processes involved with modeling media infrastructure, and related its phenomena as well. The technology had been implemented as designed and as recommended by ESRI as well. Some tools the client recommended for use did not work as well as planned; therefore, an interagency process with the National Security Agency had to be created to overcome the design flaw and included the continuation of data generated through a previous workflow.

From the start of defining the problem with the client through implementation, the project was about working with the client to develop a prototype for its needs. The project had a problem, a proposed solution, previous work, partnerships, and requirements that factored into the prototype's design. The project managed the design and implementation of the prototype through a work plan and schedule that focused on meeting the requirements of the project and kept it within the scope of its intent. Finally, the project came together in the form of hardware, software, applications, data, and people. It delivered the prototype with capabilities the client required and with the knowledge it wished to learn from.

### **7.3 Lessons Learned and Recommendations**

The project was not just another GIS from *System Design Strategies* (Peters, 2007) that focused primarily on developing a system out of all ESRI components. The project developed a prototype to learn from; it is up to the client to learn from the prototype and implement a follow-up system when it decides to do so. Had it not been for the client's enterprise license agreement for ESRI licenses, the project may have taken a very different

approach. The use of open source or other proprietary GIS software would have been an alternative technology. Design choices would not just have affected software choices but geodatabase design as well. Had the ESRI geodatabase not been available to be the core technology of the prototype, alternative design choices would have been explored. These alternative design choices could have provided the same capabilities, but the cost in time, learning and implementing the technology would also have been much higher.

An alternative to ArcGIS Server and Microsoft SQL Server would have been to implement a geodatabase based on PostgreSQL and PostGIS. PostgreSQL is a free and open source database and PostGIS is a free and open spatial data engine for PostgreSQL. This combination could have been paired with GeoServer, which is similar to ArcGIS Server, a software suite that can provide OGC services such as Web Mapping Service–Transactional (WMS-T) for editing, Web Feature Service, KML, and Geography Markup Language (GML) support. These services could then be accessed with ArcGIS Desktop or through other forms of Web interfaces such as OpenLayers, which is a JavaScript-based map viewer.

Replacements for GIS applications could be open source or proprietary. Such alternatives to ArcGIS Desktop would be Manifold, GeoMedia, Quantum GIS, uDIG, or GRASS. Web-based applications could be created and used with the afore-mentioned OpenLayers, but they could also be created using Microsoft Virtual Earth, Google Maps, Mapufacture, Mapstraction, or other Web-mapping platforms. The learning curve for implementing these open or alternative tools would have been too great to accomplish during the period of performance of the project. The emphasis was on ESRI and ArcGIS

for the project because of the client's enterprise license agreement, but could have been entirely implemented with open source.

The use of the CSPT extension for ArcMap was a disappointment in terms of how the project wanted to implement it versus how it was implemented. The lack of a full understanding of the tool prevented the project team from implementing it the way they wanted to within the system. While it could be installed on a desktop system, extensive training is required to create data with the tool. Within the period of performance for the project, it was not studied in depth as was needed. The intent of the client and the project team, neither of which knew about how CSPT was programmed, to utilize the extension as a geoprocessing task in ArcGIS did not pan out. Instead, the process of generating broadcast areas was implemented as an interagency process with NSA. A follow-up project could be to take the elements of the CSPT tool and create an improved ArcMap extension that could be used in ModelBuilder and ArcGIS Server as a geoprocessing task. As a geoprocessing task in ArcGIS, it could utilize the information from the project's geodatabase to automatically generate new features at predetermined times. These times could be after a week of updates or after transmitters and towers are moved or their attributes updated. The radio frequency generation tool could also be used for search and rescue or wildfire management communications planning in lieu of only modeling television and radio signals. The project considered performing this task, but soon realized the time, effort, and knowledge required to perform such a task were too great. It was completely outside the scope of the project. The project team had been in contact with developers at ESRI and the Department of Commerce to discuss such a project and the resources that would be required to accomplish the task.

One alternative to CSPT would have involved a software program called SPLAT!, which is a UNIX-based radio frequency mapping tool (Erle, Gibson, & Walsh, 2005). The SPLAT! application uses digital terrain models to perform a task similar to CSPT to generate a broadcast area, but on a different platform. Much of the functionality in SPLAT! is not controlled by a graphical user interface such as CSPT, and users have to build preformatted text tables for each signal they wish to model. One benefit of this application would be to write a batch script to generate the broadcast areas after the tables were generated and then write a batch converter to convert the output into raster datasets or embed the files into KML files. The tradeoff for this tool was the same as the other open source tools and CSPT: the time to learn the skills to effectively use the tool was too great. The scope and period of the project also prevented the further study and use of this tool.

Possible alternatives of the project could have taken a much different approach in the design of the geodatabase structure. The geodatabase and all of the data uses could have been de-normalized, or aggregated into one table. Google does this for its operating system, called BigTable, which supports applications such as its Earth and Map applications (Chang et al., 2006). The project could have taken the approach to create a "big table," which would have held all of the attributes of data the project was required to model. This would be similar to the shapefile with single features, which had the transmitter-station-tower combination the client had generated prior to the project. If a big table was created, applications could access specific views of the table to support the needs of the client in the application. The requisite skills to build applications were beyond the capability of the project, and the method is not widely accepted or recommended to implement on the scale of the prototype for this project.

It could have implemented an ArcGIS–open source hybrid architecture as well. Had the project upgraded to the ArcGIS 9.3 suite of tools—which was not available the time of the implementation—the project could have implemented a PostGIS database with ArcSDE. Similarly, ArcGIS Server and GeoServer could have been implemented with different tasks for different problems. From a desktop standpoint, ArcGIS Desktop could have been implemented for all users while applications such as qGIS or uDIG could have been used by external users who could not afford ArcGIS licenses to access the project's Web services. Web applications using complex geoprocessing models for analysis could have been displayed in Google Maps, Google Earth, Microsoft Virtual Earth, and OpenLayers as well. The ArcGIS 9.3 suite and the combination of open source tools could have enabled the project to serve an even larger number of users with different applications and needs than the prototype that was implemented. This hybrid design was not possible during the planning and implementation of the project due to ArcGIS 9.3 not being released until late June 2008.

#### **7.4 Summary**

The knowledge taken away from the project is that media—television, radio, satellite, and other forms of communication—can be modeled in an enterprise GIS that can support a wide variety of users within the client's organization and its partners. The objects and the relationships that make up a system of media are apparent in the real world and the relationships, although complex, can be identified and modeled. A media of interest for the client needs to be researched for its objects, actors, and relationships, as well as its social relationships and factors, which act on the landscape. An understanding of how the

relations work in a system are what makes geography and GIS an important part of OSC's, and the Intelligence Community's, toolbox, which can make an impact on the fourth front.

Finally, a note for the client and those in government who wish to implement GIS platforms for the enterprise: The technology is available, but the culture is not. Projects such as this prototype do not power themselves with electricity, servers, and software alone. Users are the driving force behind this prototype and all other systems which are implemented, especially when communication between users is required in processes that collect, analyze, and share intelligence. By engaging users first, and continuing the engagement within the system, organizations can learn about the fourth front and how to engage it.

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